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9. ABSTRACT

This volume presents 18 of the papers read at the water management workshop conducted in December, 1972, by the University of the Philippines and the International Rice Research Institute. They deal with soil-plant-water relationships, system and pilot project operations, technical problems, economic problems, and the social aspects of water management. The most provocative issue addressed by many papers is the complexity of the administrative and social organization needed to make use of irrigation water. An essential requirement for management of an irrigation system is a set of procedures for keeping informed about the situation, needs, and intentions of the farmers who use it. The farmer must be able to depend on getting the water when he needs it. The administrative system must not only build and maintain the dams, canals, ditches, and pumping systems, but ensure fair allocation and efficient use of water among farmers. Maintenance and management of the system can be confused because one individual (the ditchtender) often performs both these tasks. What often goes unnotices is the differences in these tasks and the different talents they require. The farmer's interests in water management decisions are not yet adequately served in many irrigation systems. Administrative policies and mechanisms need to be developed to solve this problem.

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WATER MANAGEMENT IN PHILIPPINE IRRIGATION SYSTEMS: RESEARCH & OPERATIONS

Papers presented at the Water Management Workshop, December 11-14, 1972, sponsored by the Department of Agricultural Engineering and the Department of Agricultural Economics, University of the Philippines College of Agriculture and by the Department of Agricultural Economics, International Rice Research Institute.

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The International Rice Research Institute, Los Baños, Laguna, Philippines

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INTRODUCTION

A water management workshop sponsored jointly by the University of the Philippines College of Agriculture and the International Rice Research Institute was held at the institute December 11 to 14, 1972. The conference was organized to encourage the exchange of ideas not only among disciplines, but also between those engaged in the actual management of systems and those undertaking research. A series of papers covering agronomic, engineering, economic, and sociological issues in the Philippines was presented. Discussion of current research activities and management practices brought to light many unsolved problems.

The selection and presentation of the papers was intended to explore ways in which research findings and system design and management could more closely support each other. The discussion of the papers provided for a representative mix of subjects each day of the workshop. In compiling this volume, however, the papers are arranged in the order of their major focus. The subject order is 1) soil-plant-water relationships, 2) system and pilot project operation, 3) technical, 4) economic and 5) social aspects of water management. The majority of the papers do not fit neatly into a single category due to their multi-disciplinary nature; some of them serve as links between the broad categories outlined above.

Perhaps the most provocative point brought out by many papers is the complexity of administrative and social organization needed for effective use of irrigation water. If the irrigation system is to be effective, the farmer must be able to depend on getting the water when he needs it. This requires an administrative mechanism that can build and maintain physical structures for providing water -- dams, canals, ditches, and pumping systems. At the same time, it requires a mechanism to insure fair allocation and efficient use of water among farmers. Maintenance of the physical structures can be confused with management of the system because these two tasks often merge in the hands of one individual (e.g. the ditchtender). Thus the ways in which the tasks differ, and the different talents they require, often go unnoticed.

One prerequisite for sound management of an irrigation system is a set of procedures for keeping continuously informed about the farmer's situation, and for making judgments, not only about his needs, but even about his preferences. Representing the farmer's interests in water management decisions calls for an ingenuity that is not yet in evidence in the management of many irrigation systems. Some administrative functions performed by government or professional bodies also require reciprocal cooperation and action from the farmer. Where these responses are essential to management success, there is a need to find policies and mechanisms of the administrative body which would help to secure them.

The physical and management requirements for successful operation vary among different systems in the Philippines. The simple communal systems lie at one extreme and the fairly sophisticated rotational irrigation schemes at the other. Choosing an appropriate level of sophistication for the design of a system, and maintaining a proper balance between physical design and human management capacities within it, are difficult tasks which demand considerable attention.

The interdisciplinary nature of water management problems is the single judgment most strongly reinforced by the discussion. Time after time, technologically sound solutions to problems were noted as "depending on whether farmers will accept them". Innovative economic or organizational solutions were referred to engineers or hydrologists for judgments of technical soundness. For example, a method was presented by which a water supply adequate to its command area for periods of peak demand, but inadequate for double cropping, could be "stretched" by staggered planting. Irrigation engineers felt that water distribution problems could be solved by dividing the systems into 16 districts and turning the water "on" or "off" by district, week by week throughout the year (rotational distribution). Sociologists agreed that farmers might be willing to shift their planting period to different times of the year to get a larger and more dependable supply of water at critical cropping periods, but only if they had confidence in the system and the schedule and could expect increased benefits in return.

When a scarce resource must be allocated, a free market system relies on price to allocate the supply among potential users with equity and efficiency. One paper proposes charging the farmer a high price which would reflect the value of the water when used in combination with a high level of farm management practices. This provoked an intensive discussion of whether such an approach is either socially desirable or administratively and politically feasible. There was agreement, however, that when the pricing system is unused or unusable as an allocation device, some alternative mechanism must be provided. Rationing through rotational distribution is one such alternative. A second alternative is to design and manage irrigation laterals to facilitate the flow of water and thereby ensure equitable distribution of water to those farthest from the source.

Some issues only briefly introduced at the workshop merit considerably greater research attention. Most of these involve reconciling conflicts in goals or dilemmas in policy, such as:

1. When the same water system has multiple uses, it becomes essential to harmonize irrigation requirements with the other demands on the system. Mining may change the quality and quantity of runoff water used in irrigation. Power generation in hydro-electric projects may require different streamflow schedules than those that are ideal for irrigation. Water channels and structures for storage and drainage that are in the farmer's interest may have less utility, or even disutility, for other sectors. What can be done to overcome physical and administrative separation of the various parties that take part in or are affected by such decisions? What kinds of data not now available are needed for informed policy-making on such matters?

2. For an irrigation project to be administratively successful does not require that it adopt all water-use policies that would be ideal from the farmer's viewpoint. Nor does it require the project administrator to re-examine his own project priorities from time to time in relation to other agricultural and non-agricultural needs of the region or nation. Thus even a highly successful project seldom does much, even indirectly, to advance the knowledge of irrigation or improved use of water outside of its borders. How can the specific goals of a project be kept in harmony with those of its own farmers and of sectors of the society and economy beyond its own geographic limits?

3. Much of the task of water management for agriculture is done by individual farmers or through communal irrigation systems. Yet both physical and human resources tend, understandably, to be concentrated on large new projects. What can be done to identify needs and find ways to improve water use in the older and smaller systems? How can they share more effectively in the technical, financial, and administrative resources that newer projects generally get?

4. Good water management, and especially good management of irrigation projects, requires a balance of at least four kinds of inputs: physical facilities, inputs of scientific or technical knowledge, management inputs, and inputs of current information and data. It is wasteful to make investments in ways that put some of these factors far ahead or far behind the others. What steps can be taken to analyze systems to see how well these ingredients are balanced, and to identify and correct points of imbalance? Development of human resources is clearly an issue here -- what kinds of persons, and with kinds of training are in such short supply that orderly development of water management is crippled?

Water management practices in flooded tropical rice

S. K. De Datta, H. K. Krupp, E. I. Alvarez, and S. C. Modgal, International Rice Research Institute

ABSTRACT

Experiments conducted for several cropping seasons on the montmorillonitic Maahas clay soil at the IRRI farm demonstrate that continual flooding is not essential for high grain yield but flooded rice can tolerate at least 15 cm if the improved varieties are grown. Tall varieties like H-4 have less adaptability under wide range of water management conditions than semidwarfs like IR8.

With adequate water supply, 5 to 7 cm of water is desirable on most soils for best weed and insect control with granular chemicals, for high nutrient availability, and for minimum losses of nutrients from fertilizer and soil.

If rainfall does not provide supplemental water, irrigation intervals longer than 8 days reduce grain yield under a rotational irrigation system. Varieties like IR5 that have a long growth duration were least sensitive to moisture stress imposed by long irrigation intervals. This is because IR5 will generally recover from high moisture stress for a short period or low moisture stress for a long period.

An experiment with IR20 indicates that the furrow irrigation of nonpuddled soil does not provide more efficient water use in rice compared with rice grown on puddled lowland soil.

INTRODUCTION

Despite occupying only 20 percent of the total estimated rice growing area in South and Southeast Asia, irrigated land accounts for 40 percent of the total rice production (Barker, 1970). Therefore, good water management in the irrigated area and to some extent in the rainfed, flooded (lowland) area is highly important for raising the production of rice in South and Southeast Asia.

Rice, like any other crop, requires an adequate supply of water to grow and develop at its maximum potential rate. Unlike other crops, rice is usually grown in flooded soil. Several reasons can be given for using this method of cultivation. For example, weed growth is drastically reduced under flooded conditions (De Datta et al., 1970). Also, nutrient availability is generally higher in flooded soil than in upland soil.

Many experiments have been conducted to measure the effects of water level and water management practices on the grain yield of flooded rice. Detailed results from some of the experiments conducted at IRRI have been reported by De Datta and Williams (1968) and De Datta et al. (1970). This paper gives a few examples to illustrate some factors which affect the water management practices and water use in flooded rice. The results reported here are from experiments conducted on montmorillonitic Maahas clay soil at the experimental farm of the International Rice Research Institute.

VARIETAL TYPE AND WATER MANAGEMENT PRACTICES

In an experiment conducted during the 1968 wet season, IR8 produced similar yield under rainfed and flooded (irrigated) paddies (Table 1). H-4, a tall variety, produced significantly higher grain yields under rainfed conditions than under continual flooding, however. While the number of panicles per square meter and the grain/straw ratio were higher in IR8 under various water management practices, the spikelets per panicle, percentage of unfilled grains, and plant height were higher in H-4. There was a fairly high percentage of unfilled grains and a low grain/straw ratio in H-4 under shallow continuous flooding and deep continuous flooding because H-4 lodged in these treatments. The 100-grain weight did not differ much in the two varieties regardless of water management treatment. These data suggest that varieties such as IR8 are more stable under wide ranges of water management conditions than the tall varieties like H-4. For rainfed areas, however, an intermediate variety, like IR5 or IR442-2-58, is better suited than a semidwarf variety like IR20 or IR22 (De Datta and Beachell,1972).

WATER USE IN FLOODED RICE

Many researchers have measured the water use in flooded rice using metal tanks installed in the middle of the field. During the 1968 dry season, an experiment was conducted with eight moisture regimes in tanks without bottoms. The most satisfactory regime in terms of grain yield was the intermediate continuous flooding although no statistically significant difference was measured between it and six other treatments (Table 2) (De Datta and Williams ,1968).

Water use efficiency (liters of water required to produce 1 gram of grain) was the highest when the soi' was kept at continual saturation (Table 2). This is primarily because deep percolation losses were negligible in the heavy clay soil.

Data obtained using tanks with bottoms are shown in Table 3. Here, no deep percolation occurred. The water use on the continually flooded plots was reduced by about 200 mm. Thus, percolation losses over the 91-day irrigation period accounted for 200 mm or about 2 mm/day. Again, the intermediate continual flooding gave the highest yield but, treatment 5 gave the highest water-use efficiency. Drainage at maximum tillering and panicle initiation reduced water use rather than increasing grain yield (De Datta and Williams,1968).

Table 1. Effect of water management practices on the grain yield, yield components, and plant height of IR8 and H-4 varieties under natural paddy condition. IRRI, 1968 wet season.

Water management treatments	Yield[1/] (t/ha)	Plant ht. (harvest) (cm)	Panicles (no./ sq m)	Spikelets (no./ panicle)	Unfilled grains (%)	100-grain weight (g)	Grain/ straw ratio
			IR8				
Continual flooding (15 cm)	6.0 a	114	250	131	13	2.8	0.7
Continual flooding (2.5 cm)	5.6 a	102	275	127	13	2.9	0.6
Saturation-field capacity	6.0 a	103	300	121	12	2.9	0.7
Rainfed	6.0 a	106	325	106	8	2.9	0.7
			H-4				
Continual flooding (15 cm)	2.1 a	198	250	167	27	2.8	0.4
Continual flooding (2.5 cm)	2.8 a	176	250	148	26	3.2	0.5
Saturation-field capacity	4.1 b	179	225	210	24	2.9	0.6
Rainfed	4.4 b	176	250	196	25	3.0	0.6

CV = 13%

1/Any two means followed by the same letter are not significantly different at the 5% level.

Table 2. Effect of water management practices on the grain yield of IR8 and efficiency of water use in plots with drainage. IRRI, 1968 dry season (De Datta and Williams, 1968).

Water management treatments	Total water applied during 91 days (mm)	Index (%)	Water-use efficiency (g/liter)	Yield[1/] (t/ha)
Intermediate continual flooding (7.5 cm)	850	60	1.14	9.7 a
Shallow continual flooding (2.5 cm)	805	57	1.19	9.5 ab
Intermediate continual flooding (7.5 cm) + continual soil saturation (1.0 cm)	800	56	1.17	9.4 ab
Continual soil saturation (1.0 cm) + flooding at panicle initiation (7.5 cm)	780	55	1.17	9.1 abc
Deep continual flooding (15 cm) + drainage at maximum tillering	1344	95	0.68	9.1 abc
Continual soil saturation (1.0 cm)	647	46	1.39	9.0 abc
Deep continual flooding (15 cm)	1418	100	0.63	9.0 abc
Deep continual flooding (15 cm) + drainage at maximum tillering + drainage at panicle initiation	1240	87	0.69	8.5 bc

CV = 3.4%

1/Any two means followed by the same letter are not significantly different at the 5% level.

Evaporation = 378 mm (91 days)	Crop duration (days) = 126
Evapotranspiration = 589 mm (91 days)	Irrigation started = 28 January 1968
Rainfall = 29.5 mm (91 days)	Irrigation stopped = 27 April 1968 (91 days)

The data in these two experiments underestimate the total irrigation requirement for rice since the measurements were taken only during the irrigation period of 91 days. For an additional 10 to 13 days, the crop used water that is not included in these water use figures. Also, water losses in the distribution system are not included. These losses vary with the efficiency and type of distribution system but may be 25 percent or more of the total water diverted to the farm.

The ratio of evapotranspiration to evaporation over the irrigated period is about 1.6. Evaporation was measured from a tank with bottom, but without a growing crop.

Similarly, during the 1968 wet season, data on evaporation were collected from the adjacent evaporation tank. These observations were taken as a general estimation of transpiration and also to ascertain the general relationship between water losses from an IR8 population and the weather factors involved in the process. Three distinct peaks of evapotranspiration occurred at the panicle initiation, heading, and dough stages (Fig. 1). At the same time, solar radiation was high. The correlation between the evapotranspiration and solar radiation was significant ($r = 0.65^{*}$). But apparently solar radiation was not the only factor responsible for the evapotranspiration losses. Evapotranspiration was low during the high-rainfall period. The 575 mm of rain received during the cropping season exceeded the total evapotranspiration. But considering the percolation loss and other losses, there seemed to be a need for supplemental irrigation. Comparing the evaporation and the estimated transpiration as the components of evapotranspiration, a higher share of evaporation as shown in the earlier stages of crop growth, gradually more water was lost through transpiration until evaporation and transpiration became almost equal at about 67 days after transplanting. Near harvest, the evaporation again increased slightly and transpiration decreased. The proportion of evaporation to transpiration in evapotranspiration is mostly a function of the leaf area index and fluctuates as the leaf area index rises and falls. The ratio of evapotranspiration to evaporation in the 1968 wet season was remarkably similar to what was obtained during the 1968 dry season.

In the 1968 wet season, $\frac{\text{evapotranspiration}}{\text{evaporation}} = \frac{445 \text{ mm}}{271 \text{ mm}} = 1.6.$

WATER DEPTHS AND WEED POPULATION

As little as 2.5 cm of water drastically reduces weed population (Fig. 2). Over 7.5 cm of water, the population of broadleaved weeds started to increase but not enough to provide major competition to transplanted IR8 rice.

WATER MANAGEMENT PRACTICES FOR CONTINUOUS RICE CROPPING

Experiments conducted during the 1969 dry season (R.K. Jana and S.K. De Datta, unpublished) confirmed our earlier findings that continual flooding is not essential for high grain yield but flooded rice can tolerate up to at least 15 cm of water depth if improved varieties are grown. In this experiment, continually saturated plots produced similar annual grain yields to continually flooded plots (Table 4). Submergence has other advantages, however, such as better weed control, higher efficiency of fertilizer, and better insect and weed control with granular chemicals. Considering all factors, continuous submergence with 5 to 7 cm of water is probably best for irrigated rice.

EFFECTS OF WATER DEPTH ON BROADCAST-SEEDED FLOODED RICE

Some experiments completed in the 1970 dry season on broadcast seeding into water clearly show the effects of differing water depths in crop establishment, weed population, and growth characteristics of rice (N. Devasundrarajah and S.K. De Datta, unpublished). A portion of the data is shown in Table 5.

As the water depth is increased, crop establishment or the number of plants per square meter decreases. The plants grow taller and the number of tillers and panicles per unit area is reduced. Weed growth is much reduced in the deep flooded plots. Finally, lodging at harvest is much greater in the deep flooded plots.

Additional treatments in the experiment included seeding into 5 cm of water followed by drainage at the maximum tillering, panicle initiation, and heading stages. The brief drainage period reduced lodging particularly if the drainage was done at the earlier growth stages. However, this drainage treatment resulted in much higher weed populations (Table 5).

ROTATIONAL IRRIGATION IN FLOODED RICE

Rotational irrigation is the application of irrigation water to fields in the required amounts at regular intervals. The field may often be without standing water between irrigations but ideally it does not dry out enough for moisture stress to develop and reduce grain yield.

This method of irrigation has not been widely adopted because it requires competent irrigation personnel as well as good farmer cooperation, the existing conveyance systems must be modified to water measuring devices installed, and weeds are more difficult to control when the plots lack standing water for a time.

Rotational irrigation is often recommended in locations where it is desirable to irrigate as large an area as possible with a limited water supply. In Taiwan, for example, rotational irrigation is as effective as the conventional method of irrigation, if not better (Chow,1959). Some researchers in Taiwan, claimed that rotational irrigation used 30 to 50 percent less irrigation water.

Table 3. Effect of water management practices on the grain yield of IR8 and efficiency of water use in plots without drainage. IRRI, 1968 dry season (De Datta and Williams, 1968).

Water management treatments	Total water applied during 91 days (mm)	Index (%)	Water-use efficiency (g/liter)	Yield 1/ (g/m^2)
Intermediate continual flooding (7.5 cm)	602	100	1.89	1152 a
Deep continual flooding (15 cm)	605	100	1.79	1085 ab
Shallow continual flooding (2.5 cm)	607	100	1.77	1078 ab
Deep continual flooding (15 cm) + drainage at maximum tillering	585	97	1.82	1065 ab
Deep continual flooding (15 cm) + drainage at maximum tillering + drainage at panicle initiation	549	91	1.94	1065 ab
Intermediate continual flooding (7.5 cm) + continual soil saturation (1.0 cm)	649	107	1.59	1035 abc
Continual soil saturation (1.0 cm) + flooding at panicle initiation (7.5 cm)	595	98	1.68	1000 bc
Continual soil saturation (1.0 cm)	639	106	1.42	908 c

CV = 7.5%

1/Any two means followed by the same letter are not significantly different at the 5% level.

Evaporation	= 378 mm (91 days)	Irrigation started	= 28 January 1968
Rainfall	= 29.5 mm (91 days)	Irrigation stopped	= 27 April 1968 (91 days)
Crop duration (days)	= 126	Date of harvest	= 7-10 May 1968

Table 4. Effects of water management on the annual production with three crops of IR8. IRRI, 1970 (R. K. Jana and S. K. De Datta, unpublished).

Treatment number	Growth stages: Vegetative	Reproductive	Ripening	Yield (t/ha): Natural paddy	Tanks with bottoms	Tanks without bottoms
1	F ⟶	S ⟶	⟶	21.1	20.0	20.4
2	S ⟶	F ⟶	S ⟶	21.1	21.5	19.5
3	S ⟶	⟶	F ⟶	21.6	20.6	20.1
4	S ⟶	F ⟶	⟶	20.9	21.3	19.8
5	F ⟶	S ⟶	F ⟶	22.0	19.7	20.5
6	F ⟶	⟶	S ⟶	22.2	21.5	20.8
7	S ⟶	⟶	⟶	22.0	21.5	21.2
8	F ⟶	⟶	⟶	21.5	20.7	20.7

S = saturated; F = flooded (5 cm)

Table 5. Effects of water depth and management on grain yield and growth characteristics of broadcast-seeded flooded rice. IRRI, 1970 dry season (N. Devasundrarajah and S. K. De Datta, unpublished).

Water management treatments	Yield (t/ha)	Plants1/ (no./sq m)	Weeds2/ (no./sq m)	Plant height3/ (cm)	Tillers3/ (no./sq m)	Panicles4/ (no./sq m)	Lodging4/ (%)
				IR22			
2.5 cm continually flooded	6.5	267	315	59	805	470	73
5 cm continually flooded	6.5	231	292	65	738	488	68
10 cm continually flooded	6.1	209	131	66	703	416	70
20 cm continually flooded	6.0	201	68	77	615	366	89
5 cm drained at MT	7.1	230	261	64	730	479	41
5 cm drained at PI	7.0	243	215	63	705	490	50
				IR8			
2.5 cm continually flooded	6.4	256	306	68	730	456	23
5 cm continually flooded	6.6	243	215	67	680	443	35
10 cm continually flooded	6.6	203	185	70	595	410	38
20 cm continually flooded	5.5	193	92	75	455	353	72
5 cm drained at MT	6.7	227	316	61	598	451	25
5 cm drained at PI	7.0	253	214	68	623	439	11

1/14 days after seeding. 2/30 days after seeding. 3/Maximum tillering. 4/At harvest.

In the Philippines, this method did not receive much attention until the Upper Pampanga River Irrigation Project was initiated. In this project, the system is designed to irrigate thousands of hectares at 5-day intervals and with a 13 mm/day irrigation rate.

During the 1971 and 1972 dry seasons, two field experiments were conducted at the IRRI farm to determine the most efficient interval and rate of irrigation. In the 1971 experiment, five varieties or selections were tested at four irrigation levels and four irrigation intervals (Table 6). The varieties were classified into two groups -- those with medium growth duration (IR20, IR127-80-1, and IR480-5-9) and those with long growth duration (C4-63 G and IR5). Ammonium sulfate was applied at the rate of 75 kg/ha N before transplanting and 25 kg/ha N was top-dressed at maximum tillering and at panicle initiation stages. Weeds, which grew most rapidly in the nonflooded plots, were pulled.

The irrigation treatments began 2 weeks after transplanting to allow full seedling recovery. The plots were flooded to the desired depth using pre-calibrated 5 cm plastic siphons. The discharge of each siphon was held constant by maintaining the pressure head difference between the standing water in the canal and the discharge level in the plot. Thus, the actual amount of water applied was calculated by measuring the irrigation time.

The plots were visually scored every morning using the following scale: 1 - standing water in plot; 2 - no standing water but soil saturated; 3 - moderately dry plot with soil cracking; 4 - very dry plot with considerable soil cracking.

The irrigation treatments were continued for 85 days. After this period, frequent heavy rains kept the plots nearly saturated or flooded until all the varieties were harvested.

The experiment was continued in the 1972 dry season with some modifications (Table 6). In addition to the five varieties mentioned, an early maturing line, IR1561-69-6 was included in the test. Granular 2,4-D, which has been found effective in controlling common weeds with 5 cm of continuous flooding, was tested with the different water management treatments. Ammonium sulfate at 120 kg/ha N was applied one-third as basal, one-third at the maximum tillering stage, and one-third at the panicle initiation stage.

Small pre-calibrated electric pumps with a discharge of approximately 60 liter/min were used to measure the amount of water that was necessary to flood the plots to the required depths. As in the 1971 trial, the plots were visually evaluated every morning using the same rating scheme.

The monthly summary of irrigation water applied is shown in Table 6. Generally, the total water applied increased as either the interval or rate of irrigation was increased for both the 1971 and 1972 trials. This increase in water applied was partially due to increased seepage and percolation resulting from greater depth of standing water. In addition, percolation losses of water were more when the irrigation intervals were longer because deeper and bigger cracks developed in the soil.

The water requirement for the same irrigation treatment was generally higher in the 1971 trial than in the 1972 trial. The 1971 crop received higher solar radiation especially during the early cropping season (Fig. 3). Moreover, regression analysis showed that potential evaporation was slightly higher in the 1971 crop.

The grain yields and other growth characteristics of the varieties with medium growth duration (IR480-5-9, IR127-80-1, and IR20) and the early-maturing line (IR1561-69-6) are shown in Table 7. In the 1971 trial, the grain yield, total dry matter, leaf area index, plant height, and tiller number generally decreased as the irrigation interval increased. But in the 1972 trial, these growth characteristics and grain yield remained practically the same under the different irrigation intervals. The crop suffered less from moisture stress during the 1972 dry season than the 1971 dry season as the irrigation interval was increased (Table 8). In the 1972 trial, the monsoon rain started as early as 90 days after transplanting which may have saved the crop from prolonged soil moisture stress. Our results indicate that the longer growth duration varieties, IR5 and C4-63, were less sensitive to moisture stress among the varieties tested (Table 7 and 9).

The grain yield as a function of irrigation interval is further illustrated in Figure 4. There was a marked decrease in grain yield at 10-day irrigation interval for the 1971 trial but it remained practically the same at different irrigation intervals for the 1972 trial. As mentioned earlier, this was due to the differences between the soil moisture stress conditions in the 1971 and 1972 dry seasons.

We have defined water-use efficiency as grain yield produced per unit of irrigation water applied. The differences in the efficiency of water use between varieties with short, medium, and long growth duration are shown in Figure 5. The water-use efficiency decreased as the growth duration and irrigation rate were increased regardless of irrigation interval.

The effects of irrigation level and interval on water-use efficiency are illustrated in Figure 6. In the 1971 trial, irrigation efficiency decreased at higher irrigation levels and intervals except at the 8-day irrigation interval where efficiency tended to increase beyond 6 mm/day irrigation rate. However, no difference in water-use efficiency was apparent between the irrigation intervals in the 1972 trial.

The effectiveness of granular 2,4-D in all irrigation treatments is illustrated in Figure 7. The grain yields with 2,4-D application followed by one hand weeding at maximum tillering stage were slightly higher than the yields with 2,4-D application alone. The slight decrease in the grain yields obtained from the plots with no hand weeding was due to the infestation of perennial sedge, *Scirpus maritimus*, which was not controlled by 2,4-D.

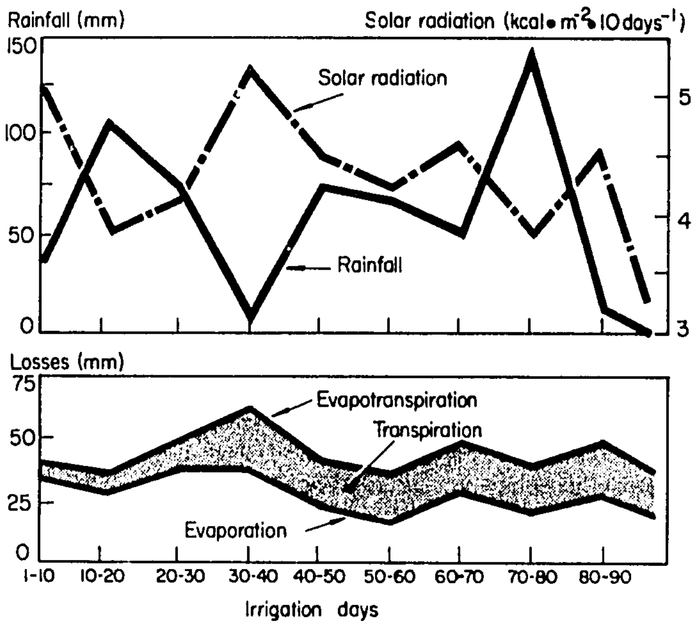

Fig. 1. Evapotranspiration from IR8, solar radiation, and rainfall. IRRI, 1968 wet season.

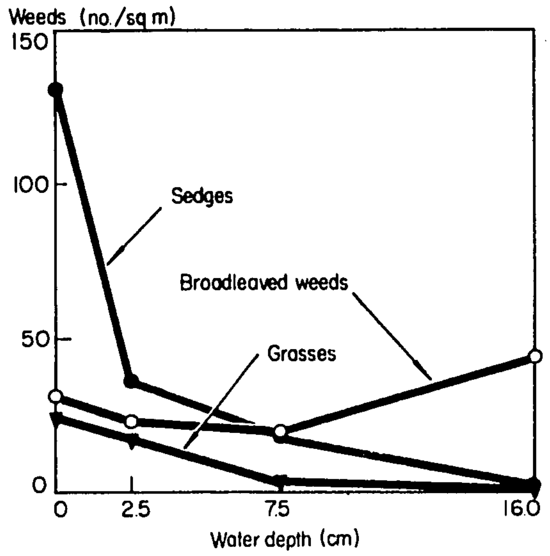

Fig. 2. Effect of water depth on weed population in an IR8 rice field at 28 days after transplanting. IRRI, 1968 wet season.

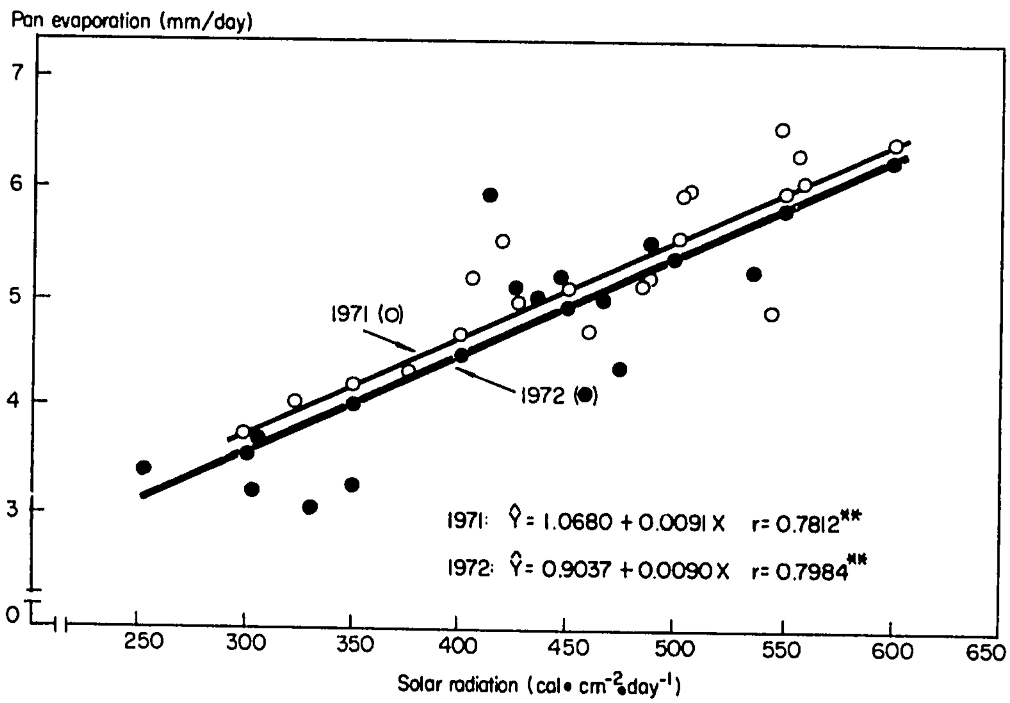

Fig. 3. Relationships between solar radiation and pan evaporation. IRRI, 1971 and 1972 dry season.

Table 6. The effects of irrigation level and intervals on the amount of water applied and the number of days without standing water in the plots. IRRI, 1971 and 1972 dry seasons.

Irrigation treatments[a]	Water applied (mm)						Days without standing water (no.)
	Feb.	Mar.	Apr.	May	Total	Per day	
			1971[b]				
4-day interval							
2 cm	75	115	235	6	431	5.1	11
3 cm	77	121	302	7	508	6.0	10
4 cm	140	192	362	14	709	8.4	10
5 cm	128	215	379	110	830	9.8	21
6-day interval							
2.5 cm	101	151	307	79	638	7.5	38
4 cm	117	186	287	49	639	7.5	37
5 cm	142	258	365	79	843	9.9	35
6 cm	195	284	326	121	925	10.9	21
8-day interval							
3 cm	108	138	298	65	609	7.2	40
5 cm	89	205	356	167	817	9.6	58
6 cm	115	196	313	104	728	8.6	33
7.5 cm	164	166	296	44	670	7.9	21
10-day interval							
4 cm	106	216	230	63	615	7.2	66
5 cm	148	293	350	93	884	10.2	58
7.5 cm	176	268	287	82	814	9.6	69
10 cm	222	321	424	87	1053	12.2	67
			1972[c]				
4-day interval							
2 cm	104	162	211	27	506	5.2	23
3 cm	150	181	252	29	612	6.3	10
5 cm	168	193	299	43	760	7.8	8
7-day interval							
3 cm	103	165	248	46	516	5.4	18
5 cm	127	184	271	49	583	6.2	11
7.5 cm	204	235	291	72	730	7.7	10
10-day interval							
4 cm	106	143	259	41	559	5.8	32
7 cm	142	151	275	65	632	6.5	25
10 cm	248	223	368	99	840	8.7	12

a/Initiated 2 weeks after transplanting.

b/Irrigation treatments were imposed for 85 days.

c/Irrigation treatments were imposed for 96 days.

Table 7. Dry matter production, leaf area index, plant height at harvest, tiller number and grain yield of three rice varieties as affected by rotational irrigation practices. IRRI, 1971 and 1972 dry seasons.

Irrigation interval (days)	Total dry matter (g/hill)	Leaf[a] area index	Plant height[b] (cm)	Tillers[b] (no./hill)	Yield (t/ha)
		1971			
		IR20 (116)[c]			
4	53	6.5	102	18	7.2
6	47	5.4	97	18	7.1
8	49	5.2	98	17	6.8
10	37	4.2	92	12	5.6
		IR127-80-1 (115)			
4	59	6.7	112	12	6.5
6	52	5.8	107	12	6.1
8	58	5.9	103	11	6.5
10	40	4.1	96	10	5.0
		IR480-5-9 (121)			
4	55	6.5	93	17	7.0
6	46	5.5	87	15	6.6
8	52	5.1	86	15	6.4
10	47	-	79	13	5.2
		1972			
		IR20 (118)			
4	32	5.2	92	18	7.0
7	32	5.6	95	15	7.6
10	37	5.7	95	18	7.2
		IR127-80-1 (119)			
4	36	5.4	112	11	5.9
7	41	5.0	108	9	6.9
10	41	5.3	109	10	6.5
		IR480-5-9 (121)			
4	39	6.6	83	14	6.1
7	36	6.0	82	15	6.0
10	40	6.0	82	11	6.5
		IR1561-69-6 (104)			
4	39	5.4	91	21	6.1
7	33	3.9	92	20	6.4
10	34	4.9	91	21	6.7

a/At flowering. b/At harvest. c/The growth duration is included by the numbers in parenthesis.

Table 8. The moisture status of the experimental plots as affected by the irrigation interval. Each value is the mean of two replications and four irrigation rates. IRRI, 1971 and 1972 dry seasons.

Irrigation interval (days)	Number of days			
	1[a]	2	3	4
		1971		
4	71	11	2	0
6	51	15	17	1
8	50	14	18	2
10	19	18	25	22
		1972		
3	83	14	3	0
7	83	13	4	0
10	73	18	9	0

a/
1 - standing water in plots - 0 centibars (cb) soil moisture tension.
2 - no standing water but soil saturated - less than 5 cb tension.
3 - moderately dry with some soil cracking - less than 10 cb tension.
4 - very dry with extensive soil cracking - more than 10 cb tension.

Table 9. Dry matter production, leaf area index, plant height, tiller number and grain yield of two rice varieties as affected by rotational irrigation practices. IRRI, 1971 and 1972 dry seasons.

Irrigation interval (days)	Total dry matter (g/hill)	Leaf area index	Plant height[a] (cm)	Tillers[a] (no./hill)	Yield (t/ha)
			1971		
			IR5 (133)[b]		
4	60	8.3	128	16	6.0
6	61	8.6	119	15	5.9
8	54	7.1	121	17	6.1
10	48	5.6	107	14	5.4
			C4-63 G (128)		
4	61	7.3	113	15	5.5
6	58	7.6	108	14	6.0
8	60	6.3	106	16	5.9
10	41	6.1	104	14	5.9
			1972		
			IR5 (135)		
4	50	7.6	112	13	6.7
7	50	7.1	110	14	6.9
10	52	7.9	117	15	6.9
			C4-63 G (132)		
4	48	8.5	112	14	6.1
7	47	6.6	109	13	6.3
10	49	6.6	115	13	6.4

a/At harvest. b/Growth duration (in days).

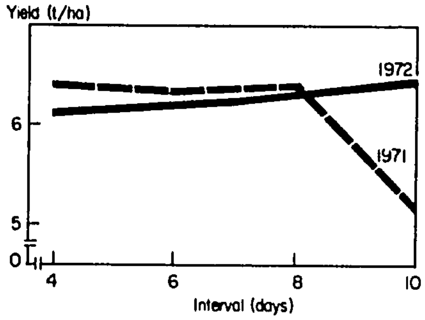

Fig. 4. The effect of irrigation interval on the grain yield of flooded rice. Each value is the mean of five rice varieties, four irrigation levels, and two replications (1971), and six varieties, three irrigation levels, and two replications (1972). IRRI, 1971 and 1972 dry seasons.

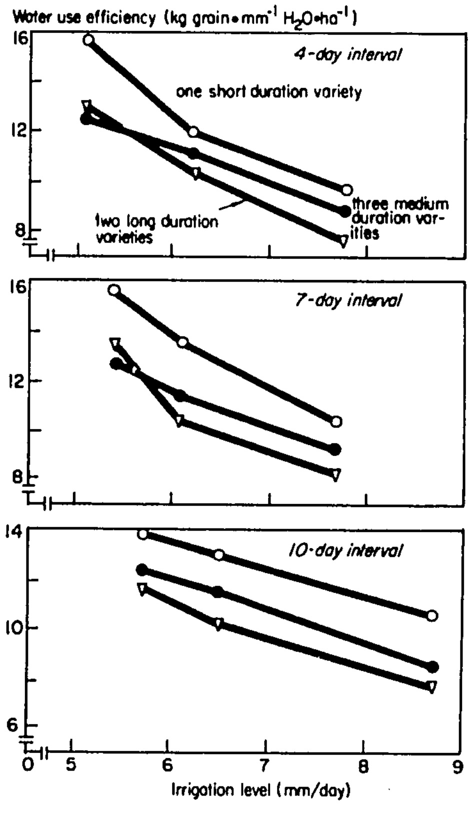

Fig. 5. Effects of irrigation level and interval on the water use efficiency of rice varieties with different growth durations. IRRI, 1972 dry season.

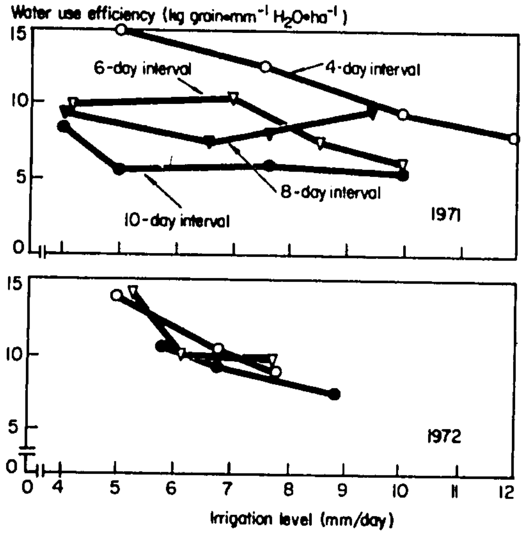

Fig. 6. Grain yield per unit of irrigation water applied as a function of irrigation interval and level. The values presented are means of five varieties for 1971 and six varieties for 1972. IRRI, 1971 and 1972 dry seasons.

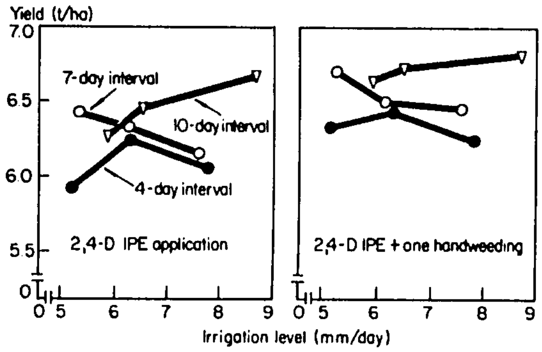

Fig. 7. Effects of irrigation levels and interval on the weed control with 2,4-D IPE in flooded rice. IRRI, 1972 dry season.

WATER REQUIREMENTS ON FURROW-IRRIGATED NONPUDDLED SOIL AND PUDDLED LOWLAND SOIL

Strong arguments have been presented which suggest that a desirable alternative to soil puddling for rice cultivation may be the practice of furrow irrigating rice grown on nonpuddled soil (Bradfield, 1970). Maintaining the soil in a nonpuddled or upland condition allows the ready insertion of other crops into a rotation centered around rice. The cultivation of other crops in rotation with rice means a large increase in both nutritional and economic benefits.

Research conducted in 1970 (IRRI ,1971) shows that more than a third of the water used in evapotranspiration is lost by evaporation from the surface of the standing water in a rice field. Thus, the practice of furrow irrigation in nonpuddled soil might lower the requirement of rice for irrigation water. Evaporation from the field would be retarded by the mulching effect of the dry surface soil. Also, deep percolation losses could be reduced. The importance and benefits to be derived by reducing the irrigation requirement of rice have been discussed by Young (1970).

An experiment was conducted in the 1971 dry season to measure the water requirement of nonpuddled irrigated rice (H.K. Krupp and M.L. Bhendia, unpublished). Two adjoining 25 x 50 m plots were prepared for planting -- one using nonpuddled dry land preparation techniques and one using lowland procedures. The nonpuddled area was plowed once and rotovated twice. The lowland area was flooded, plowed, and harrowed thoroughly. Animal power was used for lowland preparation while upland preparation permitted the use of four-wheel tractors with a substantial savings in labor. The nonpuddled dry and lowland plots were planted to upland and lowland rice cultivation, respectively, in the previous season.

The fields were both quite level so it was necessary to divide the nonpuddled field into three 8 x 50 m sections separated by secondary irrigation canals. Furrows were prepared 50 cm apart across the width of the 8 x 50 m section. The secondary canals were lined with polyethylene film to minimize seepage and permit a more uniform distribution of the irrigation water. Water was supplied to the plots at one corner of the plot. The amount applied to the field was measured using a Parshall flume with a 15 cm throat. Water was admitted to eight to ten furrows at one time.

The lowland field was irrigated daily as necessary to maintain 5 cm of standing water. Water application to the lowland field was measured by observing the depths before and after irrigation using a stilling well and hook gauge technique. The field was also divided into three 8 x 50 m sections so the water-use data are the mean of three daily readings.

IR20 was used, not because of its outstanding performance under upland conditions, but because of its broad-based resistance to many insects and diseases. The nonpuddled field was sown on a row spacing of 25 cm. Thus, there were two rows of rice at 25 cm separated by a 50 cm gap where the irrigation furrow was located. The seedbed for the lowland rice was established at the same time so the crops would mature at approximately the same time. This is important because grain yield depends greatly on the solar radiation received by the crop in the period between panicle initiation and harvest (De Datta and Zarate 1970). The seedlings were transplanted in the lowland field at a 25 x 25 cm spacing 25 days after the nonpuddled field was seeded. The 5 cm water regime was established 4 days after transplanting. Tensiometers were installed at three locations in the upland field at depths of 5, 15, and 25 cm. Rainfall was monitored daily and solar radiation was recorded with a pyrheliometer.

Ammonium sulfate was applied in a split dose (50 + 50 kg/ha N) to both the nonpuddled and the puddled irrigated lowland crop. The first application to the lowland crop was made 1 day before transplanting and was incorporated in the soil during the final harrowing. The first application was broadcast on the nonpuddled field 2 weeks after the rice emerged. The second application was broadcast in both fields at the panicle initiation stage of the crop. Yield and yield component samples were taken from six different areas in both the lowland and upland fields.

The yield and yield components of IR20 grown under both lowland and furrow irrigated nonpuddled soil conditions are shown in Table 10. The grain yield of IR20 was reduced from 7.9 t/ha to 3.6 t/ha. The large decrease in grain yield in the nonpuddled planting resulted from significantly lower panicle weight and 100-grain weight. Panicle production, however, was higher in the nonpuddled planting primarily because of the higher plant density. The grain/straw ratio was much higher in the lowland planting indicating a much more efficient portioning of photosynthate between the grain and the straw of the plant.

The water required for land preparation in the lowland field was estimated to be 150 mm (Table 11). The water use in the nonpuddled field was 50 percent of that in the lowland field despite the much longer field duration in the nonpuddled planting. The daily rate of water use in the lowland field was 7.71 mm/day (9.28 mm/day if the water required for land preparation is included). For the nonpuddled field the daily water use was 3.37 mm/day. Thus, averaged over the whole growing season the water use of the nonpuddled field was 44 percent of that in the lowland field (Table 1[illegible]) Although there are no data to show this, the water use in the nonpuddled field is at a minimum after seeding and increases to a maximum as the leaf area index increases.

Grain production per unit of water applied was slightly more efficient under lowland conditions. The lowland crop produced 9.0 kg grain/mm compared with 8.3 kg grain/mm water under nonpuddled conditions. Thus, despite the significant reduction in water use, there was a concurrent reduction in grain yield that lowered the efficiency of water use in the nonpuddled plots relative to the lowland plots.

The harvest of the nonpuddled area was delayed 9 days compared with the lowland area even though the lowland seedlings required a several day recovery period from transplanting. Also, the nonpuddled field had very uneven flowering and ripening.

Table 10. The yield and yield components of IR20 grown under puddled, continually flooded conditions and under nonpuddled, furrow irrigated conditions. IRRI, 1971 dry season (H. K. Krupp and M. L. Bhendia, unpublished).

	Puddled flooded	Nonpuddled furrow irrigated
Grain yield (t/ha)	7.9	3.6
Panicles (no./sq m)	119	154
Panicle wt (g)	2.73	1.14
100-grain wt (g)	2.26	2.00
Unfilled grain (%)	12.8	19.2
Grain:straw ratio	1.41	0.67

Table 11. Water use and growth duration of IR20 grown under puddled, continually flooded conditions and nonpuddled, furrow irrigated conditions (Field duration of the lowland crop was 96 days and of the upland crop, 131 days). IRRI, 1971 dry season (H. K. Krupp and M. L. Bhendia, unpublished).

Source	Water use (mm)	
	Puddled flooded	Nonpuddled furrow irrigated
Irrigation	692[a]	201
Water for land preparation	150[b]	--
Water for lowland field before flooding	40[b]	--
Rainfall	--	240[c]
Total water use	882	441

[a] Includes rainfall.

[b] Estimated.

[c] Total rainfall for this period was 316 mm of which 75% was assumed to be effective.

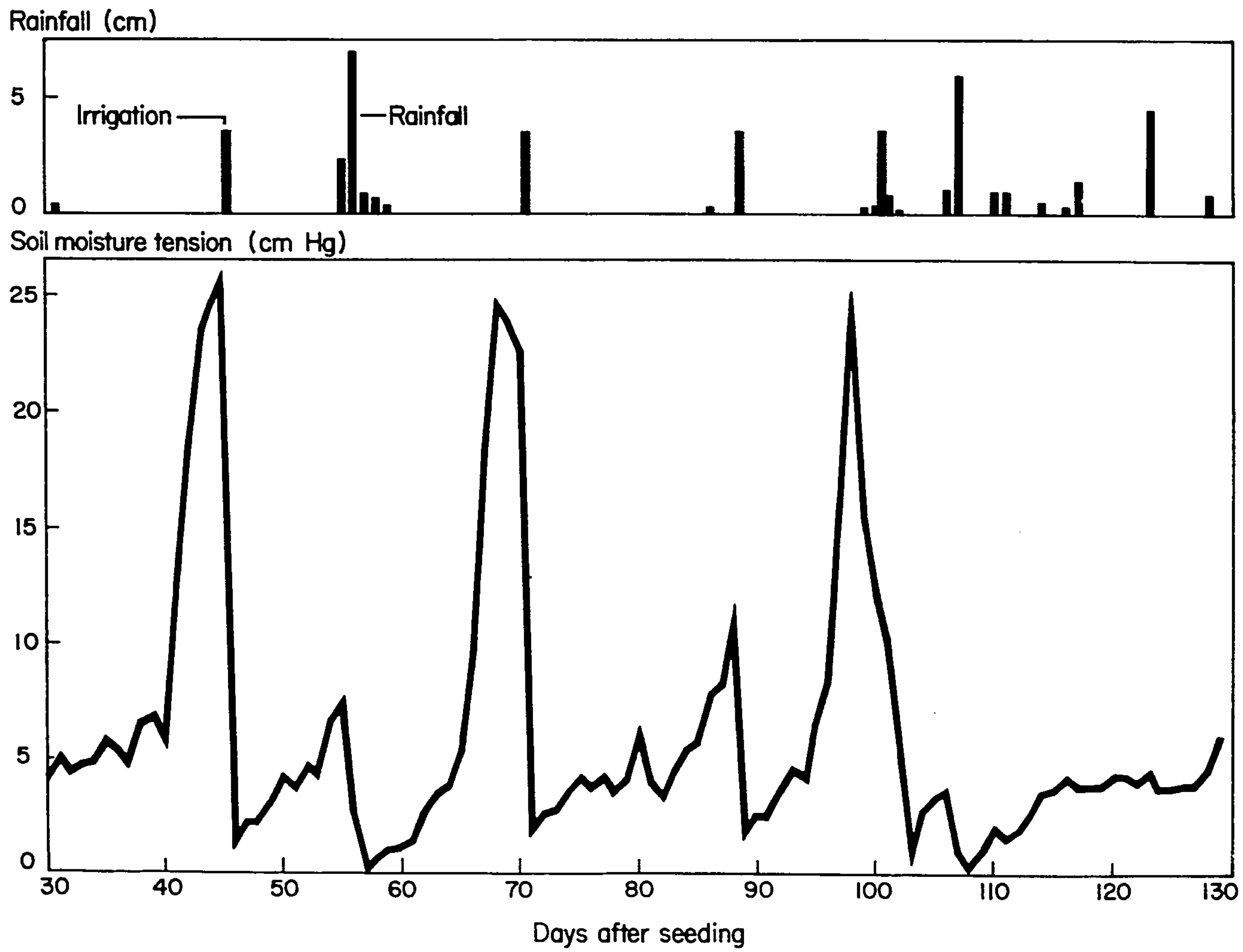

Fig. 8. Soil moisture tension and rainfall as a function of time during the upland, furrow irrigated rice experiment. Irrigations are indicated by the vertical dark lines on the rainfall portion of the figure. Two irrigations were given in the first thirty days after seeding. The average amount of water applied per irrigation was 3.4 cm. IRRI, 1971 dry season (H. K. Krupp and M. L. Bhendia, unpublished).

At no time did the soil moisture tension at the 10 cm depth exceed 0.33 bar ("field capacity") and the 20 and 30 cm depths always had even lower tension (Fig. 8).

This experiment with IR20 indicates that furrow irrigation of nonpuddled rice does not provide more efficient water use. But the use of different varieties, a more intensive irrigation schedule, or a modified planting method may yet show nonpuddled furrow irrigation of rice to have some benefit in terms of improving the water-use efficiency of rice.

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Water stress effects in flooded tropical rice

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ABSTRACT

Moisture stress often limits economical and stable yields of rainfed rice.

On the montmorillonitic Maahas clay soil, grain yields of IR8 and IR5 were less sensitive to growth stage at which moisture stress occurred and more sensitive to intensity and duration of moisture stress, while the tall variety, H-4, was sensitive to moisture stress during the reproductive and ripening stages as well as to intensity and duration of moisture stress. Our data indicate that moisture stress effects should be related to variety rather than to varietal type and growth characteristics of rice varieties. The growth durations of rice varieties were increased with increased stress level and the relationships between moisture stress and stage of the crop may depend on growth duration of the variety among other factors.

Current results indicate that soil moisture tension as low as 15 cb was enough to reduce grain yield of rainfed flooded (lowland) rice. Part of the reduction in grain yield is due to the loss of nitrogen under alternately dry and wet conditions which prevailed in the plots subjected to various stress levels.

The improved varieties, IR20, IR22, and IR24, consistently outyielded the traditional varieties Peta, Sigadis, and Intan, at all stress levels up to 33 cb. At most stress levels, however, the grain yields were higher with higher nitrogen levels, and more so with improved varieties than with traditional varieties.

INTRODUCTION

About 80 percent of rice-growing area in the world depends on rain for water. Most of this nonirrigated rice is grown in paddies, rather than in upland fields. Barker (1970) classified rice growing areas in South and Southeast Asia according to land and water management systems (Table 1). In these rainfed areas, the paddies often become dry and the crop suffers from various degrees of moisture stress. Although rice can grow under upland, lowland, and deep-water conditions, stable high yields occur only under continually flooded conditions. The factors limiting the grain yields of rainfed, flooded rice are similar to those described for upland rice (De Datta and Beachell, 1972). Moisture stress is perhaps the chief factor that limits economical and stable yields of rainfed rice.

The moisture stress effects on rice or any other plant relate to result from the function of water within the plant. Four important functions of water: (1) water is a vital constituent of cell protoplasm; (2) water is a reactant or reagent in chemical reactions (e.g., in photosynthesis, water + carbon dioxide + energy $\longrightarrow$ carbohydrate); (3) water is a solvent for organic and inorganic solutes and gases facilitating their translocation within the plant; and (4) water gives mechanical strength to plants by producing turgidity (a flaccid, water-stressed plant is much less rigid than a fully turgid plant). Despite these important functions, the plant uses less than 5 percent of the water taken up in the above roles (Kramer, 1969). The rest of the water is lost through transpiration from the plant leaves.

Low water supply rates and high water loss rates cause a decrease in plant water content which results in the development of plant moisture stress.

The specific effects of moisture stress on the physiology of the rice plant are not established. In upland crops, however, moisture stress decreases the rate of photosynthesis. Respiration rates also decrease but less rapidly than photosynthetic rates. Thus, decreased production of dry matter in water-stressed plants results both from a decrease in photosynthetic rate and also an increase in the ratio of respiration to photosynthesis. Occasionally, respiration rates greater than those in well-watered controls have been observed but the observations are not well established. The major cause of decrease in photosynthetic rate is the closing of the stomates in water-stressed plants which prevents the exchange of carbon dioxide and oxygen between the chloroplasts and the atmosphere.

Water stress affects cell division and cell enlargement. Both are slowed when plant is subjected to moisture stress. Apparently, cell division is less sensitive to water deficiency than cell enlargement. Kramer (1969) summarized the available information on the effects of moisture stress in plant growth.

The physiological basis for increase in rice yield under continual submergence than under upland conditions is not clear. Possibly, the differences in the internal water balance under the two land and water management practices could explain the physiology and growth of the rice plant. Thirty years ago, Cralley and Adair (1943) reported that rice plants grown on continually submerged plots were taller, had more tillers and produced significantly higher grain yields and higher grain-straw ratio than plants grown on plots kept moist. Based on work in California, Senewiratne and Mikkelsen (1961) reported grain yield was 53 percent lower under nonflooded condition compared with flooded condition. Chaudhry and McLean (1963) observed that nonflooded conditions caused delayed flowering, high percentage sterility, and, consequently, low yield. Jana and Ghildyal (1967) found that tissues remained highly hydrated under flooded conditions. As the water content of the soil was reduced from 3 to 6 cm flooding to 50 to 60 cm mercury tension, the water content in tissues decreased by 10 percent.

A decrease in tissue hydration in different soil-water regimes and under different evaporation demands indicates that the rate of flow of water from the soil to plant is not high enough to meet the potential transpiration demand. In unsaturated soil, a reduction in the capillary conductivity creates a water deficit in the plant accompanied by loss of turgor. As the water in soil increases the positive hydraulic head, the water moves faster in soil pores and root cortex under increased hydrostatic pressure gradients accompanied by a rapid uptake of water by plant tissues. Similarly, under high evaporative demand and unsaturated soil, the tissue hydration reaches the lowest level.

These observations partially explain the variation in rice yields under similar water management practices in different agrometeorological conditions. So the increased tissue hydration and water use due to increased hydrostatic pressure in soil appear to be important influences on the growth of flooded rice. Halm (1967) found that rice varieties grew better under submerged and unsaturated soil conditions than in the non-flooded soil at field capacity. Moolani and Sood (1967) suggested that for rice, unlike other crops, the upper limit of the range of available moisture is not field capacity. Recently, Jana and De Datta (1971) observed that the optimum soil moisture condition for high grain yield and nitrogen response in upland rice is in between the maximum water holding capacity and the field capacity.

The effects of moisture stress are widely believed to be more pronounced at some growth stages than others in many crops. Water stress reduces crop yield much more when it occurs during these "critical" stages than when it occurs at other times (Chang,1968). Salter and Goode (1967), in a summary of the effects of water stress on grain yield, concluded that cereal crops show a marked sensitivity to stress during the formation of the reproductive organs and during flowering. Slatyer (1969) states that cereal crops can withstand and recover from mild or relatively brief periods of water stress if favorable conditions are quickly reestablished. With more severe water stress, the preflowering stage is the least sensitive while the anthesis and grain-filling stages are the most sensitive. Matsushima (1962) reported that rice is most sensitive to water stress from 20 days before heading to 10 days after heading. Van de Goor (1950) reported earlier that flooded rice uses the maximum amount of water at this time. That suggests that the critical period for water stress coincides with the period in which plants use the most water.

If the "critical" stages of water requirement of the rice crop were known, the optimum allocation of limited water supplies could be easily decided. Furthermore, the planting dates for rainfed flooded or upland rice can be established so that the "critical" stages occur during the period of maximum rainfall probability.

Laude (1971) pointed out that greater attention should be directed to plant's response after the plant has undergone stress, for there is less information on this than on behavior of stress.

Furthermore, varieties are needed that will not only perform well in harsh conditions but that will also respond vigorously to increasing favorable environment at the same or different locations. Selection for such dynamic characteristics should perhaps be given as much attention as selection for specific morphological features (D.J. McDonald, personal communication).

MOISTURE STRESS EFFECTS AT DIFFERENT GROWTH STAGES

During the 1969 wet season, moisture stress treatments (Fig. 1) were imposed at various growth stages in an experiment conducted on the montmorillonitic Maahas clay soil (pH 6.5; organic matter 2%) at the IRRI farm. Tensiometers were installed 15-cm deep in the plots subjected to stress. Irrigation was stopped 1 week before the beginning of the stress period. The soil moisture tension was allowed to reach 50 centibars (cb), after which 5 cm of water was added to the plot. One moisture stress treatment (No. 8) was imposed by adding water only when the plants started to wilt, which was indicated by the rolling of the young leaves.

Table 2 shows the grain yield and water use of IR8. In both tanks with bottoms and tanks without bottoms the yield was highest in the continually flooded plots. When moisture stress was allowed to develop only between the maximum tillering and the heading stages, the grain yields remained relatively high. Moisture stress throughout the entire growth period (Treatment 8) reduced the yield to one quarter of the yield of the continually flooded treatment. The results indicated that the reduction in grain yield of IR8 grown on Maahas clay was more related to the intensity and duration of moisture stress than to the stages of plant growth at which the stress occurred (Krupp et al.,1971).

In 1970, a greenhouse experiment was conducted with IR8, IR5, and a traditional variety, H-4, to evaluate the data from the field experiment. The water-stress treatments were the same as those in the field experiment. In pots subjected to water stress, 2 cm of water were added when the moisture tension was 50 cb at 15 cm depth. In the continually flooded pots, water was added daily to keep the depth at 2.5 cm.

In the reproductive and maturing phases, IR5 appeared less sensitive to moisture stress than the other two varieties. Both H-4 and IR8 when subjected to stress from panicle initiation to heading and from heading to maturity showed significant yield reductions while the yield of IR5 remained relatively constant (Fig. 2). Moisture stress from transplanting to maximum tillering (Treatment 2) decreased the contribution of panicle number to the grain yield through a reduction in tillering (Table 3). Moisture stress from transplanting to panicle initiation (Treatment 3) and from transplanting to heading (Treatment 4) decreased the number of filled grains per panicle again, while the number of tillers was not affected. For IR5, the number of filled grains per panicle

Table 1. Estimate of rice crop area by specified land type in South and Southeast Asia (Barker, 1970).

	Effective crop area (%)		Production (%)	
Irrigated				
Single cropped	10		15	
Double cropped	10		25	
Total		20		40
Rainfed				
Deep water	10		8	
Other	50		42	
Total		60		50
Upland total		20		10
		100		100

Table 2. Grain yield and water use of IR8 grown in tanks with and without bottoms. IRRI, 1969 dry season (Krupp et al., 1971).

Treatment number	Stress period*	Time to maturity (days)	Tanks with bottoms		Tanks without bottoms	
			Yield (g/m^2)	Water use (mm)	Yield (t/ha)	Water use (mm)
1	None	123	910	618	7.16	1147
2	T-MT	131	770	653	5.84	1435
3	T-PI	133	730	632	4.63	1438
4	T-H	145	720	558	3.76	1121
5	MT-H	127	830	593	6.31	1178
6	PI-M	124	760	528	5.87	720
7	H-M	124	840	544	6.10	904
8	T-M	152	170	257	1.84	432

*T = transplanting; MT = maximum tillering; PI = panicle initiation; H = heading; M = maturity.

Table 3. Yield components of the three rice varieties subjected to moisture stress at different growth stages in the greenhouse experiment (Krupp et al., 1971).

Stress period*	Yield component				
	Tillers (no./hill)	Panicles (no./hill)	Filled grains (no./panicle)	100-grain weight (g)	Unfilled grains (%)
			IR8		
None	7.2	7.2	89	2.55	22
T-MT	4.8	4.4	114	2.57	24
T-PI	4.0	3.9	116	2.52	17
T-H	4.1	3.5	91	2.77	17
MT-H	8.2	7.7	76	2.50	18
PI-M	7.3	6.5	67	2.50	20
H-M	7.7	7.4	79	2.40	34
T-M	7.8	6.2			
			IR5		
None	8.6	8.5	112	2.67	10
T-MT	5.5	5.4	128	2.63	10
T-PI	4.7	4.7	101	2.63	16
T-H	5.4	5.4	89	2.61	15
MT-H	9.2	9.2	84	2.53	8
PI-M	9.3	9.0	92	2.55	14
H-M	9.5	8.7	109	2.43	16
T-M	4.7	4.2			
			H-4		
None	8.2	7.6	150	2.57	21
T-MT	4.2	4.1	170	2.73	25
T-PI	4.0	4.0	148	2.60	15
T-H	3.5	3.2	118	2.52	27
MT-H	6.8	6.5	95	2.75	28
PI-M	8.0	7.3	75	2.53	46
H-M	10.9	9.8	69	2.32	53
T-M	3.5	1.4			

*T = transplanting; MT = maximum tillering; PI = panicle initiation; H = heading; M = maturity.

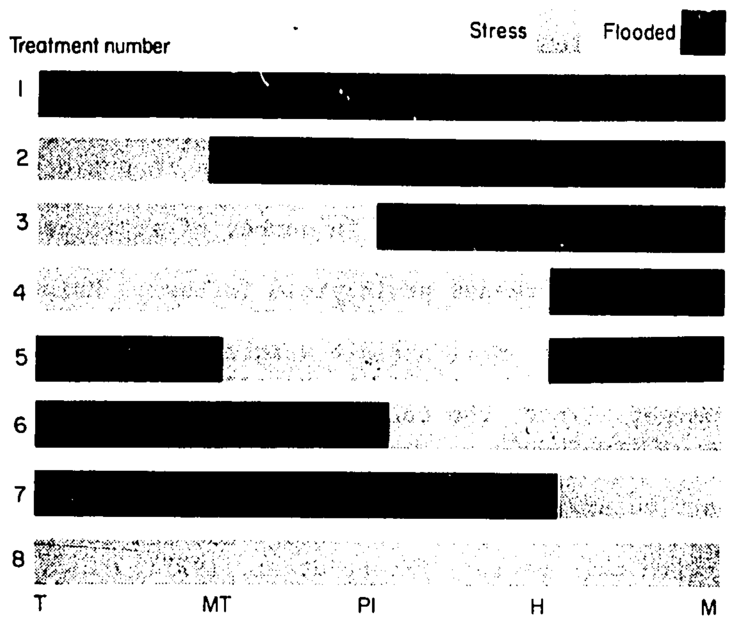

Fig. 1. The moisture stress treatments (T = tillering, MT = maximum tillering, PI = panicle initiation, H = heading, and M = maturity).

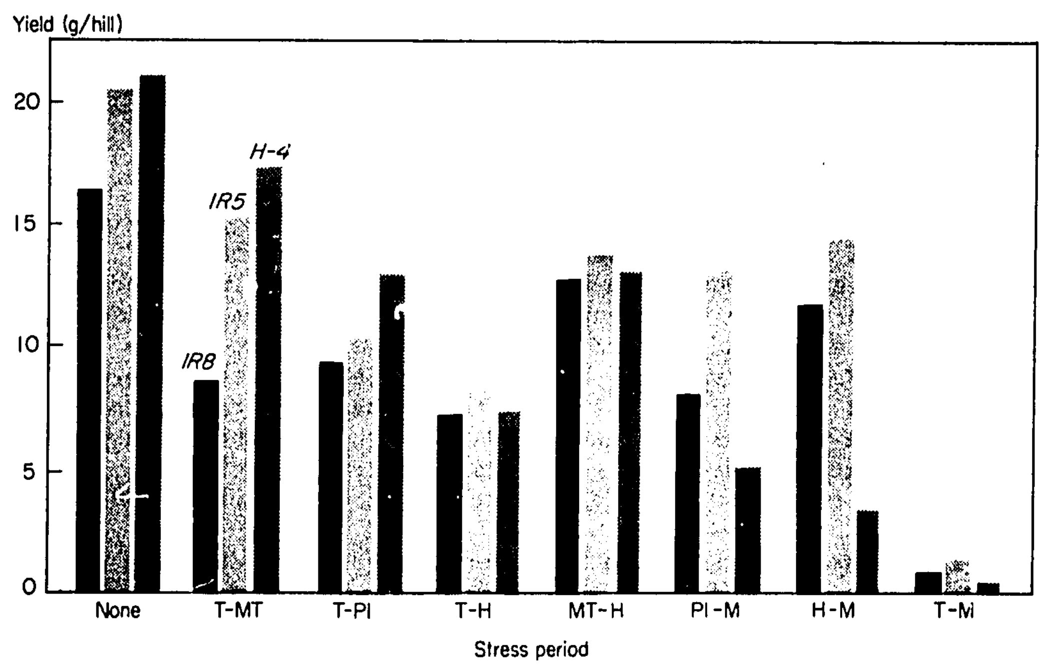

Fig. 2. Grain yield of three varieties as affected by moisture stress at various physiological growth stages.

decreased from 128 to 83, as stress was prolonged from transplanting to maximum tillering, to panicle initiation, and to heading, respectively (Table 3).

It appears that moisture stress early in the growth of the rice plant reduces tillering. This results in a reduction in grain yield. If the stress is relieved before reproductive phases begin, some recovery in grain yield occurs through an increase in number of grain per panicle. But if the stress period extends to the reproductive phase, a reduction in number of filled grains decreases grain yield further. Moisture stress in the late vegetative and reproductive phases (Treatment 4 and 7) results in a decrease in the contribution of panicle weight to grain yield through a reduction in number of grains per panicle, percentage of filled grains, and the 100-grain weight. Thus, the contribution of panicle number increases in the later treatment.

H-4 seems particularly sensitive to moisture stress in the grain filling period. Both the filled grain percentage and the 100-grain weight decreased markedly with this variety (Krupp et al., 1971).

EFFECTS OF MOISTURE STRESS ON GROWTH DURATION AND WATER USE

Moisture stress immediately after transplanting increased the growth duration of IR8 (Table 2) in the field experiment. For example, 123 days was required from transplanting to harvest in the continually flooded plot while 145 days was required when the crop was subjected to moisture stress from transplanting to heading (Table 2). The increase in growth duration due to moisture stress caused an increase in the absolute amount of irrigation water required.

RELATIONSHIP OF WATER STRESS TO YIELD

Figure 3 shows the relationship between the relative grain yield and the duration of the water stress treatment on IR8 in both the field and the greenhouse experiments. In both experiments, there was a negative linear relationship between the relative grain yield and the duration of the stress period, although the straight lines had different slopes for each experiment. For each variety, the relative yield for the treatment (No. 5) with stress from maximum tillering to the heading stages, falls significantly above the straight line of best fit to the other data points (Fig. 3). These data suggest that grain yield is less affected by moisture stress at this growth stage than at the other stages.

The relationship between the relative yield and the duration of the moisture stress period for IR5 and H-4 is shown in Figure 4. A similar straight-line relationship is obtained with IR5 indicating no growth stage is more critical than the others for susceptibility to moisture stress. This finding does not agree with the observations of other workers such as Matsushima (1962), Senewiratne and Mikkelsen (1961) who say that rice is most sensitive to water stress at the panicle initiation stage. But our results with the tall variety, H-4, do. IR5 was less sensitive to

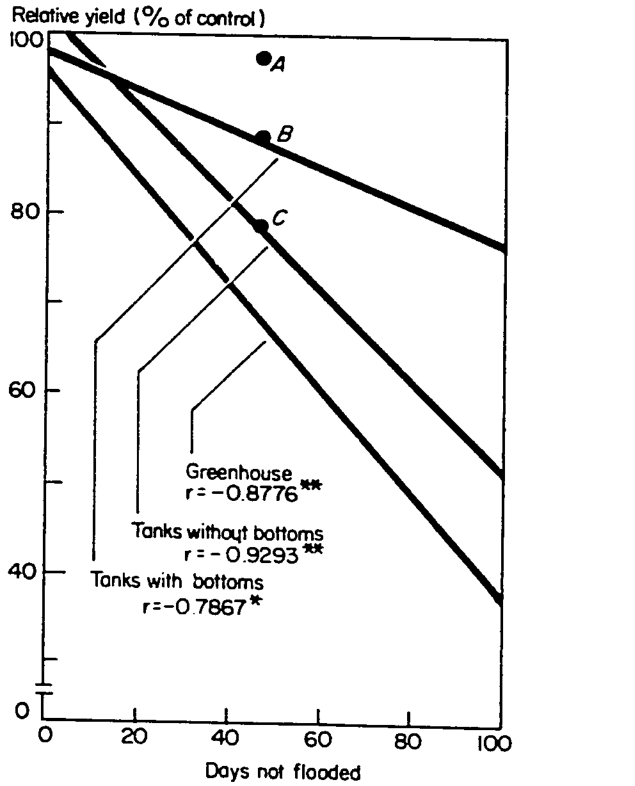

Fig. 3. Relative grain yield as a function of the number of days soil was not flooded. (Yield from treatments with water stress from maximum tillering to heading in tanks with bottoms is shown by point A in tanks without bottoms by point B, and in the greenhouse by point C). (Krupp et al., 1971).

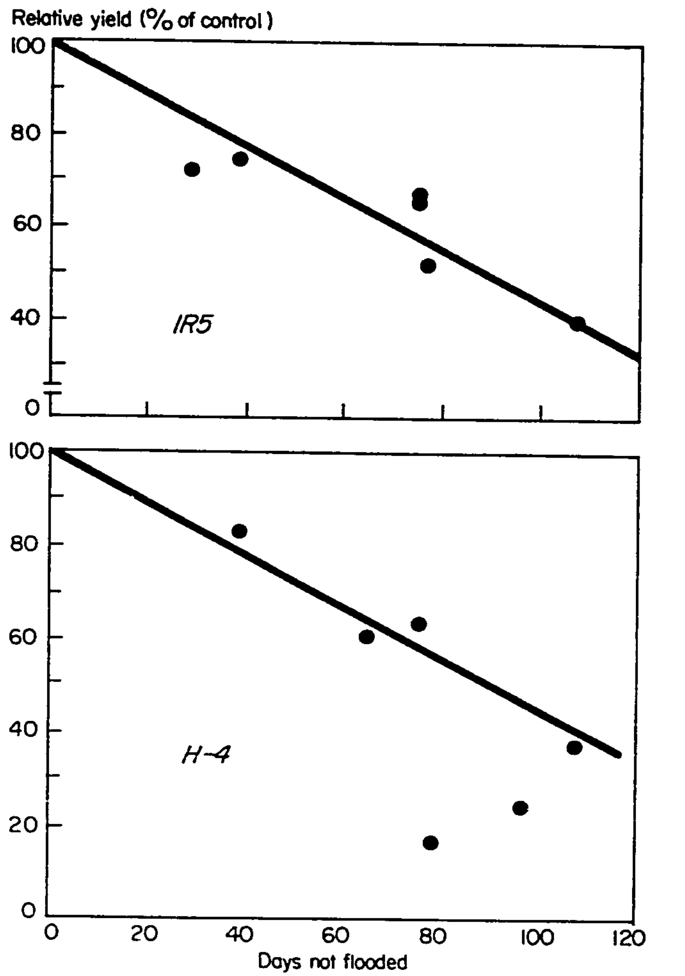

Fig. 4. Relative grain yield of IR5 and H-4 in the greenhouse as a function of the number of days the soil was not flooded. (Krupp et al.,1971

the growth stage at which the moisture stress occurred and more sensitive to duration of moisture stress while H-4 was sensitive to moisture stress during the reproductive and ripening stages as well as to intensity and duration of moisture stress. Our results with H-4 are similar to what was obtained with the Malaysian traditional rice varieties used by Matsushima. These results should not be extrapolated for all traditional varieties, however. For example, in one study, Sigadis, a heavy-tillering traditional variety from Indonesia, appeared to be more tolerant to drought conditions than H-4 (S.K. De Datta, unpublished). Similarly, some improved varieties like IR5 and to some extent, IR8, have higher drought tolerance than IR20. Varieties like IR5 will recover faster from low level moisture stress for a short period than varieties like IR20 or IR22. Nevertheless, the grain yields of IR5 and IR8 will be reduced if severe moisture stress (50 cb and above) occurs for 2 weeks or more at any stage of the growth.

Thus, each variety or selection should be evaluated separately for their tolerance to moisture stress. Any generalization in varietal tolerance to moisture stress according to plant type and growth characteristics should be avoided until more is known about physiological characteristics and morphological traits associated with drought tolerance in rice varieties.

VARIETAL DIFFERENCE IN MOISTURE STRESS EFFECTS AT DIFFERENT GROWTH STAGES

In an experiment during the 1972 dry season, 30 varieties or lines were divided into groups of 10 according to their growth durations under continually flooded condition and were subjected to soil moisture tension of 50 cb at the vegetative or reproductive stages of the crop. The stressed crops (50 cb) were compared with continually flooded (0 cb) crops.

The growth durations of these lines were changed when the varieties were grown under high stress conditions (Table 4, 5, and 6).

In the early maturing group, IR790-28-1 and the three IR1561 lines tested produced high stable yields in all moisture stress treatments (Table 4). Averaging grain yields of all varieties and lines shows that moisture stress at either vegetative stage or reproductive and ripening stages reduced grain yields significantly compared with continually flooded plots.

The grain yields of varieties with intermediate growth duration were significantly reduced only when the crop suffered from moisture stress during the reproductive and ripening stages similar to what was reported by Matsushima (1962). The experimental lines which suffered least due to moisture stress during reproductive and ripening period were IR579-92-2, IR665-8-3, and IR841-99-1 (Table 5).

The late maturing lines behaved the same as early maturing lines, i.e., grain yields were reduced equally when the crops suffered from moisture stress irrespective of growth stages (Table 6) similar to our

Table 4. Varietal (early maturing lines) response to soil moisture stress. IRRI, 1972 dry season.

Variety/ lines	Growth duration (days)	Grain yield (t/ha)		
		Stress (50 cb) during vegeta- tive period	Stress (50 cb) during reproductive and ripening periods	Continual flooding
IR747 B_2-6-3	99-103	3.9	4.3	5.9
IR1561-69-6	99-114	5.4	5.6	7.3
IR1561-149-5	99-114	5.0	5.7	7.8
Padma	99-114	5.1	3.8	4.5
Ratna	99-114	4.2	5.0	6.9
IR1561-38-5	114	5.7	6.0	7.4
IR480-5-9	121-131	5.0	4.8	6.3
IR790-28-1	121-131	5.7	6.0	6.8
IR841-5-1	121-131	5.3	4.3	7.0
IR1110-43-3	121-138	5.2	6.0	7.9
Mean		5.0a	5.1a	6.8b

LSD 5% (for each variety) = 1.8 t/ha

Note: Any two means followed by the same letter are not significantly different at the 5% level.

Table 5. Varietal (intermediate in growth duration) response to soil moisture stress. IRRI, 1972 dry season.

Variety/ lines	Growth duration (days)	Grain yield (t/ha)		
		Stress (50 cb) during vegeta- tive period	Stress (50 cb) during reproductive and ripening periods	Continual flooding
M1-48	114	4.6	1.1	2.1
Taichung (Native)1	121	6.8	4.0	6.3
CR 36-148	114-131	6.8	3.9	6.0
IR262-43-8	114-131	6.0	4.6	6.3
IR665-8-3	114-131	6.7	4.5	6.7
IR841-99-1	121-138	6.9	5.0	7.2
IR478-68-2	131-138	4.9	3.0	5.0
IR667-142-2	131-138	5.6	4.1	6.2
IR579-92-2	131-138	7.5	5.8	7.4
IR1093-148	131-142	6.1	3.0	5.7
Mean		6.2b	3.9a	5.9b

LSD 5% (for each variety) = 1.8 t/ha

Note: Any two means followed by the same letter are not significantly different at the 5% level.

Table 6. Varietal (late maturing lines) response to soil moisture stress. IRRI, 1972 dry season.

Variety/ lines	Growth duration (days)	Grain yield (t/ha) Stress (50 cb) during vegetative period	Stress (50 cb) during reproductive and ripening periods	Continual flooding
IR22	114-131	5.2	4.6	6.7
IR127-80-1-10	114-131	4.4	3.3	7.0
IR20	121-131	6.2	4.8	7.5
Jaya	121-138	5.1	4.7	6.6
IR8	131-138	5.5	5.5	8.2
IR24	131-138	4.7	5.6	7.7
IR937-55-3	131-138	5.0	5.5	7.8
IR1531-73-5	131-138	3.7	2.6	4.4
IR1531-93-3	131-138	5.3	3.7	7.0
C4-63 G	138-142	4.4	4.3	4.2
Mean		5.0a	4.5a	6.7b

LSD 5% (for each variety) = 1.8 t/ha

Note: Any two means followed by the same letter are not significantly different at the 5% level.

Table 7. Effect of irrigation at different soil moisture tensions on the grain yield and water use efficiency of two rice varieties. IRRI, 1972 dry season.

Variety	Soil moisture tension (cb)	Duration (days)	Water use (mm)	Grain yield (t/ha)	Irrigation efficiency (kg/mm of water)
IR20	Continually flooded	100	900	6.0	6.7
	15	110	500	4.1	8.1
	34	110	400	4.2	10.5
	52	110	300	3.5	11.4
M1-48	Continually flooded	102	810	4.3	5.3
	15	95	490	2.5	5.1
	34	95	390	2.2	5.6
	52	95	290	2.7	9.1

earlier results (Krupp et al., 1971). All four IRRI-named varieties tested and IR937-55-3 were among the better performers in the late maturing group.

Thus the relationships between moisture stress and stage of the crop may depend on growth duration of the variety among other factors. Here again, the relationships between growth durations of rice varieties and resistance to soil moisture stress will depend on the nature of rainfall distribution for that season. The results obtained from a dry season with controlled irrigation may not be valid for the wet season. Furthermore, if the rainfall distribution is more uniform during the first 90 to 100 days during the wet season, the early maturing varieties should have advantage over later varieties. On the other hand, if the rainfall distribution is erratic during the early part and more uniform during the later part of the rainy season, the medium to late maturing varieties should perform better than early varieties. Until a variety is developed which is drought tolerant at all stages of growth, farmers should consider planting at least two varieties with different growth durations to avoid a complete crop failure due to prolonged moisture stress.

EFFECTS OF MOISTURE STRESS LEVELS ON IR20 and M1-48

An experiment was conducted during the 1972 dry season to study the effects of moisture stress (0 cb, 15 cb, 34 cb, and 52 cb) on the water use, growth characteristics, and grain yield of a lowland variety, IR20, and an upland variety from the Philippines, M1-48. For zero soil moisture tension, plots were kept under 5 cm of water throughout the crop season.

Figure 5 shows the actual soil moisture tensions recorded in the plots subjected to 15, 34, and 52 cb treatments at different growth stages of the crop. The total amount of water used decreased with irrigation applied at soil moisture tensions of 15 cb, 34 cb, and 52 cb compared with continually flooded plots (Table 7). The total water use was reduced to about 50 percent when the crop was irrigated in response to 15 cb tension, by 60 percent at 34 cb tension, and by 74 percent at 52 cb tension in comparison to continually flooded control. When the soil moisture stress was high, M1-48 matured earlier than in the continually flooded treatment while IR20 matured later than under continual flooding.

Grain yields decreased as irrigation was delayed to allow more extensive soil drying. The maximum yield reduction occurred between saturation and 15 cb treatment (Fig. 6). No further reduction in grain yield occurred beyond 15 cb soil moisture tension. There was more $NH_4^+ + NO_3^-$-N present in continually flooded plots than under the alternately wet and dry soil conditions that prevailed in plots subjected to various soil moisture tensions (Fig. 7). Plants appeared greener in continually flooded plots suggesting higher nitrogen uptake than under conditions of moisture stress.

The grain yield differences between conditions of adequate water supply (0 cb) and conditions of moisture stress (15 cb and above) may be partly due to the differences in nitrogen status in plants and soil.

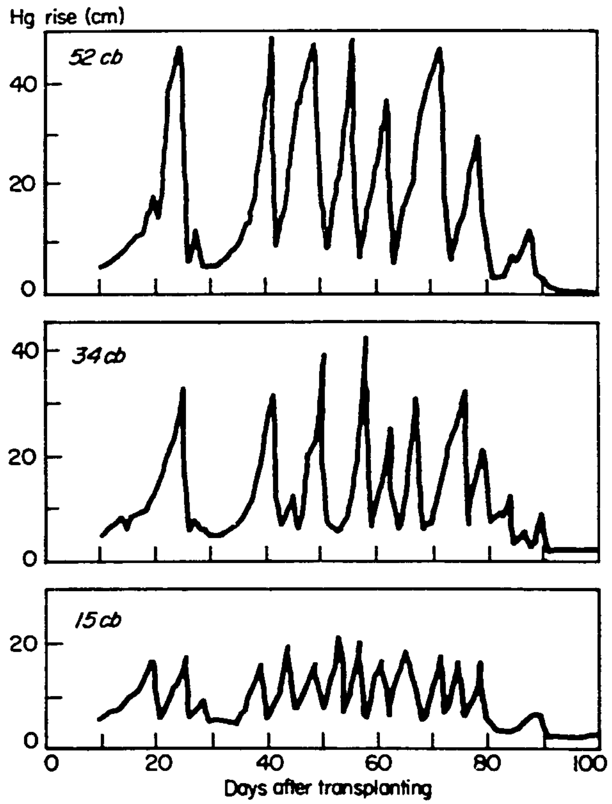

Fig. 5. Soil moisture tension at different growth stages. IRRI, 1972 dry season.

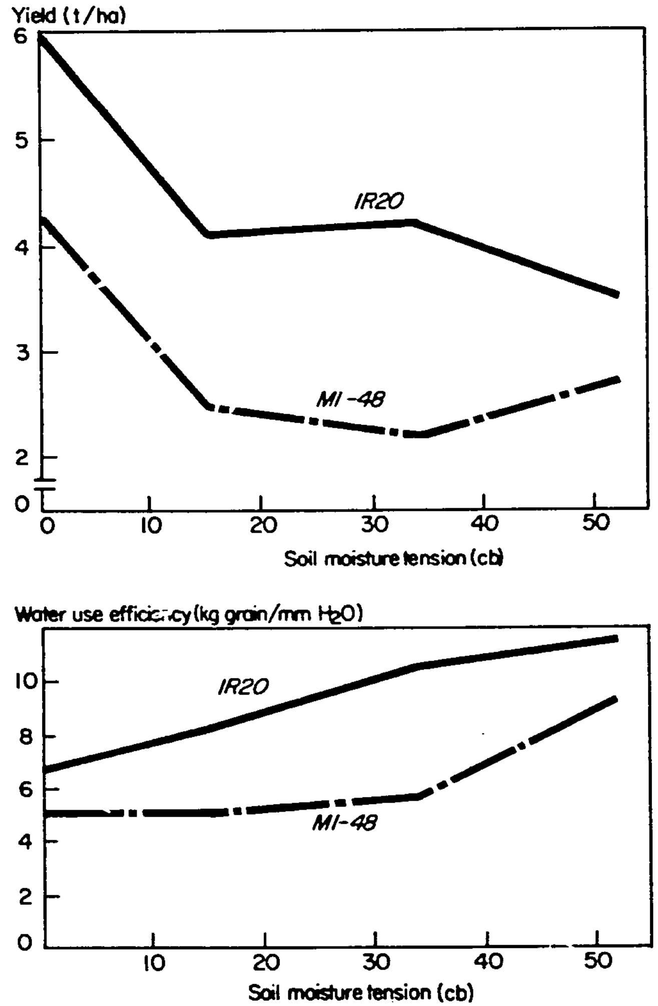

Fig. 6. Grain yield and water-use efficiency as affected by soil moisture tension at time of irrigation. IRRI, 1972 dry season.

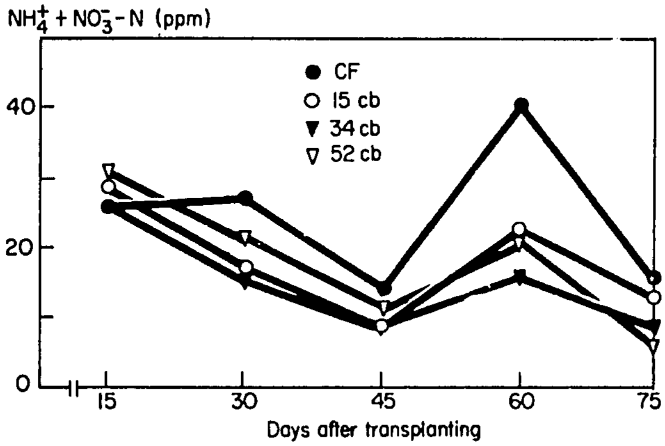

Fig. 7. Effect of soil moisture stress on the concentration of NH_4^+ and NO_3^--N. IRRI, 1972 dry season.

Table 8. Response of traditional and improved varieties to levels of moisture stress and nitrogen. IRRI, 1972 dry season.

Nitrogen applied (kg/ha)	Grain yield (t/ha)					
	Traditional variety			Improved variety		
	Intan	Sigadis	Peta	IR20	IR22	IR24
	Continually flooded (cb)					
0	1.8	4.1	4.3	5.0	4.2	5.9
50	2.2	4.9	4.3	6.0	5.9	6.6
100	2.0	3.2	2.8	6.0	6.5	7.2
Mean	2.0	4.1	3.8	5.7	5.5	6.6
	Moisture stress (16 cb)					
0	2.3	4.1	3.9	4.4	5.3	6.0
50	3.0	5.0	4.6	5.7	6.2	7.0
100	3.5	5.5	5.1	6.2	6.4	7.5
Mean	3.0	4.9	4.5	5.4	6.0	6.8
	Moisture stress (33 cb)					
0	1.2	3.5	2.2	4.4	4.3	4.7
50	2.6	3.8	3.6	5.1	6.6	6.3
100	2.0	5.3	3.8	5.2	7.6	6.8
Mean	2.0	4.2	3.2	4.9	6.2	5.9

The grain yields of IR20 and M1-48 were reduced by 30 percent when the soil moisture tension varied from as low as 15 cb and as high as 52 cb compared with continually flooded control. For upland rice, Jana and De Datta (1971) found that the optimum moisture requirement lies between field capacity and maximum water holding capacity. Our current results with flooded rice indicate however, that soil moisture tension as low as 15 cb is enough to reduce grain yield (Fig. 6). These data suggest that the upland variety, M1-48, does not have a higher resistance to soil moisture stress than the lowland variety, IR20. IR20 is not drought resistant (S.K. De Datta, unpublished), but despite that it yielded more than M1-48 at all soil moisture tensions.

MOISTURE STRESS EFFECTS ON IMPROVED AND TRADITIONAL VARIETIES

In earlier experiments (H.K. Krupp and M.L. Bhendia, unpublished), when improved, lodging-resistant rice varieties were grown under sub-optimal irrigation regimes, the grain yield was reduced. The traditional varieties showed opposite effects primarily because they lodge less often under low fertility and poor moisture level.

During the 1972 dry season, when the rice varieties were subjected to stress (0 cb, 16 cb, and 33 cb), the improved varieties, IR20, IR22, and IR24 outyielded the traditional varieties, Peta, Sigadis and Intan, at all stress levels (Table 8). At most stress levels, the grain yields were generally higher with higher nitrogen levels, more so with improved varieties than with traditional varieties.

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An analysis of some factors affecting rice yield response to water

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ABSTRACT

Yield response data from 3 dry season experiments were put together in an attempt to explain the field performance of some improved varieties. The analysis for IR5 and several other varieties shows the potential for developing varieties that could effectively respond to high nitrogen levels even under conditions of poor water supply. The analysis brings out short growth duration, vegetativeness, and high fertilizer efficiency as three criteria for varietal selection against drought. For inadequately irrigated areas, relatively higher yields are associated with climatic factors that contribute to low evaporative demand conditions.

Management of limited water supplies in irrigation systems requires sound knowledge of the relationships between crop yield and water use. To optimize economic returns, the way rice yields respond to varying conditions of water supply should influence the way in which water is distributed in an irrigation system, as well as the choice of variety and use of inputs at the farm level. For best results rice should be provided with at least saturated soil conditions (Aglibut et al., 1956; Reyes,1972). But the water environment in which rice is grown varies tremendously throughout Asia. Most tropical rice is grown under less than favorable water supply conditions. In the forseeable future, a large portion of the rice area in South East Asia probably will remain inadequately supplied with water. Thus, since the new improved varieties were developed under favorable situation where water is not a limiting factor (International Rice Research Institute, 1969), the potential of the new rice technology has not been widely reached.

This paper investigates some factors that may contribute towards improving the performance of new varieties on farmers' fields. Specifically, it aims to evaluate the effects of climatic differences, varietal differences, and nitrogen fertilizer on the yield response of rice to water.

MATERIALS AND METHODS

Three field experiments were conducted on Maahas clay (pH 6.0; organic matter, 2%; total N, 0.14%; cation exchange capacity, 45 meq/100 g) at the IRRI experimental farm during the 1969, 1970 and 1971 dry seasons (Fig. 1).

The site was somewhat isolated from other plots and is comparatively higher in elevation. It was chosen to minimize the effect of underground water movement on soil moisture conditions. Each of the 12 x 12 meter plots was bounded by a strip of corrugated galvanized iron sheets 45 cm in height and buried 30 cm. The metal enclosure was intended to control seepage to a level which approximates that for large planted areas.

In 1969, the water application treatments were 2 mm/day to 8 mm/day taken at 1 mm/day intervals, without replications; in 1970 the treatments were 4.5 mm/day to 8.0 mm/day taken at 0.5 mm/day intervals, without replication; and in 1971 the treatments were 4.0, 5.0, 6.0, 6.5, 7.0, and 7.5 mm/day, replicated twice. These treatments were applied regularly every fifth day in 1969 and 1971, and every seventh day in 1970, with the water application level being adjusted for rain that fell during the days before irrigation. Soil samples were taken 10 to 20 cm deep from each treated plot on the day before each irrigation schedule. Soil moisture content was estimated using the gravimetric technique (oven-dry basis). The soil moisture readings were related to soil moisture tension as presented in Fig. 2.

In 1969 only variety IR8 was planted. In 1970 IR8 plus IR22, C4-63G and MI-48 plus the experimental lines IR478-68-2 and IR579-48-1 were tested. The 1971 experiment included IR8 plus IR5 and the line IR773A1-36-2. In both the 1969 and 1970 experiments, 100 kg/ha N was applied basally, while the 1971 experiment had three levels of nitrogen applications: 0,50, and 100 kg/ha applied basally.

In all experiments 10-day old dapog seedlings (spaced at 25 x 25 cm) were used. The levels of other inputs and crop management were also kept constant and at high levels. Rat control was effected through an electrified wire fence around the experimental site. Handweeding was done twice (at 21 and 40 days after transplanting). The only change was in insecticide use In 1969 Diazinon granules, and Sevin and Folidol sprays were used, while Dolmix granules, and Mipcin and Folidol sprays were used in 1970 and 1971. These details are important in comparing different years in the study.

The yield response data from the experiments were separately analyzed with respect to effects of the climatic differences in 1969, 1970 and 1971 on the yield response of IR8 to varying levels of water input, effects of variety on the yield response of crops provided with 100 kg/ha of nitrogen during 1970 and 1971, average effect of nitrogen application for three varieties used in the 1971 experiment, and separate effects of three nitrogen application levels on the yield response of three varieties during the 1971 dry season.

The yield response data were fitted to the logistic equations (Rhode's method) model. This analysis involves the equation model,

$$Y_t = \frac{K}{1 + be^{-at}}$$

where $\underline{K}$, $\underline{a}$, and $\underline{b}$ are constant or parameters to be estimated and $\underline{t}$ is an index representing the water treatments, which are spaced at constant intervals

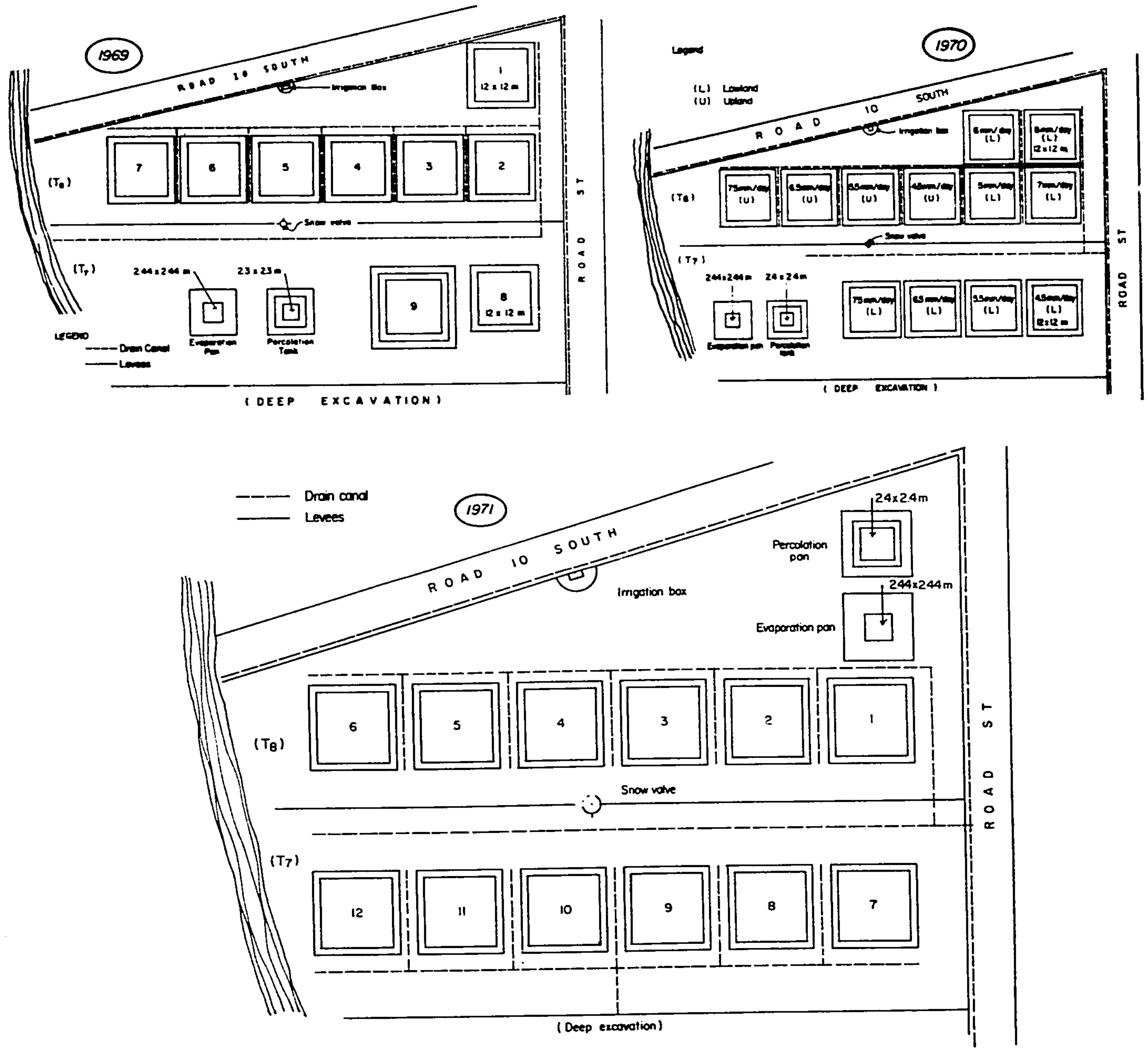

Fig. 1. Schematic layout of experimental area and plots at IRRI. Dry season, 1969, 1970, 1971.

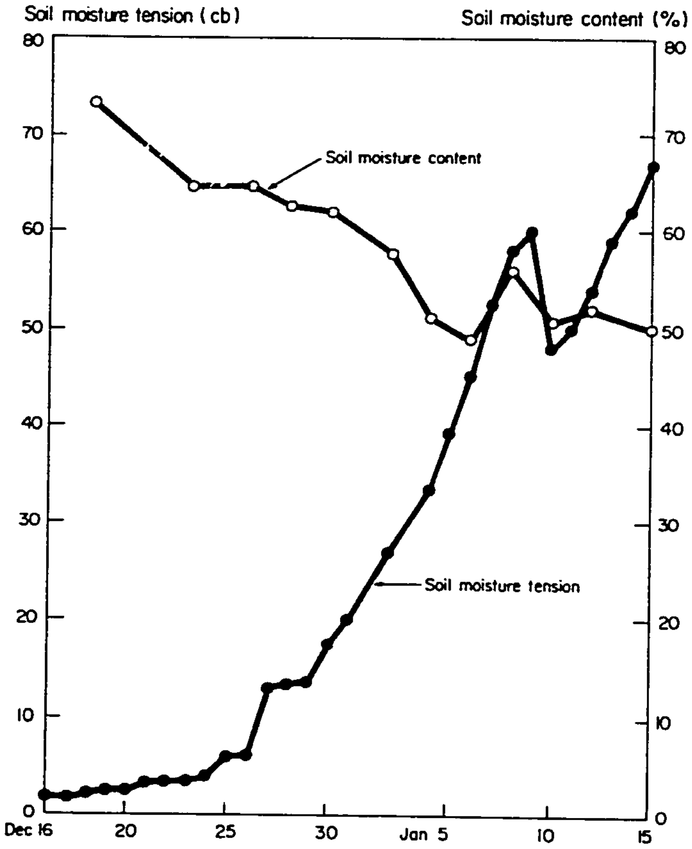

Fig. 2. Relationship between Irrometer readings and percent soil moisture content (oven dry basis, 15-cm depth) under unplanted field condition from Dec. 16 to Jan. 15, 1969, IRRI. (Irrometer readings are averages from three instruments.)

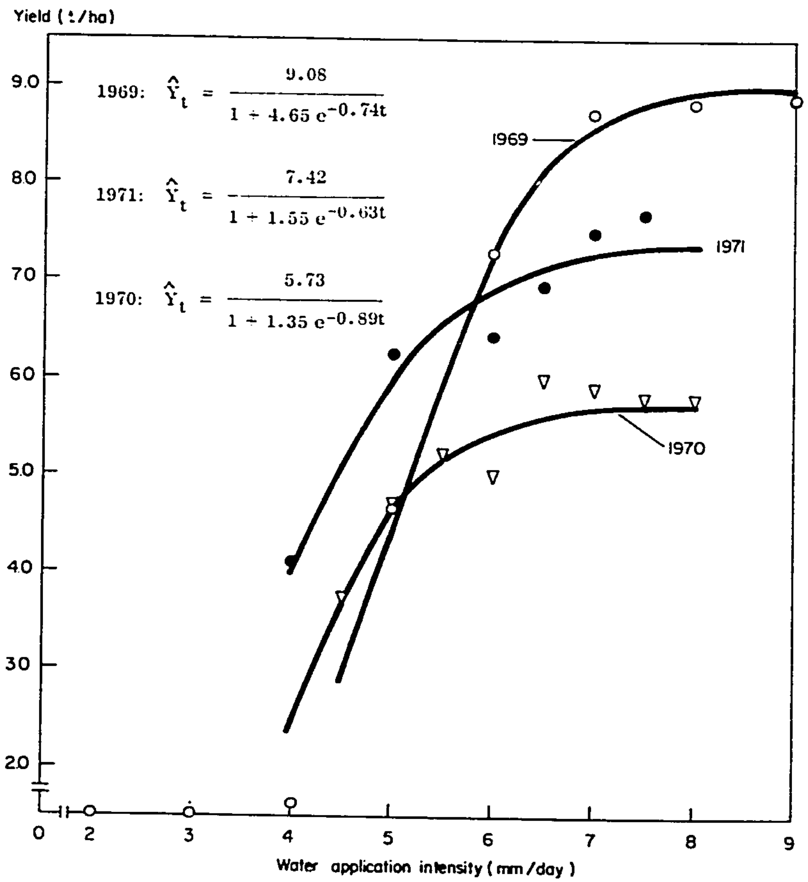

Fig. 3. The functional relationshipbs between rice yield and water application intensity for three IR8 crops (provided with 100 kg/ha N). IRRI, 1969, 1970, and 1971 dry seasons.

(t=1 for the lowest treatment t=2 for the second treatment,..., t= n for the highest treatment). The calculation procedures for obtaining the values of the parameters are described in detail by Croxton and Cowden (1955), Cowden (1947), and Nair (1964).

THE NATURE OF THE RICE YIELD - WATER USE RELATIONSHIP

The yield response to various levels of water application of IR8 in 1969, 1970 and 1971 are presented in Table 1. The functional fits from these data are presented in Figure 3. All three functions show that yields are extremely sensitive to low levels of water input, but that the critical level varies depending on the season. Above these critical water levels yields quickly approach asymptotic values.

The low yields appear to be related to the decline of soil moisture below soil saturation (Fig. 4, 5, and 6). Low water treatments decrease soil moisture through gradual field drying by providing small amounts of water at regular intervals. In 1969 soil moisture levels under most water treatments fell below field capacity. This is equivalent to 33.3 centibars of soil moisture tension. Figure 2 indicates that this tension occurs at approximately 50 percent soil moisture content. In 1970 and 1971, however, the soil moisture content for most water treatments did not fall below field capacity, but they did approach that level. Yield reduction in the 1970 and 1971 experiments affirm other findings that yields of puddled rice are reduced by soil moisture tensions as low as 15 cb (De Datta, 1972).

THE EFFECTS OF CLIMATIC DIFFERENCES

The planting of IR8 in all three dry season experiments allows evaluation of the influence of climatic differences on the yield response to water input. Figure 3 indicates clear differences in the functional relationships for the three crops. Higher yields were obtained in 1970 and 1971 than in 1969 for low water application treatments. For the ample water treatments, however, the 1969 yields were higher. To understand these yearly variations the climatic differences between the years of study should be defined.

Potential evaporation (computed by multiplying solar energy values by a constant equal to 0.01718) and sunshine hours throughout the crop seasons are shown in Fig. 7. Both are indicators of incident solar energy. Rainfall patterns are graphed in Fig. 4, 5, and 6. The 1969 crops received more solar energy during the 45 day period before harvest than the 1970 and 1971 crops (Table 2). Both rainfall and the number of cloudy days were higher in 1970 and 1971 than in 1969. The higher solar energy, lower rain, and more sunny days in 1969 seem to have increased the yield potential of the plants under the ample water treatments. But these climatic conditions appear to have depressed yields under low levels of water input. These conditions increased the rate of field drying which accelerated the decline in soil moisture.

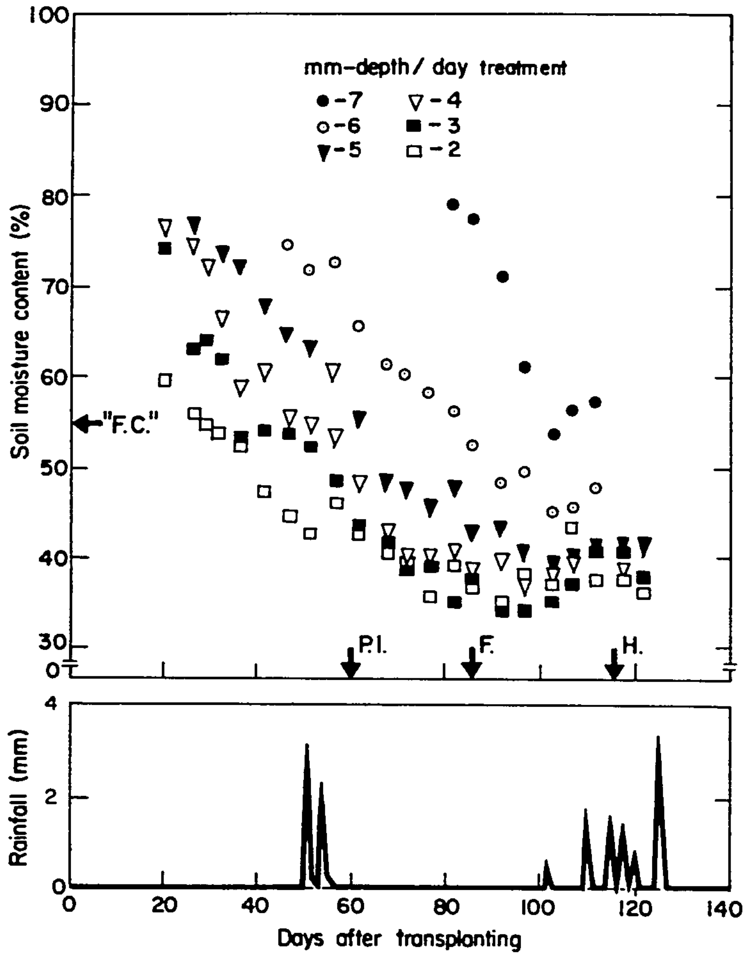

Fig. 4. Soil moisture content (oven dry basis, 15 cm profile depth) at different water application treatments and the 5-day average rainfall throughout crop growth of IR8. 1969 dry season, IRRI. ("F.C." = approximate field capacity, P.I. = panicle initiation, F = flowering, H = harvest.)

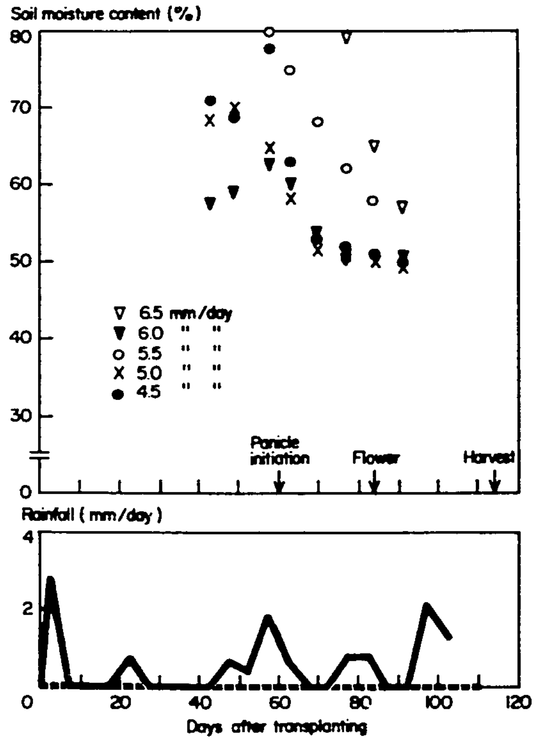

Fig. 5. Soil moisture content (at 6-inch depth, oven dried basis) at different water application treatments and the 5-day average rainfall pattern throughout crop growth of IR8 under lowland culture. IRRI, 1970 dry season.

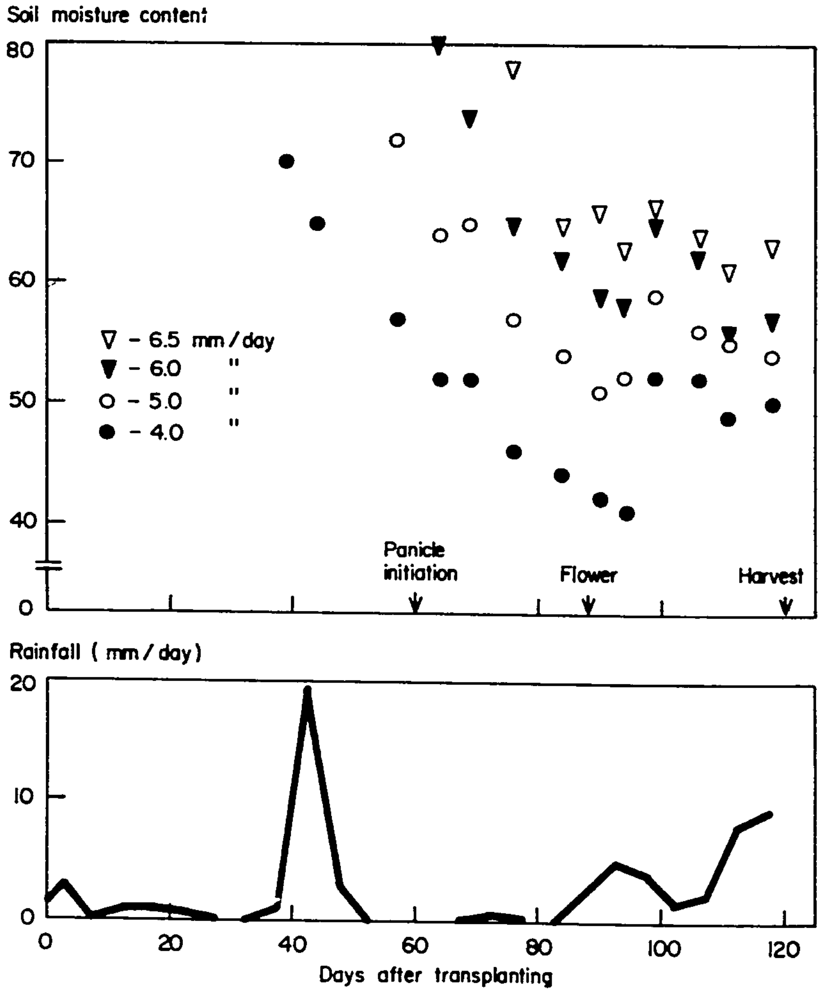

Fig. 6. Soil moisture content (oven dry basis, 6-inch-depth) at different water application treatments and 5-day average rainfall pattern throughout crop growth of IR8 under lowland culture. IRRI, 1971 dry season.

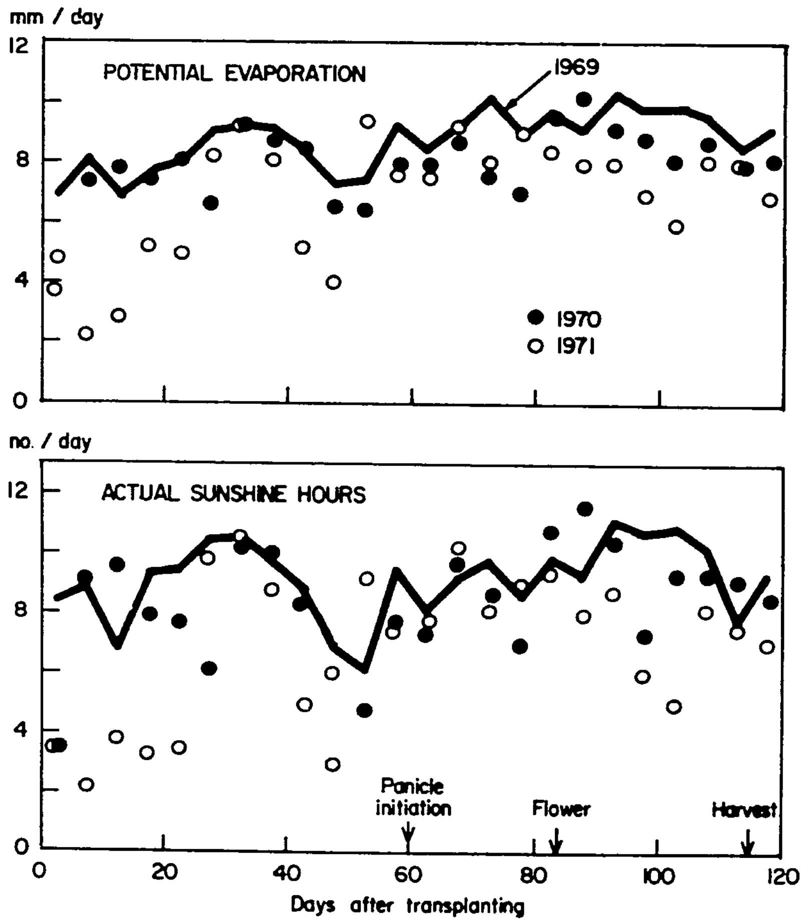

Fig. 7. The patterns for the 5-day average values of potential evaporation and actual sunshine hours during the entire crop growth of IR8 for the 1969, 1970, and 1971 dry seasons. IRRI.

The reasons for the differences between the 1970 and 1971 response functions is less clear. The greater yields obtained under low levels of water input in 1971, however, seem related to the higher rainfall and greater cloud cover in 1971 than in 1970. The climatic differences between these 2 years did not account for yield differences under the ample water input levels. The climatic conditions in 1971 reduced the rate of field water loss, which in turn decreased the decline in soil moisture; hence water stress built up slowly. These conditions enabled the crops under low water treatments to produce relatively higher yields.

Thus it appears that during years of greater cloud cover and higher and more evenly distributed rainfall (such as the 1970 and 1971 dry seasons), poorly irrigated areas may obtain yields higher than those during "normal" years, while the well irrigated areas may obtain yields lower than those during "normal" years. In locations characterized by such climatic conditions, the chances of increasing yields on poorly irrigated areas through improved crop management are greater than in locations endowed with a drier climate.

THE EFFECTS OF VARIETY AND NITROGEN FERTILIZER

Poor water environment and poor crop management have been considered as the major factors limiting the performance of improved rice varieties at the farm level. One study in Central Luzon and in Laguna showed that improved varieties outyield traditional varieties by only about 14 percent (Wickham, 1971). Individual farmers do not have control over the water environment. It is generally felt that proper choice of variety and use of improved crop management are the two major ways in which farmers can improve the field performance of the new varieties.

Effects of variety

In comparing the performance of varieties under varied water input levels, only the experimental crops provided with 100 kg/ha nitrogen were considered. Moreover, in 1970 only the results for IR8, IR22 and the IR579 line were analyzed because the others, M1-48, IR478, and C4-63G lodged before harvest which reduced their yields variably under the different water treatments.

The data and estimated functional relationships for 1970 are presented in Table 3 and Figure 8. IR8 yielded less than both IR22 and the IR579 line under all levels of water input. Under ample water treatments IR22 and IR579 produced essentially the same yields, but IR22 produced better yields under low water input levels.

Thus early maturing varieties like IR22 or the IR579 line may have some advantage over longer duration varieties like IR8. The soil in the low water application treatments dried out gradually towards maturity, so that a reduction of two or more weeks in harvest date favored higher yields. In addition while some varieties (IR22 and the IR579 line in this case) may perform equally well under favorable water situations, their performances differ in poorly irrigated areas.

Table 1. The effect of water application treatments on grain yield of IR8 during the 1969, 1970 and 1971 dry season, IRRI.

Water treatments (mm/day)	Yield (t/ha) 1969	1970	1971
4.0	0.1	*	4.1
4.5	*	3.7	*
5.0	4.6	4.7	6.3
5.5	*	5.2	*
6.0	7.3	5.0	6.5
6.5	*	6.0	6.9
7.0	8.7	5.9	7.5
7.5	*	5.7	7.7
8.0	8.8	5.8	*

* Omitted treatments.

Table 2. Solar radiation for the 45-day period before harvest and total rainfall throughout crop growth of IR8 under lowland culture[a/] during the 1969, 1970 and 1971 dry seasons, IRRI.

Year	Crop maturity [b/] (DT)	Rainfall[c/] (mm)	Solar radiation (Kcal/sqcm)
1969	116	25[d/]	25.0
1970	114	50[e/]	22.5
1971	120	304[f/]	19.9

a/ 100 kg N/ha applied basally.
b/ DT = days after transplanting.
c/ From transplanting to the day before harvest.
d/ Most of the rains fell during the ripening period.
e/ Evenly distributed throughout crop growth.
f/ 45% of the rain fell during the vegetative period, 25% during the flowering stage, and 30% during the ripening period.

Table 3. The grain yield, plant height and tiller number of IR8, IR22 and IR579-48-1-2 under different water application treatments, IRRI, 1970 dry season.

Water application treatments	IR8			IR22			IR579-48-1-2		
(mm/day)	Yield (t/ha)	Plant ht. (cm)	Tillers (no./sq.m)	Yield (t/ha)	Plant ht. (cm)	Tillers (no./sq.m)	Yield (t/ha)	Plant ht. (cm)	Tillers (no./sq.m.)
4.5	3.7	71	389	4.8	74	390	4.4	76	407
5.0	4.7	76	384	6.2	81	459	6.2	80	466
5.5	5.2	77	325	5.7	83	373	5.6	83	398
6.0	5.0	75	345	5.3	73	415	5.6	79	356
6.5	6.0	89	371	6.4	90	452	6.1	87	429
7.0	5.9	89	331	7.3	95	431	7.1	92	471
7.5	5.7	88	369	6.8	93	437	6.0	88	418
8.0	5.8	89	311	6.3	92	394	6.8	92	436

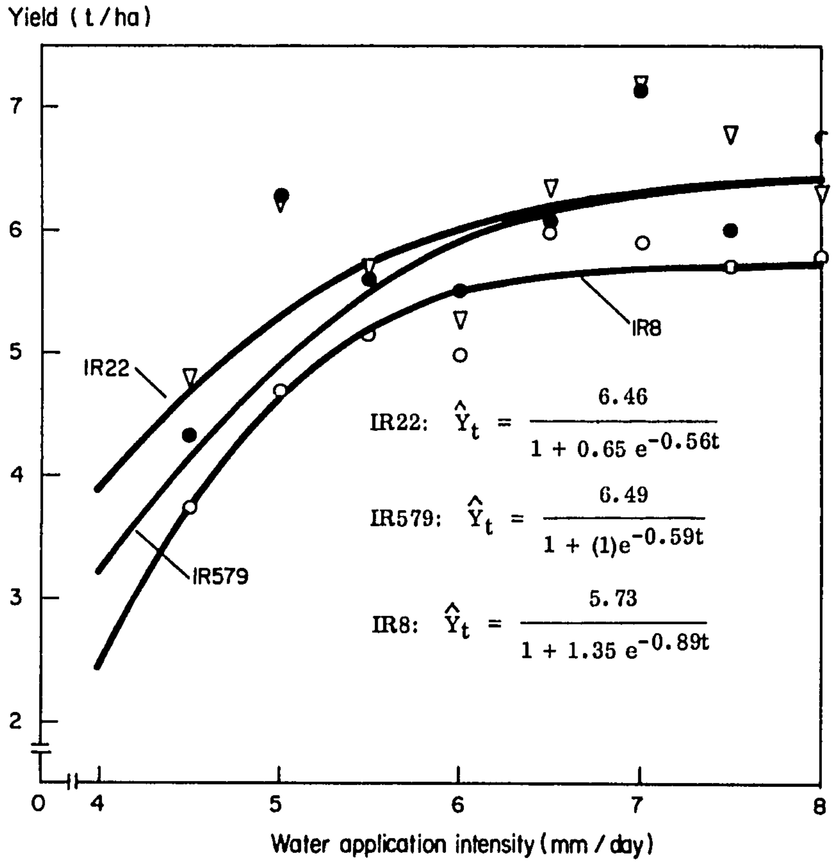

Fig. 8. The functional relationships between rice yiel. and water application intensity for IR22, IR579, and IR8 (all provi..d with 100 kg/ha N). IRRI, 1970 dry season.

Functional relationships for IR8, IR5, and the IR773 line were consequently estimated from the 1971 yield data shown in Table 4. These relationships are graphed in Figure 9. Contrary to the results of 1970, the early maturing (105 days after transplanting) IR773 line yielded less than both IR8 and IR5 (which matured later, at 120 and 125 days after transplanting, respectively) under all water levels. One prominent feature of the IR773 line is that it is much shorter in height than either IR5 or IR8 (Table 5). Unlike IR8 and IR5, the IR773 line was not able to provide a good crop cover in the field. Similarly, IR22 and the IR579 line provided at least as good crop coverage as IR8 in the 1970 crop season, while the early maturing IR773 line did not. These findings suggest that plant type and early maturity are both important for high yields at the farm level.

There is a striking difference in the way IR5 and IR8 respond to varying levels of water. Under low levels of water IR5 outyielded IR8 significantly. Under favorable water levels, however, the situation was reversed. This, too, strongly indicates that differences exist among varieties in terms of their yield response to water. The more vegetative nature of IR5 (Table 5) may be an important factor in conserving field moisture, particularly rain which falls during the vegetative stage of the crop. If so, the vegetative nature of a variety could support the role of soil puddling in reducing moisture stress build up during periods of extended drought.

Interaction effects between water and nitrogen fertilizer

Table 6 shows 1971 yield responses to water under 0, 50, and 100 kg/ha of nitrogen application. The estimated functional relationships for the three nitrogen levels are presented in Figure 10, which shows that under 0 and 50 kg/ha N treatments the yield responses to water are similar. The benefit from the first 50 kilograms of nitrogen increment is approximately the same under all levels of water input. At 100 kg/ha N, however, the yield increase due to the second 50 kilograms of nitrogen increment decreases at lower levels of water input. Thus under poorly irrigated conditions it is less profitable to apply high levels of nitrogen fertilizer. Nevertheless, it would still be logical to apply moderate amounts of nitrogen fertilizer under these conditions. High rates of Nitrogen through split applications might also be justified, although that was not studied in this experiment.

Interaction effects between water, nitrogen fertilizer, and varieties.

Functional relationships were separately estimated for IR8, IR5, and IR773 under 0, 50 and 100 kg N/ha levels (Fig.9)..At zero nitrogen IR8 and the IR773 line have approximately the same yields under all levels of water input. These two varieties are clearly outyielded by IR5 for all water treatments. At 50 kg/ha N, Figure 9 shows higher yields for all functions. IR8 now starts to show off its yield potential. It outyields the IR773 line under all water treatments and has about the same yield as IR5 under ample levels of water input. For the lower levels of water applications, however, IR5 still outperformes both IR8 and the IR773 line. At 100 kg N/ha the second 50 kg/ha nitrogen increment further increases yields for all functions. With ample water and the high levels of nitrogen, IR8 outyields both IR5 and IR773, but under low water treatments IR5

Table 4. Rice yield response[a/] to water input of three varieties under 0, 50, or 100 kg/ha N, 1971 dry season, IRRI.

Water application treatments	YIELD (t/ha)								
	IR8			IR5			IR773A-36-2-1		
	0	50	100	0	50	100	0	50	100
4.0	3.41	4.36	4.10	3.62	4.94	5.24	3.35	3.74	4.24
5.0	4.11	5.40	6.25	4.91	5.71	6.29	4.05	4.48	5.04
6.0	3.96	5.38	6.45	4.85	5.31	5.63	4.17	4.57	5.66
6.5	5.06	6.30	6.94	5.35	6.34	6.31	4.20	4.99	5.70
7.0	5.67	6.92	7.50	6.34	6.90	7.50	5.36	6.15	6.05
7.5	4.96	6.46	7.67	6.40	6.52	7.34	4.97	5.52	6.20
Flooded	5.91	6.61	7.52	5.64	6.60	7.64	4.10	4.94	5.62

a/ Average of two replications.

Table 5. Plant height and tiller number of IR8, IR5 and IR773A1-36-2 at harvest[a/] under different water application treatments, IRRI, 1971 dry season.

Water treatments	IR8		IR5		IR773A1-36-2	
	Plant ht (cm)	Tillers (no./sq.m)	Plant ht (cm)	Tillers (no/sq.m)	Plant ht (cm)	Tillers (no./sq.m)
4.0	71	351	91	352	62	353
5.0	78	305	103	324	68	315
6.0	79	296	100	315	70	304
6.5	85	281	110	334	73	292
7.0	88	279	113	308	76	298
7.5	88	297	114	316	77	318

a/ Average of three nitrogen levels and two replications.

Table 6. Average rice yield response[a/] of IR8, IR5 and $IR773A_1$-36-2-1 to water input under 0, 50, and 100 kg/ha N, 1971 dry season. IRRI

Water application treatments (mm/day)	Yield (t/ha)		
	0	50	100
4.0	3.46	4.35	4.53
5.0	4.36	5.20	5.86
6.0	4.33	5.09	5.91
6.5	4.87	5.88	6.32
7.0	5.79	6.66	7.02
7.5	5.44	6.17	7.07
Flooded	5.22	6.05	6.93

a/ Average of two replications and three varieties.

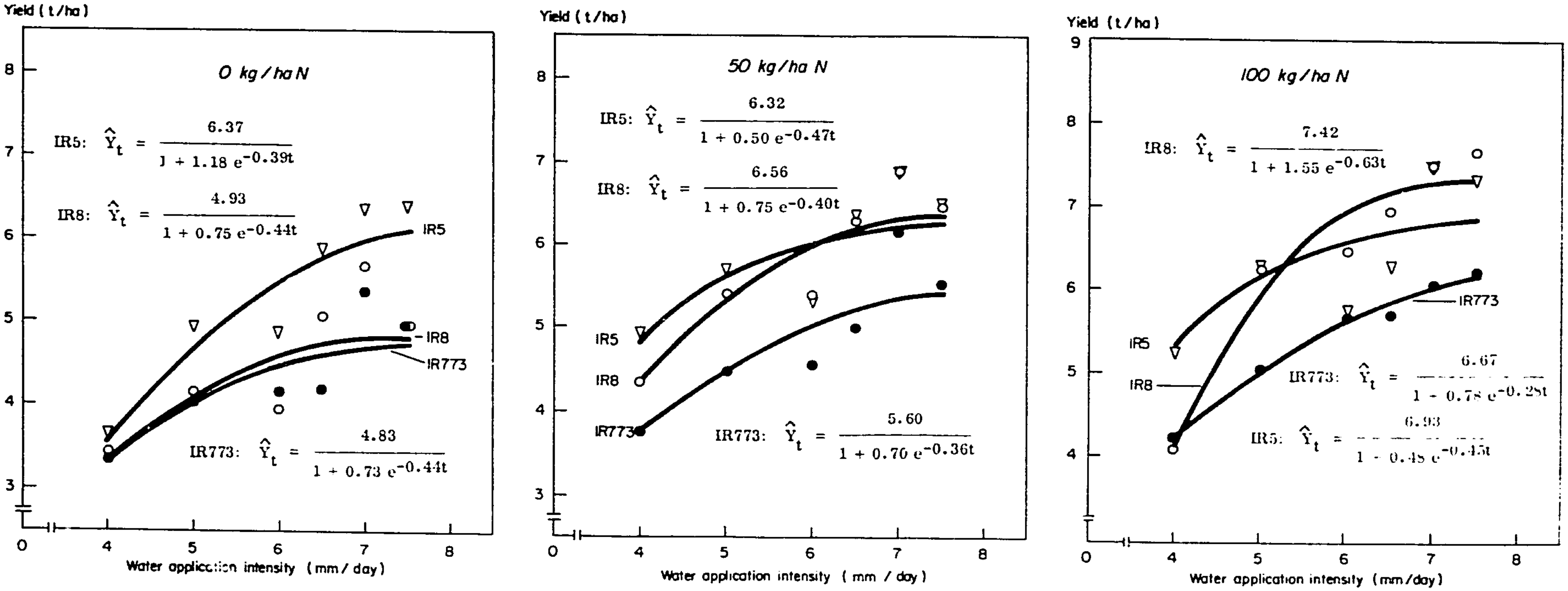

Fig. 9. The functional relationship between rice yield and water application intensity for varieties IR8, IR5, and IR773 with 0, 50, and 100 kg/ha N . IRRI, 1971 dry season.

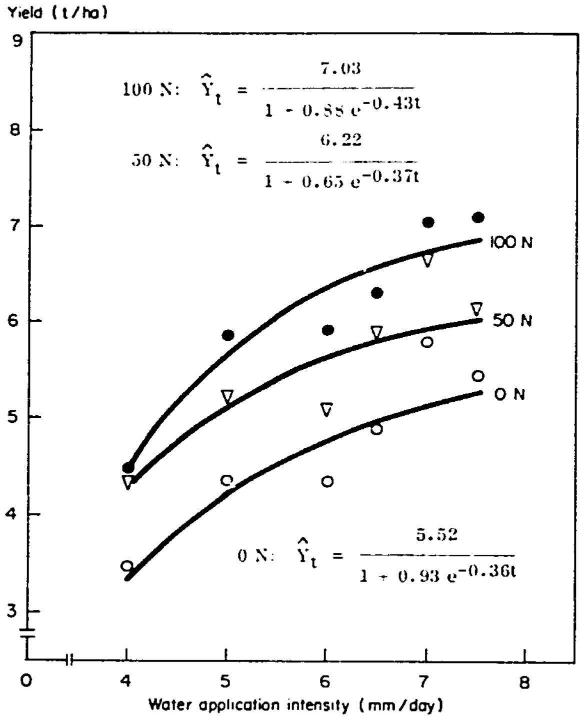

Fig. 10. The functional relationships between rice yield and water application intensity under three nitrogen levels (average for three varieties). IRRI, 1971 dry season.

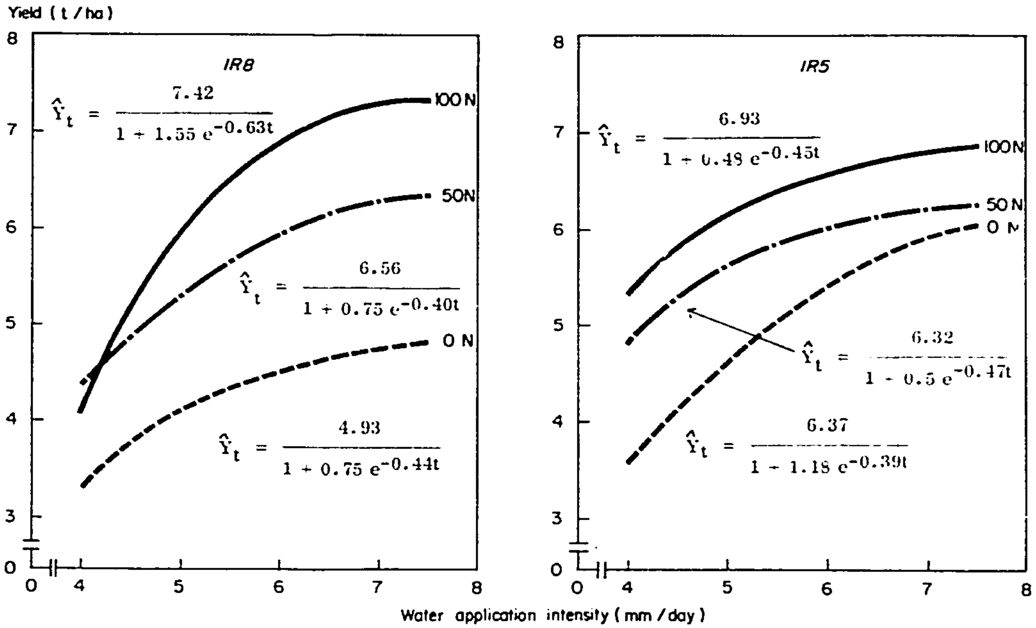

Fig. 11. Comparison of the yield increases due to application of nitrogen fertilizer under different water treatments for varieties IR8 and IR5. IRRI, 1971 dry season.

produces yields greater than the other two varieties. A comparison of the responses at the three nitrogen levels (Fig. 9) indicates that IR8 showed large yield increases due to nitrogen only under the ample water treatments, while IR5 showed consistently high yield response to nitrogen under the lower levels of water input. This comparison is also shown in Figure 11. These results suggest that a potential exists for developing varieties that would efficiently respond to fertilizer under conditions of poor water supply.

IMPLICATIONS

Where water is not a limiting factor, varieties like IR8 have the potential to increase farm yields if high levels of crop management are provided. Under favorable water conditions these varieties can effectively use large increments of fertilizer to increase yields.

Most of the varieties tested, however, were sensitive to a poor water environment, which characterizes many farmers' fields. Under poor water conditions, these varieties respond effectively only to moderate levels of nitrogen applications.

The striking response of IR5, and possibly other varieties, indicates the potential for developing varieties that could respond effectively to high nitrogen fertilizer application under conditions of poor water supply. The response of IR5, plus that of other varieties like IR22 and the IR579 line (both of which showed about the same plant type as IR8), point to vegetative nature, early maturing date, and high efficiency of fertilizer use as the major factors to consider in developing varieties that can perform well under a poor water environment. These characteristics are already found to some extent in many improved varieties.

The potential for improving the field performance of the new varieties also depends on the climatic conditions of the area. In poorly irrigated areas low evaporative demand (due to low solar energy and more cloudy days) favor relatively higher yields.

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Land classification as a tool in water management

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ABSTRACT

This paper presents and discusses the relevant principles, corollaries and rules of logic in land classification for irrigation suitability determinations. Also included are the generalized methodology and operating procedures. Most of the information used is from the material that has been developed and established by the U.S. Bureau of Reclamation, modified to fit in the Philippine setting. To maintain continuity, the land classification work already undertaken is also included and documented. The functions and uses of the land classification information in conjunction with irrigation water management are explored and stressed. It is recommended that land classification, as well as the institution of improved water management, be undertaken not only for proposed irrigation, drainage and flood control projects prior to authorization, but also in existing irrigation systems prior to rehabilitation or improvement.

INTRODUCTION

Progress on major construction works such as dams and main distribution canals most often is satisfactory. The complementary development of farm level ditches and drains, input supplies, extension services, water use and management, etc., however, are delayed. Consequently, the economic benefits of the capital intensive works are usually either not fully realized or are realized rather late. The efficient control of scarce water has been rather taken for granted, and has not been regarded as important. The introduction of double cropping, which often forms one of the principal economic justifications for irrigation projects, generally continues to be disappointingly low. There is widespread insistence on making the water available over as large an area as possible, regardless of other considerations, to reach the maximum numbers of farmers. Mismanagement of irrigation water also causes flooding of low areas. Individual farmers either have two little water for intensive cultivation and/or deteriorating soil due to excessive water logging. Such is the litany of problems identified by people looking at the irrigation situation in most places today (IBRD, 1972 and ADB, 1971).

Lending institutions therefore have introduced or expanded new techniques such as improved water control, and have provided greater attention to particular aspects of project preparation which are frequently neglected, such as the effect of irrigation on various types of soil, land classification and drainage, etc. (IBRD, 1972). In addition, while the banks formerly financed the construction only of new irrigation systems, they have now considered financing the rehabilitation of outdated and inefficient existing systems. Provision of facilities down to the farm level, to allow full water control, plus effective water management for existing systems, and the inclusion of such facilities and practices in the design of new systems, became the two areas of priority in the disbursement of the bank's technical and financial program (Hsieh, 1969).

Irrigation development in Asia and the Philippines

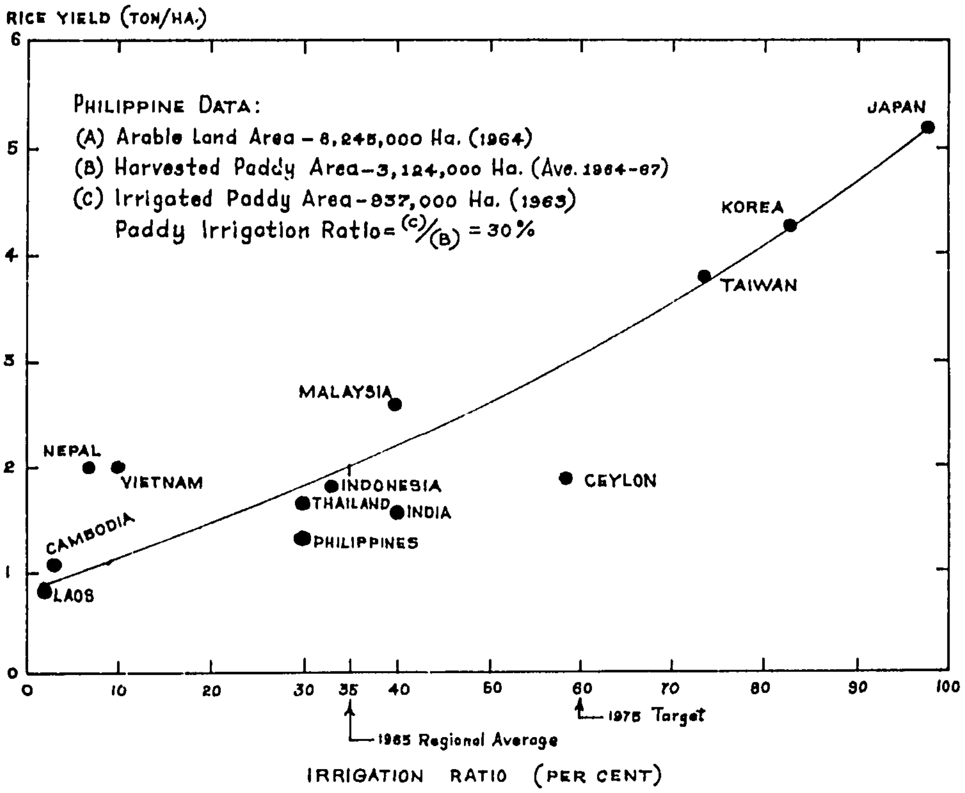
The "Development Strategy of Irrigation and Drainage"(Takase and Kano, 1968), in the Asian Agricultural Survey conducted by the Asian Development Bank, defined the irrigation ratio as the paddy area irrigated by all sources divided by the harvested paddy area. This ratio was plotted against rice yield data for different countries in Asia, and is shown in Fig. 1. The regional average of the ratio for 1965 was only 35%. The Philippine average was 30%, which corresponds roughly to 10% of the arable land of the country, using the 1964 figure of 8,245,000 arable hectares. A lot more land could therefore be provided with irrigation water both in this country and elsewhere.

Records of potential service area, irrigated area and benefitted area by season in the National Irrigation Administration (NIA) is also plotted in Figure 2. An average of only 80% of the potential area could be served during the wet season, and only 40% of this irrigated area could be served during the dry season. This amounts to only 35% of the potential area. Several reasons are available to explain this situation; one of them is that essentially all the systems operated by NIA have run-of-the-river diversion type dams, without reservoirs, and are highly dependent on river flow, which is the runoff portion of rainfall. Inefficient use and management of water is another reason. The classification of lands to indicate which areas need be irrigated is a third.

Objectives

This paper has three objectives: First, to promote understanding of land classification principles, methodologies and procedures; second, to identify the uses of land classification data; and finally to relate the function of land classification to that of water management in the development of new irrigation systems and the improvement of existing ones. When these objectives are achieved, it is hoped that land classification and water management will be undertaken in existing irrigation systems that need to be improved or rehabilitated, and that land classification be undertaken prior to the authorization of new irrigation construction.

Figure 1 IRRIGATION DEVELOPMENT, IRRIGATION RATIO AND RICE YIELD ADB REGION[1]



1/ Takase and Kano, 1968.

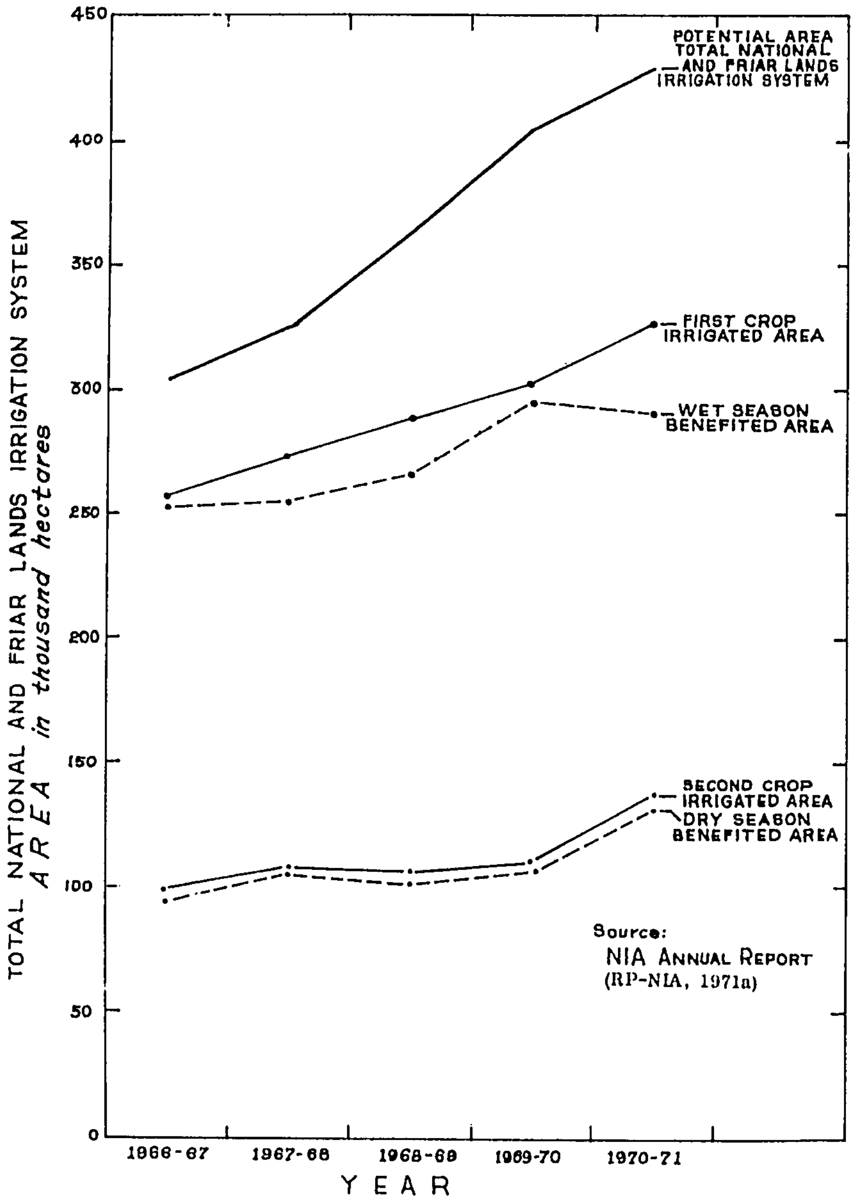


Figure 2 POTENTIAL, IRRIGATED AND BENEFITED AREA BY YEAR, NATIONAL AND FRIAR LANDS IRRIGATION SYSTEM, PHILIPPINES

Water management has been described as "the integrated processes of intake, conveyance, regulation, measurement, distribution, application and use of irrigation water to farms, and removal of excess water from farms, with proper amounts and at the right time, for the purpose of securing maximum crop production and water economy" (RP-NIA-ADB, 1970). It is within this framework that the probably uses of land classification and its function as a tool -- not only in planning and assessing irrigation projects, but also in operational programs of water management -- are explored in this paper.

Land classification is the systematic appraisal of the physical, chemical and biological chracteristics of land which include soil, topography, drainage, and water quality. Also included is the determination of irrigation suitability by categories or land classes having similar physical and economic aspects. Land classification, according to Maletic (1966), provides a sound basis for fitting land resources into a plan of development that best meets defined and realistic goals of people.

Land classification is one of the fundamental activities involved in planning, constructing, and operating an irrigation and drainage project. While most people say that land classification is best suited to new projects, it is a good tool as well in assesssing existing ones.

BASIC PRINCIPLES

Certain general principles have been developed for classifying land for irrigation(U.S. Bureau of Reclamation, 1953, Maletic, 1962, 1966 and 1970; and Maletic and Hutchings, 1967). They may be identified as the principles of prediction, economic correlation, arability-irrigability analysis, permanent-changeable factors, and three traditional rules of logic.

Prediction principles

Land classification expresses the soil-water-crop interactions expected to prevail under the new moisture regime resulting from irrigation. Since irrigation shifts the existing natural balance among water, land, vegetation, fauna, and man, the changes must be identified and evaluated in relation to the agricultural goals of the project. Environmental effects should be determined as well.

In the Philippines the water table rises during the rainy season and rice is grown where water stays close to the soil surface. The water table moves down during the dry season; hence, no rice crop is grown unless irrigation is supplied. Some diversified crops are grown instead. With year-round irrigation supply the changes that are expected in water table movement and its influence on the natural balance should be predicted. For instance, in some areas of the Magat River Irrigation System, the balance was disturbed after the irrigation system began operation. The water table does not move down during the dry season, indicating a drainage deficiency, and therefore the farmers' cropping pattern is limited to rice. Also the problem of "quick silt" or "quick clay" similar to quick sand develops on continuously cropped rice farms and sometimes becomes a problem for land preparation. In the Santa Rosa area of the Upper Pampanga River Project, carabaos and men are sometimes almost waist deep in mud.

The prediction process requires not only careful field studies of observable soil characteristics and qualities but also detailed measurements of the relevant attributes of the soil and sub-strata. When special problems are uncovered and appropriate solutions are not readily available, research studies are started or development farms are operated to test the compatability of the soil and water and to predict the most suitable cropping and management systems.

Economic correlation

In a particular project, the physical factors of soil, topography, and drainage are functionally related to an economic value. In the system of land classification of the U.S. Bureau of Reclamation, economic value is defined as payment capacity, "the residual available to defray the cost of water after all other costs have been met by the farm operator" (U.S. Bureau of Reclamation, 1953). In Philippine land classification work, economic value has been tentatively defined as the net farm returns from a crop enterprise under future conditions "with" and"without" the project. It is used as a measure of the producing ability of various classes of land.

In planning large-scale resource development projects, the economic basis of land classification should be chosen to contribute towards determining whether irrigation is feasible for increasing net farm income. It also includes studies of how irrigation might be planned to maximize benefits and optimize water use. This can be achieved by correlating the physical land factors with farm economics data under the assumption that farm income and costs in a given environment are related to soil, topography, and drainage factors.

From this principle, three important corollaries can be defined: (a) land classes are economic entitites whether payment capacity or net farm income is the accepted economic measure of suitability; (b) relevant and mappable characteristics are chosen at a given time and place to comprise the set of land class-determining factors of soil, topography, and drainage; and (c) land class differentials and their range and value within a class will vary with the economic, ecologic, technological, and institutional factors prevailing or expected to prevail.

Permanent and changeable factors

The changes in land arising from irrigation development impose a need to identify characteristics that will remain unchanged and those that will be significantly altered. This permits development of an applicable and consistent set of land class-determining factors and makes more likely a uniform appraisal of land conditions by the numerous classifiers engaged in the survey.

The permanent factors include such characteristics as soil texture; depth of soil to gravel or bedrock; depth to barrier zones such as claypan and hardpan; and macro-relief. The changeable factors include salinity levels, exchangeable sodium levels, pH, micro-relief, water table levels, flood hazard, and soil cover. Changeable factors are, of course, subject to constraints of economic feasibility.

In some places, depending on the goal of project development, sandy soils on a coastal plain can be improved for irrigation by the addition of clays from the surrounding uplands. Conversely, lowland clays can be improved by the addition of sands. Sloping lands have been improved by bench terracing as is commonly done in Northern Luzon and elsewhere. Studies indicate, however, that the slope for irrigation development should not exceed 8 percent, provided the soil is deep enough to allow considerable soil movement. The resulting field size and shape must still generate sufficient net farm returns to the operators to return the investment and, at the same time, maintain a farm family.

Arability-irrigability analyses

The selection of lands for irrigation proceeds through two stages. An initial step involves identification of land areas of sufficient productivity to warrant consideration for irrigation. This is the arability analysis. Then from the arable lands, the lands that are practical to irrigate are selected. The selection of arable lands is guided by the economics of farm production such as crop adaptability, productivity, payment capacity, and net farm income. Irrigable lands are chosen through the economics of plan formulation process, which successively eliminates identifiable increments of arable land from the plan of development. Typical adjustments include the elimination of lands too expensive to serve, drain, or provide distribution facilities for; lands that have limited water supply compared to land area; lands whose elevation is too high; isolated portions, odd-shaped and severed areas that cannot efficiently be fitted into a farm unit; existing and proposed public right-of-way; and areas unable to meet minimal criteria for economic returns.

Traditional rules and logic

Three rules from traditional logic can be considered as additional basic principles. These require that the classification-(1) must be based upon a single principle. Some aspects of the facts to be classified must be selected and adhered to for the entire classification for consistency.

Defining land class in terms of payment capacity or net returns as the case may be would meet this requirement; (2) should be exhaustive - it should include everything to be classified. For completion all lands can be assigned a payment capacity or net farm return value and no land would be left out of the system; (3) should have subdivisions that are mutually exclusive - the facts are arranged in discrete and determinate groups. With the classes defined on the basis of specified ranges in payment capacity or net farm return, mutual exclusiveness is attained. This rule is the most difficult to apply because soil and landscape transitions are continuous rather than discrete.

METHODOLOGY AND PROCEDURES

The selection of lands for irrigation must be guided by the previously discussed general principles. These principles recognize goals of people and provide an orderly basis for putting land and water resources into a plan of development for a particular area and its people. This results in organized procedures that permit the selection of irrigable land within a specific location. Provision is made for coordinating the engineering, agricultural, economic, social and other aspects of irrigation project development. This process is an evolving one, the major stages of which are stated below.

Major work activities

The first step in developing an irrigation project is a study of land resources, associated productivity, drainability, and related characteristics of a fully developed similar irrigated area. Where such studies are lacking, development farms can be operated within the project setting. Field experiments also can provide the initial data needed for sound planning which cannot be otherwise obtained.

The second step is analysis of the probable influences of specific land and water factors on the economics of production and cost of land development in the area under investigation. In this step the economic value, as influenced by the productive capacity of the land and the cost of production, together with land development, is related to the physical factors of soil, topography, drainage, and water quality.

The third step is separation and identification of the lands on the basis of physical and chemical factors into land classes having a defined range in payment capacity or net farm return. Each land class is also defined in terms of chemical and physical land class-determining factors. These are the relevant characteristics of land that determine suitability for irrigation. They are expressed in a set of specification, are tested, and are analyzed by means of farm budget studies before or during the field survey to insure that lands of equal economic value are placed in the same category.

The fourth step is the development of appraisal specfications for water and drainage requirements. These specifications create an orderly basis for obtaining and placing physical land data into categories useful for hydrologists and drainage engineers.

The fifth step is the application of land classification and its appraisal specification in the arable land classes. This involves field traverses, soil and substrate analysis, delineation of land classes and sub-classes with informative appraisals, and related procedures necessary to accomplish the field survey.

The sixth step is modification of the arable land classification as additional information is obtained. The arable classification is adjusted as the investigations, the project plan, and the costs for water and drainage become more clearly defined.

The seventh step is the application of final tests of engineering feasibility and project benefits and costs, to select irrigable land and to develop a plan which provides the optimum economic and social gains.

The specific steps of this procedure are mentioned in Figure 3, which is derived from Maletic and Hutchings (1967).

LAND CLASSIFICATION IN THE PHILIPPINES

Brief review

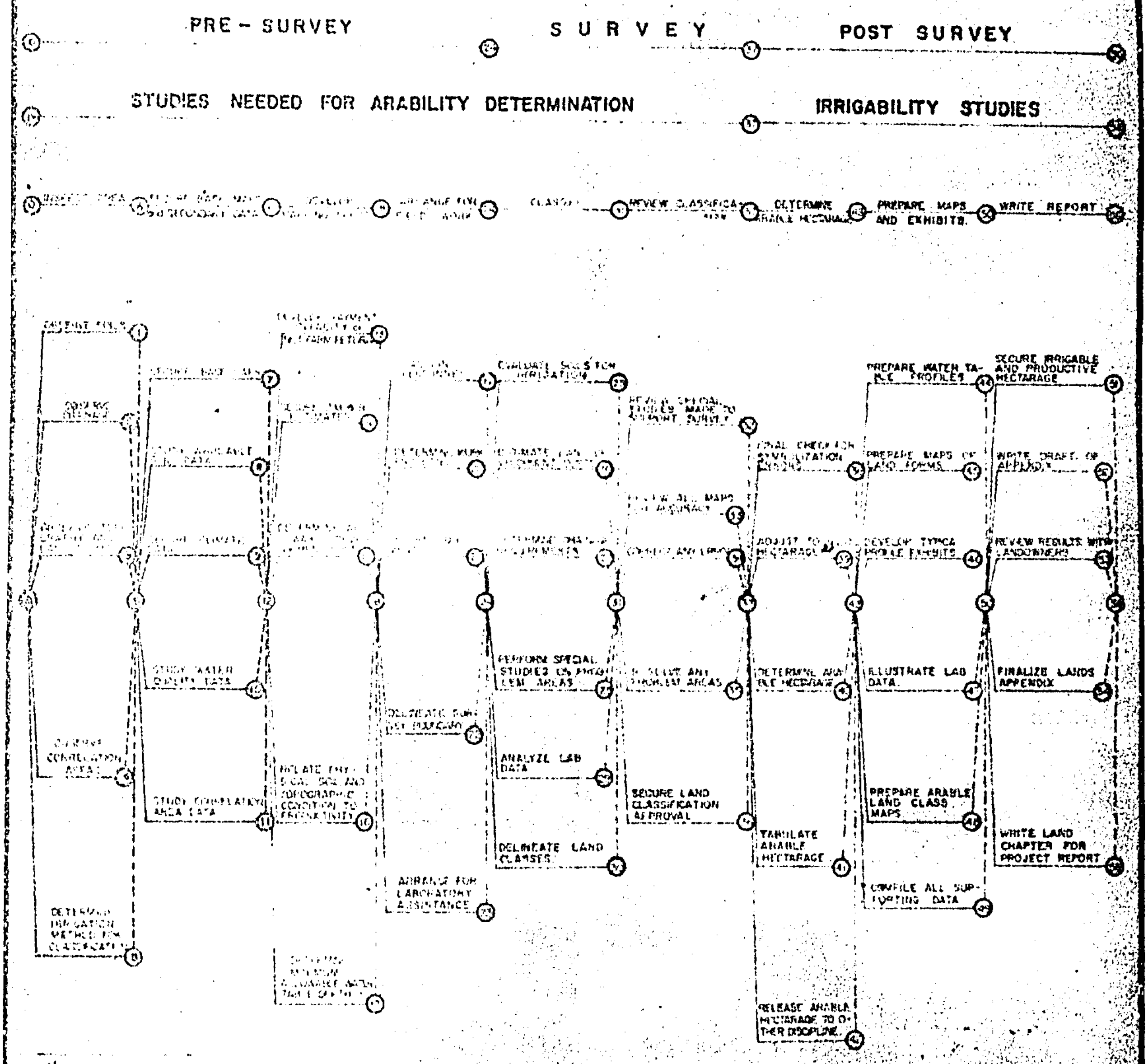
Land classification has a short history in the Philippines. Its first application was in the NIA water management pilot project in San Rafael, Bulacan. Later, land classification activities were undertaken by the Upper Pampanga River Project (UPRP) to delineate the areas suitable for rice production and diversified crops, and to determine the characteristics and best possible use of the soils within a 130,000-hectare area. Details of the work were reported in the Land Classification and Supporting Studies Report (RP-NIA, 1971b). Finally, a new land classification project has begun on the existing Magat River Irrigation System, and basin-wide studies of the Agno River and Central Luzon areas are contemplated.

Description of major land classes and sub-classes

The Philippines is basically dependent on its rice production. Nevertheless, the presence of land suitable for, and the needs of, other crops justify consideration of diversified crops other than rice. In this regard, the multi-cropping potential and associated drainage requirements must be considered. These are all appropriately included in the land classification work in the Philippines.

FIGURE 3.

U. S. B. R. LAND CLASSIFICATION WORK PERFORMANCE NETWORK 1/



1/ ADAPTED FROM MAIETIE & HUTCHINGS, 1961

2/ GENERAL LAND OFFICE, EQUIVALENT TO BUREAU OF LANDS IN THE PHILIPPINES.

There are now six major land classes recognized in land classification work in the Philippines and these are described in detail below. At the time of the UPRP land classification program, however, only five classes were recognized.

Basic segregation. The basic segregation of lands, in the arability analysis, was the delineation of the non-arable lands, (those obviously unsuitable for irrigation) from the arable lands (those likely to be served by irrigation). The non-arable lands were further segregated into two groups, a) land with serious physical deficiencies are Class 6, and b) land in cities, towns, barrios or housing subdivisions, or land in an active stage of subdividing are classified as Class M (municipal) land.

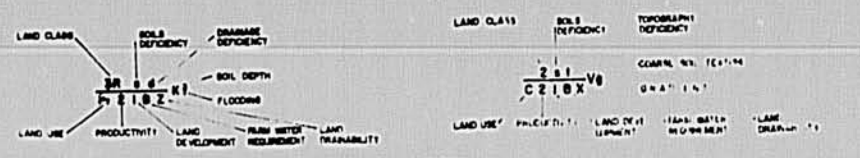
The arable lands were separated into the two main groups of a) those best suited for irrigated rice production, and b) those best suited for irrigated diversified crops. The criteria which determine whether the land is better suited for rice or for diversified crops are the soil and drainage features. Wetland rice thrives best on soil which can easily be puddled and which will maintain a perched water table under flooded conditions without excessive losses to deep percolation. Diversified crops on the other hand do best on medium-textured and well-drained soils.

Rice land classes and diversified crop land classes. The lands classified as best suited for rice production were further segregated into three classes which indicate their relative suitability for irrigated rice, Land Classes 1R, 2R and 3R. The lands classified for diversified crop production were separated into three classes which indicate their relative productivity for growing two or more diversified crops each year: Land Class 1, 2 and 3. For all arable land classes lower than class 1R or 1, both classes were segregated into appropriate sub-classes specifying the deficiencies which affect their suitability for irrigation. The deficiencies are indicated by appended letters as follows: "s" for soil, "t" for topography and "d" for drainage deficiencies. Informative appraisals to identify the particular deficiency are also provided by "v" for coarse textured soil, "u" for undulating topography and "f" for flooding hazard drainage deficiency. The informative appraisals are symbolized and presented in Table 1 while the set of specifications in Table 2 provides detailed descriptions of the several factors that are assessed by land classes.

Dual class land: multi-cropping potential. Dual class land delineation is separately mapped whenever possible. Adequate drainage facilities, however, must be provided in the future at economic costs. Lands with potential for rice or diversified crops or both are identified to show multi-crop potential. These are separately tabulated under project conditions, without satisfying the drainage requirements, but are included in the appropriate single class in the final tabulation. This could be better appreciated from the sample tabulations of land classes by hectarage for the Magat River Project Feasibility Studies (MRPFS) shown in Table 3.

Table I

EXAMPLES OF STANDARD MAPPING SYMBOL



SYMBOLIZATION

a. LAND USE

- C IRRIGATED CULTIVATED DIVERSIFIED CROPPING
- L NON-IRRIGATED CULTIVATED DIVERSIFIED CROPPING
- O ORCHARD
- Pr NON-IRRIGATED PADDY RICE
- Pri IRRIGATED PADDY RICE
- G NON-IRRIGATED GRAZING

b. PRODUCTIVITY AND LAND DEVELOPMENT

1, 2, OR 6, DENOTING LAND CLASS LEVEL OF FACTOR, SUCH AS CLASS 2 PRODUCTIVITY, CLASS 1 DEVELOPMENT COST - "21"

c. FARM WATER REQUIREMENT

- A LOW
- B MEDIUM
- C HIGH

d. LAND DRAINABILITY

- X GOOD
- Y RESTRICTED
- Z POOR OR NEGLIGIBLE

e. ADDITIONAL APPRAISALS

i SOILS

- K SHALLOW DEPTH TO COARSE SAND, GRAVEL OR PISOLITE
- B SHALLOW DEPTH TO RELATIVELY IMPERVIOUS SUBSTRATA
- V COARSE TEXTURE (SANDS, LOAMY SANDS)
- X STONINESS
- H FINE TEXTURE (CLAYS)
- Q AVAILABLE MOISTURE CAPACITY
- Y SOIL FERTILITY

ii TOPOGRAPHY

- G SLOPE
- U SURFACE
- J IRRIGATION PATTERN
- C BRUSH OR TREE COVER (CLEARING)
- R ROCK COVER

iii DRAINAGE

- F SURFACE DRAINAGE - FLOODING
- W SUB-SURFACE DRAINAGE - WATER TABLE, NON-CORRECTIBLE
- O SUB-SURFACE DRAINAGE, CORRECTIBLE

f. SOIL COLOR

i **HUE**

- Y YELLOW
- BR BROWN
- G GRAY
- B BLACK
- R RED
- O OLIVE

ii **CHROMA**

- Yi YELLOWISH
- br BROWNISH
- gr GRAYISH
- re REDDISH
- o OLIVE

iii **VALUE**

- L LIGHT
- D DARK
- P PALE
- V VERY

g. MOTTLINGS

i ABUNDANCE

- FEW (f)
- COMMON (c)
- MANY (m)

ii SIZE

- FINE (f)
- MEDIUM (m)
- COARSE (c)

iii DISTINCTNESS

- FAINT (f)
- DISTINCT (d)
- PROMINENT (p)

h. SOIL TEXTURE

- ST STONES & STONY
- K COBBLES AND COBBLY
- G GRAVEL AND GRAVELLY
- VCOS VERY COARSE SAND
- COS COARSE SAND
- S SAND
- FS FINE SAND
- VFS VERY FINE SAND
- LCOS LOAMY COARSE SAND
- LS LOAMY SAND
- LFS LOAMY FINE SAND
- COSL COARSE SANDY LOAM
- SL SANDY LOAM
- FSL FINE SANDY LOAM
- VFSL VERY FINE SANDY LOAM
- L LOAM
- S SILT
- SIL SILT LOAM
- SCL SANDY CLAY LOAM
- CL CLAY LOAM
- SICL SILTY CLAY LOAM
- SC SANDY CLAY
- SIC SILTY CLAY
- CLAY

SOIL STRUCTURE, TYPE

- GR GRANULAR
- CR CRUMB
- PL PLATY
- PR PRISMATIC
- CPR COLUMNAR
- ABK ANGULAR BLOCKY
- SBK SUB-ANGULAR BLOCKY
- SG SINGLE GRAIN
- M MASSIVE

CONSISTENCE

i DRY

- LO LOOSE, NON-COHERENT
- SO WEAKLY COHERENT
- SH SLIGHTLY HARD
- H HARD
- VH VERY HARD
- EH EXTREMELY HARD

ii MOIST

- LO LOOSE, NON-COHERENT
- VFR VERY FRIABLE
- FI FIRM
- VFI VERY FIRM
- EFI EXTREMELY FIRM

iii WET

- SO NON-STICKY
- PS SLIGHTLY PLASTIC
- P PLASTIC
- VP VERY PLASTIC

k. PLASTICITY

- PO NONPLASTIC
- PS SLIGHTLY PLASTIC
- P PLASTIC
- VP VERY PLASTIC

l. CEMENTATION

- CW WEAKLY CEMENTED
- CS STRONGLY CEMENTED
- C INDURATED

m. MOISTURE RETENTIVITY

- P 15 BAR PRESSURE

n. EXCHANGE ACIDITY

- NEA NEUTRAL SALT
- EXAL EXCHANGEABLE ALUMINUM

Table 2

Republic of the Philippines
National Irrigation Administration
MAGAT RIVER IRRIGATION PROJECT

SEMI-DETAILED LAND CLASSIFICATION SPECIFICATION FOR GRAVITY IRRIGATION

LAND CHARACTERISTICS	FOR DIVERSIFIED CROP PRODUCTION			FOR WETLAND RICE PRODUCTION		
	CLASS 1 ARABLE	CLASS 2 ARABLE	CLASS 3 ARABLE	CLASS 1R ARABLE	CLASS 2R ARABLE	CLASS 3R ARABLE
SOIL						
TEXTURE						
SURFACE, 0 - 30 cm	FINE SANDY LOAM TO FRIABLE CLAY LOAM	LOAMY SAND TO PERMEABLE CLAY	LOAMY SAND TO PERMEABLE CLAY	FINE SANDY LOAM TO	LOAMY SAND TO CLAY	LOAMY SAND TO CLAY
SUB-SURFACE	FINE SANDY LOAM TO PERMEABLE CLAY	LOAMY SAND TO PERMEABLE CLAY	LOAMY SAND TO PERMEABLE CLAY	LOAMY SAND TO CLAY	SAND TO CLAY	SAND TO CLAY
DEPTH (AFTER LAND DEVELOPMENT)						
TO CLEAN SAND, GRAVEL OR COBBLE	>90 cm	>60 cm	>30 cm if SURFACE SOIL IS FSL OR FINER	<60 cm	>30 cm	>30 cm
TO ZONE OF REDUCED PERMEABILITY	>120 cm	>90 cm	N.A.	N.A.	N.A.	N.A.
TO RELATIVELY IMPERMEABLE ZONE (WATER)	>200 cm	>200 cm	>200 cm	N.A.	N.A.	N.A.
AVAILABLE WATER STOR CAPACITY	15 cm OR MORE IN 120cm DEPTH WITH 2.5 cm IN 0-30 cm	8cm OR MORE IN 120cm DEPTH WITH 2.5 cm IN 0-30 cm	8 cm OR MORE IN [illegible] cm DEPTH WITH 2.5cm IN 0-30 cm	N.A.	N.A.	N.A.
EFFECTIVE CATION-EXCHANGE CAPACITY (AT SOIL ph) OF SURFACE SOIL, 0-30 cm	>8 m eq /100 gr	>4 meq/100 gr	>4 meq/100 gr	>8 meq/100 gr	>4 m eq/100 gr	>4 m eq/100 gr
EXCHANGEABLE CATION STATUS (CALCIUM + MAGNESIUM)	>7 m eq /100gr	>[illegible] meq /100 gr	>3 m eq /100gr	N.A.	N.A.	N.A.
NEUTRAL SALT EXCHANGE ACIDITY	<1 m eq /100 gr	<3 meq /100 gr	>3 m eq /100gr	N.A.	N.A.	N.A.
SODIUM AT EQUILIBRIUM *	<8 %	<16 %	<16 %	N.A.	N.A.	N.A.
REACTION						
pH IN 0.01 $CaCl_2$ (1:2)	>5.0 <7.5	>4.0 <8.0	>4.0 <8.0	N.A.	N.A.	N.A.
pH IN H_2O (1:1)	>5.5 <8.0	>4.5 <8.5	>4.5 <8.5	N.A.	N.A.	N.A.
pH (ANAEROBIC)	N.A.	N.A.	>5.5	>5.5	>5.0 MAYBE LESS PROVIDED ALUMINUM AND ACTIVE IRON ARE SATISFACTORY	>5.0 MAY BE LESS PROVIDED ALUMINUM AND ACTIVE IRON ARE SATISFACTORY
SALINITY (AT EQUILIBRIUM) UNDER IRRIGATION) ELECTRICAL CONDUCTIVITY						
SATURATION EXTRACT	<4.0 mmhos/cm	<10.0 mmhos/cm	N.A.	N.A.	N.A.	N.A.
SOIL SOLUTION	N.A.	N.A.	<3 mmhos/cm	<[illegible] mmhos/cm	<8 mmhos/cm	<8 mmhos/cm
SODIUM ABSORPTION RATIO (SOIL SOLUTION)	N.A.	N.A.	<20	[illegible]		<30
REDUCTION PRODUCTS IN SOIL SOLUTION AFTER PROLONGED FLOODING	N.A.	N.A.	N.A.	[illegible]	LOW	LOW
TOPOGRAPHY						
SLOPE IN GENERAL GRADIENT	<2 %	<5 %	<8 %	<2 %	<5 %	<8 %
TOTAL DEVELOPMENT COSTS **						
LAND LEVELLING	MINOR	MODERATE	MODERATE	MINOR	MODERATE	MODERATE
LAND CLEARING	MINOR	MODERATE	MODERATE	MINOR	MODERATE	MODERATE
FIELD SIZE OR SHAPE	NO RESTRICTION TO CULTIVATION OR IRRIGATION AT LEAST 150 m IRRIG RUNS	MODERATE RESTRICTION RESULTING FROM THE IRREGULAR SURFACE FEATURES IRRIGATION RUNS AT LEAST 100m	MODERATE RESTRICTION RESULTING FROM THE IRREGULAR SURFACE FEATURES IRRIGATION RUNS AT LEAST [illegible] m	NO RESTRICTION TO CULTIVATION OR IRRIGATION AT LEAST 150m IRRIG IRRIGATION RUNS	MODERATE RESTRICTION RESULTING FROM IRREGULAR SURFACE FEATURES AT LEAST 100 m IRRIGATION RUNS	MODERATE RESTRICTION RESULTING FROM IRREGULAR SURFACE FEATURES AT LEAST 50m IRRIGATION RUNS
DRAINAGE						
FLOODING	MAY BE SUBJECT TO OCCASSIONAL MINOR FLOODING WHICH DOES NOT MATERIALLY AFFECT PRODUCTIVITY	MAY BE SUBJECT TO PERIODIC FLOODING OF SHORT DURATION WHICH MAY MATERIALLY AFFECT PRODUCTIVITY	FLOODING MAY INTERFERE WITH WATER DISTRIBUTION OR MAY LIMIT CROPPING TO THE DRY SEASON	MAY BE SUBJECT TO OCCASSIONAL FLOODING OF SHORT DURATION WHICH DOES NOT MATERIALLY AFFECT PRODUCTIVITY.	MAY BE SUBJECT TO ANNUAL FLOODING WHICH MAY MATERIALLY AFFECT PRODUCTIVITY	MAY BE SUBJECT TO SEVERE FLOODING LIMITING RICE CROPPING TO THE DRY SEASON
INTERNAL ***	MODERATE TO RAPID	MODERATE TO RAPID	MODERATE TO RAPID	SLOW	SLOW	SLOW

M LANDS - LANDS IN MUNICIPALITIES OR RESIDENTIAL AREAS OR LANDS IN ACTIVE STAGE OF SUBDIVISION

CLASS 6 - NONARABLE INCLUDES LANDS WHICH DO NOT MEET THE MINIMUM REQUIREMENTS FOR THE OTHER LAND CLASSES AND ARE NOT SUITABLE FOR IRRIGATION. THEY INCLUDE [illegible] THAT ARE VERY SHALLOW OVER BEDROCK OR OTHER FORMATION IMPERVIOUS TO ROOTS OR WATER, LANDS WITH SALT-AFFECTED SOILS THAT ARE RECLAIMABLE WITH DIFFIC[illegible] BECAUSE OF TEXTURE, POSITION, SUBSTRATUM CONDITIONS, ETC., LANDS WITH EXTREMELY COARSED TEXTURED SURFACED SOILS, SOIL HAVING LOW AVAILABLE WATER CAPACITY, ROUG[illegible] HUMMOCKY AND SEVERELY CHANNEL-DISSECTED LANDS, AREAS SUCH AS HILLOCKS AND RIVER LEVEES, OVERFLOW AND [illegible] CHANNELS, PERMANENT WASTE AND DUMP AREAS [illegible] HAVING EXCESSIVELY STEEP OR COMPLEX TOPOGRAPHY, AND ALL OTHER OBVIOUSLY NON-ARABLE AREAS

* APPRAISAL FOR DIVERSIFIED CROP PRODUCTION IS DEPENDENT ON TYPE OF CLAY AND CROPPING PATTERN

** ALL LAND DEVELOPMENT IS A FARMER COST AND LAND CLASS DETERMINING

*** IN ARABILITY STUDIES, DRAIN SPACING AND ECONOMIC STUDIES WILL DETERMINE WHETHER THE LAND SHOULD BE UTILIZED FOR DIVERSIFIED CROPS OR WETLAND RICE PRODUCTION OR FOR MULTICROPPING

Table 3. Preliminary Arable Hectarage Tabulation of Dual Land Classes, Magat River Project Feasibility Studies, Isabela, as of November 15, 1972.

CLASS	AREA(HAS.)	
1R		9,143.6
1R (1)	533.5	
1R (2do)	8,610.1	
2R		967.8
2Rtj (2 tj)	236.1	
2Rtj (3 td jo)	45.2	
2Rtj (2 td jo)	110.7	
2Rtj (2 do)	105.4	
2Rtu (2 tu)	145.1	
2Rtu (3 td uo)	26.0	
2Rtu (3 td jo)	25.7	
2Rdf (2 df)	116.3	
2Rst vj (2 tj)	76.5	
2Rtd jf (2 td jf)	38.2	
2Rtd uf (3 td uo)	42.6	
3R		162.0
3Rtj (3 tj)	85.6	
3Rst yj (3 t yj)	61.9	
3Rtd jf (3 td jf)	14.5	

GRAND TOTAL ---10,273.4 has.[1/]

1/ This is a potential area for use in multi-cropping, and could be isolated if found economically feasible to provide a suitable drainage system for diversfied crop and rice farming, alternately.

The basis for multi-crop classification is the drainability of the sub-soil and substrata. Lands having unrestricted natural sub-surface drainage, having sub-soil and substrata which would respond to artificial sub-drainage, or in positions which apparently could be served by a project drain outlet system at economic costs were classified as potentially suitable for multi-cropping. Lands with slowly permeable subsoils,with barriers such as tight clay or hardpan within 2 meters of the surface, or those located where adequate drain outlets could not be provided at reasonable cost were excluded.

The basic prerequisite to develop land for multi-cropping is the construction of a suitable system of drain outlets which would allow rice farming but would also prevent water-logging or submergence of upland crops. At this stage we have not concluded our studies at UPRP and MRPFS. We are encouraging others to determine the most feasible system, at reasonable cost, as well.

USES OF LAND CLASSIFICATION INFORMATION

The primary function of land classification is to delineate the areas suitable for irrigation development. It also serves as one of the basic elements in determining water requirements, evaluating land use and management requirements including the determination of farm family size, estimating and determining good methods of land development, deriving irrigation benefits and payment capacity from farm returns, developing the engineering layout for the distribution and drainage system, appraising land values, and forming the basis for assessment of water charges. Most of these are relevant to water management and apply generally to irrigation and drainage planning, construction, operation and maintenance.

Selection of irrigable area

Once the available water and the farm water requirement, including losses, are known, it is possible to establish the maximum area that can be served. No economic practices can extend that potential area.

Land classification occurs in two stages. The first involves selection of arable land and the second the selection of irrigable lands. Arable lands are separated by the land classifiers on the basis of an engineer's preliminary consideration of possible sources and location of water after examining the diversion sites and available storage. Land that can be physically served can be roughly delineated knowing the general crops to be grown and their tentative water use requirements. When the preliminary canal locations become available, lands are further segregated by categories according to their irrigation suitability.

Any adjustments regarding irrigation, drainage, and other facilities made after the development plan has been formulated, affect the selection of the irrigable area. Engineers lay out the distribution system to reach the lands having adequate productive capacity; they determine the cost of that system, eliminate portions which are difficult or expensive to serve or unsuitable for development, and adjust the arable area to the available water supply. In this process the contributions from soil scientists, irrigation engineers, economists, agronomists, and other disciplines would be highly desirable.

The tabulation of arable and irrigable land hectarage in the Upper Pampanga River Project (UPRP) Land Classification Report (RP-NIA, 1971b) is offered in Table 4. The gross area covered was 128,490 has. The total arable land consists of 103,830 has, and non-arable land 24,600 has. Of the arable land only 101,060 has were declared as irrigable. The major reason for this reduction is Land Class 3Rd(f) which has a drainage deficiency due to flooding hazards. These areas include 2,410 has of arable land in the southwest (lowest)portion of the project within the municipalities of San Antonio, Zaragoza and Aliaga. They are beset by 2 and sometimes 3 or more flooding periods during the wet season, which often lead to crop failure due to prolonged submergence of the crop. They produced, however, successful diversfied crops (usually watermelon) without irrigation during the dry season when the floodwater has receeded. Two effects of irrigating these lands are likely: the annual flooding would greatly increase the maintenance and repair costs for irrigation and drainage structures, and, with year-round irrigation, the water table would rise even during the dry season and no diversified crops could then be grown. (Unirrigated rice during the dry season dependent only on waste water from the higher farms is, however, a possibility.) For these reasons 2,340 has of these lands were excluded from the project area as non-irrigable.

Water requirement determination

The size of the irrigable lands, the classes of land, and their location enter directly into the determination of the water requirement. To some extent, the kind and distribution of crops grown are determined by the class of land, and as crops differ in their water requirement, the overall water requirements are affected accordingly. Soils also vary widely in their percolation, infiltration, and permeability rates and in their moisture storage capabilities, mainly because of differences in texture and depth. These factors affect water requirements directly and indirectly and relate to conveyance losses in canals. Such data, although preliminary, can be used by engineers to locate sections of the canals for testing and to decide the need for linings and possible re-location. Critical information on contemplated irrigation efficiencies and on crop distribution is essential and could also be provided. Related studies on consumptive use, percolation rates and losses could also be undertaken.

In the UPRP land classification the water requirement information for the different land classes was not assessed. There were no data then

Table 4. UPRP land classification survey results: Hectarage tabulations 1/

Land class	Arable (Hectares)		Irrigable (Hectares)	Multiple crop potential (Hectares)	
A. Best suited for diversified crops					
Class 1	1,230		1,230		
2	5,550		5,550		
2s		300			
2t		2,280			
2d		350			
2sd		420			
2td		430			
2st		770			
Sub-total	6,780 has.		6,780 has.		
B. Best suited for rice production					
Class 1R	75,540		75,540	Class 1R (1)	330
Class 2R	19,100		18,670	Class 1R (2)	25,040
2Rs		6,200		Class 2R (1)	490
2Rt		4,430		Class 2R (2)	840
2Rd		7,660			
2Rst		680			
2Rsd		130			
Class 3R	2,410		70		
Sub-total	97,050 has.		94,280 has.		
Suitable for irrigation development					
GRAND TOTAL - 103,830 has.			101,060 has.		
C. Non-Arable land class					
Class 6	9,720				
Class M	6,460				
Right of way(7.5%)	8,480				
Not suitable for irrigation development: GRAND TOTAL - 24,660					
TOTAL AREA -128,490 has.			101,060 has.		26,210 has.

1/ Drawn from the land classification and supporting studies report, Upper Pampanga River Project, RP-NIA, 1971b).

to be used, and nobody could tell us what to use. At a later time, however, farm level studies on consumptive use and percolation losses indicated that lands within a given project area have similar consumptive use but different percolation rates due to differences in soil texture and profile, position with respect to drains, and elevation. The percolation rates found in our field studies, however, were obtained on very small areas and were not representative of farms. The data indicated nevertheless that the percolation rates in our Land Class 1R are within the range of 0 - 4 mm/day. Hence, it was decided that a qualitative assessment of water requirement could be made based on physical characteristics that could be observed by our land classifiers. These include the field appraisal of soil (depth, texture, and water holding capacity), topographic (uneven surfaces, feasibility of leveling and slope), and drainage characteristics. The following three farm water requirement classes were mapped for the Magat River Land Classification.

1. Low farm delivery requirement, symbol "A". For Rice Classes: Clay surface soils and subsoils, or medium textured soils underlain by a barrier zone which prevents significant deep percolation losses; smooth, level surface which permits efficient water application with a minimum amount of surface loss. For Diversified Crop Classes: Medium to coarse textured soils with good subsurface drainage and therefore subject to low to moderate deep percolation losses; may have reduced irrigation application efficiency because of uneven, gently undulating, or sloping surface.

2. Medium farm delivery requirement, symbol "B". For Rice Classes: Medium textured surface soils underlain by medium textured subsoils and substrata, or fine-textured surface soils underlain by coarse pervious materials which will permit moderate deep percolation losses, or fine-textured soils combined with sloping or irregular surfaces which will permit lateral movement of the perched water table and thus increase the farm irrigation requirement. For Diversified Crop Classes: Coarse-textured or shallow soils with good subsurface drainage, subject to moderate deep percolation losses; likely to have reduced irrigation application efficiency because of irregular or sloping surface.

3. High farm delivery requirement, symbol "C". For Rice Classes: Medium to coarse-textured surface soils subject to water table build up with full irrigation, accompanied by moderate to high water loss from deep percolation or lateral movement of ground water; may exist in combination with irregular or sloping surface which will decrease irrigation application efficiency. For Diversified Crop Classes: No "C" farm delivery requirement classes are anticipated for diversified crops. The highest water use with normal application methods should be no higher than average or medium water use for paddy.

Land use and farm size

The suitability of land for various crops reflects probable water use. The size and shape of farms also influence water deliveries and distribution.

The data collected in the land classification is utilized in projecting land use patterns and adequate farm family size based on economic parameters of productivity and cost of production. These parameters are in turn related to crop adaptabilities and land development costs. Crop selection influences the water requirements as well as the total income that can be derived from the development of land.

Land development and cost

In water resource development planning facilities are considered complete only when the water is brought to the individual farm. This means that irrigation and drainange facilities beyond the turnout must be provided. Whether these facilities are part of project costs or the farmers' costs must be resolved beforehand. Land classifiers can provide basic information regarding the improvements that must be pursued on the farm before the lands can be considered adequately developed. The location of the farm turnout, its elevation and capabilities frequently determine the best way to grade and improve the land for irrigation, and the best methods of irrigatinn. Where topography is rough, yet the possibility to develop the lands at economic cost is great, the costs of leveling or bench terracing need to be obtained.

Irrigation benefits

An economist identifies the benefits of the project to the general economy of the country. People who have worked on water management have concluded that to improve water management through increases in irrigation efficiency requires a corresponding increase in investment. For any project, the total return to the economy of all resources committed regardless of who in the society contributes them and regardless of who receives the benefits, is the foremost consideration. This will merit a separate economic analysis of the whole project, which is distinct from the financial analysis whereby the concern is with the return to the equity capital which each individual farmer-operator contributes.

Land classification information provides a measure of the increased production which would result from irrigation development. The stream of benefits is derived from the information provided and related directly to the justification of the project, or the magnitutde of the benefit-cost ratio. For the financial backers of the project this analysis serves as the basis for determining the internal economic rate of return which forms the basis for setting priorities for several projects.

Economic farm value of water

Improved water management implies an integrated agricultural development which involves adoption of improved cultural practices. Financial analysis of individual farm businesses should indicate the profitability of using new practices to increase production. Likewise the increased cost of better managing irrigation water must be reflected t indicate the farm value of water.

The determination of payment capacity (which is here taken to be the same as the farm value of water) helps to delimit the irrigable area, provides an appraisal of land productivity and development, and governs the projected land use pattern. Payment capacity varies with land classes and provides a direct means for arriving at reasonable estimates of the total payment capacity of a given irrigation project area. Financing institutions commonly use this as a criterion for determining the contributior to the individual entitites to be involved in the project development.

Economists use land classification as their basic data and guide to measure economic viability and financial soundness of the project. This is useful in studying the desirability of including or excluding land and investment in the project.

Irrigation and drainage layout

Engineers use the land classification maps, field sheets, and detailed topographic maps to develop the layouts for irrigation and drainage systems. Irrigation-engineering decisions rely upon information provided by the hydrologist and drainage engineers to adjust the arable area and come up with the irrigable area that could be served. A better canal layout could be made if information provided by land classification were also used.

Land appraisal and valuation

Land valuation for taxation purposes,or for settlement, selling or buying has become basic in agrarian reform and business transactions. Lands classified in accordance with productivity and land development costs (together with the economic value in terms of net farm returns) provide a good guide for the valuation of agricultural lands. Preliminary estimates for cost of right-of-way can also be obtained from the information collected in land classification. A basis thus exists for establishing a fair market value of the land.

Irrigation water charge

The total and irrigable area by land classes, together with allocation costs and payment capacity, can be used for determining irrigation water charges. The farm value of water, considering the economics of farm production, should be related to the costs incurred by the project. Accordingly, land classification enables administrators to arrive at a basis for the collection of project costs and investments. Whether the payment is based on the farm value of water or an arbitrary rate related to the annual cost of operation and maintenance is a political decision. When making such a decision, however, sufficient information should be available so that if subsidized irrigation water charges are used, alternative sources of repayment are identified.

SOIL SURVEY AND LAND CLASSIFICATION RELATIONSHIP

The selection of irrigable lands must be a closely coordinated, well-organized scientific inquiry into the behavior of soil, water, and plants under defined systems of land management and use. To this end a soil survey makes a valuable contribution to land classification. Careful study of the areal pattern, qualities, and characteristics of the natural soil bodies is related to land form and geology. These provide an excellent basis for determining the problems to be encountered, potential cropping patterns, selection of sampling sites, and intensity of laboratory analysis as required for the land classification studies. Availability of soil survey data further provides means for the transfer of research and experience. The two works are distinct but soil surveys do complement the land classification studies.

Although most soil scientists would claim that soil surveys are capable of other uses simply by interpretation, the resulting classification does not comply with the four principles and three rules of logic presented, and it therefore loses its practical value. The temptation to use the soil survey as an end in itself when selecting lands for irrigation should be avoided. Classification of lands to be irrigated cannot be done by mere interpretation without the prediction and other principles outlined above

Natural soil bodies can seldom be grouped directly into land classes; the difficult tasks of synthesis and interpretation cannot be avoided. In this process, the concern is not only with soil but also with the quality of irrigation water; the natural configuration of the land surface and substrata; anticipated distribution and movement of ground water; porposed locations of canals; and water requirements. A critical analysis of irrigability cannot be made without careful appraisal of the substrata. For example, the change in moisture status may induce intolerable drainage problems that would destroy the productivity of an otherwise highly suitable soil. In such cases the substrata rather than the soil is the determinant of irrigation suitability.

Land classification has been shown to be based upon economic, social, and other factors which are subject to change. The soil survey, however, provides a collection of facts which are less subject to change. The soil survey, by defining the initial conditions, provides a good basis for making predictions of anticipated changes. While the soil survey defines existing soil bodies, the land classification survey must recognize and appraise the changes in order to properly select irrigable lands.

Where soil surveys have been completed before the start of irrigation project planning they should be carefully studied and the soil interpreted for irrigation suitability. Detailed soil surveys are required. The interpretation process should be conducted systematically following principles and procedures established for the land classification survey, and it should be done in the field, augmented by recorded profile observations. These should include location, field measurements and observations of topography, drainage, and water quality. The field work is still essential since land class boundaries and the natural soil bodies do not generally coincide.

Soil surveys serve many different purposes and can be interpreted as needed for each purpose. Land classification is a specific undertaking and cannot replace the need for a systematic soil survey. Where arrangements can be made to conduct each job cooperatively, a more useful soil survey and a better land classification will result.

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Water management plan for the Upper Pampanga River Project

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ABSTRACT

Water management activities within the National Irrigation Administration are outlined, with special emphasis on those adopted by the Upper Pampanga River Project. This project, not yet complete, will have reservoir storage for the dry season crop. The system of rotational irrigation being implemented in the project area is described, and its problems are discussed. The problems include improving the effective use of rain water, and organizing and educating farmers for more efficient water use. The findings are supported with water-use data from a pilot area.

AN IMPROVED WATER MANAGEMENT SCHEME IN THE NATIONAL IRRIGATION ADMINISTRATION

Water management has always been an activity in all irrigation systems operated and maintained by the National Irrigation Administration (NIA). The scope of this activity is best described by the definition drawn up by the staff of the NIA-ADB (Asian Development Bank) Water Management Project: "Water Management is the integrated processes of diversion, conveyance, regulation, measurement, distribution, and application of the rational amount of water at the proper time, and removal of excess water from the farms to promote increased production in conjunction with improved cultural practices." Clearly maximum benefits from investments in irrigation systems depend upon proper control and use of water in combination with other agricultural inputs and cultural practices.

A few years ago, water supply in national irrigation systems was not a problem. There was more than enough irrigation water to fully irrigate the service area of these systems. Water management was ignored, it was not even considered a necessity. But, as the systems began to deteriorate for lack of sufficient funds for their maintenance and as the forested mountains became denuded, surface water became less and less available. Now, stream flow during the dry season is so limited that at times there is no flow at all.

NIA embarked in a crash program of rehabilitation of existing irrigation systems all over the country. New irrigation projects were constructed whenever economically feasible. But the need for more irrigation water became increased as new areas were opened up. At this stage water management, which had not previously been given due attention, loomed as the best solution to the problem.

NIA-ADB PILOT PROJECTS

In 1968, the Philippine government, through the NIA and ADB, drew up a technical assistance agreement for the establishment of eight water management pilot projects throughout the country. The pilot projects were established (1) to demonstrate the most suitable water management to increase the crop area, (2) to demonstrate a more practical cropping pattern to increase production and income, (3) to organize irrigators' associations for the successful implementation of a well-coordinated water distribution scheme, and (4) to adopt the pilot area as a training center for on-the-job-training of NIA personnel and farmers.

To attain these objectives irrigation superintendents and other NIA personnel underwent training on water management for 2 to 3 weeks. In the second year of operation (1970) a comprehensive water management manual was written for the use of various NIA engineers and personnel. Continuous research was undertaken and guidelines were developed for use in all systems.

SETBACKS TO PROGRAM IMPLEMENTATION

Upon completing the water management training seminars, the NIA engineers were expected to implement water management in the systems they represented. But most of the systems lacked on-farm water management facilities.

The purpose of irrigation development should not be just the construction of irrigation systems which supply water to large tracts of land. Rather water should be delivered directly to the fields in ways which allow the farmer to control its entry and exist and to use it in conjunction with improved cultural practices to increase his production. In short, there was a need for gated turnouts, measuring devices, and farm ditches, for which funds had to be provided. And even where these terminal facilities were available a more serious problem appeared to be the lack of technical guidance for farmers. For water management to succeed, the farmers need a continuing program of information, guidance, and education on water management and irrigated agriculture. The farmer should be taught to use the water at the proper time and in the right amount. He must know how to combine water with agricultural inputs, how to prepare his fields for the application of water, and how to remove excess water. Finally, he must know how to conserve water and soil which are his most valuable resources. If the farmer learns his role in irrigation development it should be easy to get his cooperation.

IMPLEMENTATION IN THE UPRP

Despite some setbacks in implementation in some systems, the NIA launched a wide-scale water management scheme when it undertook the Upper Pampanga River Project (UPRP). UPRP is the largest single item of infrastructure being undertaken by the Philippine government today.

It is located in the upper reaches of the Pampanga River in Nueva Ecija province. The multi-purpose project will control, regulate, and use the irregular flows of the Pampanga River and its tributaries for irrigation, domestic water supply, hydroelectric power, flood control, and will provide facilities for recreation and fish conservation. Full operation of the system is expected in 1975.

The principal function of the project is irrigation. It will be capable of irrigating 77,000 hectares during the wet season and 72,000 hectares during the dry season. Upon completion of the project, rice production within the project area is expected to reach more than 570,000 metric tons, and the production of other crops will increase correspondingly.

To irrigate the project area adequately, rotational irrigation will be used along the main farm ditch. Increased use of rainfall during the rainy season will be emphasized as this would enable the project to service a wider area.

ROTATIONAL IRRIGATION METHOD OF WATER MANAGEMENT

The rotational irrigation method of water distribution, which is under study in pilot areas in the Philippines, is not difficult to implement if farm-level terminal facilities within the service area are complete and more intensive water management is practiced.

In the existing irrigation systems of the NIA, terminal facilities such as those to be provided for by the UPRP, are not available. Complete control of water supply in these systems is therefore almost impossible.

The principle of rotational irrigation is simple. It is based upon continuous water deliveries to relatively large areas which are subdivided and receive water by rotation. In the UPRP, the larger areas are approximately 50 hectares, and are served by one turnout. They are called rotation areas (Fig. 1). The rotation areas are further divided into rotation units of about 10 hectares each.

Each rotation area has a gated turnout which can discharge as much as 75 liters per second, the approximate water requirement of 10 hectares for 5 days. This amount of water is delivered within a 24-hour period, after which it is delivered to the next rotational unit until the 5-day rotation cycle is completed. Rotational delivery of water is done by turning in the required amount of water from the turnout to the main farm ditch. In most cases, this main farm ditch, which is about 800 to 1,000 meters long, runs parallel to the lateral. Just a few meters from the outlet of the turnout a parshall flume is constructed to measure the flow of water into the main farm ditch.

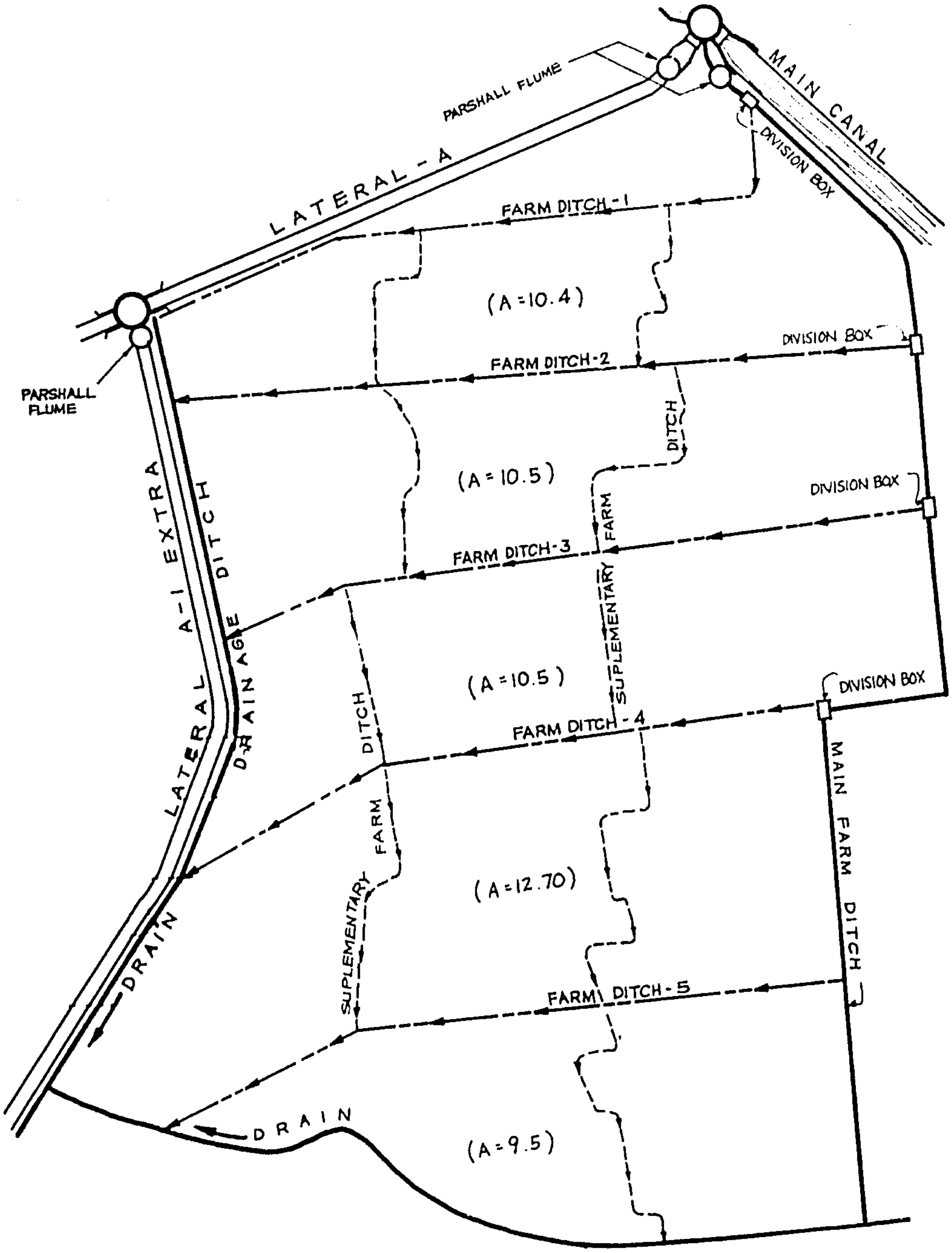

Fig. 1. Rotation area MC-1. Upper Pampanga River Project. (Scale: 1:6,250)

Each of the five rotation units are provided with supplementary farm ditches which are approximately 500 to 700 meters long. Usually, these supplementary farm ditches are about 200 meters apart if the terrain is flat. At the point where the supplementaty farm ditch leaves the main farm ditch, a division box is provided. This box is fitted with grooves on the sides where wooden gates can be inserted when there is need to control the flow of water in the main or supplementary farm ditch. Through off-take structures installed along the supplementary farm ditches, water flows into internal farm ditches built by farmers to serve 3 to 4 hectares. Farmers can simply construct another paddy dike along their paddy dikes, and thereby build an internal farm ditch. At the end of each main and supplementary farm ditch an end check is also constructed. This is necessary to impound the water flowing into the farm ditches during irrigation. When water is no longer needed in the farm ditch, the gates at the end checks are removed and all excess water discharges into the drainage ditch constructed at the lower end of the five supplementary farm ditches. The excess drainage water may either be drained into a nearby creek or be partially reused in the lower areas of the project.

The storage capacity of the Pantabangan reservoir is about 2.3 billion cubic meters, yet it is estimated that the live storage would not be enough for the year-round irrigation needs of the whole service area unless water is used wisely, or rainfall is used efficiently. For this purpose, 19 hydrometeorological stations were constructed throughout the service area. Each station is equipped with an automatic or self-recording rain gage, a standard rain gage, an evaporation pan and an observation well to determine water table fluctuation. Studies by the provincial irrigation office and the agricultural development office are under way for the formulation of an effective irrigation suspension schedule based on the intensity of rainfall as recorded by these stations.

Since all efforts towards effective water management would be useless without the involvement, participation, and cooperation of the farmers in the UPRP, farmers within a rotation area served by a common turnout are banded together to form an irrigators' group. The group selects a leader from among themselves. Through this leader, the group is made responsible for the operation and maintenance of irrigation and drainage ditches and other structures below the turnout level within the rotation area. Each group will contain between 6 and 20 farmers.

Irrigators' groups are organized to promote cooperative work and a spirit of working together for a common cause, to help and cooperate in operating and maintaining irrigation facilities and appurtenant structures, and to obtain a clear undertaking among the farmers and UPRP personnel regarding the water management scheme that is being implemented.

Organization of farmers does not stop at this stage. Irrigators' groups within a barrio or within a command area of one canal are further organized into a farmers' association. This multi-purpose cooperative or association considers the irrigators' group as a committee on irrigation water management. The irrigators' group, therefore, does not lose its legal identity after it is brought into the larger organization. In credit operations, loans are granted to the group and the members are jointly and severally liable for all unpaid loans.

In 1971, 1,200 hectares within the UPRP were provided with complete terminal facilities. This area was developed to serve as a testing ground for all water management practices that would be implemented throughout the service area upon completion of the project in 1975.

After the end of the first year of rotational irrigation in this area, several problems were identified. Some of these problems were farmers' uncooperative attitudes, irregular supply of water in the system, inaccurate measuring structures, lack of conscientiousness in the use of rainwater, disorganized activities of the farmers and inadequate drainage facilities in some low areas.

To immediately cope with the needs of farmers within the service area, two types of training courses are being conducted, the Farmers' School of the Air, and the Training Course for Farmers, Watermasters, and Ditchtenders. The farmers' school is a daily 1-hour broadcast of lessons on water management and agricultural technology through a local radio station. The reactions of farmer-participants are measured through feedback questions also aired at the end of every lecture hour. Initial implementation of this type of training was satisfactory. The first batch of trainees numbered about a thousand. The other training course lasts for 3 days and uses conventional classroom-type lecture and discussion. The course is conducted at the barrio hall, barrio school, or even under the shade of trees when no buildings are available. It serves as a follow-up to the school on the air and has also provided an opportunity to organize the farmers into an irrigators' group and a farmers' association. Water management mechanization and a field trip are covered.

While the reservoir is being constructed and irrigation facilities are being rehabilitated, the farmers are being prepared for the use of the new system through the training courses. It is expected that upon completion of the project in 1975, the farmers within the project area will accept the water management scheme to be implemented and at the same time be more knowledgeable about the use of rainwater.

WATER BALANCE PROJECT

Among other things, the UPRP also conducts applied research studies within the service area to measure more accurately the water requirement of crops and water movement from farm ditches to the paddies. It also conducts other studies relevant to water management.

Water balance studies being conducted should establish benchmark data for water use, determine the assistance needed by existing irrigation systems and farmers in the implementation of a new scheme of water delivery, and provide a measure of rainwater use in the area.

In the studies conducted during the 1972 rainy season on a 30-hectare rehabilitated area (provided with terminal facilities) the following were observed and recorded over a 46-day interval:

Inflow from irrigation canal	436 mm
Rainfall	463 mm
Water applied (irrigation + rainfall)	899 mm
Outflow from drainage canal	610 mm
Net water use (total - drainage)	289 mm
Evapotranspiration by plants (measured from lysimeter tanks -- 5.04 mm/day)	232 mm
Percolation losses (measured from percolation drums -- 1.01 mm/day)	47 mm
Seepage losses (Net water used less evapotranspiration and percolation)	10 mm
Estimated re-use of drainage water (46% of drainage)	281 mm
Field efficiency of water use (net water used/total water applied)	32%
Estimated project efficiency of water used (Net water use divided by total water applied less estimated re-use of drainage)	47%

Two important findings from this study are that farmers are wastefully diverting irrigation water and that rainfall in the area may be enough to sustain normal plant growth during the wet season without irrigation. Wasteful practices could readily be seen from the excessive inflow from the irrigation system. Farmers continuously took water despite abundant rainfall. This practice resulted in practically zero utilization of rainwater, and greatly contributed to drainage losses.

Applied research is being continued to determine the amount of assistance needed in the existing irrigation systems to effectively use irrigation water, and to establish a benchmark for benefit analysis in the future. Such studies will also provide ready information on water management practices within the area, so that remedial measures may be initiated.

The development of the Diezmo Irrigation System: a case study

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ABSTRACT

The National Irrigation Administration (NIA) and the United Nations Development Program (UNDP) are undertaking a 3-year groundwater development project in the Diezmo Friar Irrigation System, to supplement its gravity irrigation supply and to expand and improve the irrigation facilities. Twenty drilling sites have been selected and seven or eight are being developed for the 1973 dry season, to make up the dry season deficiency. New maps of the farming area have been drawn showing in detail the individual paddy fields. Land classification work is in process, and an agroeconomic survey has been completed. Water management is being organized around irrigation blocks containing 20 to 30 farmers each, through which all institutional and organizational services are to be channeled. Despite initial problems in farmer cooperation and participation, work is now proceeding smoothly. The gain in both area irrigated and yield per hectare should result in a substantial rise in farm prodution and income.

The Diezmo Friar Irrigation System is located in Santa Rosa Laguna. The Diezmo system was selected as a pilot demonstration area by the joint National Irrigation Administration - United Nations Development Program groundwater project. A 3-year program was begun in July 1972 with the objective of increasing the production of farm crops by improving irrigation facilities water management and other farming practices.

The Diezmo system was chosen because of the abundant groundwater resources in the area, and an above-average shortfall of available surface water during the dry season. In the Laguna Bay area as a whole, the average shortfall of irrigation supplies results in dry season plantings of only half the potential irrigated area. In the Diezmo system, however only about a third of the potential irrigated area is planted in the dry season.

PRE-PROJECT SITUATION

The Diezmo Friar Land Irrigation System was built by the Spanish Friars in 1850. The system came under the NIA in 1964. The gross area of the Diezmo system is 1305 hectares including lowland rice fields, sugarcane, municipalities, roads canals, etc. The gravity irrigation system is supplied by water from the Diezmo River which has a catchment area of about 31 square kilimeters. In the rainy season some creeks from the Canlubang Sugar Estate occasionally give water to the system. Supplementary water is pumped from some 60 privately owned shallow wells inside the system. These wells are all far from the main canal.

A dam was built in the Diezmo river approximately 13 kilometers from Laguna de Bay (Fig. 1). The dam has a fixed weir and a sluice way. Facing the sluice is the headgate of the main canal of Diezmo. The first 1.5 kilometers of the main canal is a tunnel dug in soft rock (adobe) without lining and with 15 manholes. The open portion of the main canal is approximately 8 kilometers long and ends as a small lateral.

There are 11 laterals with a total length of about 50 kilometers. Lateral C is the biggest and has six sub-laterals. Lateral C collects drainage water from Laterals E, F, G, H, I, and J. Most laterals are dual-purpose canals for irrigation and drainage. Their cross-sections get larger downstream and in most years drainage is no problem. The system has only one steel gate; everywhere else, water is diverted through rectangular gates with wooden boards. In most gates and checks the wooden boards are missing.

In the wet season, water flows more or less freely in the whole system, and the farmers ask their ditchtender for water when they need it. In the dry season the system is divided into two equal-sized priority areas. Priority 1 gets water, priority 2 does not. Usually there is not enough water to serve priority 1 fully. The farmers closest to the main water source get enough water and the farmers further downstream get supplemental water from shallow wells or they do not plant at all.

There is a lack of data regarding land use and only approximate figures can be given. NIA's records show that 1174 ha of lowland rice were served by the system in 1971. Rice and sugarcane are the major crops grown in the area.

Most rice farmers grow high-yielding varieties using straight row planting, dapog seedlings and quite good management practices. Average yield for the 1971 dry and wet seasons was about 2.3 t/ha per crop. All farmers can plant rice in the wet season. Actually it is more correct to refer to the first and second crop than the wet and dry season crop in Diezmo. There is a peak planting time in June and July for the first crop and in November and December for the second crop. The planting report submitted by the watermaster for March to September 1, 1972 shows 903 hectares planted to rice. The report is not complete.

The watermaster's report for the 1971-72 dry season (second crop) shows 415 hectares transplanted between September 1 and March 1. All 415 hectares were charged irrigation fees, but the area transplanted was actually larger due to the private shallow wells. The whole picture is unclear because many farmers served by NIA in the dry season do supplemental irrigation with water from their own wells.

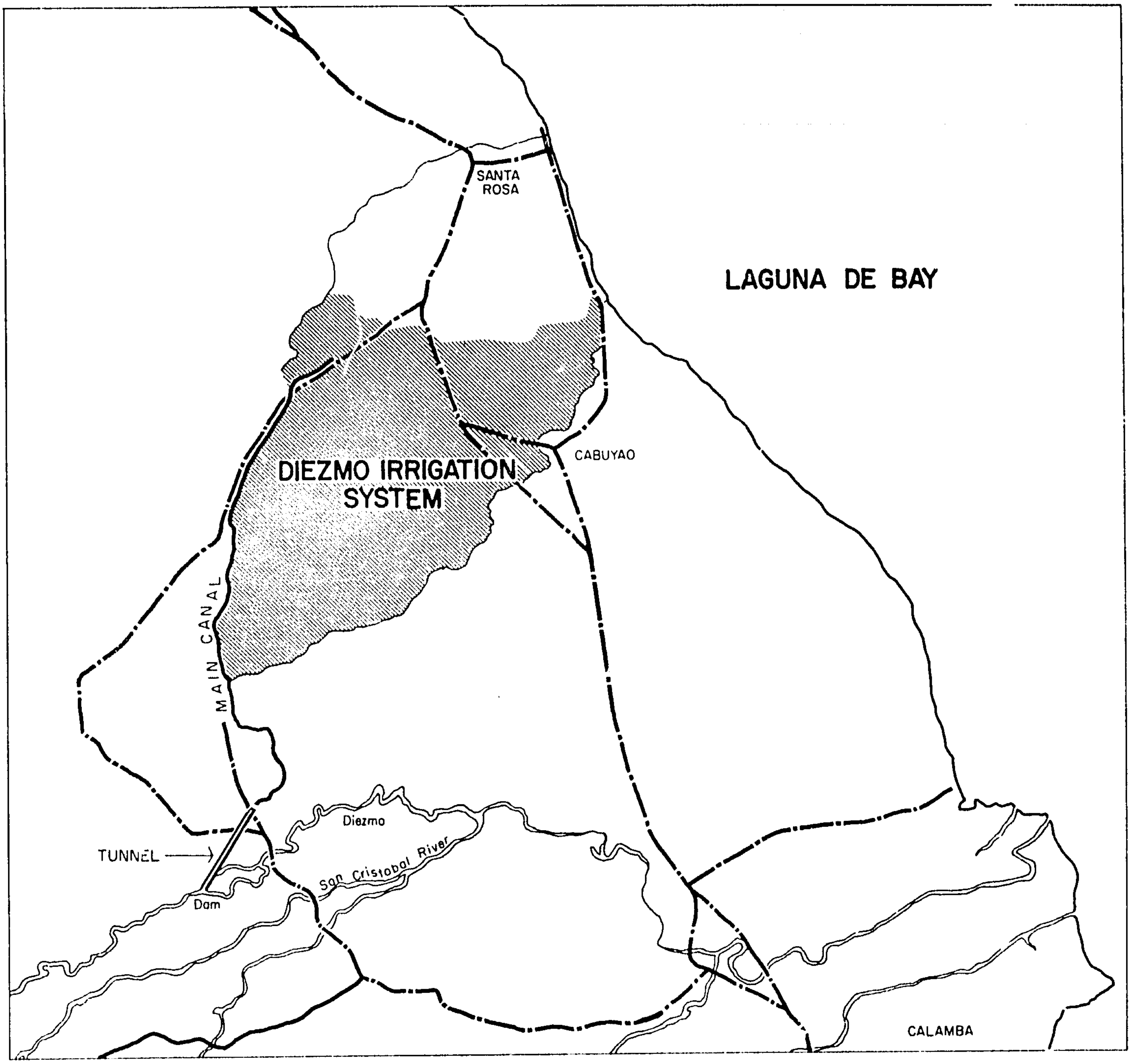

Fig. 1. Location of the Diezmo Irrigation System.

There are no exact figures for the area planted to sugarcane but it is estimated to be 175 to 200 hectares. The growing period is slightly less than 1 year. Planting is normally done in February and irrigation in the first 2 months is usual, but later there is no irrigation. Some sugarcane fields can be reached by gravity from the system, while for others the water is pumped from the laterals or from shallow wells. NIA does not charge any irrigation fee for sugarcane irrigation in Diezmo.

IMPLEMENTATION

The UNDP review mission which approved the choice of the Diezmo as a pilot demonstration area, insisted that a minimum operating period of three dry seasons would be required to implement the project objectives. The project terminates in September 1975, so at least a portion (200 to 300 ha) of the project area must be fully operational by January 1973. Since operations in the area did not start until July 1972, and were delayed 2 to 3 weeks by floods, this task demands a tight schedule and a high level of planning and cooperation among the three project sections - hydrogeology, irrigation-agronomy, and farm management.

Selection of drilling sites

Approximately 20 alternative drilling sites were selected, with seven or eight tubewells to be installed before January 1973. Negotiations have been undertaken between the NIA and the landowners to establish the rights for developing the well sites. The difficulty of contacting absentee landowners caused an unforseen delay.

There were several restrictions for the selection of drilling sites: (1) The distance between each production well should be at least 800 meters, if possible, to avoid interference. (2) The distance from a good road should be as short as possible. The drilling rigs weigh 18 tons each. (3) Sites in the upper parts of the system and along the main canal are best for water distribution. (4) If possible, the sites should be close to the existing power supply in the area. The last requirement was the most difficult to meet and some of the pumps will be run by diesel engines.

Estimate of groundwater requirement

To decide the groundwater requirement, the necessary prerequisites were knowledge of the safe discharge in the Diezmo River, the rainfall in the area, and the water requirement of the system.

River discharge. No records of the discharge in the Diezmo River were available. In the main canal the discharge was measured with two 1-foot Parshall flumes between February and May 1972. In this period all the water in the Diezmo River was diverted to the main canal. To estimate the flow in a 12-month period it was assumed that the discharge of the Diezmo River was in proportion with that of Santa Cruz River about 40 kilometer from Diezmo. The estimated safe flow is shown in the irrigation plan in Figure 2.

Rainfall. Four-year records of daily rainfall (1968-1971) were available from the adjacent Canlubang Sugar Estate. The daily records of the second lowest monthly record during these 4 years were selected for design purposes. Effective rainfall was calculated as 80 percent of all rainfall between 3 mm/day and 20 mm/day.

System scheduling. The system was divided up into three major blocks of equal size each with a planting time of 20 days (see Fig. 2). That means that the whole area will be planted in 60 days. Planting schedules for two crops, two-and-a-half crops, and three crops per year were prepared. The planting times were often a compromise between availability of water and a good harvesting time.

Water use data

The water use requirement is estimated to be 150 mm for land preparation, and daily rates of 7 and 9 mm for the wet and dry season crops. All irrigation will be terminated 15 days before harvest. The land preparation method is that of a constant discharge of 1.53 liter s^{-1} ha^{-1} through the whole period of land preparation in each block. The use of a constant discharge to the block during all 20 days of land preparation implies that the area transplanted per day decreases every day. With the planting schedule used in the irrigation plan, the greatest shortage of water is in February when water requirement is 1,590 liter/s,while the surface water can supply only 560 liter/s, so 1,030 liter/s must be supplied from groundwater.

Additional data requirements

A wide range of additional information is needed on agro-climatic and socio-economic factors to develop and operate the pilot system efficiently. A functional survey has been completed for the main canal and the laterals. The design of the main canal and a wasteway to the Santa Rosa River is finished, and excavation and construction started in late October. The wasteway will make it possible to divert excess water to the adjacent Macabling system which is also under NIA management. Gaging stations are established in the Diezmo River and the main canal. Cutthroat flumes and Parshall flumes are being installed in Block B. A small meteorological station was built along the national highway in October, and in the watershed area an automatic rainfall recorder and an evaporation pan have been installed. Two rainfall recorders were installed within the irrigation system.

The only original map showing the irrigation system was a cadastrial map with a scale of 1:10000. This map is inaccurate and many sublaterals are missing or misplaced. A topographic map, scale 1:10000,

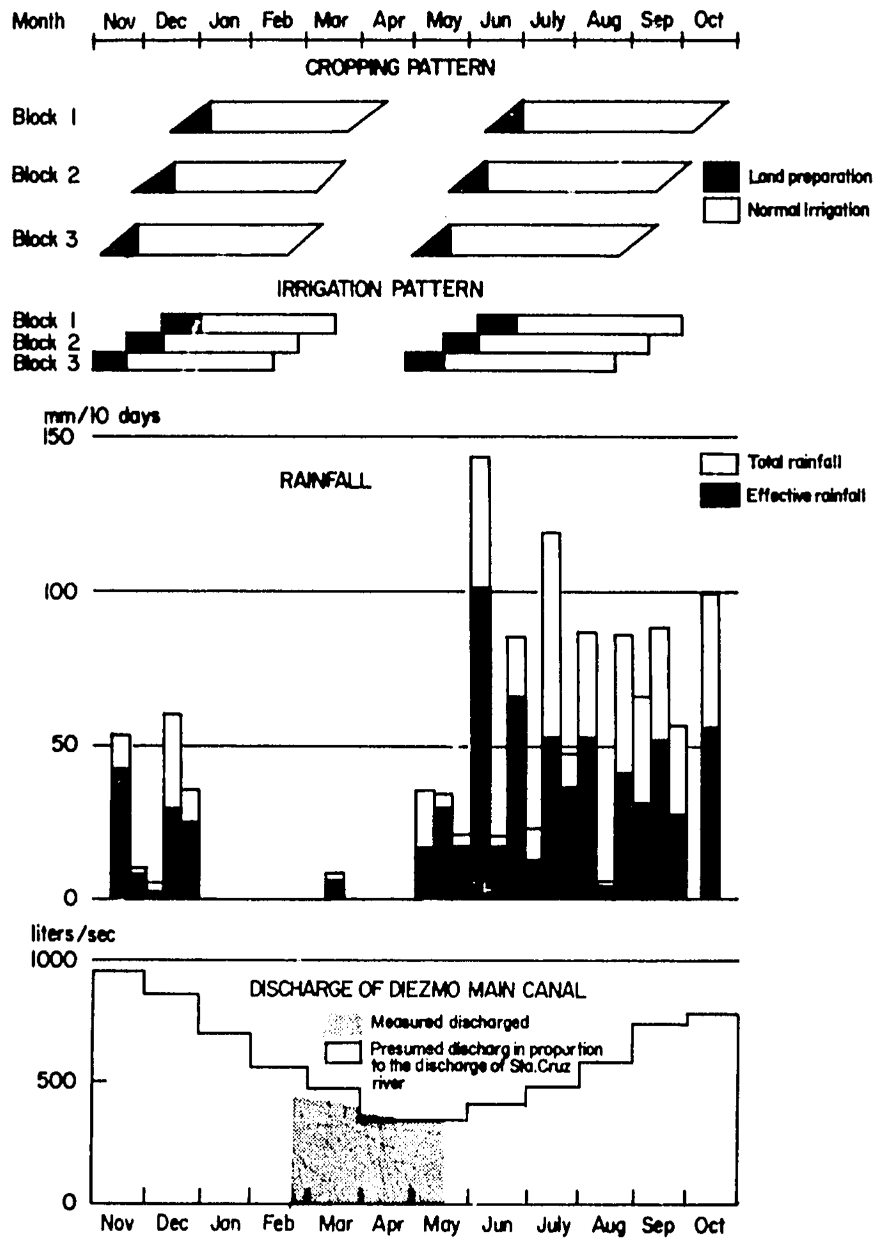

Fig. 2. Proposed planting schedule, expected rainfall, and river hydrograph for the Diezmo River Irrigation System.

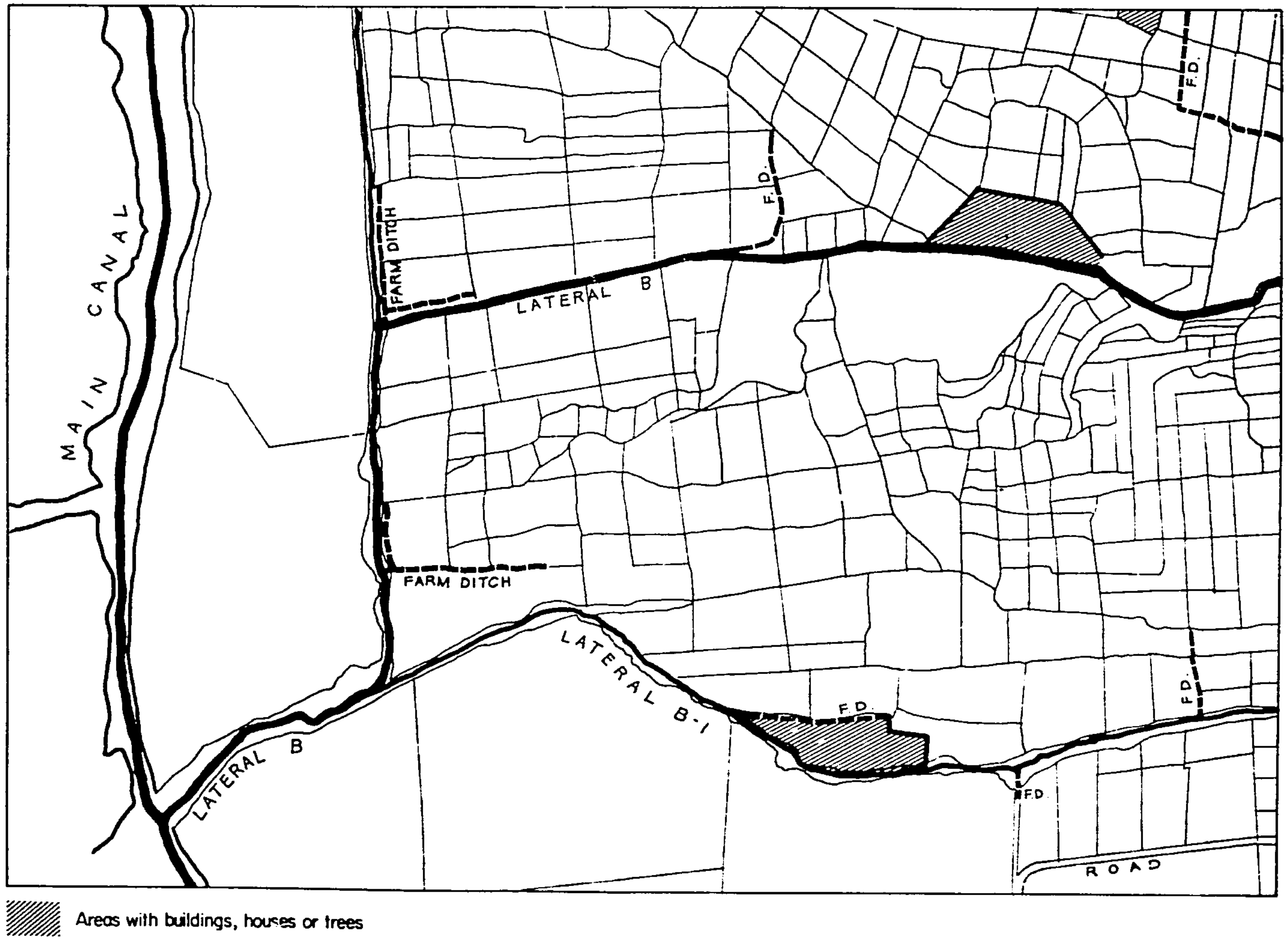

Fig. 3. A portion of block-level mapping to identify features of individual farms.

with contour intervals of 2 meters was available through the Department of National Defense. To make an accurate map of the area, aerial photos with a scale of 1:4000 taken in 1966 were brought to the field and the following information was marked with different colors on plastic overlays: (1) Main canals, laterals, sub-laterals, farm ditches and creeks, (2) Roads, railroads, municipalities, etc. (3) Present land use and estimated harvesting time of the present crop. (4) Location and size of shallow wells. (5) Water direction from paddy to paddy irrigation. With the help of a pantograph, the photos were enlarged to 1:2000 scale and the information from the field survey was transferred. By the end of November maps of three irrigation blocks were finished. They cover a total area of 370 hectares of which 180 hectares are irrigated lowland rice and 140 hectares are sugarcane. Figure 3 shows a limited portion of the Block B map.

Soil survey and land classification

The soil sampling is finished and the samples are being analyzed at the Bureau of Soils. Two teams from the Upper Pampanga River Project are doing the soil survey and land classification. Sampling densities were 250 hectares each for the hand dug master pits, 40 hectares for 3 meter deep angerholes, and 10 and 4 hectares each for 1.5 and 0.5 meter sampling depths. Three major soil series have been identified.

Agro-economic Survey

An agro-economic survey of approximately one-third of the cultivators in the system was made to assess the existing land utilization rate, project area net output, level of extension services, credit assistance, community development markets and farmer attitudes. The survey showed that the level of technical, financial and community development services would have to be raised considerably to enable farmers to take advantage of the improved irrigation facilities. The survey also revealed an ignorance of project objectives, suspicion of motives, and initially a lack of cooperation with survey field technicians, all of which could hamper farmer cooperation.

Development of the irrigated block system

On the basis of information gathered during the initial months of the project, a decision was made in September to develop pilot demonstration blocks (Fig. 3) within the Diezmo system. The system was to be divided into irrigation blocks 50 to 100 hectares in size, each block containing 20 to 30 farmers. The main criterion for delineation of individual blocks was to be, as far as possible, a single water supply. Farmers will be responsible for water distribution within the block at farm ditch level.

All institutional and organizational services will be channeled through individual blocks, which hopefully will be of a convenient size for the formation of farmers associations. This system permits the intensive use of project resources over a limited area.

The block system should facilitate the attainment of the proposed controlled planting schedule to replace the existing random planting of rice which extends almost continuously from May to December. The main criteria in making a final choice of blocks are present harvest dates, and the availability of tubewell water. On this basis, the system has tentatively been divided into 13 irrigation blocks. It was decided that the project could deal with the implementation of up to three blocks for the coming dry season. The plan for Block B is described as follows.

Two sub-laterals, B-1 and B-2, are servicing Block B which covers 62 hectares of lowland rice. Block B is divided into four rotation units with 5 days planting period in each unit so that the whole area will be planted in 20 days. In the 1973 dry season, the farmers have agreed to plant between January 11 to January 31 and have been told that they will get water for land soaking 20 days before they are supposed to plant. Block A will have the same planting time as Block B.

The variation between harvesting dates for the present crop in Block B is unusually small compared with other parts of the system. In Block B, the first harvest is November 10 and the last harvest December 31 for the present crop. Block A, at present, has rice fields at all stages of growth. That means that planting cannot be uniform in Block A in the 1973 dry season. To get a uniform planting as soon as possible, some farmers will be asked to wait and some will be asked to plant a variety with a short growing period.

Before the land-soaking water is due, the structures must be repaired and a few new structures and ditches must be constructed. The farmers must be told when they can expect water during the growing season and how long each water application will take. Trials are being run now to enable us to make final water delivery plans for Blocks A and B.

The farmers in these 2 demonstration blocks have agreed to try to keep the desired water depth in all their paddies after each irrigation. Conventionally, farmers cut a notch in the paddy dike with the result that the high paddies are drained soon after each irrigation. We hope to get bamboo spillways installed so that the water depth is automatically controlled.

To get the farmers involved as much as possible, it will be their responsibility to maintain and improve the farm ditches and, with guidance from the ditchtender, to distribute the water after the turnout from the sub-laterals.

Working with the farmer

The main reason for the initial passive attitude and noncooperation among farmers is undoubtedly a lack of information and understanding of project objectives. It is therefore vital to keep both tenants and landowners fully informed of project objectives. In short, the farmers must be motivated and to achieve this, they must be involved, give their opinions, and share the responsibility for the eventual success of the project. This involvement and joint responsibility will hopefully lead to mutual trust, cooperation, and enthusiasm.

Working on these principles, the farm management section of the project organized a series of meetings in each of the five barrios of the system with the help of the barrio captain and the NIA water master and superintendent. Lease and share tenants were thus informed of project plans and timetables. About 150 farmers out of a potential 350 to 400 attended these meetings.

One problem in the Diezmo area is the high proportion of share tenancies. Of the 375 cultivators identified, 61 percent are share tenants and 32 percent are lease tenants. The rest of the cultivators are landowner. This breakdown excludes the sugarcane plantations which have not yet been included in development plans. The number of share tenants makes landowner cooperation very important. Landowners were thus invited to a series of four meetings at the NIA offices, at which project aims were again explained, and landowners opinions and cooperation were sought. Only about 25 percent of known landowners attended these meetings, but the meetings with both the landowners and the tenants were most successful and a good rapport was established. The attitudes of both groups towards the project changed noticeably after these meetings, and it became apparent that once the potential benefits of the project were understood almost all concerned were prepared to cooperate.

A visit to the Social Laboratory in Pila, Laguna, led us to conclude that success in block development could only be achieved by the intensive involvement of the project down to the individual farmer level. To do this, individual holdings and cultivators in each block have to be identified. The best way to identify holdings and farmers at the block level is to use the 1:2000 scale map of the individual block (Fig. 3). Armed with this map, the technician can identify holdings by walking through the paddies and enlisting the aid of the farmers working in the vicinity.

The essential information and input requirements needed at the farm level are: (a) Explanation of proposed planting schedule and water distribution system down to block and field level. (b) Recommended cultural practices and level of inputs. The College of Agriculture of the University of the Philippines and the International Rice Research Institute were contacted, and promised to assist with recommended packages of cultural practices, aiming at yield levels of 4.5 t/ha per crop. (c) Farmer short term credit requirements. The Rural Bank of Santa Rosa was approached, and the importance of extending credit to cultivators in the three blocks to finance the higher level of inputs required was explained to the manager. A subsequent meeting with the manager and Central Bank officials resulted in agreement to lend to all farmers in the three blocks requiring credit, regardless of tenure status, under the supervised credit scheme of the Agricultural Guaranteed Loan Fund.

This specifies that groups of four or five farmers become collectively responsible for the default of any member of the group. Granting of loans is conditional upon full supervision of cultural practices and marketing of rice by project staff. (d) Organization and responsibility for extension advice. The availability of high level all-round extension technicians is essential for farmer cooperation and successful project implementation. On the Pila model, it was decided that one extension technician should be placed in each irrigated block, to live in the barrio, and to be available to give advice on cultural practices, water management, farm budgeting, and community development. The cooperation of the Agricultural Productivity Commission (APC) was sought, but local APC staff were already engaged in flood rehabilitation work. Fortunately, the project was able to find an experienced extension technician on the recommendation of IRRI, who will act as the leader, and the APC agreed to "loan" two technicians working in Laguna province to the project on a full-time basis. The project agreed to pay them an incentive bonus. (e) Further training of extension technicians and NIA gate keepers. The two APC technicians have already attended a 2-week training course at IRRI. (f) Design and construction of necessary improvements in the distribution system. To implement more efficient water distribution and water management, certain canal improvements and structures are necessary.

FUTURE PLANS

The interdisciplinary development of Blocks A, B, and C is proceeding successfully, and high yields with two crops of rice annually seems likely. Farmer attitudes are such that these blocks may continue to lead the way with five crops in 2 years of even three crops per year. Efficiency of water management should continue to improve with resultant water savings. It is to be expected that farmers will play an increasing role in the future in organizing affairs at the block and even above the block level, not only in production and marketing, but also in the running of the irrigation scheme. The main aim of these pilot blocks is of course to demonstrate the benefits of integrated development, so that within 2 years the whole system, consisting of 13 blocks, should be functioning at a high level of technical, institutional, and organization efficiency.

Water management innovations in the National Irrigation Administration

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ABSTRACT

The water management program of the National Irrigation Administration is described in this paper. It focuses on the Asian Development Bank-supported pilot project in the Angat River Irrigation System in Bulacan. That project has combined applied research and extension with operational innovations which have enabled improved irrigation both in terms of quality and area served. The project is now being expanded to several thousand hectares of the system preparatory to its implementation in other systems.

The National Irrigation Administration (NIA) was created in 1964, as successor to the Irrigation Division of the Bureau of Public Works to undertake the tasks of irrigation development and the subsequent operation and maintenance of the national irrigation systems plus the Friar Lands Irrigation Systems in Laguna and Cavite. These systems were in very poor condition. Canals were heavily silted and covered with thick growths of vegetation, embankments were below grade, and structure outlets were seriously eroded.

To improve the efficiency of NIA systems, massive rehabilitation was undertaken in 1965. Nevertheless the area serviced and unit yield did not increase significantly. Farmers diverted the irrigation water at will, wherever and whenever needed. Farmers commonly believe that the best condition for the rice crop is to maintain running water over their paddies. Thus, farmers along the canals allow water to flow continuously over their farms toward the lower areas, wasting water and causing inundation and waterlogging in some areas. There is therefore a need for research and demonstration projects on irrigated farming.

THE NIA-ADB WATER MANAGEMENT PROJECT

In 1968, NIA requested technical assistance on water management from the Asian Development Bank (ADB). After a series of meetings ADB and NIA reached an agreement which called for the formulation and implementation of water management projects in eight irrigation systems. ADB financed a panel of experts to provide technical assistance in water management. The panel was composed of an irrigation engineer, a water management expert, an irrigation agronomist, an irrigation economist, and a land-use expert. ADB also financed 40 percent of the cost of additional facilities and equipment needed to carry out the project. The NIA provided the counterparts for the experts of ADB, and other costs of the project not provided by ADB. The project began operation in 1968.

To clarify the scope of the work to be undertaken, the team defined water management as the integrated processes of diversion, conveyance, regulation, measurement, distribution, and application of the right amount of water at the proper time and removal of excess water from farms to promote increased production in conjunction with improved cultural practices.

The work was divided into research, implementation, extension, and production. Increasing the productivity of the land through proper land and water use and encouraging modern agricultural practices will greatly improve the living conditions of the people within a water resource development project.

Water management innovation in the NIA has four distinct objectives: (1) to work out and demonstrate the most suitable water management practices to increase the crop areas served satisfactorily and profitably, (2) to work out and demonstrate a workable and proper cropping pattern to increase productivity and income, (3) to organize irrigators' association for the successful implementation of well-coordinated water distribution and cropping schedules, and (4) to adopt the pilot area as a social-technical laboratory for on-the-job training of NIA personnel and farmers.

Scientific knowledge of how to manage the water in agricultural fields is available, but the problem is how to transfer this knowledge to the millions of farmers who need it; how to transform the knowledge of sophisticated plant-soil-water interrelationships into simple guidelines for the irrigators. This is a problem where cooperation, through the exchange of information and experiences in seminars and workshops, is needed.

STRATEGY OF IMPLEMENTATION

Proper water management in an irrigation system can only be possible if terminal facilities and other irrigation structures are completely installed. Therefore, when the project began an inventory of terminal facilities was undertaken for subsequent functional planning in the construction of additional ones.

Data on meteorology, agronomy, soil, water, and other items needed for water management were collected, to serve as a guide for the initial operation of the project on a pilot basis. A survey was conducted to determine the socio-economic status of farmers in the project area. The data were used to identify weak points in farm management and to recommend proper approaches on farm work schedules, varieties of rice to use, and fertilizers and other chemicals to apply.

Eight pilot projects in eight irrigation systems representing the six irrigation regions, were pre-selected, and accessible areas were selected for implementing water management practices. The pilot projects served as on-the-job laboratories for social, economic, and technical innovations in irrigation water management.

The main pilot projects are the Angat River Irrigation System in Bulacan and Peñaranda River Irrigation System in Nueva Ecija, where detailed technical assistance in planning and field implementation were concentrated. Field offices in all the pilot project areas were constructed as the common meeting place of farmers and of farm-level water management technicians.

In the 140-hectare pilot area in the Angat system (Fig. 1), rotational distribution by farm ditch was the method adopted with a 6.5 day rotation interval. In the dry season 12 mm/day applied and in the wet season, 10 mm/day. These figures were found to be higher than necessary, so they were subsequently reduced to 8 and 6 mm/day for the 2 seasons.

To enhance the technical capability and efficiency of the NIA professional staff in improved water management operation, four training courses were conducted at the project headquarters in Bulacan. Sixty-four participants were taught the techniques of water management during the three in-service training courses conducted by the NIA-ADB team. The fourth training course conducted in 1970 was for watermasters, ditchtenders, and NIA technical personnel to be designated as water management trainers in their respective areas. In addition to the local training program, four NIA engineers were sent abroad for 4 months to observe advanced management of irrigation systems.

Special classes for ditchtenders have been conducted. The special classes have the following objectives: (1) to teach the most practical ways of implementing improved water management practices, including the proper use of production inputs, such as fertilizers, good quality seeds, farm chemicals, and the wise use of irrigation water to insure increased production; (2) to develop effective and responsive ditchtenders equipped with competence in improved water management, as well as the ability to disseminate their knowledge; (3) to train NIA field workers, who understand the concept of group work, thus enabling them to practice democratic principles in the process of cooperation; (4) to enable the ditchtenders to recognize typical problems in improved water management and to find on-the-spot solutions to problems including irrigation priorities depending on the conditions and stages of crop growth.

As a pilot project, the area served by Lateral D (about 1500 hectares) at the south main canal of the Angat system in Bulacan was selected. Records of previous operations undertaken in the Angat system showed that six barrios (villages) do not receive the appropriate supply of irrigation water even during the rainy season which contributed to the failures of rice production resulting in confusion and disappointment among farmers.

Details of the water management program proposed for the area and the strategies of implementation were discussed with the watermaster and 10 ditchtenders of the division. In 1970, fifteen farmers planted a dry season crop on a trial basis under the new program. The crop received adequate water.

Lateral D, with its sub-laterals and farm ditches, was calibrated to make sure that it could carry the peak water requirement and deliver water to the service area when needed. Ditchtenders attended religiously to their work. Gaps were closed. Turnouts were gated. Ditchtenders were taught to read and record water discharge measurements. Strict adherence to the rules and strategies of implementation were carried out. Meetings with farmers were held and supplemented with farm and home visits and personal calls to convey the message that -- water supply has been assured water is coming -- a second crop of rice can be raised profitably. Despite these assurances, the farmers were still reluctant to plant a second crop of rice. They had several bad experiences in previous years. During one of the campaign meetings with farmers, various remarks were heard like: "That is not true," "It's only a gimmick," "We are fed up with similar promises."

A series of educational campaigns was launched to show farmers that the irrigation system could supply the needed amount of water to sustain their rice plants for a profitable level of production. Through existing barrio associations and organized interest groups, the idea of improved farming practices as a corollary to improved water management gradually gained a foot-hold among farmers. The farmers felt secure in their farming ventures later on. The idea of improved water management has swept the barrios and spread among the farmers. Fear of lack of water to sustain crop requirements has been broken and the advantages of improved water management are being accepted by farmers.

Crop failures have been avoided. The average production is 2.6 t/ha (60 cavans), where the farmers harvested no dry season crop before. The role played by the water management team coupled with the spirit of cooperation of the farmers and their eagerness to improve their standard of living have provided a very encouraging atmosphere.

Timing is an indispensable factor in proper water application, weeding, plant protection, and fertilizer application. Despite the widespread tungro infestation, farmers in the Angat pilot area got a highly profitable harvest. Water management, therefore, is one of the insurance factors against crop failures.

In a rice production contest sponsored by the Irrigators-Seed Growers' Association, Inc. and the NIA water management project, the first prize winner got an average yield of 6.8 t/ha (155 cavans); second prize winner, harvested 5.4 t/ha (123 cavans); and the third prize winner, got 5.1 t/ha (116 cavans). The majority of the contestants got at least 3 t/ha (70 cavans).

Double cropping of rice gained a strong adherence among farmers in the area. Average rice yield increased from 1.3 t/ha (30 cavans) to 2.6 t/ha(60 cav). From the 15 hectares in rice in the 1970 dry season, the area has increased to 450 hectares.

WATER MANAGEMENT

Innovative programs for improved water management are not easily accepted by the end-users during the early stages of implementation. With proper dialogue among farmers and NIA personnel, however, water management is now happily accepted in areas where it has been introduced.

A change to control water delivery can be achieved only through frequent adjustment of turnout openings which farmers have previously tended to tamper with to suit their desire (Mercado, 1972). For rigid control, service roads are needed to carry at least motorcycle traffic along distribution canals, to effectively pursue our water management programs on a larger scale. External financing is being secured for service roads to give mobility to our watertenders, and to facilitate transportation of inputs to farms and of agricultural products from farms to market.

To be able to introduce innovation in water management, research and establishment of trials and demonstration plots, are being regularly undertaken. The full benefit of improved water management practices can be realized only with the use of proper production inputs, including the use of properly selected seeds from high yielding varieties of rice.

Two general methods of water distribution are possible. Simultaneous distribution involves supply of irrigation water to all distributary canals while water application from the turnouts through the farm ditches can either be continuous or intermittent. Rotational distribution sends the supply of irrigation water to units of the distribution system in rotation. Rotation may be by section in the main canal - water is conveyed in turn to the different sections of the main canal; by sections in the laterals or sub-laterals - the main canal has a continous flow, while water is conveyed successively to the different sections of the laterals or sub-laterals; or by farm ditch - water is applied in turn to the different rotation units, while conveyance of water in the main canal, laterals, and sub-laterals is continuous.

Since our irrigation systems were all designed to meet a water requirement of 1.5 liter s^{-1} ha^{-1} , the only method of water distribution that could be adopted without modification of the existing canals was rotation by farm ditch. During paddy field irrigation, however, when the water supply becomes lower than the normal or designed requirements, rotation by section in the main canal, or rotation by sections in the laterals can be adopted, depending on the conditions in the irrigation system. But for land soaking and land preparation, irrespective of the water supply available, rotational distribution should be practiced to avoid oversupplying the canals and to make optimum use of available farm labor.

The number of days to complete one rotation cycle is called a rotation interval. Advanced technology is needed to determine the rotation interval based on soils and agronomic requirements. During the implementation of the NIA-ADB Water Management Project, however, water management experts from Taiwan recommended that irrigation rates and rotation intervals should correspond to the clay content of soils as shown in Table 1. In the Angat system area where field water requirements vary from 6 to 8 mm/day, a 6-day rotation interval is being adopted.

In the rotational distribution method, the discharge applied into the farm is concentrated on one rotation unit in accordance with the water distribution schedule. The time required per application to irrigate each rotation unit is based on the area, water requirement, conveyance losses, and the rate of discharge. A detailed computation used in the Angat pilot area is given in Table 2.

The method that we now use in distributing water in the Angat pilot area and at the watermaster's division level is shown in Table 3. The process of land soaking and land preparation was designed to comprise one plowing followed by three harrowings with an interval of 6 days for each plot. The first irrigation of 150/120 mm (wet/dry season) for land soaking is made 7 days before plowing, the second irrigation of 60/50 mm is made after 3 days to prevent the field from drying out. The last irrigation of 60/50 mm is made 6 days before the last harrowing.

The time to finish land preparation within one irrigation district/ unit (the area served by a turnout) is 30 days. Therefore, within these 30 days, the transplanting schedule will be one-third of the area every 10 days. Irrigation and land preparation schedules are illustrated in Figure 2. Since one-third of the area should be finished every 10 days, the crop water requirement weighted by an area factor was calculated for successive 10-day stages. The peak water requirement appears at the late booting stage at 8.27 mm/day. Computation of weighted water requirements(Chin,1971 & Huang,1972) corresponding to the different stages are shown in Table 4.

In the Angat area, because of lack of effective and complete control facilities, water use at the upstream portion of the canal has been wasteful. Water turned into the field is allowed to flow continuously over the plots. During land preparation periods, however, farmers in the area served by one turnout use rotational distribution of water themselves.

Irrigation periods vary with respect to the growing period of the crop, which is somewhat more during the rainy season. Studies at the Angat pilot area show that the irrigation period of paddy rice varies from 90 days in the dry season to 100 days in the wet season.

The amount of water used at farm level was measured in the experiments at the pilot area. A comparative water use study was also conducted between the pilot area and non-pilot area in 1969 wet season crop. The results of the study are shown in Table 5. The data in the table do not include water-use during land preparation period.

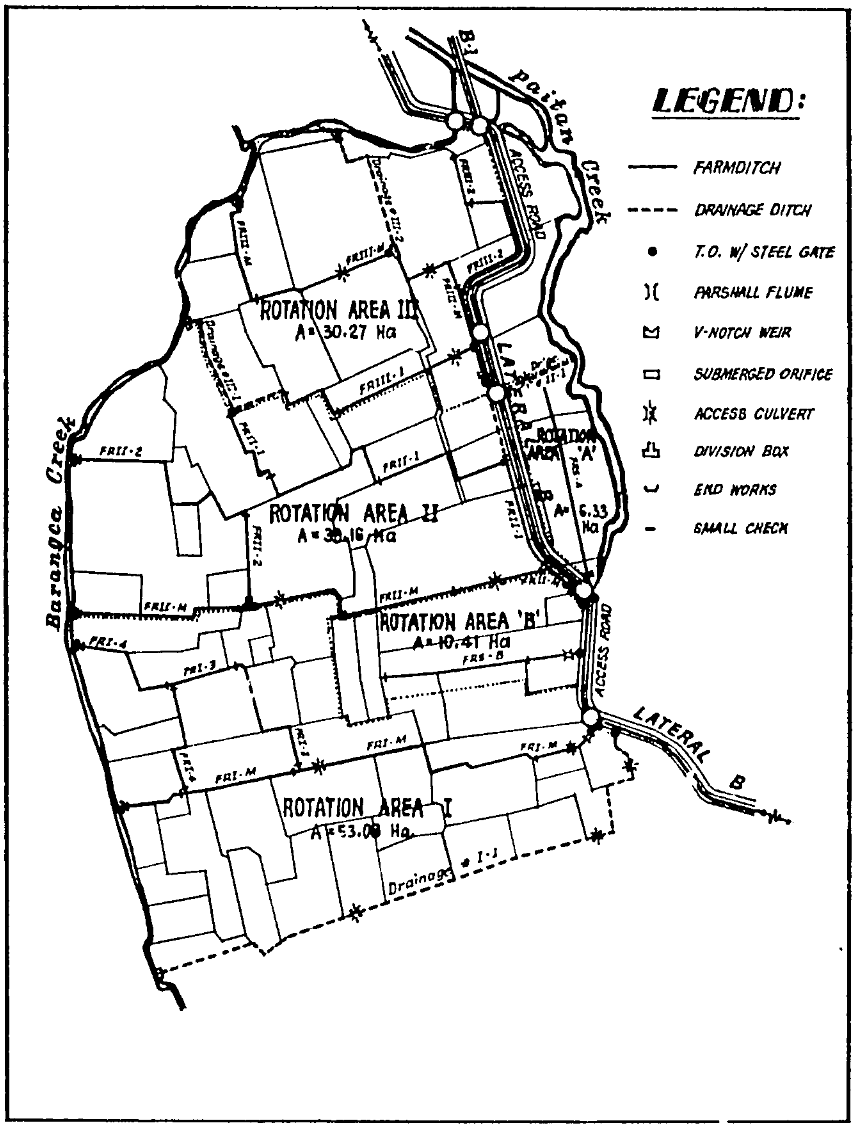

Fig. 1. Pilot Farm of 140 ha. along Lateral B, North side of Angat River Irrigation System. Scale 1:16,500

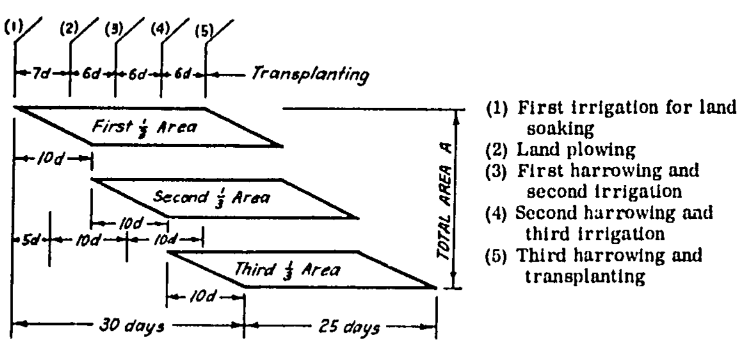

Fig. 2. Time to finish land preparation within one irrigation unit.

Table 1. Relation between irrigation rate and rotation interval.

Percentage of clay content, by weight (less than 0.005 mm)	Irrigation rate (ha/cm)	Water requirement (mm/day)	Rotation interval (days)
Less than 5%	500	17.24	4-5
5-10	700	12.34	5-6
10-15	850	10.16	5-6
15-20	1000	8.64	6-7
20-25	1100	7.67	6-7
25-30	1200	7.20	6-8
35-40	1300	6.65	6-8
More than 40%	1400	6.17	6-8

Table 2. Water requirements for paddy field.

	ROTATION UNITS					TOTAL
	1	2	3	4	5	
(1) Irrigated area, (ha)	12.79	10.67	9.94	10.98	9.09	53.47
(2) Daily water requirement in field, (mm/day)	6/8	6/8	6/8	6/8	6/8	
(3) Distribution losses, (%)	10	10	15	20	20	
(4) Rotation interval, (days)	6	6	6	6	6	
(5) Water depth required per irrigation, (mm)	36/48	36/48	36/48	36/48	36/48	
(6) Weighted area, $\left[\frac{(2)}{1-(4)}\right]$ (ha)	14.11	11.82	11.7	13.7	11.4	62.8
(7) Water required at turnout, $\left[Q=(6)\times(7)\times 10\right]$ (m^3)	5115.6/ 6820.8	4266.0/ 5688.0	4208.4/ 5611.2	4942.8/ 6590.4	4089.6/ 5452.8	22,622 30,163
(8) Period required for every rotation unit, $\left[T=\frac{(5)\times(7)}{\text{Total weighted area}}\right]$ (hrs)	33	27	27	31	26	144
(9) Water required at turnout, $\left[Q=\frac{(8)}{(9)\times 86,400}\right]$ (m^3/sec)	0.0436/ 0.0582	0.0436/ 0.0582	0.0436/ 0.0582	0.0436/ 0.0582	0.0436/ 0.0582	
(10) Time for land soaking and preparation, (days)	4.52	3.77	3.72	4.37	3.62	20
(11) Water required at turnout for land soaking, $Q=\frac{0.150\times(7)\times 10,000}{(11)\times 86,400}$ (m^3/sec)	0.0545	0.0545	0.0545	0.0545	0.0545	
(12) Water required at turnout for land preparation $Q=\frac{.060\times(7)\times 10,000}{(11)\times 86,400}$ (m^3/sec)	0.0218	0.0218	0.0218	0.0218	0.0218	

Table 3. Irrigation water requirements at turnouts and laterals (without effective rainfall)

Month & decade		On farm m^3	At turnout b/ m^3	At turnout b/ L/S	Lat. B c/ m^3	Lat. B c/ L/S	Lat. D & J d/ m^3	Lat. D & J d/ L/S
May	1	25 a/	31	0.72	33	0.76	37	0.85
	2	54	68	0.78	71	0.82	79	0.92
	3	70	38	1.01	92	1.07	103	1.19
June	1	76	96	1.10	101	1.16	112	1.30
	2	70	88	1.02	93	1.07	104	1.20
	3	78	97	1.12	102	1.18	114	1.32
July	1	71	89	1.03	94	1.08	105	1.21
	2	76	95	1.10	100	1.16	112	1.29
	3	81	101	1.16	106	1.23	119	1.37
Aug	1	83	103	1.20	109	1.26	122	1.41
	2	82	102	1.19	108	1.25	120	1.39
	3	68	84	0.98	89	1.03	99	1.15
Sept	1	40	51	0.59	53	0.62	60	0.69
		14 a/	17	0.37	18	0.41	20	0.46
	2	34 a/	42	0.98	44	1.02	49	1.14
	3	44	54	0.63	57	0.66	64	0.74
Oct.	1	57	71	0.82	75	0.86	83	0.96
	2	63	79	0.91	83	0.96	93	1.07
	3	59	74	0.85	77	0.90	87	1.00
Nov	1	65	81	0.94	86	0.99	97	1.11
	2	60	75	0.86	78	0.91	88	1.02
	3	63	79	0.91	83	0.96	93	1.07
Dec	1	66	83	0.96	87	1.01	98	1.13
	2	68	85	0.98	90	1.03		1.16
	3	68	85	0.98	90	1.03		1.16
Jan	1	57	71	0.81	75	0.86	83	0.96
	2	34	42	0.49	45	0.52		0.58
	3	11	14	0.16	15	0.17		0.19

a/ Water requirements in 5 days.

b/ 20% for farm losses are included.

c/ 5% for conveyance losses are included.

d/ 15% for conveyance losses are included.

Table 4. Calculation of weighted paddy field water requirements.

Land soaking, preparation & growing stages at 10-day interval	Water requirement (mm)	First crop (May-Aug) Weighted 10-day water requirement (mm)	Ave. Daily (mm)	Second Crop (Aug-Nov) Weighted 10-day water requirement (mm)	Ave. daily (mm)
1. Land soaking (5 days)	S_1	$\frac{1}{3} \times \frac{1}{2} \times 150 = 25.0$	2.50	$\frac{1}{3} \times \frac{1}{2} \times 120 = 20.0$	2.00
2. Land soaking continued	S_2	$\frac{1}{3} \times (150 + \frac{2}{10} 60) = 54.0$	5.40	$\frac{1}{3} \times (120 + \frac{2}{10} \times 50) = 43.3$	4.33
3. Land preparation	P	$\frac{1}{3} \times (150 + 60) = 70.0$	7.00	$\frac{1}{3} \times (120 + 50) = 56.7$	5.67
4. Transplanting	I_1	$\frac{1}{3} \times (\frac{1}{2} \times 150 + 60 + 60 + \frac{1}{2} \times 69) = 76.5$	7.65	$\frac{1}{3} \times (\frac{1}{2} \times 120 + 50 + 50 + \frac{1}{2} \times 62) = 63.7$	6.37
5. Early tillering	I_2	$\frac{1}{3} \times (\frac{8}{10} \times 60 + 60 + 69 + \frac{1}{2} \times 69) = 70.5$	7.05	$\frac{1}{3} \times (\frac{8}{10} \times 50 + 50 + 62 + \frac{1}{2} \times 62) = 61.0$	6.10
6. Active tillering	I_3	$\frac{1}{3} \times (60 + 69 + 69 + \frac{1}{2} \times 69) = 77.5$	7.75	$\frac{1}{3} \times (50 + 62 + 62 + \frac{1}{2} \times 62) = 68.3$	6.83
7. Maximum tillering	I_4	$\frac{1}{3} \times (\frac{1}{2} \times 69 + 69 + 69 + \frac{1}{2} \times 83) = 71.3$	7.13	$\frac{1}{3} \times (\frac{1}{2} \times 62 + 62 + 62 + \frac{1}{2} \times 77) = 64.5$	6.45
8. Panicle initiation	I_5	$\frac{1}{3} \times (\frac{1}{2} \times 69 + 69 + 83 + \frac{1}{2} \times 83) = 76.0$	7.60	$\frac{1}{3} \times (\frac{1}{2} \times 62 + 62 + 77 + \frac{1}{2} \times 77) = 69.5$	6.95
9. Booting stage	I_6	$\frac{1}{3} \times (\frac{1}{2} \times 69 + 83 + 83 + \frac{1}{2} \times 83) = 80.7$	8.07	$\frac{1}{3} \times (\frac{1}{2} \times 62 + 77 + 77 + \frac{1}{2} \times 77) = 74.5$	7.45
10. Booting stage continue	I_7	$\frac{1}{3} \times (\frac{1}{2} \times 83 + 83 + 81 + \frac{1}{2} \times 81) = 82.7$	8.27	$\frac{1}{3} \times (\frac{1}{2} \times 77 + 77 + 77 + \frac{1}{2} \times 72) = 76.2$	7.62
11. Heading	I_8	$\frac{1}{3} \times (\frac{1}{2} \times 83 + 81 + 81 + \frac{1}{2} \times 81) = 82.0$	8.20	$\frac{1}{3} \times (\frac{1}{2} \times 77 + 77 + 72 + \frac{1}{2} \times 72) = 74.5$	7.45
12. Milky ripe		$\frac{1}{3} \times (\frac{1}{2} \times 81 + 81 + 81) = 67.5$	6.75	$\frac{1}{3} \times (\frac{1}{2} \times 77 + 72 + 72) = 60.8$	6.08
13. Dough ripe		$\frac{1}{3} \times (\frac{1}{2} \times 81 + 81) = 40.5$	4.05	$\frac{1}{3} \times (\frac{1}{2} \times 72 + 72) = 36.0$	3.60
14. Yellow ripe		$\frac{1}{3} \times \frac{1}{2} \times 81 = 13.5$	1.35	$\frac{1}{3} \times \frac{1}{2} \times 72 = 12.0$	1.20

Table 5. Results on water use studies at farm level

Crop & Year	Irrigation Period (days)	Irrigation Water use (mm)	Effective Rainfall (mm)	Total Water Use (mm)	Average Water Use (mm/day)
Water use study					
Wet season, 1970-A	110	142	731	873	7.93
Wet season, 1970-II	126	89	903	992	7.88
Dry season, 1970-71-A	93	534	165	679	7.30
Dry season, 1970-71-II	93	478	144	622	6.69
Comparative study (1969 Wet season)					
Pilot area-II	100	417	534	961	9.61
Non-Pilot area ARIS	100	1125	534	1659	16.59

RESEARCH UNDERTAKINGS

Several research studies have been made. Results of these studies have been compiled in a pamphlet-form for all field technical personnel of the National Irrigation Administration.

Soil moisture stress

In one study, soil cracks were measured in relation to soil moisture content. Results of the study showed that the mean yields as affected by the treatments were not significantly different. Submergence from panicle initiation to heading gave the highest mean yield, 4.2 t/ha (95 cavans), while the treatment that caused soil cracks about 0.5 cm wide from panicle initiation to heading gave the lowest mean yield, 3.6 t/ha. The soil moisture depleted daily ranged from 0.51 mm to 14.21 mm. The results obtained showed an irregular pattern of depletion. As the average moisture content decreased, size of cracks increased.

In another study, three treatments -- continuous submergence, 2 weeks stress at booting, and 3 weeks stress at booting -- caused no significant difference in yield of IR5 rice. Continuous submergence gave the highest computed yield, 8 t/ha (187 cavans). Slight cracking of the soil was observed 3 days after water was drained. After a stress period of 2 weeks, the average size of cracks was 14 mm and after 3 weeks of stress, 28 mm. The size of cracks increased as the soil moisture content decreased.

Determination of effective rainfall

Paddies with either improved (mud-lined) dikes or ordinary (unlined) dikes were tested in relation to rainfall efficiency and total water use, and for their relation to rainfall efficiency. Paddies with improved dikes yielded 4.0 t/ha compared with 3.5 t/ha for paddies with ordinary dikes. Paddies with improved dikes used less irrigation water (424 mm compared with 444 mm), had about the same retention of rainwater (127 mm compared with 124 mm), and had a lower total water requirement (542 mm compared with 568 mm).

Comparative study on methods of transplanting

Ordinary random transplanting was compared with straight row planting in relation to yield of variety IR22. Straight row planting significantly outyielded ordinary random planting. However, insignificant difference in yield was observed between 20 x 15 cm and 20 x 20 cm spacings.

Continuous submergence vs. intermittent irrigation

The effects of continuous submergence and intermittent irrigation on the growth and yield of IR20 were studied. There was no significant difference in yield between the two irrigation methods. Continuous submergence gave an average yield of 4.2 t/ha, while intermittent irrigation gave a mean yield of 3.9 t/ha.

Effects of drainage on the growth and yield of IR5

The effects of midseason drainage on growth and yield of IR5 were studied on a silty clay loam. The farm ditch serving the area was concrete-lined. Four treatments were used, with two replications each: 10 days drainage at maximum tillering, 10 days drainage at booting, 10 days drainage at heading time, and continuous submergence. Every 7th day 42 mm of water was applied. There were no significant differences among any of the treatments. Plots drained at tillering produced 5.9 t/ha, those drained at booting yielded 4.6 t/ha, and those drained at heading yielded 4.2 t/ha. Continuous submergence resulted in yields of only 3.9 t/ha. This experiment had a good effect on the farmers in the area, who recognized that short periods of drainage did not reduce their yields.

In a study of production costs, the average cost per cavan (44 kg) was P13.26 for irrigated areas with 2 crops, while in rainfed areas the cost was P14.98 per cavan. For the NIA pilot area, the cost of production per cavan was P14.14.

SUPPORTING EXTENSION SERVICES

Improved water management can be well understood by the farmers, if taught in a way that considers their level of education, beliefs, and traditions, and that approaches the problem on an "as-is-where-is" principle.

The implementation of improved water management is being carried out through a unified team approach. The processes of water management at the farm level need supporting services from the agricultural sector. The program itself involves changes in approaches in the engineering and agricultural aspects. Many avenues were tested and tried by the NIA water management team to strengthen the extension work of the group, on a grassroots approach via the printing of popular literature about the project and its objectives: leaflets on modern farming practices, preparation and showing of slides, use of the radio, public meetings, and barrio forums.

PROJECTED PROGRAM

Based upon the successful experience of the Philippine water management team, the approach and practice has been projected to a division level scheme. Two watermasters' divisions, with a combined area of about 5,000 hectares, have been selected for division-level improved water management implementation preparatory to intensified system-wide operation in all NIA systems. If successful in Division II, Southside of the Angat System, the practices can be successfully radiated to all NIA irrigation systems. Figure 3 illustrates the layout for Division II.

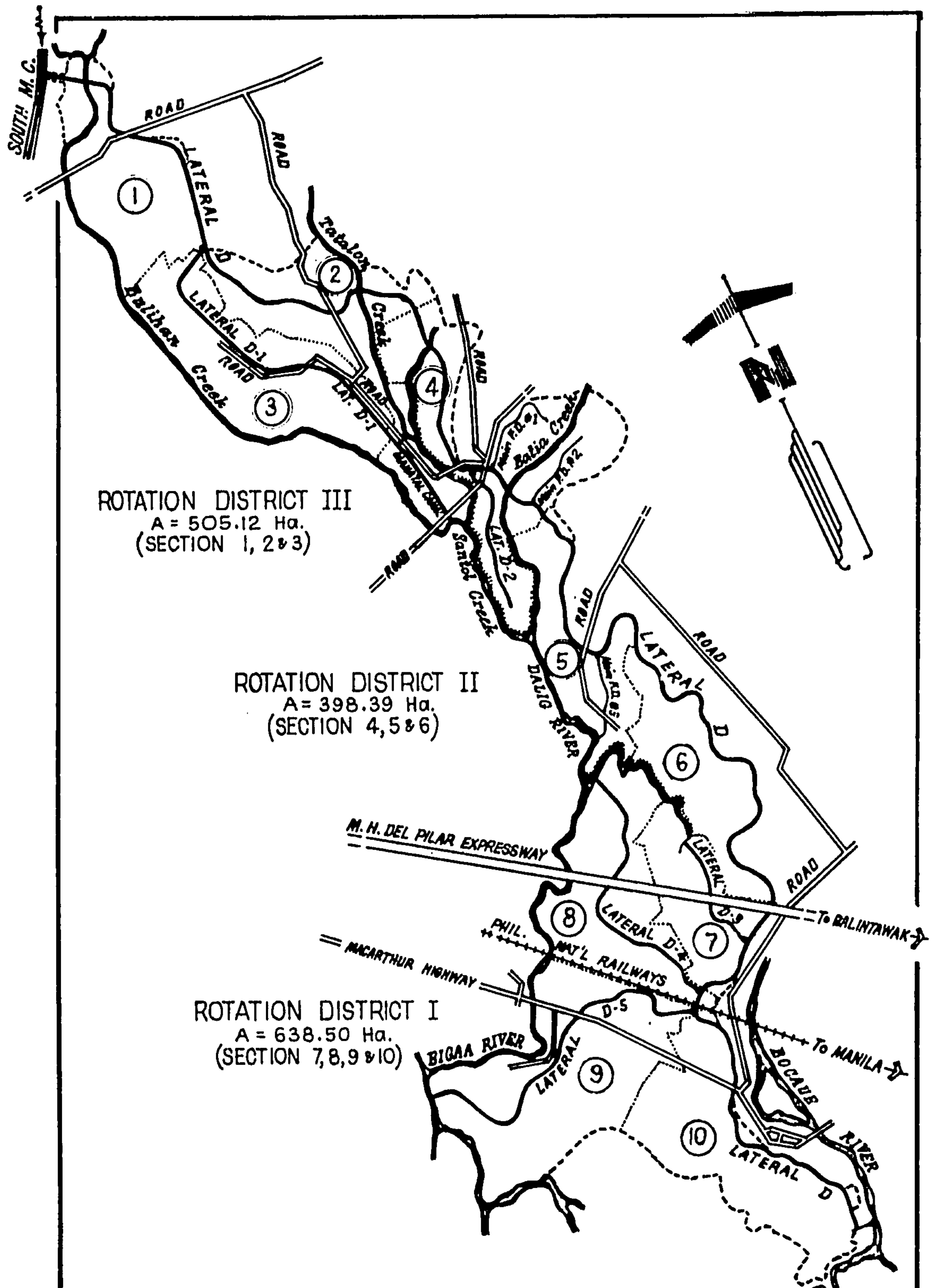

Fig. 3. Layout of Division 2 Lateral D, ARIS-SS. Scale 1:100,000

Division offices of the watermasters were constructed to bring the management of the system closer to the end-users, the farmers. Construction of necessary turnouts and farm ditches in the whole service area of the Angat system has been given a high priority for funding. To facilitate closer supervision and inspection, posting of ditchtenders' whereabouts has been strictly required. A day of the week has been set aside to thrash out problems encountered during the previous week of operation.

Improved water management services cannot be successful in raising yields without good seeds from high yielding varieties, appropriate fertilizers and farm chemicals, and other modern farming practices. A program of adult farmers' education campaign and ditchtenders' training is a continuing part of the undertaking.

Inadequate capital outlays were taken as a limiting factor to the provision of essential project works, such as turnouts, farm ditches, and other terminal facilities in the irrigation systems (Juinio, 1971). Construction of farm ditches used to be the responsibility of the farmers. Very often the construction was done haphazardly. Gaps were simply made in canal embankments to serve as turnouts, resulting in waste of water and therefore, low irrigation efficiency. This become a convenient excuse for farmers to refuse to pay their irrigation fees. The maintenance and operation of the system suffered.

The NIA aims to recast its work programs to include terminal facilities and, also, access roads to facilitate the movement of supplies to the farms and the transport of products from the farms. Drainage facilities are now becoming an integral part of new projects.

Two crops of rice annually is the regular pattern of production within the service area of the Angat system. The NIA water management team, however, has prepared a cropping program to raise five crops of rice within 2 years. This scheme can be expected to increase the income of farm families whose land area is being served with water by the Angat system in Bulacan and Pampanga, and eventually to other NIA irrigation systems in the Philippines.

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Estimation of dry season streamflow from rainfall for selected diversion irrigation systems

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ABSTRACT

Two multiple regression models are used to relate antecedent rainfall to dry season flow of 14 rivers serving diversion irrigation systems in the Philippines. The first model expresses streamflow as a function of the bimonthly rainfall totals in centimeters from the preceding 8 months, and the second model relies on the two bimonthly totals most highly correlated to flow and the number of rainy days with 25 mm or more rainfall from the preceding 6 month period. The models have little difference in their predictive accuracy. Although the standard error of estimate is relatively high, equations for half of the rivers studied could explain more than 60 percent of the variation in streamflow, and for some rivers over 80 percent in the second model.

INTRODUCTION

Streamflow represents all the water that drains from a watershed by surface channels into which the water collects from above ground and subsurface flow. The amount of streamflow is determined by climatic and physiographic factors. The former include rainfall, wind, humidity, and temperature, while the latter comprise the geometry of the basin, land use, vegetation, soil type, stream channels, and other factors. No single mathematical expression has so far been derived to include all these factors because they are unique for each watershed. Work that has been conducted deals mostly with empirical analysis and therefore the equations derived are not generally applicable to any specific watershed.

Three sources of water for agriculture can be identified. In rainfed areas, especially where upland crops are produced, atmospheric water comes in the form of rainfall with probabilistic occurrence except when there is artificial rain stimulation. Many irrigated areas depend on streamflow that can be controlled. Since this is usually a stochastic process, its day-to-day variation is more predictable than that of rainfall. Groundwater supply is probably more reliable still, but its amount and location below the ground surface is uncertain, unless intensive hydrogeologic studies are made. In addition, it is an expensive source of water supply.

In the Philippines most irrigation systems do not have storage structures to ensure a year-round water supply for crop production. Dry season streamflow, often called baseflow in hydrology, usually is insufficient to meet the irrigation requirement from January to May. If this amount of runoff can be estimated in advance, proper allocation of irrigation water supply and scheduling of deliveries could result in better water use for run-of-the-river type (diversion) irrigation systems. Forecasting can also be useful in reconciling the conjunctive use of surface and underground water supplies. Where land classification has been done, farmers can be advised to practice multiple cropping so that crops requiring less water will be planted during the dry season.

Rainfall reaching the surface of the earth is partly transformed into surface runoff, partly absorbed by the soil through infiltration and depression storage, and partly spent through evaporation and transpiration. Partial clearing of forested areas, for example through <u>kaingin</u> farming, definitely affects the infiltration capacity of drainage basins. While there have been some observations that river runoff is gradually decreasing in some rivers of the Philippines, no analysis of available quantitative data has been reported. During the wet season, rainfall refills moisture and groundwater storage which eventually becomes the primary source of dry season runoff. The amount of water stored greatly depends upon the amount of rainfall during the preceding months, and the geologic and physiographic characteristics of the watershed.

Some workers have attempted to forecast runoff from recorded precipitation. Ford (1959) used precipitation during the fall and early winter months in Idaho, USA as an index to groundwater recharge. Using the April 1 accumulated snow total, and April to July rainfall as independent variables he found a correlation coefficient of 0.98 between them and seasonal runoff. He used 14 years of data from five rainfall stations in the watershed. Pryadchenko, a Russian worker cited by Chebotarev (1966), investigated the relationship of summer runoff and precipitation in the rainy season for the Dnieper River and found a correlation coefficient of 0.82. For small watersheds Knisel et al. (1969) developed a model to relate runoff to rainfall and soil moisture at the beginning of storms and found that accumulated runoff computed for an 11-year period agrees within 1% of observed amounts. They also concluded that by using long term climatic records good results could be obtained from a water yield prediction.

This study was conducted to determine whether current data on rainfall near the watershed can be used to develop an estimating equation for dry season streamflow. By physical intuition, rainfall within the watershed area should contribute to streamflow. By means of isohyets I hypothesized that rainfall data near the watershed divide is correlated with runoff. The results can provide a basis for planning raingage installation and runoff measurement for efficient use of water resources.

METHODOLOGY

The sources of monthly rainfall and runoff data are publications of the Weather Bureau and the Bureau of Public Works. Data from 1966 to the latest year available were copied from unpublished raw data compiled by the two agencies of the government. Rainfall data are considered accurate and reliable. Runoff data, however, may be questionable because of the difficulty in maintaining stability at control sections. Even the extension of the stage-discharge relationship to high values may be unreliable. Nevertheless, the data are still useful because the Bureau of Public Works has occasionally applied corrections. Table 1 shows the location of selected irrigation systems, irrigable areas, and years of record available. Missing observations were estimated by using the mean of known observations for the particular period considered. For example, if the data for August 1962 are missing the mean of all available August observations is computed. This method was similarly applied to missing runoff observations.

Fourteen rivers were selected from a list of national gravity irrigation systems operated by the National Irrigation Administration. The most important criterion in selection was the location of the gauging station with respect to the diversion site. Table 2 describes the gauging station location relative to the irrigation diversion. For some rivers, however, the amount of mean monthly diversion from the records of the National Irrigation Administration was added to the mean river flow measured downstream by the Bureau of Public Works. This is a rough approximation but it is the only way in which reasonable estimates of streamflow can be made. Table 3 shows watershed area, elevation and relative location of each gauging and rainfall station as determined from 1: 50000 scale topographic maps published by the Board of Technical Surveys and Maps.

A linear, normal, multiple regression model was used to develop the estimating equation for dry season runoff. This is one of several models with hydrological applications which involves some degree of lumping of the input and output parameters as reported by Toebes and Ouryvaev (1970). Some of the characteristics of this model are that the residuals are not normally distributed owing to non-random effects, that the prediction equation cannot be generalized to other similar systems, and that inverse correlations with some of the variables occasionally appear when such relationships are illogical from physical considerations.

The input parameters to the system are bimonthly rainfall totals, in centimeters. The output (runoff) is likewise expressed in bimonthly totals. It is assumed for purposes of this analysis that bimonthly rainfall is a normally distributed random variable.

The dry season is limited to four consecutive months starting in January. Two regression models were used to develop the estimating equation for the combined January-February runoff and the combined March - April runoff, as follows:

Table 1. Location of Irrigation System and Years of Record Analyzed

IRRIGATION SYSTEM	SERVICE AREA (ha)	PROVINCE	YEARS OF RECORD
Agus River	1,500	Quezon	1953-1968
Aklan River	5,600	Aklan	1953-1968 a/
Ambayaon River	10,800	Pangasinan	1959-1969
Aringay River	1,700	La Union	1949-1969
Banurbor River	800	Cagayan	1953-1968 b/
Bonga River	1,040	Ilocos Norte	1953-1966
Dumacaa River	2,400	Quezon	1953-1965
Mabacan River	1,300	Laguna	1955-1967
Magat River	20,000	Nueva Viscaya	1959-1968
Nasisi River	1,610	Albay	1952-1966 c/
Palico River	1,800	Batangas	1957-1968
Siffu River	8,900	Isabela	1953-1967
Sta. Cruz River	4,000	Laguna	1953-1969 d/
Talavera River	11,950	Nueva Ecija	1957-1967

a/ 1954, 1955, 1961 missing b/ 1960 to 1962 missing c/ 1955 to 1957 missing
d/ 1958 to 1962 missing

Table 2. Description of Gauging Station Location[a]

	Description of Location	Location of Irrigation Diversion [b]	Record
Agus	About 4.5 kms. soutwest of Infanta, Quezon at Bo. Banugao	-	Good
Aklan	Approx. 500 m. downstream of confluence of Aklan and Baliwan R.	-	Fair
Ambayaoan	About 7 km. north of Cabalitian R. bridge at Bo. Sta. Maria, San Nicholas, Pangasinan		
Aringay	About 2.5 km. NE of Tubao, La Union	20 m. upstream	Good
Banurbor	Right bank, 50 m. downstream of bridge along the Camalaningan-Gonzaga highway	-	Good
Bonga	About 500 m. SE of Bangay barrio school building, 2 km upstream of junction with Gasgas R.	-	Good
Dumacaa	About 5.5 km from Tayabas, Quezon	2.5 km downstream	Good
Mabacan	Approx. 6 km. upstream from Laguna de Bay at Calauan, Laguna	500 m. upstream	Good
Magat	About 150 m. downstream of Bato steel bridge in Bato, Bayombong, N.V.	-	Good
Nasisi	On center pier of bailey bridge along the Polangui Guinobatan Road 2.5 km. NE of Ligao	2 km. upstream	Good
Palico	Approx. 1 km. upstream of highway steel bridge and 400 m-from Post 93, Manila-Balayan Rd.	-	Good
Siffu	About 1 km north of Roxas, Isabela near the concrete steel bridge	7 km. upstream	Good
Sta. Cruz	Approx. 50 m. downstream of dam, 800 m. from abandoned Calumpang Railroad Sta.	50 m. upstream	Good
Talavera	About 200 m. E of Highway 3, north of San Jose	5 km. downstream	Good

[a] Adapted from Surface Water Supply of the Philippines, Bulletin No. 7, 1964, BPW, Manila

[b] Relative to gauging station.

Table 3. Watershed Data and Relative Location of Rainfall Station.

River	Watershed Area (Km)^2	Town	Rainfall Station: Distance from gauging station (Km)	Rainfall Station: Direction from gauging station	Elevation above sea-level (m.): Gauging Station	Elevation above sea-level (m.): Rainfall Station a/
Agus	879	Infanta	4.1	E	5	6
Aklan	705	Balete	8.3	SE	90	4
Ambayaoan	281	Mabini	92.8	W	108	22
Aringay	273	Masalep	13.0	SE	20	-
Banurbur	112	Guising	33.5	SW	1	66
Bonga	534	Bangay	3.8	N	24	-
Dumacaa	54	Lucena	17.8	S	110	12
Mabacan	46	College	4.6	W	14	41
Magat	1784	Salinas	13.2	SW	294	659
Nasisi	39	Guinobatan	7.1	SE	100	132
Palico	158	Ambulong	34.5	NE	5	11
Siffu	686	Ilagan	34.7	E	51	50
Sta Cruz	103	Sta. Cruz	9.6	N	29	5
Talavera	261	Sta Barbara	81.5	NW	144	8

a/ Adapted from Annual Climatological Review, Publication of the Weather Bureau, Manila.

Model A: $Y = a + b_1 x_{12} + b_2 x_{34} + b_3 x_{56} + b_4 x_{78}$

where $\underline{Y}$ is bimonthly runoff in centimeters, $\underline{x}_{12}$ is total rainfall for first and second preceding months, $\underline{x}_{34}$ is total rainfall for third and fourth preceding months, $\underline{x}_{56}$ is rainfall total for fifth and sixth preceding months, $\underline{x}_{78}$ is rainfall total for the 7th and 8th preceding months, $\underline{a}$ is a constant, and $\underline{b}$ is the regression coefficient.

To determine whether the estimating equation can be improved by the inclusion of the two most highly correlated independent variables and the number of rainy days with 25 mm. or more rainfall, a second regression model was expressed as follows:

Model B: $Y = a + b_1 x_1 + b_2 x_2 + b_3 x_n$

Where $\underline{x}_1$ is rainfall total from the previous model which shows the highest correlation to runoff, $\underline{x}_2$ is rainfall total which has the second highest correlation, and $\underline{x}_n$ = number of days with 25 mm or more rainfall during the preceding 6 months.

Regression analysis computation was carried out using an IBM 1620 computer at the University of the Philippines, Los Baños. The constant, regression coefficients, standard error of estimate, and other statistical parameters were extracted from the computer output.

RESULTS AND DISCUSSION

The constant and regression coefficients of the estimating equations for January - February runoff are shown in Tables 4A and 4B, and for March-April runoff in Tables 5A and 5B. The coefficients are not consistently positive as anticipated (ordinarily rainfall should positively contribute to runoff). Nevertheless, most of the negative coefficients are much lower than the positive values. Although the number of years of data varies from 10 to 21, there is no improvement in the linear relationship, as shown by the correlation coefficients, $\underline{R}$, even with many years of data.

The standard errors of estimate (SEE) are quite high relative to the mean runoff. This means that the observed rainfall does not always give an accurate estimate since the SEE is a measure of the closeness with which the observed runoff approaches the estimated runoff. To minimize this bias as many years of record were used as available. It appears, however, that even with 21 years of record for the Aringay River, the SEE is still high (Tables 4 and 5).

The square of the correlation coefficient $\underline{R}$ indicates the percentage of the variation that has been accounted for in the regression equation. It can be found from Tables 4 and 5 that this value varies from 0.15 to 0.94. More than half of the equations have coefficient (R^2 values) greater than 0.6, and for some rivers over 0.8.

Table 4A. Regression Parameters of Estimating Equation for January-February Runoff Using Model A.

RIVER	Mean Runoff (cm)	RAINFALL STATION	No. of Years	a	b_1	b_2	b_3	b_4	SEE	R
Agus	87.39	Infanta	16	101.46	-0.05	-0.35	-0.32	0.78	14.73	0.65
Aklan	82.32	Balete	13	28.86	0.7	0.56	-0.65	0.19	38.73	0.63
Ambayaoan	9.13	Mabini	11	3.35	0.08	0.05	0.01	0.01	2.57	0.76
Aringay	5.86	Masalep	21	3.46	0.20	-0.02	0.01	0.01	1.79	0.74 ***
Banurbur	12.04	Guising	13	16.16	-0.05	0.00	-0.27	0.31	6.17	0.43
Bonga	5.30	Bangay	13	-5.67	0.07	0.46	0.04	0.04	2.88	0.58
Dumacaa	63.28	Lucena	17	-0.33	0.88	0.20	0.59	-0.55	22.45	0.71 *
Mabacan	19.90	College	13	-2.00	0.14	-0.08	0.44	-0.02	4.20	0.85 *
Magat	14.85	Salinas	10	3.69	0.28	0.11	-0.28	0.74	7.62	0.87 *
Nasisi	30.86	Guinobatan	15	36.67	0.20	-0.17	-0.11	-0.02	13.00	0.53
Palico	6.97	Ambulong	12	4.46	0.05	0.02	0.00	0.01	1.44	0.61
Siffu	12.81	Ilagan	16	7.83	-0.01	-0.04	0.20	-0.01	5.52	0.73 *
Sta Cruz	33.30	Sta. Cruz	15	-12.85	0.73	0.02	0.42	0.45	18.85	0.52
Talavera	7.89	Sta Barbara	11	8.42	0.47	-0.05	-0.06	0.05	1.85	0.95 **

Table 4B. Regression Parameters of Estimating Equation for January-February Runoff Using Model B.

RIVER	Mean Runoff	RAINFALL STATION	No. of years	a	b_1	b_2	b_3	SEE	R
Agus	87.39	Infanta	16	84.26	0.37	-0.30	0.04	15.93	0.51
Aklan	82.32	Balete	13	32.63	0.64	0.93	-2.24	37.50	0.60
Ambayaoan	9.13	Mabini	11	- 3.05	0.05	0.06	0.31	1.74	0.87 **
Aringay	5.86	Masalep	17	4.09	0.01	0.17	-0.07	1.52	0.69 **
Banurbur	2.04	Guising	13	11.88	-0.16	-0.07	0.61	5.75	0.46
Bonga	5.30	Bangay	13	-3.59	0.01	0.00	0.33	1.87	0.76**
Dumacaa	63.28	Lucena	16	-11.18	1.00	1.22	-1.73	17.62	0.78 ***
Mabacan	19.90	College	13	-12.22	0.95	0.40	-1.93	2.92	0.92 ***
Magat	14.85	Salinas	10	0.41	0.85	0.42	-1.82	7.02	0.93 ***
Nasisi	30.86	Guinobatan	14	24.03	-0.22	0.13	0.58	12.95	0.53
Palico	6.97	Ambulog	10	3.87	0.03	-0.01	0.08	0.90	0.72
Siffu	12.81	Ilagan	16	7.76	0.28	0.03	-0.12	5.11	0.76 **
Sta. Cruz	33.30	Sta Cruz	10	35.88	0.32	0.20	2.77	20.70	0.66
Talavera	7.89	Sta Barbara	10	7.58	0.07	0.40	-0.33	2.52	0.83 *

* Significant at 0.1 probability level
** Significant at 0.05 probability level
*** Significant at 0.01 probability level

Table 5A. Regression Parameters of Estimating Equation for March-April Runoff Using Model A.

RIVER	Mean Runoff (cm)	RAINFALL STATION	No. of Years	a	b_1	b_2	b_3	b_4	SEE	R
Agus	45.53	Infanta	17	7.06	0.29	-0.16	0.39	0.07	26.20	0.49
Aklan	55.07	Balete	13	36.86	-0.15	-0.06	0.56	-0.01	27.40	0.57
Abayaoan	7.13	Mabini	11	4.39	-0.17	0.04	0.06	-0.01	2.04	0.85 *
Aringay	4.48	Masalep	21	2.67	0.53	0.11	-0.02	0.02	0.96	0.81 ***
Banurbur	5.93	Guising	14	1.29	0.03	0.03	0.10	0.02	2.80	0.78 *
Bonga	3.08	Bangay	18	1.96	0.12	1.81	-0.25	0.01	1.68	0.63
Dumacaa	40.61	Lucena	13	19.50	0.65	0.06	0.27	-0.25	15.81	0.54
Mabacan	13.60	College	13	1.66	0.27	-0.01	0.25	-0.04	2.92	0.82 **
Magat	10.08	Salinas	10	109.06	-0.48	-0.49	-0.15	-1.63	12.30	0.57
Nasisi	24.44	Guinobatan	13	-5.05	0.19	0.10	0.19	0.13	5.86	0.64
Palico	8.33	Ambulong	12	0.27	0.77	-0.04	-0.12	0.20	2.56	0.94 ***
Siffu	12.12	Ilagan	15	6.13	0.02	0.07	0.04	0.02	4.25	0.48
Sta Cruz	23.33	Sta. Cruz	15	-16.88	2.22	-0.04	0.28	0.14	8.58	0.82 **
Talavera	4.70	Sta Barbara	10	5.55	0.27	0.15	-0.03	-0.01	0.36	0.97 ***

Table 5B. Regression Parameters of Estimating Equation for March-April Runoff Using Model B.

RIVER	Mean Runoff (cm)	RAINFALL STATION	No. of years	a	b_1	b_2	b_3	SEE	R
Agus	47.05	Infanta	16	26.22	0.34	0.19	-0.68	22.00	0.39
Aklan	57.20	Balete	11	34.79	-0.98	0.69	1.80	17.40	0.83 **
Ambayaoan	7.13	Mabini	11	1.65	0.09	0.06	-0.16	1.89	0.85 **
Aringay	4.29	Masalep	17	3.41	0.01	0.14	-0.16	0.73	0.86 ***
Banurbur	4.26	Guising	13	1.99	0.02	0.04	0.64	1.32	0.81 **
Bonga	2.73	Bangay	14	1.76	0.00	0.01	0.87	0.58	0.54
Dumacaa	40.61	Lucena	13	15.38	0.15	0.41	0.65	15.22	0.51
Mabacan	13.57	College	13	1.33	0.24	0.27	-0.17	2.82	0.81 **
Magat	10.08	Salinas	10	78.87	-1.26	-0.50	0.50	11.67	0.52
Nasisi	22.57	Guinobatan	13	4.81	0.10	0.05	0.65	5.58	0.64
Palico	8.33	Am ulong	12	-0.28	0.08	0.80	0.03	2.96	0.90 ***
Siffu	12.11	Ilagan	15	6.07	0.03	0.07	0.12	3.95	0.49
Sta Cruz	24.33	Sta Cruz	10	-17.19	0.24	2.97	0.65	9.38	0.86 **
Talavera	4.70	Sta Barbara	10	4.56	-0.02	0.15	-0.00	0.49	0.93 ***

* Significant at 0.1 probability level
** Significant at 0.05 probability level
*** Significant at 0.01 probability level

Using Model B gave a slight decrease in standard error of estimate, and an increase in the correlation coefficient of nearly all rivers studied. This shows that in general, incorporation of the number of days with 25 mm or more rainfall does not greatly add to the accuracy of Model A.

With the occurence of extremely low and extremely high events in hydrology, wild points can occur and the scatter of points about the regression line may be poor. There are, however, statistical tests which can be applied to test whether or not a particular point should be rejected as not belonging to the group.

An example of the results of computation for Model B is shown in Table 6 for the Mabacan River in which the gauging station is located 4.6 kilometers west of the rainfall station at College, Laguna. There is an obvious correspondence between the observed and estimated runoff. The coefficient of determination for January-February runoff and March-April runoff are 0.85 and 0.67, respectively. Table 7 shows for all rivers studied the two 2-month periods of rainfall found most highly correlated with streamflow, and therefore used in Model B.

As an application of the results of the analysis, the case of the Mabacan River Irrigation System is examined as follows. The watershed area is 46 square kilometers and the irrigation service area is 1300 hectares. Using the basic equation $dA = qt$ where $\underline{d}$ is depth of water, $\underline{A}$ is area, $\underline{q}$ is discharge in liters per second and $\underline{t}$ is time, the unit flow is approximately 1.93 liters per second per square kilometer per centimeter depth of water over the watershed. Refering to Table 6, in 1956 the observed total depth of water for January and February is 10.55 cm and in 1960, 31.09 cm. These are equivalent to 940 and 2760 liters per second respectively. With a basic irrigation water use assumption of 1.5 lit/sec per hectare the irrigable area for those years would have been 627 and 1840 hectares. Thus, relying solely on the mean of 19.90 cm. (1770 lit/sec), the irrigable area is fixed at 1180 ha which is 120 ha less than the potentia service area. If the dry season streamflow can be estimated in advance the service area can be adjusted yearly.

CONCLUSION AND RECOMMENDATION

The high correlation coefficients obtained for many of the rivers studied clearly indicate linear relationship between bimonthly runoff and bimonthly rainfall. This is expected since the rainfall stations are located in climatic regimes similar to those of the gauging stations. Although the standard errors of estimate are relatively high, the estimating equation can be used to predict the dry season streamflow with reasonable confidence, assuming that the historical trend of changes in the watershed remains the same.

Table 6. Mabacan River Runoff Estimation for Model B, in cm, using Rainfall Data from College, Laguna.

YEAR	January - February Runoff[1/]		March - April Runoff[2/]	
	Observed	Estimated	Observed	Estimated
1955	14.34	19.18	10.94	11.13
1956	10.55	13.76	10.60	10.23
1957	29.42	30.52	18.17	13.85
1958	15.53	15.26	16.23	14.97
1959	11.03	14.11	9.57	13.89
1960	31.09	30.19	11.30	11.68
1961	17.92	15.60	22.40	19.71
1962	21.39	21.45	14.29	12.78
1963	27.61	25.86	19.04	18.86
1964	21.22	19.99	12.48	16.56
1965	19.96	19.70	11.48	13.28
1966	15.85	11.24	8.66	7.46
1967	23.11	22.16	11.20	11.92

1/ $Y = 0.95\ X_1 + 0.40\ X_2 - 1.93\ N - 12.22$ $R^2 = 0.853$ **

X_1 : July-August total rainfall
X_2 : November-December rainfall
N : No. of rainy days with 25 mm. or more rainfall from July to December

2/ $Y = 0.24\ X_1 + 0.27\ X_2 - 0.17\ N + 1.33$ $R^2 = 0.672$ **

X_1 : September-October total rainfall
X_2 : January-February total rainfall
N : No. of rainy days with 25 mm. or more rainfall from August to February.

Table 7. Two Two-month periods for which rainfall is most highly correlated with stream runoff (X_1 is more highly correlated than X_2).

RIVER	January-February Runoff		March-April Runoff	
	X_1	X_2	X_1	X_2
Agus	May - Jun	July - Aug	Sept - Oct	Jan - Feb
Aklan	Sept- Oct	Nov - Dec	July - Aug	Sept- Oct
Ambayaoan	Sept- Oct	Nov - Dec	Sept - Oct	Nov - Dec
Aringay	July- Aug	Nov - Dec	July - Aug	Nov - Dec
Banurbor	July- Aug	Sept - Oct	Sept - Oct	Nov - Dec
Bonga	May - June	July - Aug	July - Aug	Nov - Dec
Dumacaa	July - Aug	Nov - Dec	Sept - Oct	Jan - Feb
Mabacan	July - Aug	Nov - Dec	July - Aug	Sept- Oct
Magat	May - June	Nov - Dec	July - Aug	Nov - Dec
Masisi	Sept - Oct	Nov - Dec	Sept - Oct	Nov - Dec
Palico	July - Aug	Nov - Dec	July - Aug	Jan - Feb
Siffu	July - Aug	Nov - Dec	Sept - Oct	Nov - Dec
Sta Cruz	May - June	July- Aug	Sept - Oct	Jan - Feb
Talavera	May - June	Nov - Dec	Sept - Oct	Nov - Dec

Application of the methodology to as many rivers serving irrigation systems as possible is recommended, provided at least 15 years of record exist. Further development of the model should be considered with the inclusion of other factors. To improve the standard error of estimate, the raingage should be placed within the watershed area. Information about vegetation, physiographic conditions, and soil moisture conditions prior to the occurrence of rainfall should be determined to account for a greater extent of variation of streamflow in the regresssion equations. Perhaps the government could give priority to watershed management for diversion irrigation systems whose drainage area can be delineated and declared for forest reforestation. This will permit the development of more accurate and reliable estimating equations for dry season streamflow.

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Water scheduling for diversion irrigation systems

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ABSTRACT

A methodology is outlined for determining weekly estimates of the area that can be safely irrigated by diversion irrigation systems. The method uses a regression model based on river flow, rainfall, and evaporation data. The analysis was carried out on two irrigation systems in the crop year 1970-71, and data were collected from the systems to check the predicted area irrigated. Recommended schedules of planting and water distribution were constructed from the analysis. These schedules, if followed, would lead to increased area planted and irrigated especially in the dry season.

The National Irrigation Administration presently operates and maintains around 100 gravity irrigation systems with a potential area of about 380,000 hectares, almost all of it riceland. In addition, there are Friar land and communal irrigation systems. Most of these irrigation systems are of the diversion type, that is, they have no reservoir to store water. They thus depend only on the available stream flow which is diverted into a main canal that branches out into several laterals and sublaterals, and, to a very limited extent, into farm ditches. The present practice is to irrigate fields far from the canal by allowing water to flow across neighboring farms upstream.

The primary objective of this type of irrigation systems is to insure the success of the wet season crop, since the available river flow during the dry season is insufficient to serve the entire area. Farmers within the service area, however, expect more than this; they expect to have enough water for two crops per year. But under present procedures, this is quite difficult to accomplish on a system-wide scale.

One solution would be to rehabilitate existing systems by repairing the conveyance facilities and if possible constructing reservoirs to impound water for use during the dry season. Another possibility is the adoption of a rotational irrigation method such as that used in Taiwan. Proper planning of water distribution in conjunction with a planned planting schedule is another possible improvement.

Although the government has placed top priority on the rehabilitation of existing irrigation systems, it will be a long time before all the systems are developed to full advantage.

Implementing rotational irrigation requires improvements in the present conveyance facilities and the installation of more control structures and measuring devices. A thorough research and extension program on water requirements and farmer participation is also needed. All these entail money which might not be easy to get.

While rehabilitation of existing systems should be continued and further efforts made toward the adoption of rotational irrigation, some remedial measures should be taken which can be adopted in the immediate future. Improving the efficiency of existing systems could partially satisfy the demand of farmers for continuous cropping and the resulting increased production would contribute to the economic development of the country.

DATA REQUIRED FOR SCHEDULING

Through proper scheduling, I believe that the performance of most diversion irrigation systems can be improved without much change in facilities and with little expense. Planting could be staggered in such a way that the areas in need of water at any time of the year will not exceed the expected area that could be supplied by the expected river flow. To accomplish this, however, requires careful study of the characteristics of river flow, of climatological conditions within the service area, and knowledge of the irrigation capability of the system under the present management. Every irrigation system has qualified personnel who could gather these data (diversion flow, rainfall, evaporation, and irrigated areas) without sacrificing their present activities.

Rainfall and evaporation. Rainfall can be measured with the standard 8-inch rain gage while the amount of evaporation can be obtained using the class A evaporation pan with a diameter of 4 feet (1.22 m) and a height of 10 inches (25 cm). At least three instruments of each kind should be installed at strategic places within the service area of each system studied. The readings in these instruments should be averaged and the resulting averages adopted as the rainfall and evaporation for the entire service area of the system.

Extent of irrigated area. The area served sufficiently with water throughout the season can be obtained with the help of all the ditchtenders of the system. Through the water-masters, individual ditchtenders' records can be easily aggregated. But before the actual gathering of data, the ditchtenders should be properly appraised of the purpose of the project, which would require them to submit regular reports on the extent of irrigation in their area of jurisdiction. They might be suspicious that the reports they are making will reflect on their efficiency and thus they might report larger areas as sufficiently irrigated. This would greatly affect the accuracy of the prediction equation. It is also necessary to explain to the ditchtenders the ten "fully irrigated," "partially irrigated," and "not irrigated." The ditchtenders should report all three categories to provide an arithmetic check on their reports. The total of these items must be equal to the total area. Random spot checking is also necessary.

Diversion Flow. All irrigation systems keep records of the daily diversion flow at the dam with the aid of staff gages, but in some systems the gage must be recalibrated. This is important because silting may have occurred around the gage and thus erroneous discharges will be recorded. A new rating curve must also be used.

Prediction equation. Using historical data on rainfall, evaporation, and river flow, an estimate of the area that could be provided with sufficient water can be made using the multiple regression model, $A = a + bQ + cR + dE$, where $\underline{A}$ is the area that can be fully irrigated, $\underline{Q}$ is the average diversion flow, $\underline{R}$ is the average daily rainfall, $\underline{E}$ is the average daily evaporation, and $\underline{a}$, $\underline{b}$, $\underline{c}$, and $\underline{d}$ are constants. Weekly or even semi-monthly averages may be used in the analysis. The average weekly stream flow and rainfall based on the lowest values, and the average weekly evaporation based on the highest values for several years' record should be substituted in the developed equation to make the results conservative. For diversion flow, the maximum amount that can be diverted based on the weekly average of the lowest flow for serveral years should be used. From this, a conservative estimate of the area that can be provided with sufficient water in any week of the year can be determined.

River flow and climatological data for generalized prediction. The Bureau of Public Works keeps records of stream flow of all major streams in the country. From these, the flow characteristics of streams serving the diversion type of irrigation systems can be found. Records on stream flow for 10 years would be sufficient, although records for longer periods would be better. Not all irrigation systems keep records on climatological conditions within their service areas. Data on evaporation are especially rare. In the absence of any other source, records from the nearest weather station will suffice. Minimum riverflow, maximum rainfall and maximum evaporation were substituted into the generalized prediction equation.

Once the area that can be fully irrigated has been estimated, the system can be divided into several sections to facilitate the scheduling of planting and water distribution. This schedule would then be consistent with the estimated area that could be provided with sufficient water.

RESULTS OF A PILOT STUDY

During the crop year 1970-71, a study on the operation of two gravity irrigation systems of the diversion type -- the Peñaranda River Irrigation System and the Santa Cruz River Irrigation System -- which are under the management of the National Irrigation Administration, was conducted following the procedure outlined.

Peñaranda River Irrigation System

The Peñaranda system was constructed in 1930. It serves an area of 18,579 hectares in Nueva Ecija, Bulacan, and Pampanga. It derives its water supply from the Peñaranda River with the aid of a diversion dam with a capacity of 21,000 liters per second. The service area has nine divisions grouped into three zones. Water service during the dry season is rotated among the three zones every year so that each zone has two crops every second or third year. The general layout of the system is shown in Figure 1.

The prediction equation for the area in the system that could be supplied with sufficient water was

$$A = 7845 + 0.609Q + 16961R - 21606E \qquad (R^2 = 0.88^{**})$$

Using the developed prediction equation, a conservative estimate of the area that could be provided with sufficient water throughout the year was made by computing the minimum river flow (which took the place of the diversion flow in the equation), minimum rainfall, and maximum evaporation within weekly periods. Twenty-four years' record of river flow and 10 years' record of rainfall was used. For evaporation, only records for 2 years were available.

A graphical presentation of the estimated area that could be supplied with sufficient water as estimated using the equation is shown in Figure 2. The smallest area that could be provided with adequate water is around 2000 hectares and this is predicted during the period April 16 to 22. The largest area that could be provided with sufficient water is found during August.

The usual practice in the Peñaranda system is to have the entire service area planted during the rainy season and only zone (about a third of the service area) during the dry season. This practice, however, was modified during the crop season 1970-71 which was the period of the study. The planting schedule for the three zones was staggered to decrease the water demand during critical periods. Although the modification was an improvement over the usual practice, the situation could be further improved if an expected volume of water were known from week to week during the year.

It was suggested that the entire service area of the system be divided into 16 sections (Table 1 and Fig. 3). The recommended planting and water distribution schedule is shown in Figure 4. An "X" in the figure indicates weeks of irrigation application, a circled "X" indicates that irrigation may be cut in case of water shortage, and a circle indicates no irrigation.

From April 16 to 22, only section 1 will receive water and land preparation in this section will also begin. From April 23 to 29, water will be allowed to flow into sections 1 and 2; from April 30 to May 6, sections 1, 2, and 3 will receive water, and so on until the week July 30 to August 5 when the entire system will be receiving irrigation water.

GENERAL LAYOUT
PEÑARANDA RIVER IRRIGATION SYSTEM
GAPAN, NUEVA ECIJA

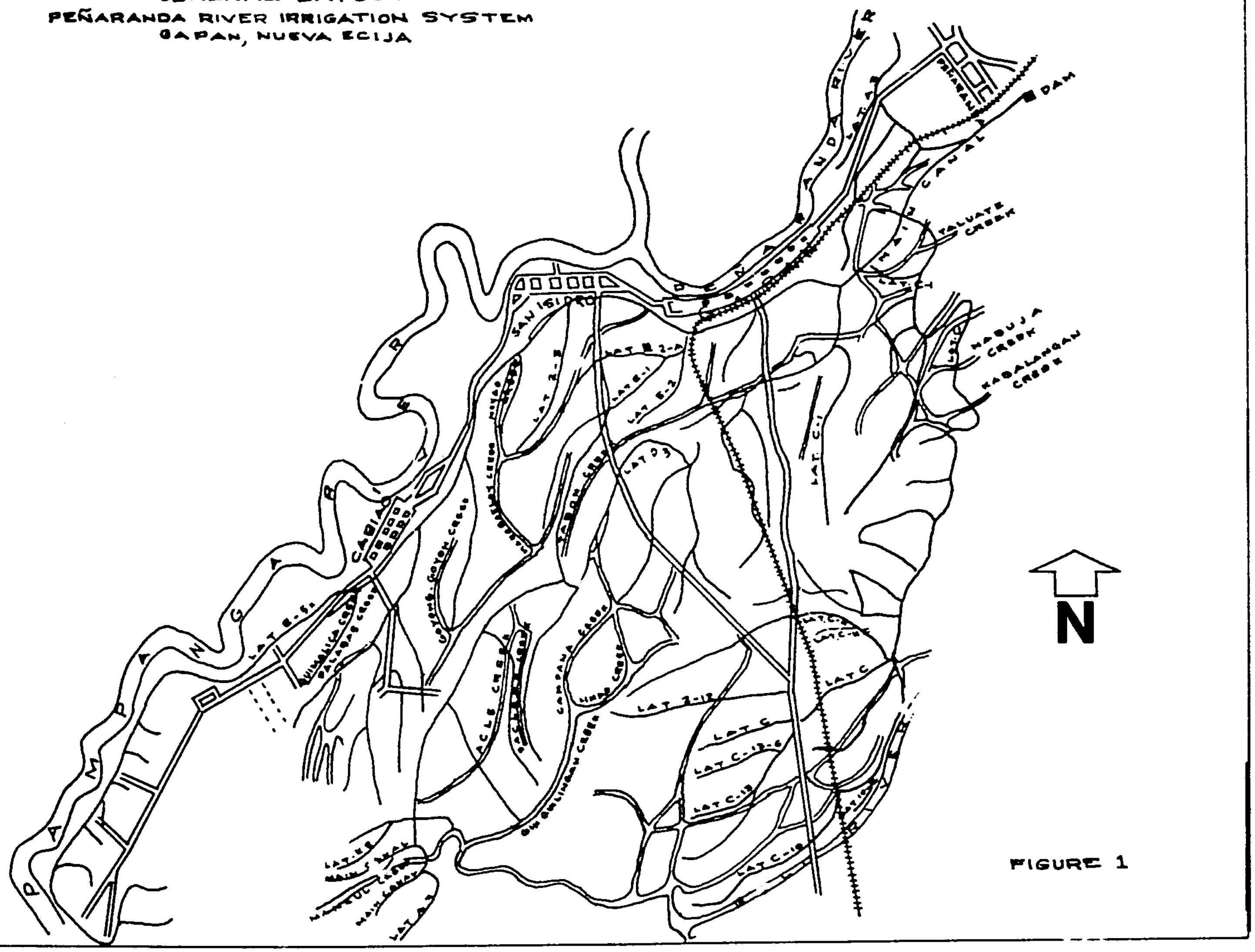


FIGURE 1

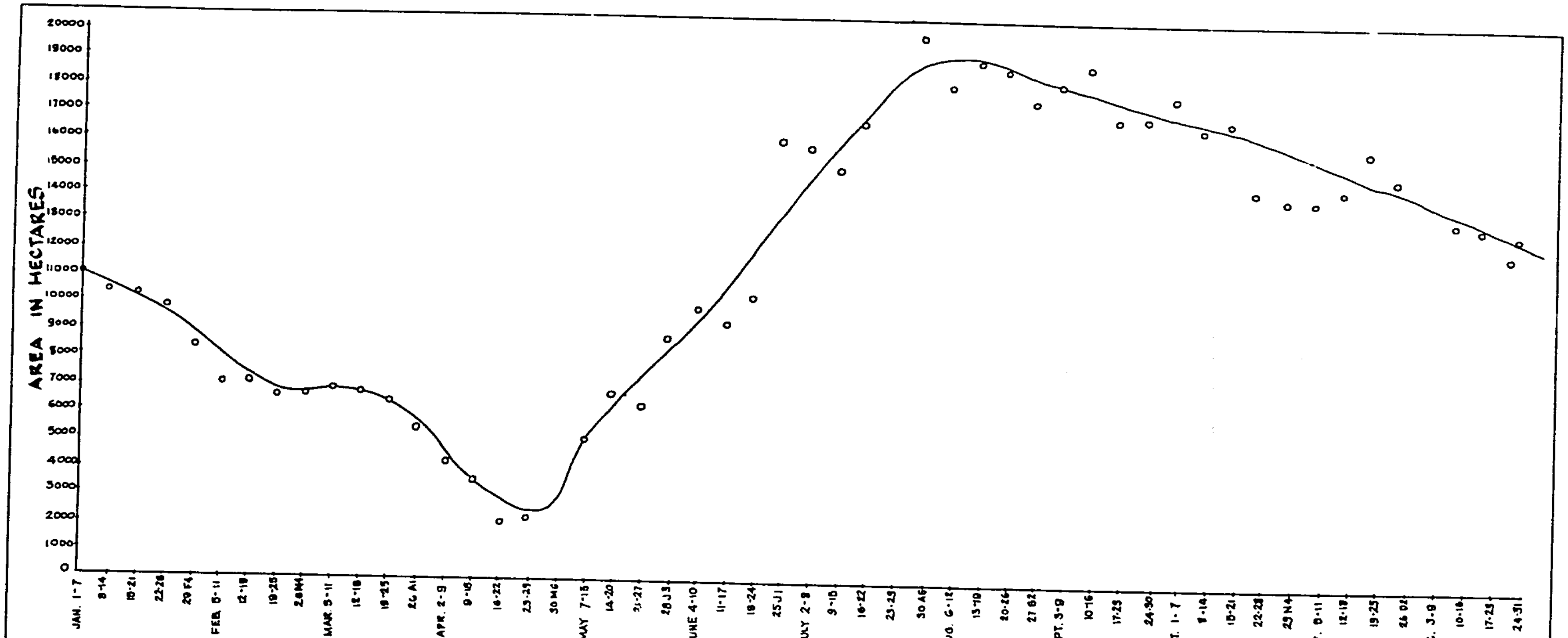


FIGURE- 2
ESTIMATED AREA THAT COULD BE SUPPLIED WITH SUFFICIENT WATER
PEÑARANDA RIVER IRRIGATION SYSTEM

Table 1. Area of sections in the Peñaranda River Irrigation System.

Section	Area (ha)
1	1040
2	862
3	590
4	1000
5	1192
6	623
7	1203
8	949
9	738
10	1338
11	1274
12	1697
13	1555
14	1527
15	1371
16	1074

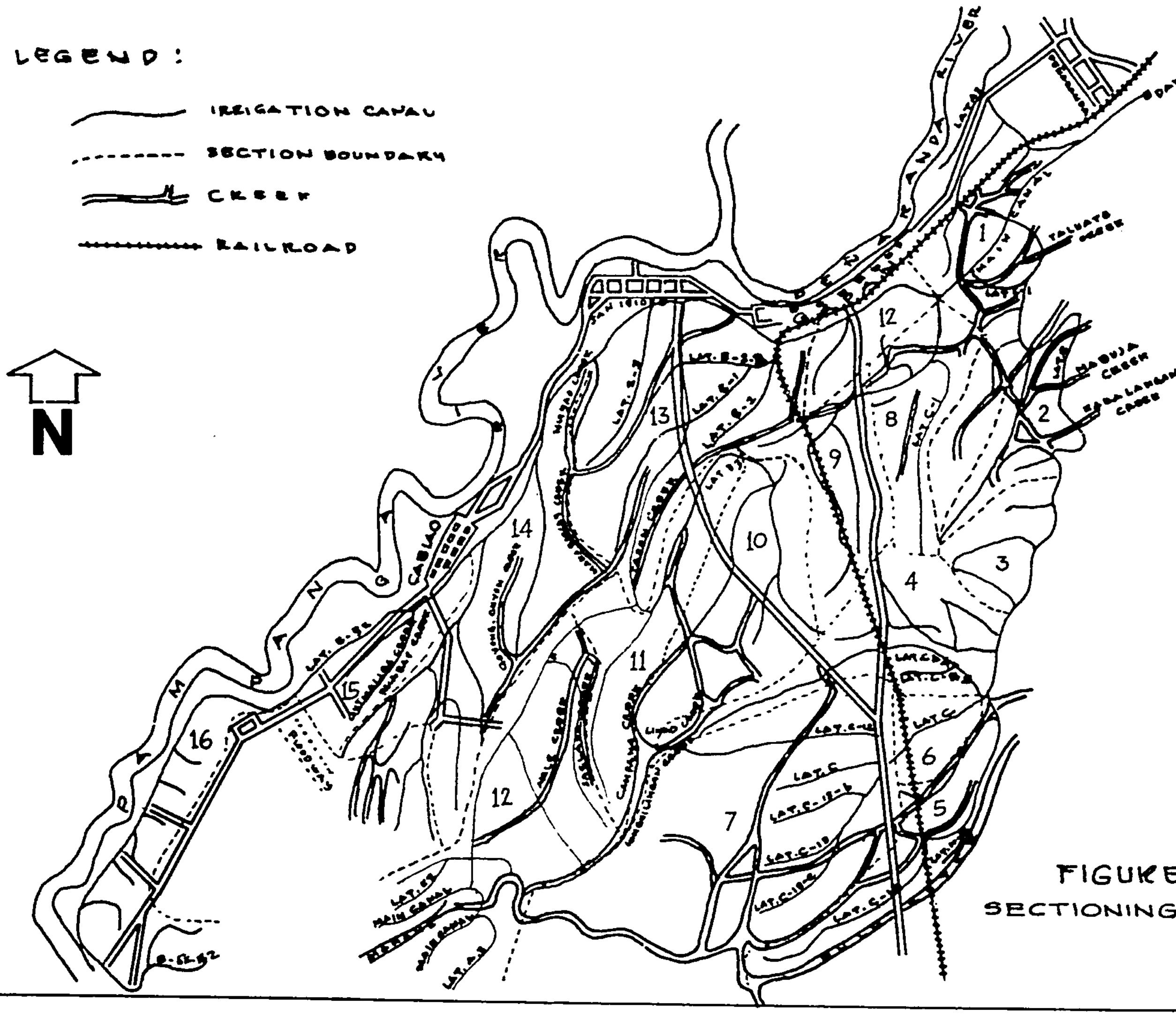
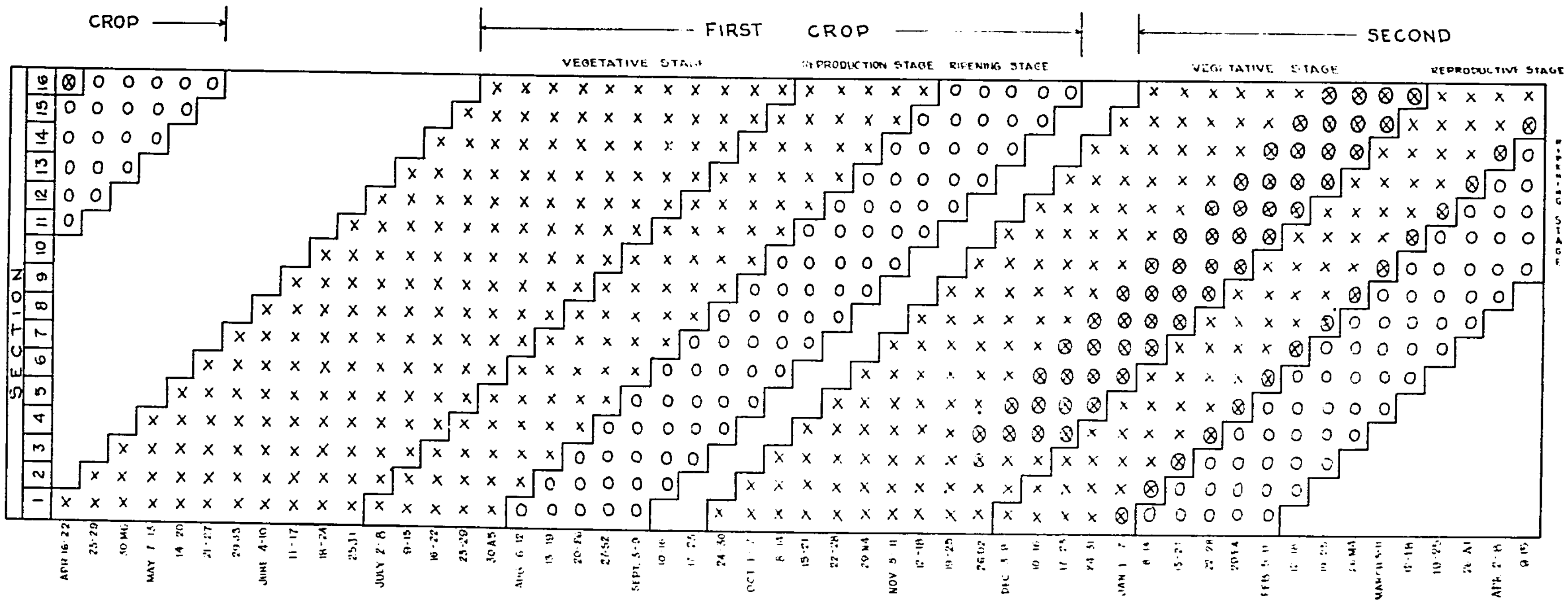


FIGURE 3
SECTIONING OF PRIS



X WITH IRRIGATION
O WITHOUT IRRIGATION
⊗ WATER APPLICATION MAYBE STOPPED

FIGURE - 4

SUGGESTED PLANTING & WATER DISTRIBUTION SCHEDULE
(PEÑARANDA RIVER IRRIGATION SYSTEM)

Starting August 6, when the crop in section 1 is expected to be in its ripening stage, water supply will be stopped until the crop is harvested. The following week the water supply will be stopped in section 2, the next week water application will be stopped in section 3, and so on until all the first crop will have been harvested.

Land preparation for the second crop starts on September 24 in section 1 and continues from section to section in weekly intervals.

Starting November 26, the predicted available water supply would not be sufficient to irrigate the planted area which normally should be supplied with water, so the supply in some areas should be stopped. The areas where the irrigation will be cut will be those where the plants will not be seriously affected if water is lacking. This should be in the later part of the vegetative stage (during maximum tillering) (Yamada, 1964). On November 26, the crop in section 4 (Fig. 4) will be in the late vegetative stage, so irrigation can be with withheld there. It could be resumed on December 24 when the crop is expected to enter the reproductive stage. Irrigation is then discontinued in the later part of the reproductive stage until the crop is harvested. The cut-off of irrigation will be done similarly in other sections whenever there is a shortage of water.

If this schedule were implemented, the area in need of water in relation to the predicted area that could be adequately supplied is shown in Figure 5.

Santa Cruz River Irrigation System

The Santa Cruz River Irrigation System opened for service in 1953. This systems serves 3900 hectares of ricelands in Laguna province. The system derives its water supply from the Santa Cruz River which drains a watershed area of about 103 square kilometers. The water is diverted from the river through a main canal, and serves five laterals, 11 sublaterals, and a limited number of farm ditches. The service area is divided into two divisions which alternate each year in water use priority for the dry season. The general layout of the system in shown in Figure 6.

The prediction equation for the Santa Cruz system is

$$A = 1551 + 0.559Q + 1375R - 3641E \qquad (R^2 = 0.86^{**})$$

The predicted area that could be supplied with adequate water, the suggested sectioning, and the recommended planting and water distribution schedule are shown in Figures 7, 8, and 9, respectively. The comparison between the estimated area that could be supplied with sufficient water and the area in need of water according to the schedule is shown in Figure 10.

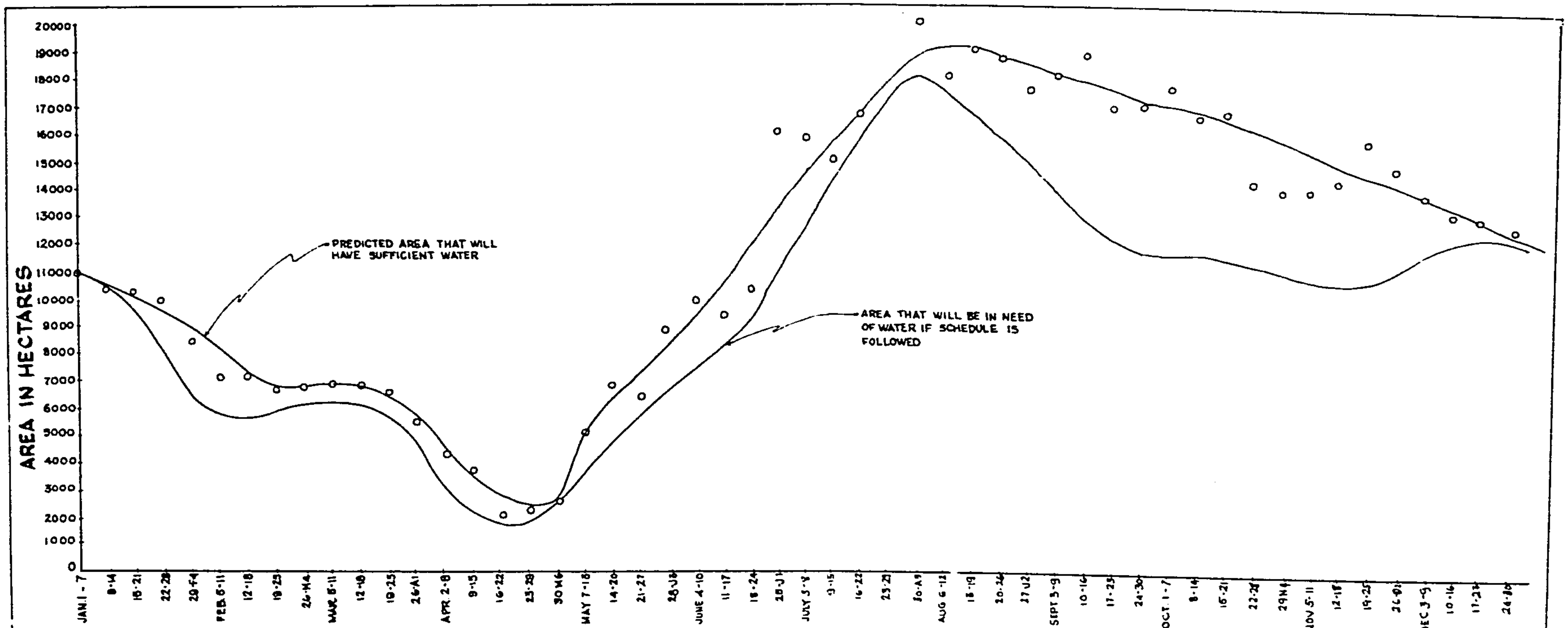


Fig. 5. THE AREA THAT WILL BE IN NEED OF WATER IF SUGGESTED SCHEDULE IS FOLLOWED
PEÑARANDA RIVER IRRIGATION SYSTEM

STA. CRUZ RIVER IRRIGATION SYSTEM
PILA, LAGUNA

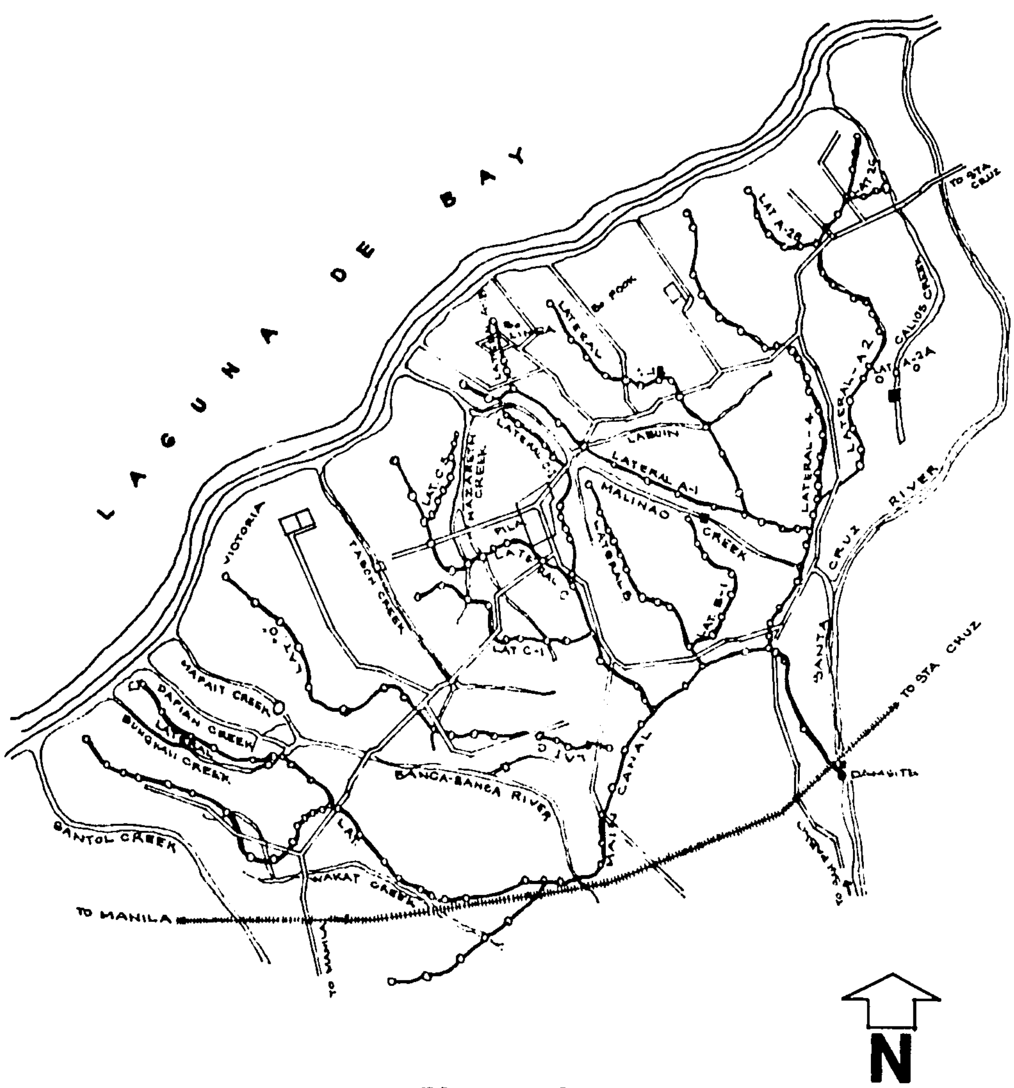


FIGURE 6
GENERAL LAYOUT

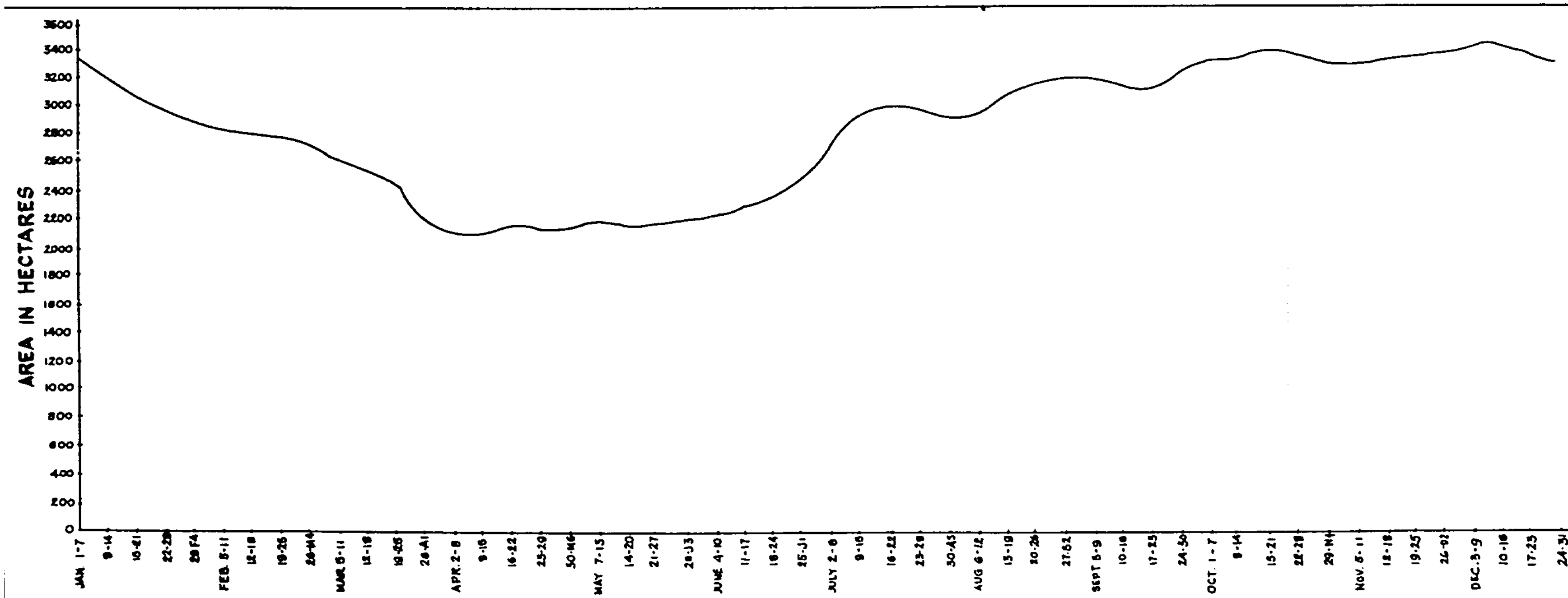


FIGURE - 7

ESTIMATED AREA THAT COULD BE SUPPLIED WITH WATER
STA. CRUZ RIVER IRRIGATION SYSTEM

STA. CRUZ RIVER IRRIGATION SYSTEM
PILA, LAGUNA

SECTION	AREA
1	424.26
2	466.67
3	441.87
4	472.77
5	385.61
6	342.75
7	476.61
8	472.46
9	477.73

Legend:
IRRIGATION CANAL
SECTION BOUNDARY
CREEK

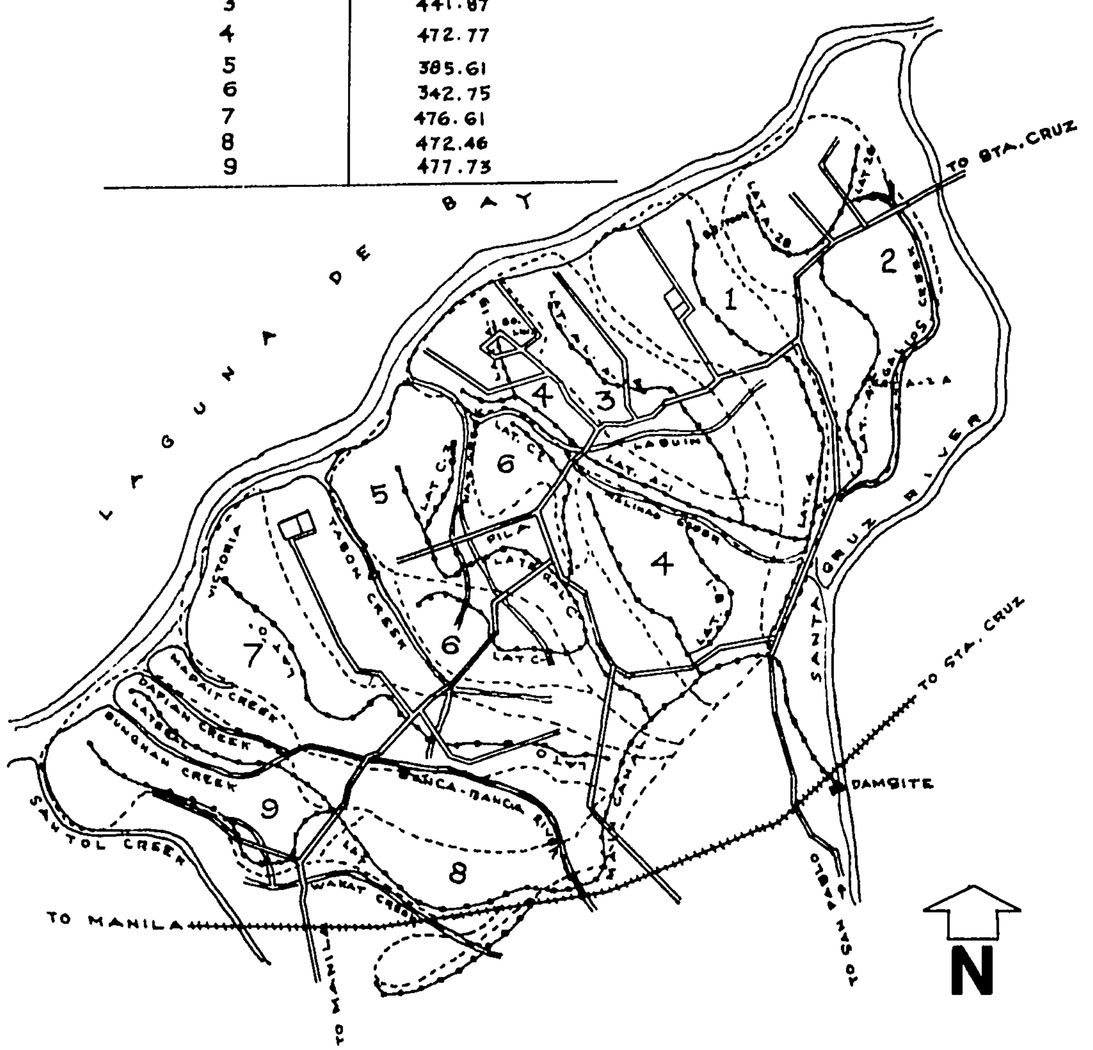
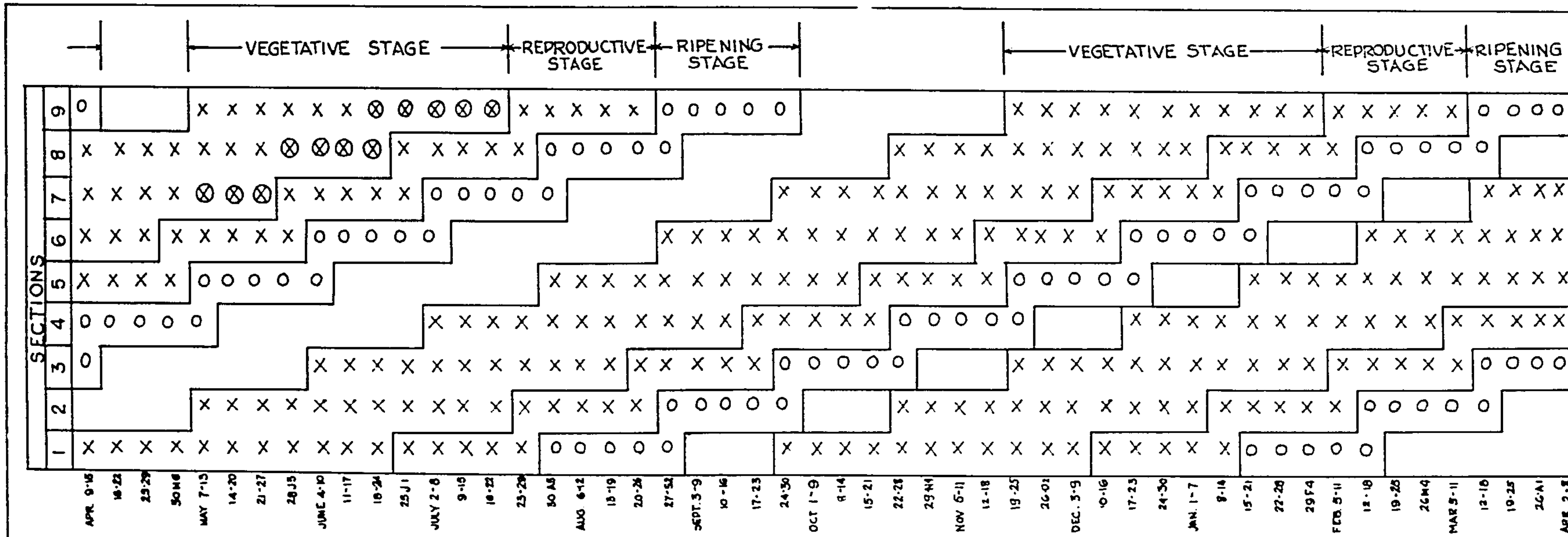


FIGURE 8
SECTIONING OF SCRIS



X – WITH IRRIGATION APPLICATION
O – WITHOUT IRRIGATION
⊗ – IRRIGATION MAY BE STOPPED

FIGURE – 9

SUGGESTED PLANTING AND WATER DISTRIBUTION SCHEDULE
STA. CRUZ RIVER IRRIGATION SYSTEM

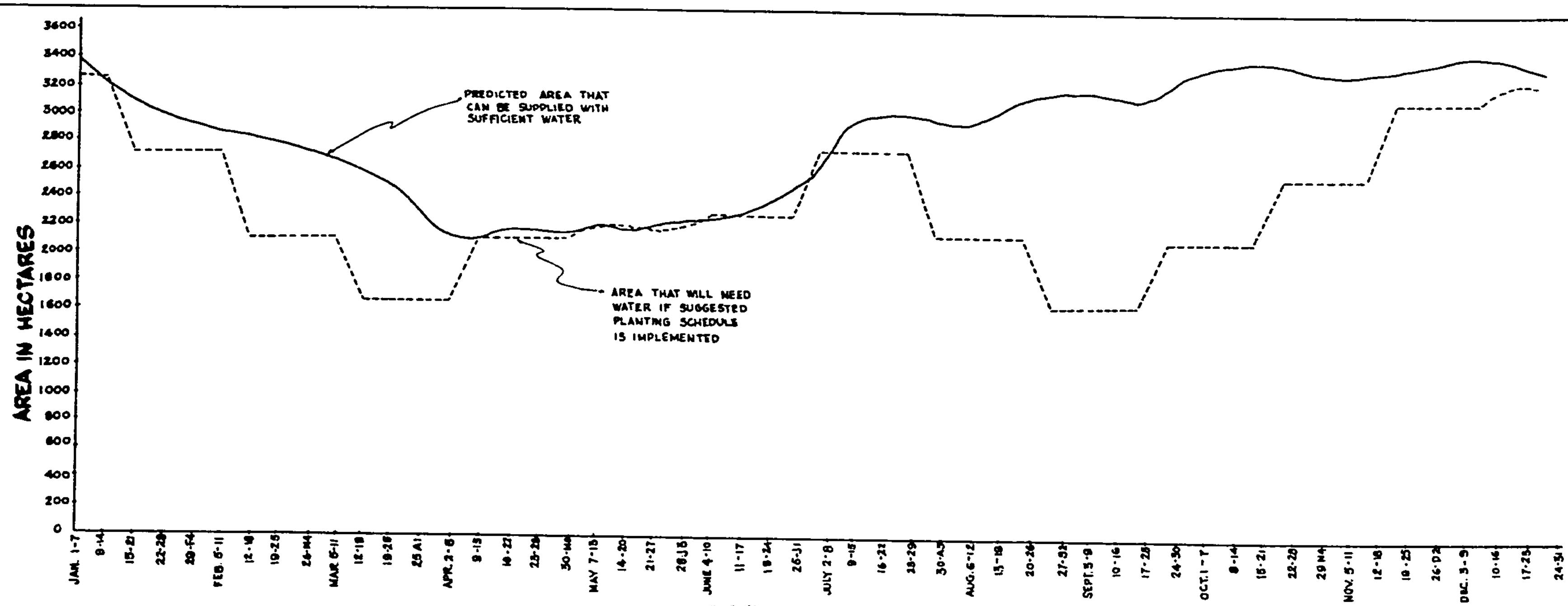


FIGURE — 10

AREA THAT WILL BE IN NEED OF WATER IF SUGGESTED SCHEDULE IS FOLLOWED
STA. CRUZ RIVER IRRIGATION SYSTEM

CONCLUSIONS

If adopted, the suggested procedure should improve the performance of most diversion irrigation systems under the NIA. The result would be more irrigated land and increased opportunity for farmers to grow two crops a year. The methodology could also serve as a guide in drawing out a priority list for the NIA rehabilitation program. Some systems might not need further rehabilitation since the desired objectives could be achieved through proper scheduling of planting and water distribution. In such cases, funds intended for rehabilitation could be alloted to other purposes such as the construction of new projects.

The cooperation of the farmers within the service area is essential. Only if the farmers are willing to follow definite schedules of farm activities can the method succeed. An educational program must be conducted to convince the farmers in the service area that cooperation will improve everyone's welfare.

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Formulas developed for farm-level irrigation of lowland rice

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ABSTRACT

The paper describes scientific management of irrigation for the seedbed, land preparation, and growth periods of lowland rice. The land preparation period is found critical for canal design, and appropriate formulas are discussed relating the area to be prepared with the duration of the period and available water supply. Water management for the crop after transplanting is also defined through formulas. Experience from Taiwan is used to estimate rotation intervals under conditions of variable soils, sources of water, and seasons.

For centuries, the rice crop and rice growers of th humid tropics have adapted themselves to the rainy season. The rice varieties are mostly photoperiod-sensitive and the farmers usually plant whenever the monsoon rains begin. They harvest at a fixed date after the rains stop and the water recedes. As a result, farmers of the humid tropics, accustomed to growing one rice crop a year, seldom realize the importance of water management for better irrigation.

With the development of photoperiod-insensitive rice varieties in recent years, the growers of Southeast Asia are equipped to grow more rice crops in 1 year and to develop rice-oriented multiple cropping patterns, because they are not limited by temperature. The only environmental defect left to hamper the cultivation of more crops of rice in the humid tropics is rainfall variability. Development and management of water resources are the only ways to remedy it. This paper summarizes some up-to-date information on improved water management practices for lowland rice.

BACKGROUND OF FORMULA DEVELOPED FOR RICE IRRIGATION

Transplanted rice has distinctly different water requirements in the seedbed period, the land-soaking and preparation period, and the transplanted field irrigation period. The seedbed period requires about 600 mm of water in 20 to 30 days (wet-bed method in the Philippines), but it covers only 4 percent of the total irrigation area. The land-soaking and preparation period requires about 200 mm of water for only 1 to 3 days, through 1 to 3 applications for all field plots. After the land is thoroughly soaked and puddled, a 5 or 6 mm depth of water must be added to the fields daily to compensate for evaporation and percolation losses, and to maintain the

30 to 60 mm of ponding water until the day of transplanting. After transplanting, continuous application of 6 to 8 mm per day or intermittent application of 25 to 45 mm of water at 3 to 8 day intervals should be done except at the time of weeding and possible fertilizer application. Irrigation should stop 2 to 3 weeks before harvesting.

These procedures indicate that irrigation of transplanted lowland rice is quite complicated, but it can be organized. It also indicates that a peak demand for water occurs when the land-soaking period overlaps the transplanted-field irrigation period. Thus, there is no single design discharge for a given area. For canal design, the maximum possible discharge should be used. For irrigation planning a weighted discharge following cropping and irrigation patterns should be used. For water management, the discharge should vary in accordance with the effective rainfall and irrigation efficiencies.

Formulas have been developed in Asia for land-soaking water and transplanted-field water separately, but they neglect the water for the seedbed period. The application of the formulas in canal design, irrigation planning, and water management is of the utmost importance for modern irrigation.

FORMULAS DEVELOPED FOR CANAL DESIGN

The formulas developed for calculating the discharge required during the so-called land soaking, land preparation, or pre-saturation period in transplanted rice culture can be grouped into two schools of thought: (1) keeping constant rate of progress of land preparation, and (2) keeping a constant rate of water delivery. The former results in varied rates and higher peak delivery of water, while the latter results in a varied rate and higher speeds of land preparation. Both of them imply careful planning, measuring, and control of irrigation water. The basic conception of these two schools of thought can be best explained through Figure 1, in which curve "A" represents variable rate of land preparation, and curve "B" represents constant rate progress of land preparation. These curves were developed on the assumption that the water supplied by an irrigation scheme during a short period of time in the pre-saturation period is used partly to maintain the water layer in the already saturated area, and partly to saturate a new area. Based on this assumption, the following equations were developed for curve "A" by Van de Goor and Zijlstra.

$$I = \frac{Me^{\frac{MT}{s}}}{e^{\frac{MT}{s}} - 1}$$

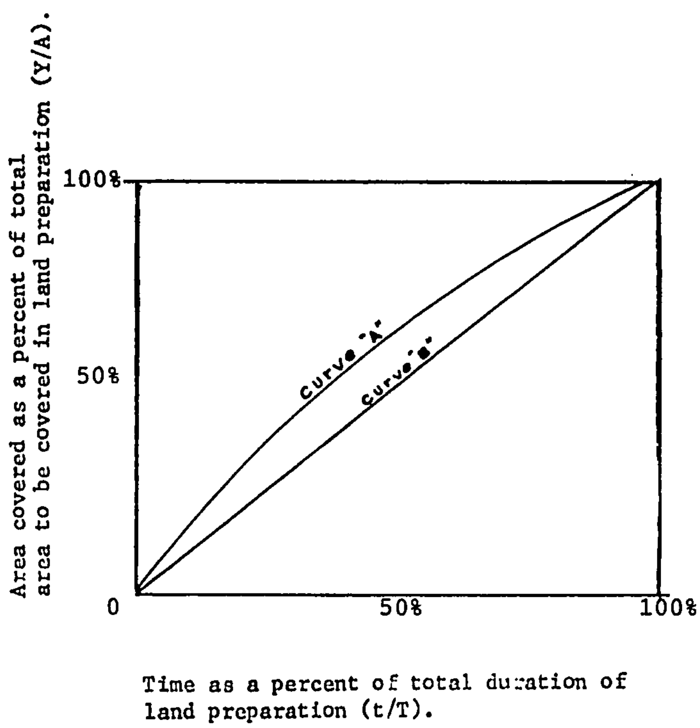

Fig. 1. Rate of advance of area covered vs. time for two methods of land preparation.

$$\frac{t}{T} = \log_e \left(\frac{I}{I-M\frac{Y}{A}} - \frac{I}{I-M} \right)$$

$$T = \frac{S}{M} \cdot \log_e \frac{I}{I-M}$$

where

I = supply required during the land preparation or pre-saturation period, expressed as millimeter per day over the total area, A, to be irrigated;

t = time in days, taken from the start of the pre-saturation period;

M = supply required for maintaining the water layer after pre-saturation is completed, in millimeter per day;

Y = area pre-saturated at time t;

S = water required for pre-saturation, in millimeters;

T = duration of pre-saturation period, in days.

From the graph and the equations, it follows that with constant I and M, T would be directly proportional to S, i.e., the more the water required for pre-saturation the longer the pre-saturation period.

Moreover, with constant I and M, there is a fixed relationship between t/T and Y/A. From curve "A" which represents this relationship, it can be seen that the saturated area advances more than proportionally with time. Two thirds of the area is saturated, for example, in the first half of the period.

The first group of formulas, which correspond to curve "A" are (Wen, 1970)

$$Q \text{ (in m}^3\text{/day)} = \frac{AD_t}{E_c\left(1 - e^{-\left(\frac{D_t}{D_s}\right)N}\right)}$$

or

$$Q \text{ (in m}^3\text{/sec)} = \frac{A_h \cdot D_t}{8.64\ E_c\left(1 - e^{-\left(\frac{D_t}{D_s}\right)N}\right)}$$

where

Q = canal or pump capacity (maximum discharge)

A = area to be irrigated in square meters

A_h = area to be irrigated in hecares

D_t = water requirement in meters per day in the transplanted field. In rotational irrigation D_t will be Dr/Pr in which Dr is the depth of water for each application of rotational irrigation and Pr is the rotation interval in days

Ds = puddling water requirement in meters required for soaking the field prior to transplanting

N = period of land preparation, in number of days, for the entire area of A

E_c = conveyance and/or distribution efficiencies in decimals instead of percentage

and (Cheng, 1971)

$$Q = \frac{A}{8.64} \cdot \left(\frac{d}{1 - K^n}\right) \cdot \frac{1}{1 - L}$$

or

$$Q = \frac{A}{8.64} \cdot \left(\frac{d}{1 - K^{\frac{T}{r}}}\right) \cdot \frac{1}{1 - L}$$

where

$$K = \frac{\frac{D}{r} - \frac{d}{2}}{\frac{D}{r} + \frac{d}{2}} \quad \text{and} \quad T = nr \text{ or } n = \frac{T}{r}$$

Q = canal or pump capacity required at any number of unit duration "n" of time "T", in cubic meters per second.

A = total area to be irrigated, in hectares.

d = amount of water required for evaporation, seepage and percolation during land preparation stage after supplying water for land soaking and flooding; or water requirement for paddy field during initial growing stage after transplanting, in meters per day.

D = water required in depth to make the soil saturated and flooded for land preparation, in meters.

L = rate of conveyance and/or distribution losses in decimals.

The second group of formulas, which correspond to curve "B" are (Provincial Water Conservancy Bureau, 1967)

$$Q \text{ (in } m^3/\text{day)} = \left(\frac{AD_s}{N} + AD_t\right) \cdot \frac{1}{1 - L}$$

or

$$Q \text{ (in } m^3/\text{sec.)} = \left(\frac{AD_s}{NT} + \frac{AD_t}{T}\right) \cdot \frac{1}{1 - L}$$

where

Q = canal or pump capacity (maximum discharge).

A = area to be irrigated in square meters.

D_t = water requirement in meters per day in the transplanted rice field.

D_s = puddling water requirement in meters required for soaking the field prior to transplanting.

N = period of land preparation in number of days for the entire area A.

T = number of seconds in 1 day, 86,400, and

L = conveyance and/or distribution losses in decimals.

and (Chow, 1960)

$$Q = \frac{A}{8.64} \cdot \left(\frac{d_s}{P_s} + \frac{d_r}{P_r}\right) \cdot \frac{1}{1 - L}$$

where

Q = the required canal capacity in cubic meter per second.

A = the area to be irrigated, in hectares.

d_s = the depth of water, in meters, required for soaking the field.

d_r = the depth of water, in meters, for each application to the transplanted field.

P_s = the period of soaking the field in days.

P_r = rotation interval of irrigation, in days.

L = canal conveyance and/or distribution losses, in decimals.

and (Fukuda and Tsutsui, 1968)

$$R_x = \frac{10A}{n} \cdot \left(s + (x-1).d\right)$$

for calculation of maximum daily water requirement for the xth day from the beginning of land preparation, and

$$R_{max} = \frac{10A}{n} \cdot \left(s + (n-1) \cdot d\right)$$

for calculation of maximum daily water requirement in the period of land preparation, where

R_{max} = maximum daily water requirement, in the period of land preparation in cubic meters per day.

A = area to be puddled, in hectares.

d = unit water requirement, in millimeters per day, in the transplanted field.

n = number of days in land preparation.

s = puddling water requirement, in millimeters.

The two groups of formulas both give the maximum discharge for canal designs. But the first group of formulas results in 20 to 30 percent smaller discharges than those obtained from the second group. Alternatively, for the same size of discharge, the first group of formulas indicate a 20 to 30 percent increase in irrigable area. The important requirement for the use of the first group of formulas is that the water supply must be reliable. This is often met through pumps and reservoir storage. The increase in irrigable area should be considered an important benefit of reservoir or tubewell water irrigation projects if controlled water management can be carried out. In either case, the above-mentioned formulas can be used in irrigation planning to determine the irrigable area for a given water supply, provided other hydrologic and meteorologic data are available.

FORMULAS DEVELOPED FOR WATER MANAGEMENT

Formulas developed for water management generally include the factors of effective rainfall, irrigation efficiency, and an allowance for dry fields. The water management formulas are similar to those for canal design.

The amount of water required during the seedbed period is small but the plots are scattered over the whole irrigable area. It does not vary much with the type of soils, but is related to the length of time. In Taiwan, the first crop (dry season crop) seedlings require about 40 days, while the second crop (wet season crop in warmer climate) seedlings may only need 15 to 20 days to be ready for transplanting.

The total amount of water and the number of applications required for land soaking, land preparation, and transplanting varies considerably with the type of soils. For sandy or light soils, one application of 150 to 180 mm would be enough, if all three operations could be carried out in not more than 2 days. For clayey or heavy soils, three applications are generally required. A total amount of 180 mm is usually divided into 100 mm for land soaking, 50 mm for land preparation, and 30 mm prior to transplanting. In cooler places, like Taiwan, the three applications may be spread out for as long as 15 days, while in warmer places they may be completed in 5 to 10 days.

The rotation interval of water applications during the growth of the crop varies with the type of soils, the water source, and the season. Generally speaking the rotation interval should be longer for heavier soils and shorter for lighter soils. On heavy soils in Taiwan with low percolation losses 7.5 day rotation intervals are usually used while on light soils with greater percolation losses 2.5 to 3.5 day intervals are recommended.

Because of differences in percolation losses for heavier and lighter soils, the depth of water delivered per application does not vary much. It generally ranges from 25 mm to 45 mm per application at the farm level. The relationship between the length of rotation interval and the type of water source is that for run-of-the-river water sources the interval should be shorter (2.5 to 3.5 days) while for regulated water sources (either from surface or from groundwater reservoirs) the interval could be longer (5.5 to 7.5 days). Finally, in Taiwan, the relationship between the length of rotation intervals and the growing season specifies that for early maturing varieties of 120 to 140 days after sowing, the interval should be halved for the first month. This is to better protect young seedlings in a cool environment.

Formulas developed for water management can best be explained by the example of those currently adopted by the Chianan Irrigation Association of Taiwan. These formulas are divided into two groups: one for calculating on-farm water requirements and the other for calculating turnout water requirements (Tsai, 1964).

On-farm

$$P \text{ (in ha/cms)} = \frac{8640}{\left(WR\ (1 - \frac{D}{R}) - ER\right)}$$

$$FC \text{ (in mm/day)} = WR\ (1 - \frac{D}{R}) - ER$$

At farm turnout

$$P_1 \text{ (in ha/cms)} = \frac{8640 \cdot (1 - c)}{\left(WR\ (1 - \frac{D}{R}) - ER\right)}$$

$$FC \text{ (in mm/day)} = \frac{\left(WR\ (1 - \frac{D}{R}) - ER\right)}{(1 - c)}$$

where

P = irrigation rate in hectares/$m^3.sec^{-1}$day

WR = water requirement per day in millimeters per day.

R = rotation interval of irrigation in days.

D = dry-field days during the rotation interval.

ER = effective rainfall in millimeters per day.

$$8640 = \frac{86400 \times 1000}{10000}$$

c = water distribution losses in decimals.

It should be noted that only the water requirement (WR) for the transplanted fields is included in the equations; they do not include land preparation. The water requirements (WR) vary mainly with soil type. Effective rainfall deals only with those rainfall records ranging between 5 mm and 30 mm per day. The dry-field days (D) can only be obtained through trial and error (feedback) processes. The water distribution losses (c) also vary mainly with soil type. Practices of the Chianan Irrigation Association are to further refine the water requirements (WR) in accordance with the growth stage of the crop. These factors can all be considered in irrigation planning and water management through the proper use of the equations.

CONCLUSION

The formulas presented bring out the factors to be considered in canal design and water management for rice irrigation. In order to have better water management and irrigation, the effects of these factors should be better understood. Figures supporting them are available in Taiwan. The application of the formulas in planning and management would help convince farmers that they are benefitted by project water, that they should maintain the system in good condition, and that they should pay an appreciable amount for the water. Once the farmers are convinced, the possibility of further development of rice-oriented multiple cropping patterns will follow.

Scientific water management has gradually developed in Taiwan. Two rice crops a year are grown over an area of about 350000 hectares. Recent developments in the irrigation of rice-oriented multiple cropping in central and southern Taiwan have reached an area of about 100000 hectares. It is hoped that through better water control and management double-cropping rice culture can be stabilized and further development of multiple cropping can be achieved rapidly throughout Southeast Asia.

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Predicting yield benefits in lowland rice through a water balance model

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ABSTRACT

A research project was carried out on large sites within irrigation systems to determine the benefits of irrigation to yields of lowland rice. Data were collected under farm level conditions to establish yield response to days of moisture stress. A model was then developed and employed to relate irrigation, rainfall and water-use parameters to days of moisture stress, and thus to yields. Although yield benefits due to irrigátion were substantial for both seasons, they were seriously depressed because of imperfect irrigation, particularly in the dry season. Neither the height of paddy bunds nor the amount of rainfall in the sites were of major consequence to grain yield. Considerable variation in water-use was observed among the sites, but it was generally found that sites with low water-use efficiencies showed the greatest yield benefits, and vice versa.

Two of the most frequently asked questions in the field of irrigation are "what are the yield benefits derived from irrigation?" and "how are these benefits related to certain water management practices?" This paper presents a methodology and some data useful in answering both these questions. The conclusions are not intended to be final, for refinements in the analysis or altogether new approaches could lead to more precise predictions. The results reported here, however, appear valid for the conditions under which the research was undertaken.

These conditions involve three qualifications. First, they represent lowland rice production in which the soils are puddled and individual rice paddies are bunded. These bunds are typically 30 cm high, and the paddies about 1000 m^2 in area. The main effect of puddling is to greatly reduce the amount of water percolating into the soil. Second, the results apply to farms served by diversion irrigation systems that supplement existing rainfall. Diversion systems are severely limited by their lack of storage capability, and depend completely on the stage of the river for their daily discharge. The stage declines sharply after the wet season, and even during periods of relatively little rainfall in the wet months, leaving the systems with reduced supplies just when the demand for water is greatest. Due to the contraints of economy and topography, these are the dominant irrigation systems throughout Southeast Asia. Finally, the results are applicable to actual farm level conditions as they existed in 11 selected areas of the Philippines in 1969 and 1970. These areas averaged 24 hectares each, and were in irrigation systems of the National Irrigation Administration (NIA) in the provinces of Nueva Ecija, Bulacan, and Laguna. Although the sites were not randomly selected within the systems, they were chosen to represent a wide range of irrigation and drainage conditions. They do not reflect sites on which pilot schemes of water management and distribution were being tried out.

The field research was undertaken with the support of the Department of Agricultural Engineering of the U.P. College of Agriculture, the U.P.-Cornell University Graduate Education Program, and the NIA. Portions of the research have already been reported (Wickham, 1971).

The yield response of crops to irrigation water supplied throughout the season is difficult to establish, due to wide variation in the amounts of water percolating into the soil, the distribution of the supplies throughout the season, climatic factors such as evaporative demand and rainfall, and many other parameters of plant growth which differ widely from place to place. To assess the impact of water on yields under these circumstances an intermediate index of water adequacy must be developed which can be shown to affect yields, but which is itself sensitive to the supply of water under farm level conditions.

This paper first defines such an index and relates it to yield variation in lowland rice. Irrigation supply is then shown to affect the index, and through it, grain yields under different management assumptions.

YIELD RESPONSE TO WATER ADEQUACY

Procedures

The water status of 15 to 30 paddies selected from each of 11 sites was monitored daily. Approximately 6 percent of the total site area was represented in these paddies, which were selected by stratified randomization. Stratification was based on relative elevations and drainage conditions as revealed through aerial photographs. Individual paddies were used as the unit of analysis because within each there is relatively little variation in water status and in cultural management. The same paddies were used for both the wet and dry season crop at each site.

Although tensiometers are commonly used (Holmes et al., 1967) to measure moisture stress for upland crops, it was not possible to install and care for 400 instruments in eleven sites. Besides, tensiometer measurements become highly unreliable when dried paddy soils crack, thereby breaking the seal between the soil and instrument. Furthermore, soil moisture stess is difficult to relate to the supply of water. For this research project, therefore, the local NIA ditchtender checked the presence or absence of standing water on each paddy every day. If water was present I assumed that it was not limiting to the plant. If there was no standing water, the ditchtender used a field penetrometer to estimate the hardness of the soil. This was done to differentiate between soils which had no standing water but were still soft and essentially saturated, and those which were very dry and hard.

Yield measurements were made at harvest by taking two crop cut samples of approximately 2 m^2 each from all the sample paddies. In each paddy the variety planted, dates of planting and harvest, weed and disease incidence, timing and amounts of nitrogen fertilization, distance from the source of water, elevation above a datum, and the texture and organic matter content of the soils were noted. No attempt was made to impose a standardized crop management of the paddies. There was, therefore, in each site a wide diversity of water control and farm practices reflecting the farm level environment.

Stress indices

Although soil moisture stress was not used in this project, other experiments (IRRI, 1970) in which it was used have shown that the duration of periods of moisture stress has a cumulative effect on the amount of yield reduction in rice. Other experiments involving different depths of flooding (Williams, 1969) as an indicator of stress have not shown consistent differences in yield. Research to date indicates that rice is particularly sensitive to moisture stress, and that yield reduction can be expected as soon as the root zone is less than saturated. Reyes (1972) supports this view with experimental data showing yield reductions roughly proportional to the duration of dried soil conditions.

A major weakness of these experimental efforts is that their moisture stress treatments do not describe well the way stress actually occurs on farms that depend on rainfall and diversion irrigation. The field problem is more typically one of discrete periods, often exceeding several weeks, in which essentially no additional water is supplied. There may be several such drought periods during a season; they occur because diversion irrigation systems tend to supplement rather than complement rainfall which itself is highly unpredictable during the wet season. Droughts in the dry season are in part caused by the tendency of farmers to double-crop in excess of the systems' stable water supply. In both the wet and dry seasons the ability of the crop to recover after a drought period is more important than the yield response to extended but low levels of stress.

The elements of stress measurement which appear important in describing farm level water adequacy are, then, the intensity of stress, its duration, and the stages of growth of the crop during which it occurs. In corn, stress during the early reproductive stage greatly reduces yield

(Denmead and Shaw. 1960), but the evidence for rice is not conclusive. While Matsushima (1963) found a similar effect for rice, other workers (IRRI, 1970) have found that there is insignificant difference among stages, or that the early stages are more critical. There is reason to expect varietal difference in this regard, moreover (Krupp et al. 1972).

The best measure of these elements of moisture stress appears to be "stress days", a daily criterion for stress intensity greater than a prescribed value. "Non-stress days" are reported by Dale and Shaw (1965) for their positive effect on corn yield. Stress days, with a negative effect on yield, are more suitable for lowland rice due to the usual condition of flooding, for which no stress is presumed. For another use of stress days, see also Godwin et al.,(1971). Such stress days can be accumulated over the whole crop duration or portions thereof, and the required field measurements are limited to a daily index of stress intensity. The criteria of presence or absence of standing water, together with the soil hardness values, constituted that index for the paddies studied.

The first problem in using these data, however, was to find a suitable soil hardness level at which to start accumulating stress days. Trial equations were computed in which yields were related directly to the number of stress days computed for different soil hardness values, but the results did not show much difference in the relationship for the different hardness values. These results were surprising because unflooded but very soft (saturated) soils still hold a large amount of water. It was observed, however, that the bulk of stress days computed at all threshold levels occurred in a few prolonged drought periods in which the soil become quite hard within several days. That suggested an alternative approach: to use a soft soil threshold, but to pass over the first several days of each stress period as days for which soil moisture is not yet limiting. Three-day, 6-day, and 9-day transition periods were tried. The 3 day transition explained the highest extent of variation, and closely approximated the previous results using intermediate soil hardness values. Therefore, for all subsequent analysis, stress days were computed as those days in excess of three for which the paddy was continually without standing water. If a stress period lasted for 3 days or less, no stress days were computed; total stress days were summed over all stress periods.

The regression model

Before specifying a model to account for yield reduction due to stress days, it is necessary to find out whether the stress effect varies over crop duration. Table 1 shows the results of the multiple regression model:

$$\text{Yield} = A + B(N) + C(N^2) + D(S)$$

where A is a constant, N is nitrogen fertilizer in kilogram of nitrogen per hectare, and S is the number of stress days. All four trial equations use the same data set (improved varieties; half of these planting were IR5, a quarter were C4-63 and the rest were mostly IR8), but the number of stress days is computed from within different periods of crop growth for each equation. The table shows that stress days from 60 to 30 days before harvest are much more critical in affecting yield than stress days occurring earlier. The critical period is roughly from panicle initiation to heading of the crop. Identification of this period by the conventional count of days after transplanting does not show the critical stage so clearly, however, due to the wide variation within the sample in days to panicle initiation. Different varieties reflect some variation in their duration of vegetative growth, but the effect of stress early in crop growth is more important in delaying subsequent plant development. For all plantings of improved varieties the growth duration of the crop was extended by 83 percent of the number of stress days encountered prior to 60 days before harvest. A similar effect was not found for stress days during the reproductive period. On the basis of the fourth equation in Table 1, I decided to build two stress terms into the model, one operating essentially over the vegetative stage of growth (from transplanting until 60 days before harvest), and the second during the first month of reproductive growth (from 60 to 30 days before harvest). The two stages, together with their count of stress days, are shown for five sites in Figure 1.

The final yield-response model incorporates both nitrogen and stress effects:

$$Y = A + B(N) + C(N^2) + D(S_1) + E(S_2) + F(NxS_1)$$

where Y is grain yield from sample crop cuts, corrected to 14 percent moisture content in kilograms per hectare, N is amount of nitrogen in kg N/ha applied by the farmer, and S_1 and S_2 are the number of stress days during the two periods of crop growth. The model only accounts for the effects of nitrogen and moisture stress in explaining yield variation from farm to farm. But other more qualitative factors also cause variation in yield levels and response. Those factors have largely been taken into account by stratification of the sample before computing the regressions. Levels of stratification used include different varieties (IR5, all improved, all traditional), seasons (wet and dry), soils (light, medium, heavy), and region (Central Luzon, Laguna, and both regions). The seasonal breakdown is a way to standardize the effect of solar radiation. Dry season crops are those harvested between 1 January and 1 June. Light soils contain more than 25 percent sand-sized particles in the top meter of soil; heavy soils have more than 40 percent clay-sized particles, while all others are classified as medium textured.

The interaction of nitrogen and stress is expressed by the N x S_1 term. Stress during the later stage of growth (S_2) is not included in the term since most nitrogen uptake occurs during vegetative growth.

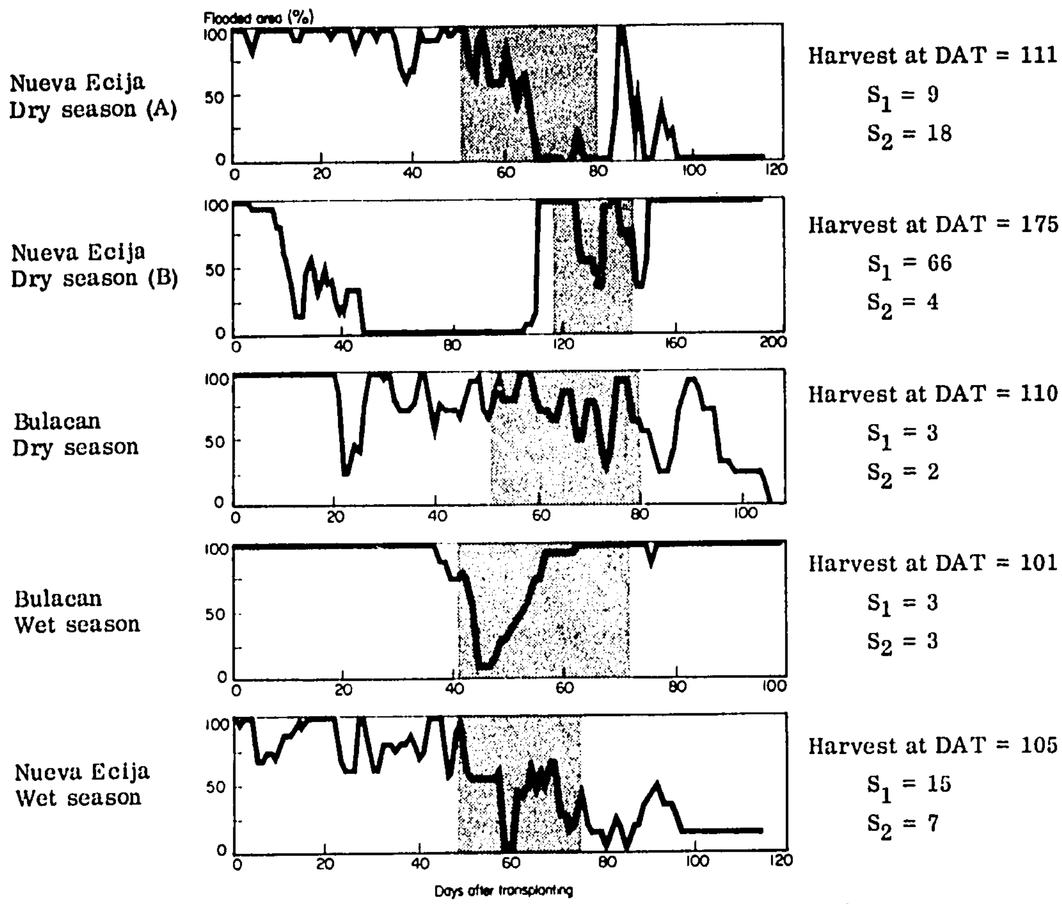

Fig. 1. Percent of site covered with standing water throughout the season, five sites, Luzon, Philippines, 1969-70. Shaded portion refers to the the critical stress period 60 to 30 days before harvest (S_2).

Little fertilizer remains available to the plant beyond 6 weeks after application (Yoshida and Padre, 1972). The trial regression term $\underline{N} \times \underline{S}_2$ in fact was insignificant under all conditions.

Results

The regression parameters are presented in Table 2. Mean yields of improved varieties on these paddies were 3.36 t/ha with 34 kg N/ha applied, and 5.9 stress days during the vegetative stage and 3.5 stress days during the reproductive period. Traditional varieties were found chiefly on the Bulacan sites; they had mean yields of 2.89 t/ha with 33 kg N/ha, and 3.9 and 2.4 stress days for the two periods. The improved group outyielded traditional varieties by 14 percent.

The improved varieties showed a stronger nitrogen response than traditional varieties, but there was also greater stress reduction, particularly during the reproductive stage, for improved varieties. This yield reduction in improved varieties is more than compensated by the strong nitrogen response, provided the stress occurs as $\underline{S}_1$. Stress during the reproductive period can make the absolute yield levels of the improved group lower than those of traditional varieties. One reason is the surprising finding that traditional varieties suffered no yield loss due to $\underline{S}_2$ under the conditions of the research. Williams (1969), however, reported similar findings in a controlled experiment with the variety H-4.

Figure 2 compares the yield response to nitrogen for the traditional and improved variety groups for three levels of $\underline{S}_1$ and $\underline{S}_2$. The curves are drawn from the regression equations of Table 2. In general, the traditional group was more sensitive to $\underline{S}_1$ while the improved group, particularly IR5, was more sensitive to $\underline{S}_2$. This can be explained by the relatively low tillering nature of the traditional group, approximately half of which was Binato, and by the tendency of the improved varieties to postpone plant development during extended periods of vegetative stress. When water is supplied after such a drought the crop resumes its tillering and subsequent panicle development. IR5 showed the strongest recovery after drought.

The varietal comparisons lump wet and dry seasons together. A more informative picture of the response of improved varieties is found in the seasonal breakdown, also in Table 2. The dry season equation shows an unexpectedly low first-order nitrogen response, although it is offset by a correspondingly low second-order response. The effect of $\underline{S}_2$ is more serious in the dry season than in the wet season, although the same does not appear to be the case for $\underline{S}_1$. However, the magnitude of $\underline{S}_1$ coefficients is misleading due to the presence of strong interaction terms. Heavy applications of nitrogen clearly seem able to mitigate the effects of early stress. Thus, a more complete picture of the seasonal differences can be found in Figure 3, in which the interaction effect is incorporated. Positive $\underline{N} \times \underline{S}_1$ interaction can be

Table 1. Parameters for selected yield regressions[1/] on nitrogen and stress at different growth stages, new varieties, Luzon, Philippines, 1969-70.

Trial No.	Period for which stress-days computed 2/	Constant	Coefficients B(N)	C(N^2)	D(S)	Relative[3/] weight of the stress term	Mean no. of stress days	R^2
1	30-60 DAT	2605	45.8	-0.35	-65.4	18	3.0	0.20
2	45-75 DAT	2620	45.9	-0.33	-62.3	19	4.0	0.21
3	55-85 DAT	2595	46.0	-0.32	-56.8	19	4.4	0.20
4	60-30 DBH	2840	37.8	-0.27	-83.8	25	3.5	0.25

1/ Grain yield = a + B (Nitrogen) + C ($Nitrogen^2$) + D (Stress-days). All values are in kg/ha except stress-days, which is in days. All coefficients are significant at least to the 0.05 level. N = 218. 2/ DAT is days after transplanting; DBH is days before harvest. 3/ Relative weight of the stress term is a measure of its importance, in percent, relative to that of stress and fertilizer together. It is computed from standard partial regression coefficients.

Table 2. Coefficients for grain yield regressions[1/] on nitrogen fertilizer and stress-days at two stages of growth,[2/] farm-level data, Luzon, Philippines, 1969-70.

	Constant	B(N)	$C(N)^2$	D(S_1)	E(S_2)	F(N$\times S_1$)	No. of observations	Coefficient of Determination
By varieties:[3/]								
All traditional	2680 *	8.9	-0.00	- 25.7 *	7.7	-0.08	74	0.34 *
All new	3040 *	30.1 *	-0.22 *	- 26.0 *	-60.8 *	0.41 *	218	0.28 *
IR5	2690 *	53.9 *	-0.55 *	-12.1	-71.4 *	0.18	96	0.40 *
New varieties, by season[4/]								
Wet season	2790 *	41.5	-0.50	-50.2*	-20.4	0.76 *	126	0.21 *
Dry season	3600 *	17.9	-0.14	-35.2	-94.4 *	0.54	92	0.49 *
New varieties, by soil texture:[5/]								
Light soils	2280 *	29.0 *	-0.09	-106.1 *	-17.1	1.30 *	50	0.40 *
Medium soils	3260 *	79.0 *	-0.80 *	-7.5	-99.4 *	-1.68	76	0.55 *
Heavy soils	2880 *	26.3 *	-0.15	+103.6	-73.2 *	-1.51	92	0.19 *

1/ For the model Y = A + B(N) + C(N^2) + D(S_1) + E(S_2) + F(NS_1). Asterisks denote significance at the 0.05 level or higher. 2/ SD_1 is the number of stress-days computed for the period from transplanting to 60 days before harvest; SD_2 is the number computed in the period 60 to 30 days before harvest. 3/ New varieties include C4-63 and all IRRI varieties. 4/ Wet season crops are those harvested from 1 June to 31 Dec.; others are dry season crops. 5/ Sandy soils are those with more than 25% sand sized particles in the top meter of soil; clay soils contain more than 40% clay sized particles in the top meter of soil; medium soils are all others.

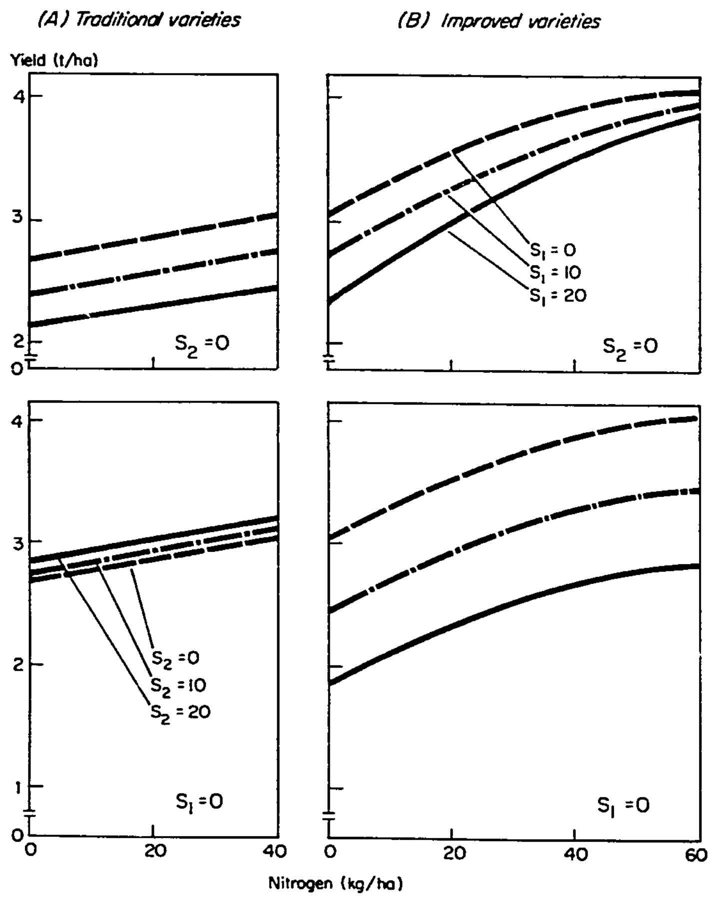

Fig. 2. Grain yield response to nitrogen fertilizer under farm level conditions, for A) Traditional, and B) Improved varieties, at three levels of moisture stress in the vegetative (S_1) and reproductive (S_2) stages, Nueva Ecija, Bulacan, and Laguna, Philippines, 1969-1970.

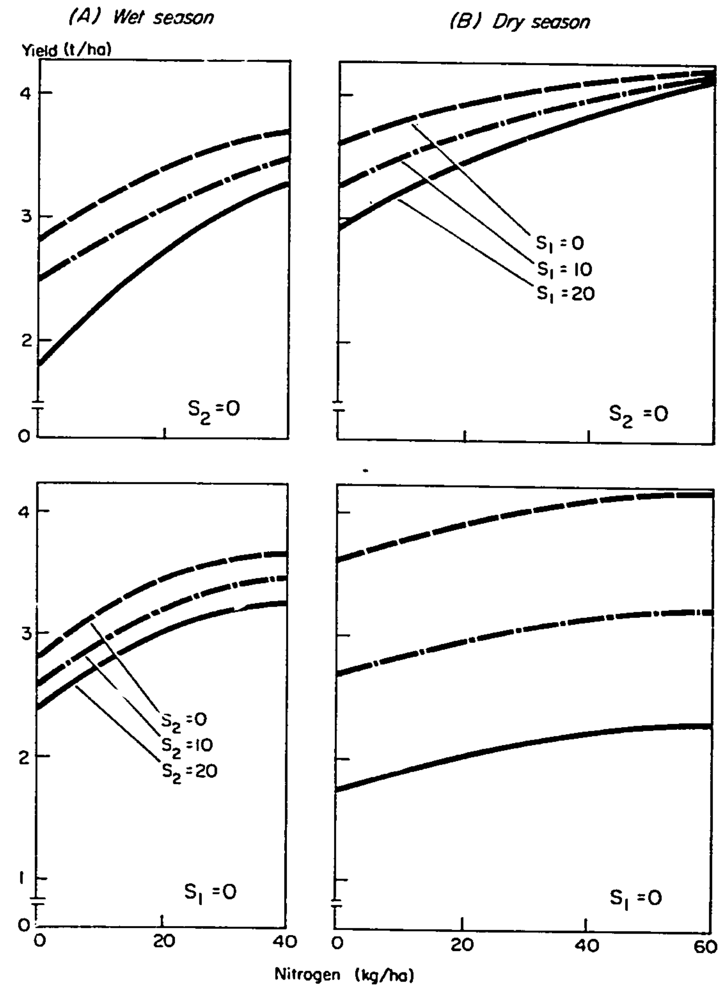

Fig. 3. Grain yield response to nitrogen fertilizer under farm level conditions for A) Wet, and B) Dry season crops of improved varieties, at three levels of moisture stress in the vegetative (S_1) and reproductive (S_2) stages, Nueva Ecija, Bulacan, and Laguna, Philippines, 1969-70.

expected for two reasons, neither of which were studied, however, in this project. First, higher nitrogen levels encourage greater root development which expands the volume of soil from which the plant can attempt to extract moisture. Second, extensive losses of soil nitrogen have been documented for puddled soils which have been allowed to dry out, and then flooded again. When nitrogen is lost this way the crop's subsequent requirement can only be met by additional application. This point is already accepted by many farmers in the sites who frequently applied heavily after a major drought was over. Taking into account the interactions at mean levels of nitrogen, 1 stress day in the reproductive period lowered yields of improved varieties twice as much as 1 stress day in the vegetative period. In the dry season, stress days during the reproductive period were four times as costly as stress days in the vegetative period. Although $\underline{N} \times \underline{S_1}$ interaction appears able to offset the effect of early stress in new varieties, similar results were not found for the traditional group.

Analysis according to soil texture (Table 2) shows a strong fertilizer response relative to that of stress in the case of light soils. The interaction is strong so stress effects are small at either stage of growth on these soils. This is unexpected in view of the lower moisture holding capacity of light soils. At low to moderate stress levels, however, more water is available for plant uptake from light soils than from heavy ones. In addition, resupply of water into the soil is also quicker for lighter soils. Some moisture stress could be an important factor, moreover, in keeping nitrogen from being leached beyond the root zone. That could explain the strong $\underline{N} \times \underline{S_1}$ interaction.

A common problem in regression analysis is the presence of association between two or more of the independent variables, or between one of them and a factor used in stratifying the sample. Association between $\underline{N}$ and $\underline{S_2}$ was not significant in any equation of Table 2; $\underline{N}$ and $\underline{S_1}$, however, were significantly related in the wet and dry season breakdown, and for the equation representing IR5 in both seasons. The association was positive in the wet season and negative in the dry, indicating that greater incidence of $\underline{S_1}$ was accompanied by more nitrogen use in the wet season, and less in the dry. $\underline{S_1}$ and $\underline{S_2}$ were positively correlated in all equations representing varietal and seasonal breakdowns except for that of IR5 in both seasons. Variety group and season were also associated, but neither texture and season, nor soils and region (Central Luzon and Laguna) were. Fertilizer use was significantly greater in the dry season than in the wet.

Another source of distortion in response functions exists if the quality of farm management varies with input levels. This quite likely occurs in farm level data since farmers investing in high amounts of nitrogen could otherwise be expected to take better care of their crops. The association is difficult to measure because of the qualitative nature of management levels. To explore this problem, separate functions were computed for the Laguna sites in which a high degree of farm management was observed, and for the Central Luzon (Nueva Ecija and Bulacan) sites, in which virtually no management inputs except nitrogen applications were made by the farmers. I assumed, therefore, that unmeasured management variation could not be a problem on the Central Luzon farms. The results of these regressions, (Figure 4), show relatively steeper slopes for the Laguna curves than for those representing Central Luzon, which confirms the likelihood of improved cultural management on farms using higher nitrogen rates. Nevertheless, the slopes of the curves from Central Luzon correspond closely with those computed for both regions, so that the latter appear to be a sufficiently reliable and conservative measure of the effects of stress and nitrogen.

Summary

The regression equations of Table 2 for new varieties in each of the seasons provide a satisfactory basis for assessing the impact of nitrogen and stress-days on grain yield. Not enough difference exists among the varieties represented within the new variety group to require separate relationships for each variety, and there is little value in developing more precise equations for the traditional varieties since farmers clearly prefer improved varieties. Although the seasonal breakdown might be more accurate if it were stratified according to soil and region, the increased statistical precision would be unlikely to be meaningful because of the strong association found between the factors, and the relatively small number of observations on which each equation would then depend. Despite the modest amount of variation they explain, the following functions are taken from Table 2 for use in the next section, in which the irrigation and rainfall pattern is related to stress days, and through them, yields:

$$\text{Wet season: } Y = 2790 + 41.5(N) - 0.50(N^2) - 50.2(S_1) - 20.4(S_2) + 0.76(NxS_1)$$

$$\text{Dry season: } Y = 3600 + 17.9(N) - 0.14(N^2) - 35.2(S_1) - 94.4(S_2) + 0.54(NxS_1)$$

THE EFFECTS OF RAINFALL AND IRRIGATION ON WATER ADEQUACY

Procedures

In addition to the plant response data previously described, flow of water into and out of each site was measured. These measurements were conducted over both cropping seasons in such a way as to interfere negligibly with existing water management patterns. All irrigation channels and drains crossing the borders of each site were fitted with flow measuring devices, usually Parshall flumes (USBR, 1967), which were read daily. Daily measurement of rainfall and evaporation, the latter with Class A above-ground pans of 4 feet diameter, was also made. The volume water flows were divided by the site areas to give effective depths of of water applied or removed on a daily basis. Most sites required more than twenty flumes distributed along the periphery of each site, which often exceeded 3 kilometers. Ditchtenders located at each site made daily readings from each device. Although considerable flow variation within days was observed for many sites, secondary tests, including the use of continuous water level recorders, confirmed the accuracy of daily readings summed over weeks.

The water balance

Definitions. A water balance refers to an accounting of water movements into and out from the site according to a simplified equation:

$$\text{net irrigation} + \text{rainfall} = \text{seepage \& percolation} + \text{evapotranspiration} + \text{surface drainage}$$

Since irrigation canals frequently extend through the sites, net irrigation is claculated as the incoming irrigation less throughflow, that portion passed on to irrigated areas outside the site. Similarly, net drainage is the balance of water drained from the site, less that drained from other areas into the site. Figure 5 shows these terms in a typical site. During periods of extended water shortage there was occasionally a net accumulation of drainage within a site; in these cases net drainage was negative and computed as irrigation. Irrigation, drainage, rainfall and evaporation data are all expressed as depths of water in millimeters over the area of the site.

Total supply of water is the sum of net irrigation plus all rainfall. Seepage and percolation (S&P) losses, usually referred to together, account for horizontal and vertical movement, respectively, of water into the soil. The sum of evapotranspiration (ET) and S&P is called net use, and may be considered the minimum water requirement for rice production at a particular site. Changes in the amount of water stored in the soil are assumed to be negligible in flooded paddies analyzed over whole seasons.

Water-use efficiency is defined differently for the periods of land preparation and plant growth. For the former, only the water used in land soaking is considered productively used, so efficiency is computed as the land soaking requirement divided by total supplies. Efficiencies after transplanting are conputed as net use/total supplies. Kampen (1970) and others define efficiency during crop growth as ET/Total supplies, considering S&P an unproductive loss. However, for lowland rice S&P cannot be reduced materially by alternative water management programs. It is a function primarily of soil and groundwater conditions, and hence a more appropriate measure of land use than water-use efficiency.

Land preparation period. The water requirement for land preparation depends in part on the initial moisture content of the site when water is first turned in. Complete data on the pre-planting period

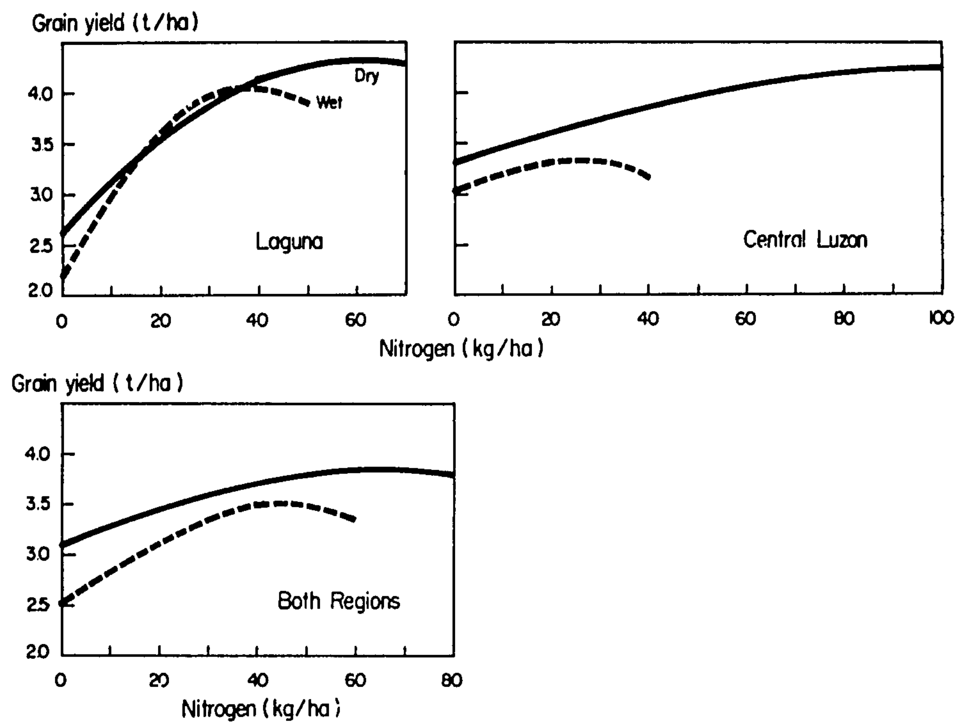

Fig. 4. Yield response of improved varieties to nitrogen at mean values of S_1 and S_2 for 1) Laguna, 2) Central Luzon, and 3) Combined regions, 1969-1970.

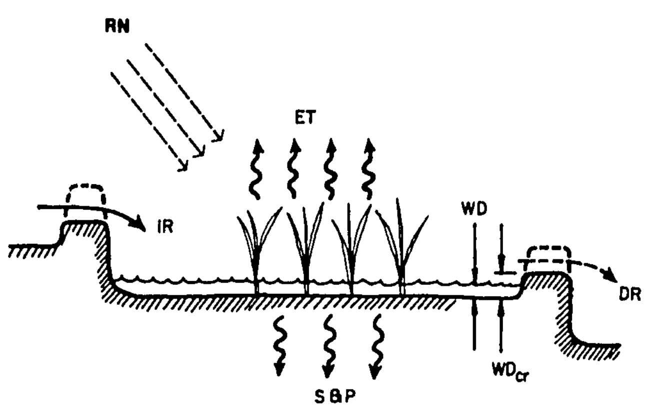

Fig. 5. Water use model for lowland rice.

were obtained from nine first crop sites which received essentially no water for several months before plowing, and from five second crop sites in which land preparation began shortly after the harvest of the previous crop. Mean values of water use for both groups are listed in Table 3. First crop sites received 1140 mm of water, 500 mm of which fulfilled the land soaking requirement. Drainage accounted for 417 mm of water loss, and evaporation 223 mm. The mean efficiency was 44 percent. Excluding the highest and the lowest value, the range of land soaking requirements for individual sites was from 329 to 604 mm. The wide range reflects different soil and topographic features.

Second crop sites used a mean of 171 mm for land soaking, which came from total supplies of 708 mm. The mean efficiency of these sites was 24 percent. Comparing the land soaking requirements of the same five sites in both seasons, second crop sites required uniformly only 40 percent of first crop values.

A major cause of low efficiencies and high land soaking values for most sites was the extended duration of land preparation. The mean duration of almost 8 weeks was about the same for both seasons. Daily evaporation and S&P over that period resulted in extensive losses and greater land soaking requirements than are generally reported (cf. Van de Goor and Zijlstra, 1968).

Total water (irrigation + rainfall) supplied to first crop sites during land preparation was 38 percent of total seasonal supplies (land preparation plus crop growth); for second crop sites this figure was reduced to 32 percent.

Plant growth period. Tables 4 and 5 summarize the water balance data for wet and dry season sites. All figures were recorded between the median dates of transplanting and harvest for each site, and usually covered the entire growing period. Evaporation rates are slightly depressed because the pans were sometimes located at low elevations in the rice paddy.

Total supplies, the sum of irrigation and rainfall, range from about 1000 to 3000 mm for wet season sites, and from 700 to 2500 mm for dry season sites. Mean values for 112-day crops are 1940 and 1685 mm for the wet and dry seasons, respectively. Although net use values in the dry season are substantially greater than in the wet season, efficiency of use is also much higher and total supplies are thus actually less in the dry season. Rainfall in the wet season ranges between 23 and 80 percent of total supplies.

Table 3. Mean values of water balance components for the land preparation period, Luzon, Philippines, 1969-70.

	First crop sites 1/	Second crop sites 1/
Depths of water (mm)		
Net irrigation	851	526
Rainfall	289	182
Total supplies	1140	708
Drainage	-417	-339
Net Use	723	369
Evaporation	-223	-198
Land Soaking	500	171
Efficiency 2/ (%)	44	24
Duration 3/ (days)	52	56
Sites (No.)	9	5

1/ First crop sites received water after several months of dry, fallow conditions, while second crop sites were plowed and planted shortly after a previous crop from which the soil was still wet. Most of the first crop sites were planted in the wet season, and all second crop sites in the dry season. 2/ Efficiency = Land soaking requirement/total supplies. 3/ Duration is measured from the first day of turning in water (or from the median date of harvest of the preceding crop, for second crop sites) until the median date of transplanting.

Table 4. Water balance components after transplanting for 11 wet crop sites, seasonal sums in mm of water, Luzon, Philippines, 1969-70.

Site	Days	Irrig.	Rain.	Drain	Net use (Total)	Net use (Daily)	Evap. (Daily)	Effic. (%)
111	98	1577	458	69	1966	20.0	4.3	96
121	40	258	205	146	317	7.9	4.5	68
131	93	916	410	1004	322	3.3	4.3	24
141	115	1038	863	1421	480	4.2	3.0	25
211	98	270	1050	715	605	6.2	3.5	46
221 *	94	1026	864	1321	569	6.1	4.0	30
231	98	1894	970	1884	980	10.0	4.0	34
311	119	1232	1059	1607	684	5.7	3.2	30
321 *	106	311	650	520	441	4.2	3.4	46
331	70	240	412	427	225	3.2	3.7	34
341	105	1261	1011	2066	206	2.0	2.5	9
Mean	112	1090	850	1210	730	6.5	3.4	38

* Sites less than 19 ha.

Surface drainage is a major loss in almost all sites and particularly in the wet season when its mean value exceeds the amount of rainfall, irrigation, or net use, taken separately. Drainage results from the supply of additional water to filled paddies. Although water that drains into creeks is sometimes available for re-use as irrigation through a downstream check-dam, it was nevertheless lost to the systems under study.

Evapotranspiration (ET) values are not shown directly in Tables 4 and 5, but can be approximated roughly by the evaporation rate, as explained later. Evaporation shows less variability among sites (and among weeks within a given site) than any other component of the water balance. The dry season mean of 5.6 mm/day is about 40 percent higher than the wet season mean of 3.4 mm/day, but both underestimate actual evaporation by 10 to 20 percent because of the location of the pans. Corrected ET values constitute 20 percent and 37 percent of total supplies in the wet and dry seasons, respectively.

Seepage and percolation estimates can be made by subtracting ET from net use. Taking only those sites which are not associated with major seepage sinks and are larger than 19 hectares, a range in S&P rates from 0 to 2.5 mm/day for the wet season, and 0 to 6.5 mm/day for the dry season, can be shown. Less variability occurs in the wet season because the groundwater table is higher, and the perimeter-area ratios of the irrigated tracts are smaller. Special conditions, however, are responsible for excessive seepage and percolation losses which reached more than 16 mm/day for two sites and more than 7 mm/day for five others. The most serious and common cause is the attempt to irrigate marginal areas planted along the banks of rivers and creeks, where soils are light and there is a ready sink to carry away the seepage. High rates also occur in small irrigated areas separated from unirrigated paddies only by conventional bonds, a situation often found in the dry season. It is apparent that seepage is highly variable due to relief, and that its estimation from a few relatively small sites cannot be extrapolated directly to basin-wide averages.

Field efficiencies. The mean dry season water use efficiency, 68 percent, was almost double that of the wet season (Tables 4 and 5). To some extent, this was due to site selection which, because of the double cropping capability sought for all sites, resulted in somewhat excessive irrigation during the wet season. However, low efficiencies can generally be expected when paddies are flooded to maximum depth and when additional supplies are provided in a poorly distributed and unpredictable manner. These conditions are most often fulfilled through rainfall. Significant negative correlations between percent efficiency and a) water adequacy (percent of the site flooded), and b) rainfall (as a percent of total supplies), indicate the importance of these two effects in causing low wet season efficiencies. (Eff = 159.0 - 1.3 (a); $r = 0.84$, $N = 22$ sites; Eff = 71.6 - 0.6 (b); $r = 0.48$, $N = 22$ sites).

If wet season efficiencies were computed only on the basis of irrigation supply (ignoring the contribution of rainfall to total supplies), the resulting value, 67 percent, is almost identical to the mean dry season efficiency. It is apparent that wet season irrigation operates much like that of the dry season: farmers tend to rely on irrigation as the sole source of water for growing their crop. This is not to say that effective rainfall is zero. Rainfall fills critical deficits in irrigation supply; furthermore, one cannot assume that all surface drainage is composed of water supplied through rainfall. That farmers rely heavily on irrigation is not surprising in view of the risk of insufficient rainfall at almost any given time. Nor is there serious inconvenience if a heavy rainfall should follow a thorough irrigation, since rice is sensitive to moderate flooding, and excess water can usually be drained easily. Farmers in the sites studied regarded rainfall as a supplement to their irrigation supply, rather than vice versa. The nature of diversion irrigation systems supports this interpretation since there is no storage capability in the systems and hence no future benefit from irrigation water "saved" through economizing during an earlier period. Large drainage losses and low efficiencies are quite logical under these circumstances. Difficulties can be anticipated, however, in current efforts to economize in the use of water in traditional diversion systems to which storage reservoirs are now being added.

The dynamic water balance model

Description and operation. The seasonal totals listed in Tables 4 and 5 show overall sums of the water balance, but they do not indicate the adequacy of water supplied to the sites, nor do they explain relationships and dependencies among the terms. To do this, a dynamic model was constructed based largely on a daily operation of the water balance. A term to reflect the depth of water (WD) in the paddy is introduced in the model since the previous assumption of constant storage is not valid over single-day intervals. Negative values of WD reflect depletion of stored water to levels below the soil surface. The dynamic balance can be represented by the equation

$$WD_t = WD_{t-1} + RN_t + IR_t - ET_t - S\&P_t - DR_t$$

where t refers to daily time periods.

Assuming for the moment that daily values of RN, IR, ET, and S&P can be determined, there remain two unknowns (WD_t and DR_t) for the equation. An additional equation is needed linking drainage with the depth of water on the paddy. Such a relationship is suggested by the paddy-to-paddy method of water movement observed for both irrigated and rainfed flooded rice throughout the humid tropics. In this environment, water passes over the bund from one paddy to the next when the water depth reaches the effective bund height, or critical depth (WD_{cr}). At lower depths there is no surface drainage, and at greater depths all the excess drains off. The effective bund height is somewhat less than the maximum height since farmers usually dig a control section part way into the bund to facilitate maintenance. Generalizing this mechanism from individual paddies to large areas, we have

$$WD_t = WD_{t-1} + RN_t + IR_t - ET_t - S\&P_t.$$

For WD_t less than WD_{cr} then $DR_t = 0$; for WD_t greater than WD_{cr} then $DR_t = WD_t - WD_{cr}$, and WD_t is reset to WD_{cr}. The system is represented in Figure 5.

Specification of daily values of RN, IR, ET, and S&P ~~is~~ as follows. RN, IR and evaporation (EV) are provided as input data. Daily values of ET are computed according to the equation ET = a + b (EV), where a and b vary slightly for the two seasons, and for different stages of crop growth. The relationship is adapted from Kampen (1970). Values of a are 0.25 and 0.50 mm/day for the wet and dry seasons respectively; b is 0.8 and 0.9 in the vegetative and reproductive growth stage, respectively. However, for severely stressed conditions, ET_t is depressed by a factor related to WD_t.

Daily values of S&P are also computed as a linear function of WD_t. Fifty percent of the maximum S&P value for a site is assumed to occur when $WD_t = 0$.

Model operation is possible once the maximum S&P and the initial WD are specified for each site. Data for estimating either of these values are scarce, so a two-parameter optimization routine was used for each site to seek a least squares best fit of measured DR, and DR computed from model operation over whole seasons. Figure 6 shows the best fit path of cumulative drainage (computed and measured) for two sites. The relatively close congruence between the two in almost all sites confirms the models' assumptions regarding water movement.

Prediction of moisture stress. Daily values of WD_t were computed for each site by the model. If these values could be used to predict the fraction of each site in the unflooded stage on a daily basis the incidence of stress days could be computed. Stress days in turn can be used to calculate grain yield according to the yield response regression equations.

A relation between WD_t and percentage of the site flooded (or unflooded) is logical in view of the single-paddy analogy of the system. In that case, the paddy would become unflooded (lose its standing water) as soon as WD_t falls below zero. A large site is a collection of paddies, however, and when the mean WD_t for the whole site is zero it is likely that some paddies will remain flooded while others dry up. A comparison of weekly WD_t values was therefore made with the observed count of dried paddies for the corresponding period, expressed as percentage of the total site area. The general relationship for all sites collectively is shown in Figure 7. With daily values of WD_t converted through this curve to the percentage of the site in the unflooded stage, stress days can be computed readily for each site.

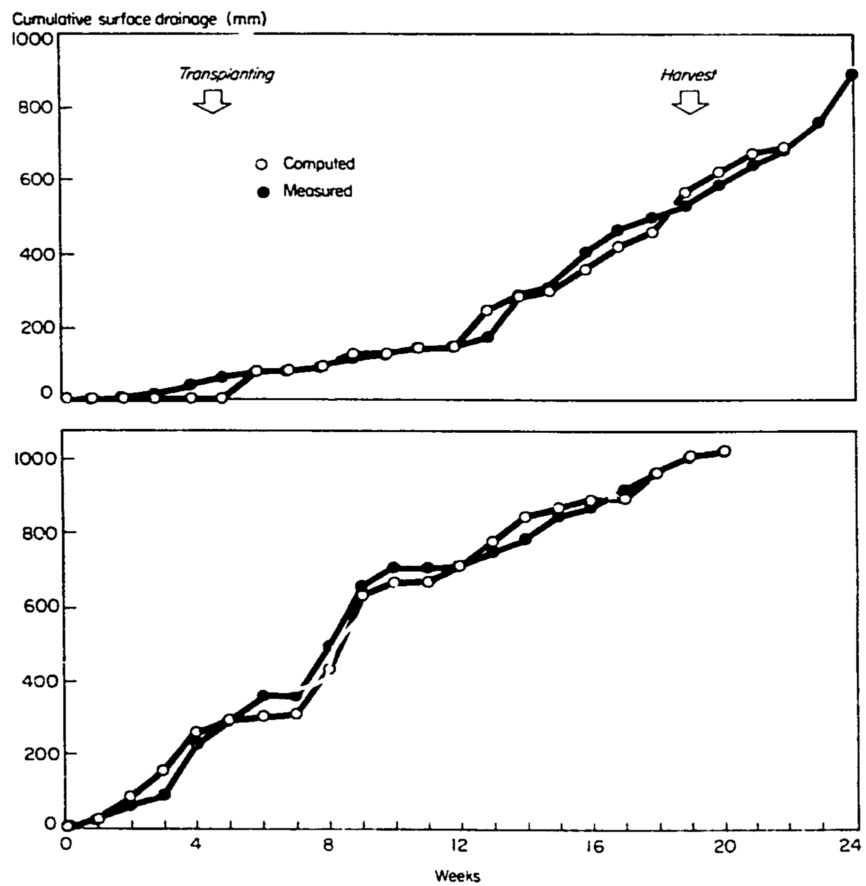

Fig. 6. Comparsion of computed and measured drainage for 2 sites, Luzon, 1966-70.

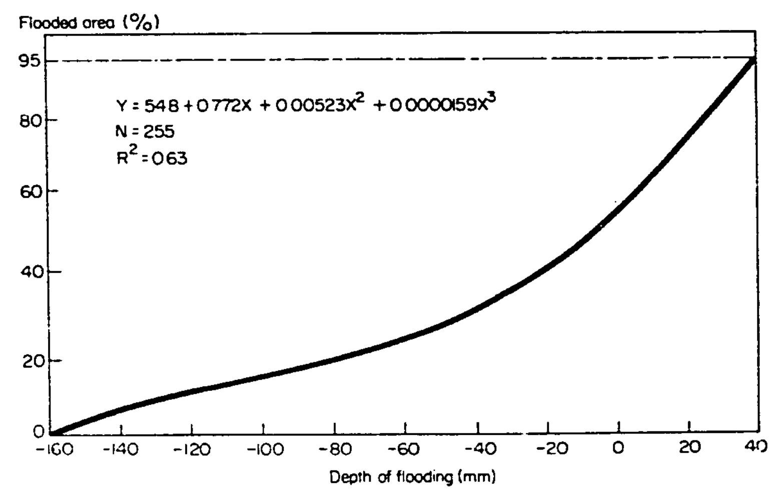

Fig. 7. Percent of site flooded vs. computed average depth of flooding, 22 crop sites, Luzon, 1969-70.

A test of the model was conducted using input data (RN, IR, and EV) for each site exactly as it was recorded during the project. The number of stress days computed by the model was within 10 percent of the number calculated from direct observation, for all sites.

YIELD PREDICTION

Yield prediction is based on appropriate yield response equations as discussed in earlier sections of this paper. The following analyses show the yields computed from stress days generated by operation of the model under different parameter values. Sites which had few new variety plantings were omitted since the prediction equations apply only to new varieties. Rates of nitrogen used in the equations are the mean values recorded for each site.

Dry season sites

Complete water adequacy is reflected by $SD_1 = SD_2 = 0$, for which yields vary only in response to nitrogen input. Computed yields for this condition range between 3.85 and 4.17 t/ha for eight dry season sites. The mean is 4.06 t/ha.

Actual rainfall and irrigation as recorded in the field for the dry season sites generated yields ranging from 2.46 to 4.02 t/ha, with a mean of 3.51 t/ha. The crop-cut yield data for these sites indicate a wider range (2.11 to 4.17 t/ha), but a comparable mean value, 3.40 t/ha.

The difference between yields generated under optimum and under actual water conditions is a measure of the yield shortfall due to insufficient irrigation. The shortfall varied from approximately 0.14 to 1.62 t/ha, with a mean of 0.55 t/ha. At 1972 prices (₱30/cavan of 44 kg) this shortfall is valued at ₱375/ha. Figure 8 shows for the eight dry season sites and their mean the zero-stress and actual stress yields computed by the model, and mean crop-cut yields.

Wet season sites

Complete water adequacy for eight wet season sites generated yields ranging from 3.19 to 3.56 t/ha, with a mean of 3.46 t/ha. This is 0.6 t/ha less than the dry season no-stress yields, which reflect more favorable solar radiation levels.

Actual rainfall and irrigation in the wet season sites generated yields between 2.98 and 3.44 t/ha (mean 3.23 t/ha). Crop-cut yield sampling from these sites indicated yields from 2.44 to 5.08 t/ha (mean 3.48 t/ha). The wider crop-cut range reflects extensive variation in factors other than those (nitrogen and stress) incorporated in the model. Thus, the model underestimated by about 1.5 t/ha the yields of the three Laguna sites which received much better farm management, particularly in regard to weeding, insect control, and care in transplanting. Yields in the other sites were correspondingly overestimated as seen in Figure 9.

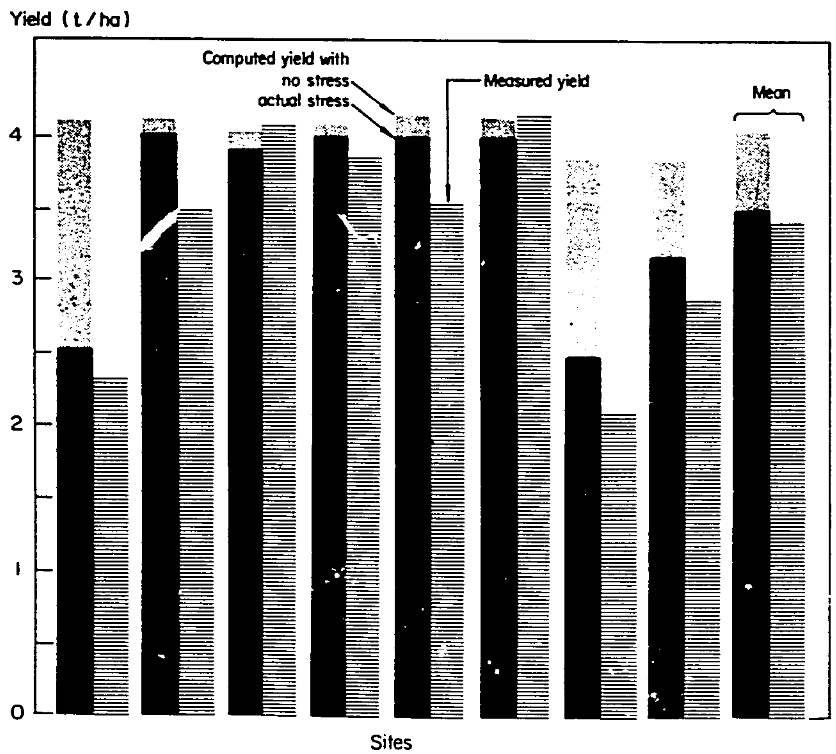

Fig. 8. Computed no-stress yields, actual-stress yields, and crop-cut yields for 8 dry season sites and their mean, Luzon, 1969-70.

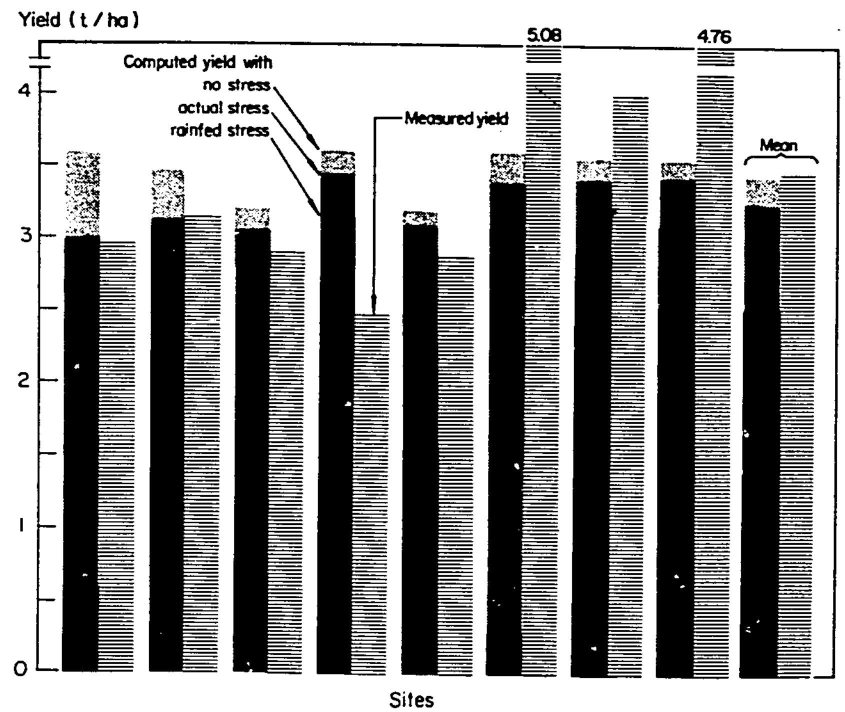

Fig. 9. Computed no-stress yields, actual-stress yields, rainfed yields, and crop-cut yields for 8 wet season sites and their mean, Luzon, 1969-70.

Very little of the theoretical advantage of the dry season crop, as seen in no-stress yields, remains in comparing yields under actual water supply conditions for the two seasons. Mean yields in the wet season are within 0.28 t/ha of those in the dry season.

The shortfall from no-stress to actual stress yields ranged from 0.11 to 0.62 t/ha in the wet season. The mean, 0.23 t/ha, is less than half that of the dry season shortfall, and is worth ₱157/ha. The mean results for both seasons are summarized in Table 6. The water use fee is also shown for comparison with the shortfall. Delinquency in fee payment exceeds 67 percent for the systems studied. Many landowners pay on behalf of their tenants.

Rainfed yields can be generated by setting all irrigation inputs in the model equal to zero. This was done for the wet season sites. The resulting yields ranged from 1.61 to 3.17 t/ha, with an average of 2.55 t/ha. The difference between rainfed yields and those generated through actual stress incidence can be considered a measure of the value of irrigation to the sites studied. Thus, the provision of irrigation increased yields by as much as 1.76 t/ha for one site, and as little as 0.25 t/ha for another. The mean benefit attributable to irrigation is 0.68 t/ha for the eight sites primarily planted to new varieties. This benefit is worth approximately ₱455. The outcomes for each wet season site and their means are shown in Figure 9, and are summarized in Table 6.

The preceding analyses were computed using rainfall and irrigation data for 1969 and 1970. The findings can be expected to differ for years in which rainfall is different. Expected rainfall was computed from 20 years of rainfall data at different stations near the sites, and it was concluded that the 1969 wet season was only slightly drier than the average. On the average, 46 years in 100 would have less rain than that which fell during the critical 30-day period of crop growth at all 11 sites.

Effect of bund height

Experimental studies have frequently concluded that farmers could make better use of scarce water supplies by making their bunds higher. Not only would this result in fewer stress days and higher yields, it would also reduce drainage losses and improve the irrigation efficiency of the system. The hypothesis is subject to test by the model. Different values of effective bund height (WD_{cr}) were assigned, and their effect on stress days, predicted yields, and efficiency were computed. Since the effect would be strongest on sites with limited water supplies, the analysis used simulated rainfed wet season sites. The results (Fig. 10) show very small improvement in the water-use parameters as bund height increases from 2 to 8 cm. Mean grain yield and water-use efficiency increased by only 5 percent and 7 percent, respectively. The slopes indicate that even smaller benefits could be expected for bund height higher than 8 cm. These findings are not surprising in view of the nature of drought at

Table 5. Water blance components after transplanting for dry crop sites, seasonal sums in mm. of water, Luzon, Philippines, 1969-70.

Site	Days	Irrig.	Rain.	Drain.	Net Use (Total)	Net Use (Daily)	Evap. (Daily)	Effic. (%)
112	112	1861	2	411	1452	13.0	7.6	78
122	166	1547	585	245	1887	11.4	6.8	88
132	116	873	716	800	789	6.8	4.7	50
142	119	1641	92	492	1241	10.4	4.1	72
212	108	562	87	272	377	3.5	3.2	58
222 *	98	1687	119	1192	614	6.3	4.0	34
232	93	1970	114	1254	830	8.9	4.0	40
312	119	1654	158	1044	768	6.5	5.2	42
322 *	84	1182	48	60	1170	14.0	4.9	95
332	105	2316	231	184	2363	22.5	5.3	93
342	112	946	148	-35	1129	10.1	4.0	(100)
Mean	112	1475	210	537	1148	10.2	5.6	68

* Sites less than 19 ha.

Table 6. Summary of model predictions, means of eight wet and dry season sites. Improved varieties, Luzon, Philippines, 1969-70.

	Wet	Dry
Predicted yield (t/ha)		
No stress conditions	3.46	4.06
Actual stress conditions	3.23	3.51
Shortfall		
Yield (t/ha)	0.23	0.55
Value (P/ha)	157	375
Predicted rainfed yield (t/ha)	2.55	-
Production directly attributable to irrigation:		
Yield (t/ha)	0.68	3.51
Value (P/ha)	455	2400
Irrigation fee (P/ha)	(25)	(35)

the farm level. Periods of water shortage are generally long and severe so that water stored by the bunds is relatively unimportant. Recovery of the crop after water is again available is instead critical.

Effective use of rainfall

The design of diversion irrigation systems is grounded largely in their capacity to supplement rainfall during the wet season. How much irrigation should be provided depends upon how much rainfall is considered effective over the service area. Since rainfall frequently occurs in a poorly distributed pattern, only a portion of total rainfall is effective for crop growth; the rest runs off as drainage. What proportion is used is the subject of a wide range of opinion. Although the model cannot directly determine the effectiveness of rainfall, it can compute stress days and yields for crops served exclusively by irrigation water. Comparing that with stress days and yields computed for irrigation plus rainfall provides a measure of the utility of rainfall in the selected sites. The analysis was conducted on 10 sites and their means were compared.

Yields from sites served exclusively by irrigation averaged 2.91 t/ha (S_1 = 13.6; S_2 = 7.6), compared with 3.26 t/ha (S_1 = 4.1; S_2 = 2.2) for irrigation plus rainfall. Rainfall contributed only 0.35 t/ha additional yield to that produced by irrigation alone, an increase of less than 10 percent. Almost all the difference was brought about by three sites; for the other seven the yield benefit due to rainfall was less than 3 percent. The analysis also showed greatly improved irrigation efficiencies for modeled wet season sites wholly dependent upon irrigation water. The mean efficiency of the 10 sites was 60 percent, almost as high as their efficiency in the dry season. From these findings it can be concluded that in the wet season farmers rely upon irrigation as their primary source of water and rainfall as their secondary source. This is consistent with farmers' dry season management, and is not surprising since most diversion irrigation projects have excess capacity during the wet months. Since the river flow cannot be stored, there is no direct value to economizing in its use, and farmers act logically in using it liberally. Under such management the value of rainfall within the system is very small.

Efficiency and stress days

Two of the most important parameters of water management are the adequacy of water service, and the efficiency of the system. The former is a measure of how completely the system can serve its farms, while the latter is a measure of water wastage which, if saved, could be used to irrigate a larger area. Farmers tend to look at water adequacy, while irrigation research has traditionally concentrated on efficiencies. One interesting finding was that well irrigated sites generally had low efficiencies and few stress days, while poorly irrigated sites had very high efficiencies but large numbers of stress days. It is clear that

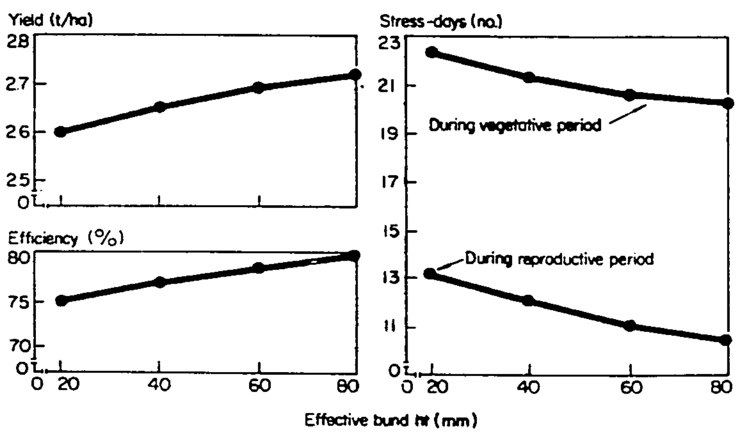

Fig. 10. The mean effect of modelled bund height on grain yield, stress days, and water use efficiency of 10 synthesized wet season rainfed sites, Luzon, 1969-70.

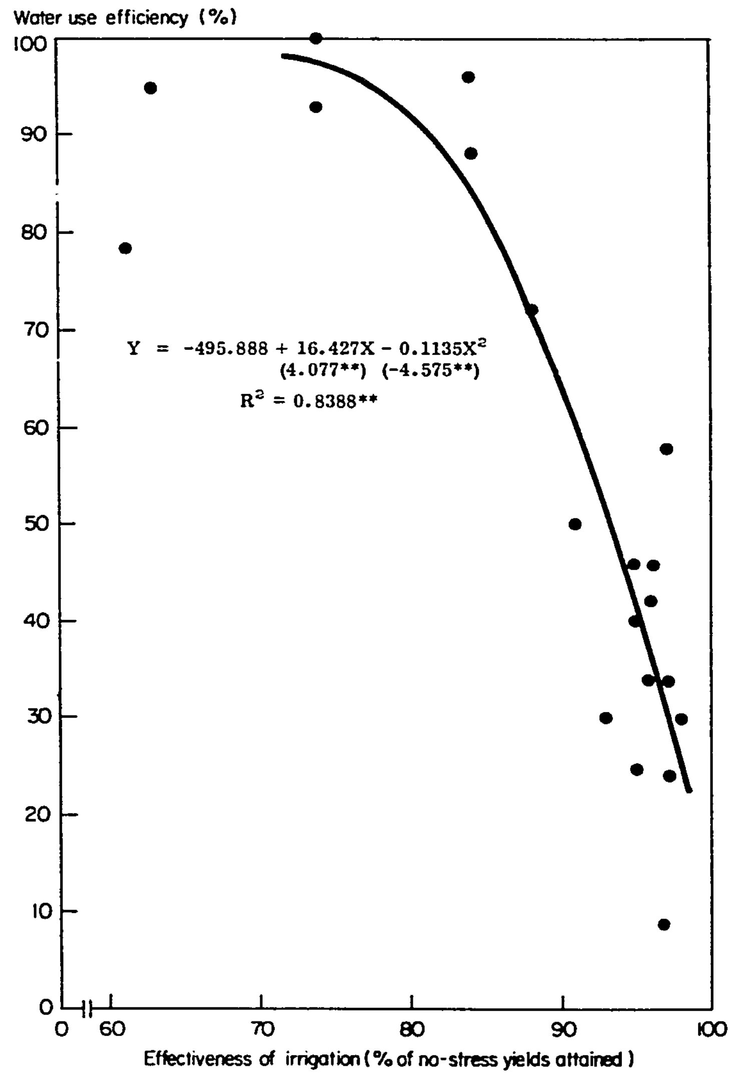

Fig. 11. Relation between water use efficency and service effectiveness, 22 crop sites, Luzon, 1969-1970.

as the system starts to dry up its efficiency increases rapidly. The reduced yields resulting from stress days are a measure of the systems' failure to adequately irrigate all farms. A system's effectiveness can thus be defined as its reduced yield relative to that produced under no-stress conditions. Figure 11 shows the relationship between effectiveness and field efficiency, and demonstrates the substitutability of the two terms. Each observation represents one of the study sites. The consistency of the relationship is surprising in view of the wide differences between the sites. It is clear that important crop losses occur as soon as efficiencies improve even to 50 percent. One of the major challenges to irrigation management is to make better use of available water without sacrificing yield potential. To do so will require further research to find the best ways of distributing water equitably to farmers.

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Pricing irrigation water

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ABSTRACT

The present system of pricing of irrigation water in the gravity irrigation systems of the Philippines results in inefficient allocation and use of water. Furthermore, the low price of water results in the capitalization of irrigation benefits into land values. Hence, landowners are the major beneficiaries.

Gradually increasing the price of water so that it is more in line with its opportunity cost under optimum management would improve the economic efficiency of water use and encourage the collection of government revenues for further public investment. As soon as practicable, water should be metered directly to farmers' paddy fields and the water charged based upon the amount actually diverted.

While recent breakthroughs in rice technology appear to have overcome formidable constraints, many environmental factors still severely limit the attainment of desired levels of food output. The most strategic resource in rice production is irrigation water -- water which must be supplied at the right amount at the right time.

Recognition that irrigation water is a scarce resource can lead to its efficient use. The first step is selling water at a price to which prospective water users can react meaningfully. This paper presents the economic theory involved in pricing irrigation water, discusses the drawbacks of an inefficient water price, and develops an economically tenable pricing scheme based on an empirical study of a gravity irrigation system already in operation.

THE THEORY OF WATER PRICING

Received theory asserts that every productive service should be employed until its discounted marginal revenue is equal to its discounted marginal cost.(The theory expounded here draws on neoclassical theory pertaining to a competitive economy which assumes mobility of resources, profit maximizing goal of resource users, and knowledge of alternative resource employment. Additionally I am assuming a "monoperiodic" time horizon in the production function and other relations.) Assuming that irrigation water is the only resource limiting rice output, one can envision a production function:

$$Y_i = f\ (M_i \mid X_j) \tag{1}$$

where Y_i is the quantity of rice yield associated with the ith moisture level, ($i = 1, \ldots, n$), M_i is the moisture level, and X_j is the input of the jth resource used in combination with water ($j = 1, \ldots, m$) The vertical bar indicates that X_j values are assumed to be fixed at some level while M is being varied.

Multiplying the right hand side of equation (1) by the appropriate input prices and the left hand side by the rice price, the decision criterion for efficient water use can be derived:

$$MVP_M = \frac{\partial Y}{\partial M} \cdot P_Y \geq P_M$$

where MVP_M is the marginal value product of water, $\partial Y/\partial M$ is the marginal physical product of water given fixed levels of inputs X_j, P_y is the price per unit of rice, and P_M is the price of water.

Water application is then said to be efficient if such quantum of water is used as long as its marginal value product is at least as large as the water price. A rice producer aiming to maximize his return from water must first of all know the technical relation between rice output and water so that at a given water price he can decide how much to apply to his crop.

In gravity irrigation systems in the Philippines, water is priced in three ways: an institutionally set water price, the resource cost of water, and the opportunity cost of water. Depending on the value chosen by the water authority for the price of water, different levels of moisture, M can be considered optimum.

Institutional water price

The institutional water price in gravity irrigation systems in the Philippines refers to the irrigation fee levied against users of water by the National Irrigation Administration. The charge is based on a per-hectare rate and does not vary with the volume of water actually used. The institutional price is indicated by $\underline{P}_o$ in Figure 1. Since the total cost of water to the farmer is fixed per unit area, the TC curve is drawn as a horizontal line. The curve TR represents the total revenue realized from successive inputs of water, net of the variable costs of production, e.g., fertilizer, plant protection, and pre-harvest and harvest labor costs.

A rational farmer maximizing his net return from water will apply water to his fields up to that point where the marginal value productivity of water to him is equal to its marginal cost. He therefore uses water as long as MVP $\geq$ MC = 0. Since the marginal cost of water to the farmer is zero, he will apply water until he attains the maximum total revenue, i.e. where MVP is also zero. This condition holds if he uses $\underline{M}_o$ of water per unit area for which he pays the price $\underline{P}_o$. Given an invariant TR curve it is highly likely that an upward shift in $\underline{P}_o$ will not alter the rate of water use at all.

Resource cost

The resource cost of providing irrigation water has two components. One refers to the capital charges based on the cost of construction of the irrigation system and the other encompasses the cost of day-to-day operation and maintenance. The sum of these two components, converted into a charge per unit volume of water per unit time can also be considered as the marginal factor cost of water. Conceptually it refers to the value of the bundle of resources used in making the water available. The framework for pricing water on the basis of marginal factor cost is set forth in Figure 2.

As before, the curve TR reflects the net value of output attributable to water alone. The total cost curve, TC is so drawn to depict the rational stage of production. (Under the assumptions of a Cobb-Douglas production function, where only Stage II is rational, total cost will be an increasing function of output. While the horizontal axis of Figure 2a shows units of M, it can be drawn too with output levels on the horizontal axis. Since output is a direct function of M, and for the purpose of showing the same graph the optimal level of input use, the horizontal axis for output has been omitted.) This implies that from the system's viewpoint additional units of irrigation water can be supplied only at increasing costs. In a system that has no storage facilities, the increase in cost can come about through constructing and maintaining more distributaries and drainage canals given a fixed command area of the system.

Optimization of water use at the system level can be carried out by using water up the point where the marginal value product is equal to or greater than the marginal factor cost. The MVP curve in

Figure 2b is marginal to TR of Figure 2a; MFC is the marginal curve to TC. The water amount which equates MVP to MFC is OM_1.

For the system, therefore, the maximum net benefits from water can be obtained by using OM_1 of water per unit area and charging each farmer the price OP_1. Since in general attaining maximum total revenue (TR) entails the use of more water inputs than attaining maximum net benefits, i.e., the difference between total revenue and total cost (TR-TC), on a per hectare basis the water volume implied by OM_1 in Figure 2a will be less than OM_0, the optimal amount corresponding to the institutional price in Figure 1.

Opportunity cost

The opportunity cost of water refers to the value of the net output realized from using water in its best alternative use. An illustration may help clarify this concept (Fig. 3a and 3b). The curves TR_1 and TR_2 can be conceived of as two levels of the net value of water accruing to users who vary in their capacity to manage the water resource. Also, defining differences in technology narrowly to refer to variation in the quality of a resource-in this case the resource is management of water -- then TR_1 and TR_2 can be taken to mean net values to water under two levels of technology.

For the system in particular and for society in general, the water productivity depicted by MVP_2 represents the best alternative use of each additional unit of water. By assumption, no other technology for use of irrigation water now exists that will make water use more productive than that implied by MVP_2. The framework here draws from the concept of Ricardian rent -- the return that accrues to owners of a resource, specifically applied to land which yields different net income arising solely from quality difference. /Robinson, 1933: 102-119/. This curve can then be considered as showing the opportunity cost of water. Hence to maximize the net benefits from water use, the water authority should price the water according to its opportunity cost.

Figure 3a indicates that amount of water which maximizes net benefit under the two technology levels. These are OM_1 for those with a water-response curve consistent with TR_1 and OM_2 for TR_2. Figure 3b indicates the appropriate water charge. Having determined the water level that maximizes net benefits, and knowing that MVP_2 depicts the opportunity cost of water we can calculate the appropriate water price as the value of MVP_2 corresponding to the water amount OM_2. This price is labelled as OP^* in Figure 3b. Charging a price lower than OP^* will lead to waste in water use. For instance if OP_2 is levied, farmers producing under the superior technology would use OM_2', an amount greater than the efficient level OM_2.

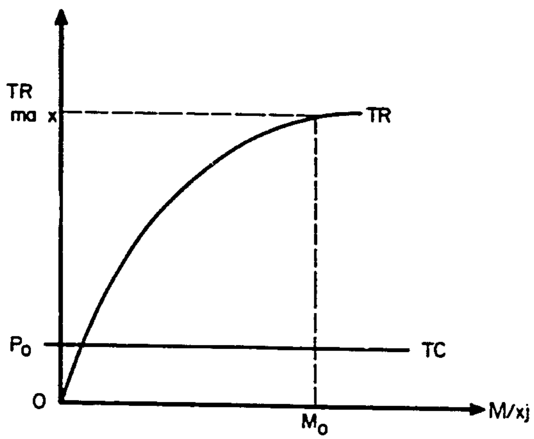

Fig. 1 - Optimum Water Input Given An Institutional Price of Water Per Unit Area Irrigated

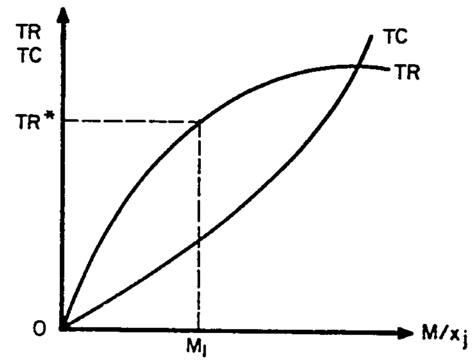

Fig. 2a - Determination of the Optimum Level of Water Use Under Increasing Cost of Supplying Water at the System Level

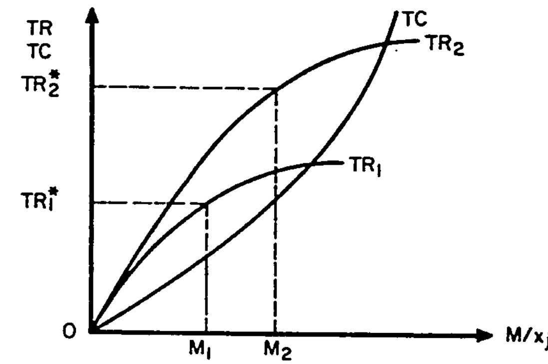

Fig. 3a - Net Contribution of Water Under Two-Levels of Efficiency in Water Use

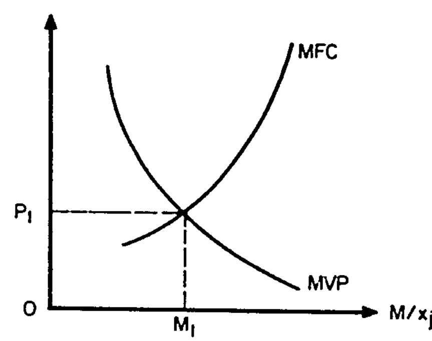

Fig. 2b - Optimum Water Price Conditions of Increasing Water Cost

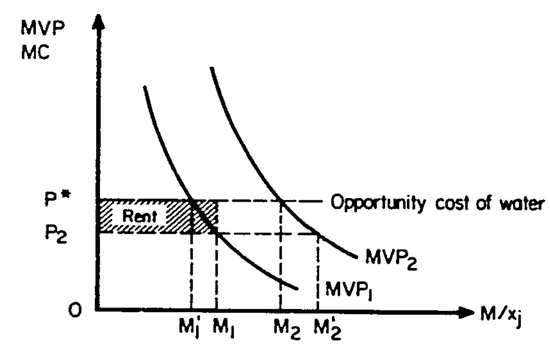

Fig. 3b - Opportunity Cost of Water and Economic Rent

Economic rent will accrue as long as there is a divergence between (a) the present level of the value productivity of water and (b) its value productivity in its best alternative use. Thus, if every farmer is equally efficient in the use of water-applying $\underline{OM_2}$ and paying $\underline{OP}$*-- no rent will accrue. If, as is more likely, a difference exists, economic rent accrues to the supplier of the resource. If the supplier of the resource is the public sector, the economic rent can be accumulated for investment wherever it gets the greatest return.

Collecting an irrigation fee consistent with the opportunity cost of water satisfies both the allocative and distributional roles of price in a competitive economy. Equating $\underline{MVP}$ to $\underline{MFC}$ helps attain the efficiency goal; accumulating economic rent and reinvesting it in the economy will contribute both to the equity and the growth goals of public investment.

The drawbacks of inefficient water pricing

A number of disadvantages can be cited for charging irrigation fees which are lower than the productive value of the water. The following discussion emphasizes those directly involved in the attainment of the three-pronged goal of efficiency, equity, and growth of the economy.

First, water charges that are less than the value of the water will lead a farmer to apply more water to his land than is economical. In particular, he does this if the water charges are based on units of land served rather than on units of water delivered. If possible the farmer continues to apply water to his land as long as the expected value of the additional output is greater than his cost of application.

Second, water charges much less than the value of the water lead to excessive use of the complementary factors, particularly fertilizer. If water is underpriced, fixed combinations of water and fertilizer will also be underpriced, and the application of fixed combinations of inputs (say, water and fertilizer) will continue beyond the optimum. Thus, underpriced irrigation water causes the farmer to whom it is made available to use on his fields water and other inputs that would produce more in the way of additional output on other fields.

Third, defining the amount by which the productive value of water exceeds the charge for water as a subsidy, we can follow the subsidy through the economic processes of the market. It may be thought that the subsidy helps the small farmer (usually some form of tenant).

But, if the man is a tenant, his benefit is rather small if the landlord acts rationally. If the supply of farm labor is highly elastic (as it is in the Philippines), then owner of the land is the chief beneficiary. The amount of the subsidy (or nearly all of it) is capitalized into the value of the land. At the very least, the landowner receives a higher return on a "more valuable" piece of land. The gain to the supplier of labor is not large unless he also owns the land, and even then, the returns accrue to him as a land owner not as a worker. Whether he also provides labor is irrelevant.

The effect on land prices of the new rice technology and of bringing irrigation water to the land is shown dramatically for San Bartolome, Mayantoc, Tarlac (International Rice Research Institute, 1971: 182). Prices paid for land in this village, based largely on the value of the expected yields, rose from ₱2000 per hectare in 1950-56 to ₱3200 in 1957-59 when the Camiling Irrigation System was completed. The land value more than doubled to ₱7500 in 1967-69 when high yielding varieties of rice were introduced.

Another effect of the subsidy is that a fund of potential capital is allowed to become higher incomes and higher land values for the landowner rather than being invested in the private sector to provide additional employment and additional output, or in the public sector, to provide a larger flow of infrastructural services.

EMPIRICAL RESULTS

I previously made a study of the Santa Cruz River Irrigation System in Laguna, a typical of gravity system in the Philippines (Torres, 1972). The production period covers the crop year of 1970; historical data on system wide expenses for operation and maintenance date back to 1965.

The institutional price (the irrigation fee set by the National Irrigation Administration) is ₱35 per hectare of rice irrigated during the dry season and ₱25 per hectare for the wet season. As can be expected, an irrigation fee which does not vary with the amount of water actually applied, usually resulted in overuse of water. As much as 70 percent of water diverted into fields is wated (Kampen, 1970).

The resource cost of the water in the Santa Cruz system refers to the outlays for operations and maintenance plus an imputed cost of depreciation and interest on the capital investments. While the cost of operations and maintenance varies from year to year, the cost of depreciation and interest is, by assumption, constant. From 1967 to 1970 the expenses for operations and maintenance amounted to slightly more than ₱10 per hectare per year (Table 1). The imputed depreciation and interest costs based on the construction cost of about ₱625 per hectare (total construction cost, ₱2.5 million, divided by area commanded, 4000 hectares) amounts to ₱56.25 per hectare per year (construction cost per hectare multiplied by 0.09 /interest rate of 7% per annum and depreciation of 2%/). The total resource cost amounts to ₱66.47 per hectare per year. Perhaps a common misconception among officials of the water authority is to consider only the operations and maintenance expenses as the resource cost of water. But since the larger part of the expenses in providing water is the construction cost, water pricing should consider the total resource cost.

The opportunity cost of water is computed for the Santa Cruz system assuming that farmers avail themselves of the existing technology in rice production and that the management of the system is such that irrigation water can be moved around fields in the system whenever the demand arises. The specific technology involved applying 90 kg/ha N during the dry season and using an average of 6.5 mm of water per day throughout the season (Table 2). The shadow price of dry season water derived from a linear programming solution is P1,275 per hectare. This amount represents the net contribution of water to the value of rice output. From this, however, must be deducted the value of operator and family labor and the opportunity value of land. From the result of the farm business survey of the Santa Cruz system, an average farm employed 45 man-days of operator and family labor per hectare which is valued at P227. Since no dry season crop is grown without irrigation water, no value is imputed to idle lands. This leaves a net contribution of water amounting to P1,048 per hectare of P171 per hectare-millimeter.

It would be naive to recommend outright that an irrigation fee of P1,048 per hectare be collected. Although on purely theoretical grounds, the opportunity cost of water is the price that can induce efficient water use, the price of obtaining irrigation water from an alternative source must also be considered. For instance, within the service area of the Santa Cruz system are farms served by pumps. Toquero (1969) found that in this area it costs P116 per hectare to own and maintain an irrigation pump. This amount can be considered as the price pump owners pay to irrigate 1 hectare of rice land.

As an initial step, the NIA should collect an irrigation fee which is not much less than the price pump owners pay for water. While massive campaigns in implementing improved water management at the farm level start to gain acceptance NIA can gradually raise the water price until such level is reached when no more rent accrues. As soon as practicable, water should be metered directly to farmers' paddy fields and the water charge should be based on the amount actually diverted. In this manner the farmer will buy only the amount of water that maximizes the net contribution of water on his farm. Any farmer who chooses to use more water than his crop needs can effectively be made to pay for the amount he applies. His water bill will therefore increase correspondingly with the amount of water he wastes.

CONCLUSION

Pricing of an economically productive service provided by the public sector is usually a serious administrative problem. While equity considerations dictate that public investment induce income redistribution, a common observation in irrigation development is that direct beneficiaries largely are landowners and not the tenants. Sharp increases in land prices in areas recently opened for irrigation emphasize that benefits from irrigation easily become capitalized into land values instead of generating a fund for further public investments. Charging an irrigation fee consistent with the opportunity cost of water can help effect both efficient utilization of the water resource and encourage the accumulation of revenues which the public sector can invest wherever returns are greatest.

Table 1. Resource Cost of Irrigation Water in the Santa Cruz River Irrigation System, 1967 to 1970.

	Costs (P/ha. per year)	
	Operations and maintenance	Depreciation and interest
1967	7.18	56.25
1968	7.60	56.25
1969	12.27	56.25
1970	16.87	56.25
Average	10.22	56.25

Table 2. Computation of the optimum level of water use given a fixed water volume for the dry season and a fertilization rate of 90 kg. N/ha.

Water Input (mm/day)	Yield a/ (t/ha)	Area b/ Served (ha)	Total c/ Output (thousand tons)	Value of Output d/ (thousand P)	Total Cost e/ (thousand P)	Net Revenue f/ (thousand P)
5.0	2.72	4000	10.90	4903	2819	2084
5.5	3.70	3671	13.60	6114	2856	3258
6.0	4.37	3282	14.35	6456	2718	3738
6.5	4.73	2968	14.06	6326	2540	3786
7.0	4.91	2708	13.30	5987	2353	3634
7.5	4.99	2490	12.43	5594	2178	3416

a/ Synthesized from logistic water response function given in Reyes (1972).
b/ Computed by dividing fixed water volume by water applied per hectare.
c/ Quantity of paddy produced system-wide. Calculated by multiplying area served by yield per hectare.
d/ Computed using an assumed paddy price of P450 per metric ton.
e/ Included cash (fertilizer, plant protection, land labor) and non-cash costs (own seeds, harvesting and threshing services). Excludes cost of operator and family labor and charge for use of farmer's own capital.
f/ Difference between value of output and total cost.

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The economics of groundwater irrigation

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ABSTRACT

A survey of 52 small-scale pumping units in Quezon and Batangas provinces in 1971-72 reveals that pump irrigated rice farms had positive net returns, with the wet season returns slightly greater than those of the dry season. But pump systems in the study areas performed poorly: they had low pump discharge rates and served limited areas. Four inch pumps had a greater average pump discharge than 5-inch pumps operating even at lower revolutions per minute. No substantial differences were found in yields of farms irrigated from different water table depths, or of different soil types. There were significant differences in pump discharge among soil types although they were not significant with respect to depth of water table. It was also found that area served was more dependent on available irrigable land than on soil type or water table depth. The study revealed that water is often conveyed through poorly maintained earth canals which we believe considerably reduced the efficiency of water use. The most common method of irrigation fee payment is 20 percent of net product shared by the tenant and landlord in both the wet and dry seasons. The major problem of pump owners is the lack of cash for pump repairs.

The Philippine government in its effort to increase production through the expansion of irrigation facilities has turned its attention to the exploitation of groundwater sources through the Irrigation Service Unit (ISU) under the National Irrigation Administration. The ISU is entrusted with distributing and supervising the installation of pump units. It has released thousands of pumps but there has been little research on the physical performance of these pumps in the field, and their impact on the economic status of farmers. There is a vital need to define existing levels of operation and management and to identify problems and potentials related to the improvement of irrigation capability.

We conducted a study to evaluate the economic status of pump-irrigated lowland rice farms and to assess the efficiency of pump use. The specific objectives were (1) to assess the physical performance of pumps, as measured by pump discharge, and to determine the area irrigated in the wet and dry season, (2) to relate the physical and economic performance of pumps to different soil types and water table depths, (3) to compare the physical performance of pumps with the yield of pump-irrigated lowland rice farms of different soil types and water table depths, (4) to describe the water management practices and irrigation fee arrangements of farmers using water from pump systems, and (5) to identify problems regarding pump use.

METHODOLOGY

The survey was conducted in San Juan and Rosario, Batangas, and in Sariaya, Quezon. Our sample consisted of 52 pumps serving 65 farms. The stratified sampling technique was employed in drawing the samples. The stratification factors used in grouping the pump units were soil type and water-table depth. There were seven soil-water table depth combinations: light soil-shallow water table, medium soil-shallow water table, medium soil-medium water table, medium soil-deep water table, heavy soil-shallow water table, heavy soil-medium water table and medium soil-deep water table. Light soils included sands and loamy sands. Medium soils included sandy loam, loam, silt loam, silty clay loam and sandy clay loam. Heavy soils included sandy clay, silty clay and clay. Shallow water tables have a depth of less than 4 meters below the surface, medium water tables have a depth of 4 meters to 6.5 meters and deep water tables are greater than 6.5 meters. After setting up the seven strata, we picked 10 pump units at random from each stratum. We should have had 70 sample units but for reasons such as the inaccessibility of a barrio (Laiya in San Juan, Batangas), permanent pump breakdowns during the cropping season, and inability to contact pump owners, we eventually came up with only 52 sample units.

RESULTS AND DISCUSSIONS

Farm characteristics

Forty five percent of the farms have medium soils, 41 percent have heavy soils and the rest of the farms have light soils (Table 1). Forty percent of the farms are served by pumps drawing water from shallow water tables while 34 percent are being served by pumps drawing from medium water tables and 26 percent from deep water tables. Of the 65 palay farmers, 72 percent are share-tenants and the rest are owners. Virtually all the share-tenants are under the 50-50 sharing arrangement. Most farms cultivated during the wet and dry seasons have areas less than 2 hectares (Table 2).

Cropping pattern

Rice is the only crop grown in the farms studied. After every harvest, the land is left idle until threshing is done; it is then prepared for the next cropping season. The planting season in the farms usually falls in June and July during the wet season and in November and December during the dry season. Practically all farms were planted to high yielding varieties in both the wet and dry seasons. A few farmers planted traditional varieties, like Malagkit, Wag-wag, Pinursige, and Quezon, especially in the dry season because of inadequate funds to defray costs of hired labor, insecticide, and fertilizer.

Pump characteristics

Four out of five pumps serve farms with medium and heavy soils (Table 3). Forty-four percent of the pumps drew water at shallow water tables while 31 percent and 25 percent pumped from medium and deep depths, respectively. At the time of the survey, most of the pumps had been in operation for 1 to 5 years (Table 4). Five inch pumps are coupled with engines of higher brake horsepower and higher operating RPM than 4-inch pumps (Table 5).

Pump investment

The average capital investment needed to purchase and set up a pump unit is over P12,000, although a 5-inch pump is more costly than a 4-inch pump by approximately P4,000 (Table 6). As expected, the value of the pump and engine compose the bulk of the total cost, followed by the costs of construction, equipment and fittings, and unpaid labor in that order. Capital investment, (Table 7) seems to be directly related to depth of water table. The increase in capital investment as the water table gets deeper can be partly explained by the increasing costs of labor and construction materials such as hollow blocks, cement, sand, and gravel required for a deeper excavation.

Pump performance

Both 4-inch and 5-inch pumps serve somewhat smaller areas during the dry season than during the wet season (Table 8). This could be explained by the lower pump discharge and greater evapotranspiration during the dry season. Another reason might be the physical limit on available irrigable land that 4-inch and especially 5-inch pumps command in the dry season. In this connection, it was surprising to find that the mean discharge of 4-inch pumps exceeded that of 5-inch pumps even though their mean operating speed was slower (Table 9).

In relating pump discharge to soil type, Table 10 shows that as soils become heavier, the discharge decreases. The supply of water is perhaps more abundant and more easily replenished in aquifers of lighter soils because their water conductivity is better than that of heavy soils. Table 11 shows that pump discharge actually increases as the water table gets deeper. This relationship holds quite well for 5-inch pumps but is not so consistent with 4-inch pumps. The apparent reason is the presence of good aquifers at greater depths.

Table 1. Distribution of farms according to soil type, depth of water table and pump size, 65 farms in Batangas and Quezon, crop year 1971-72.

Farm Characteristic	Pump Size				Total	
	4-inch		5-inch			
	Number	Percent	Number	Percent	Number	Percent
Soil type 1/						
Light	5	14	4	14	9	14
Medium	14	39	15	52	29	45
Heavy	17	47	10	34	27	41
Depth of water table 2/						
Shallow	13	36	13	45	26	40
Medium	11	31	11	38	22	34
Deep	12	33	5	17	17	26

1/ Light - sand, loamy sand; Medium - sandy loam, loam, silt loam, silty clay loam, sandy clay loam; Heavy - sandy clay, silty clay, clay. 2/ Shallow - less than 4 m. measured from the ground level to the water table; Medium - 4 m. - 6.5 m. measured from the ground level to the water table; Deep - greater than 6.5 m. measured from the ground level to the water table

Table 2. Size distribution of 65 pump-irrigated farms in Batangas and Quezon, crop year 1971-72.

Size (ha)	Farms cultivated			
	Wet season		Dry season	
	Number	Percent	Number	Percent
Less than 1	13	21	14	25
1 - 1.99	34	56	31	56
2 - 2.99	11	18	8	14
Greater than 3	3	5	3	5

Table 3. Distribution of pump units according to soil type and depth of water table, 52 pump units in Batangas and Quezon, crop year 1971-72.

Farm Characteristic	Pump size				All pumps	
	4-inch		5-inch			
	Number	Percent	Number	Percent	Number	Percent
Soil type						
Light	5	19	4	15	9	17.3
Medium	12	46	10	39	22	42.3
Heavy	9	35	12	46	21	40.4
Depth of water table						
Shallow	11	42	12	45	23	44
Medium	8	31	8	31	16	31
Deep	7	27	6	23	13	25

Table 4. Length of operation of 52 pump units in Batangas and Quezon, crop year 1971-72.

Age range	Pump size 4-inch (no.)	5-inch (no.)	All pumps (no.)
Less than 1 year	1	5	6
More than 1 but less than 3 years	11	14	25
More than 3 but less than 5 years	10	5	15
More than 5 years	4	2	6
Average age (years)	3.2	2.3	2.8

Table 5. Rated brake horsepower (BHP) and revolutions per minute (RPM) of 23 pump units in Batangas and Quezon, crop year 1971-72.

Pump size	Number	BHP	RPM
4-inch	15	8 - 12	1634
5-inch	8	12 - 14	1706

Table 6. Average capital investment per pump unit, for different size pumps, 52 pump units in Batangas and Quezon, crop tear 1971-1972.

Item	Pump size 4-inch (P)	5-inch (P)	All pumps
Pump and engine	5475	8904	7190
Construction cost	4154	4482	4318
Equipment and fittings	620	696	658
Unpaid labor	75	83	79
Total	10324	14165	12245

Table 7. Average capital investment per pump unit for different water table depth, 52 pump units in Batangas and Quezon, crop year 1971-72.

Water table depth	Pump size 4-inch (P)	5-inch (P)	All size
Shallow	8153	13563	10976
Medium	11710	12502	12106
Deep	12365	17592	14777
Average	10324	14165	12245

Table 8. No. of farmers and average area served per pump by season, Batangas and Quezon, crop year 1971-72.

Size range (ha)	Pump size 4-inch (no.)	5-inch (no.)	All pumps (no.)
	Wet season		
1.1 - 3.6	10	10	20
3.1 - 5.0	10	8	18
5.1 - 7.0	4	3	7
7.1 and above	4	4	8
Average area (ha.)	4.4	4.6	4.5
	Dry season		
1.1 - 3.0	12	11	23
3.1 - 5.0	13	5	18
5.1 - 7.0	2	2	4
7.1 and above	2	2	4
Average area (ha.)	3.0	4.0	3.9

Table 9. Pump discharge and revolutions per minute (RPM) measurements on 41 pump units in Batangas and Quezon, crop year 1971-72.

Measurements	Number of pumps reporting	Average [a/]
	4-inch pumps	
Discharge (liters/sec)	25	9.02
Revolution per minute	25	1413
	5-inch pumps	
Discharge (liters/sec)	16	8.14
Revolutions per minute	16	1445
	All pumps	
Discharge (liters/sec)	41	8.70
Revolutions per minute	41	1426

a/ Average is based on four measurements of discharge and RPM for each pump unit. First measurements were done from May 24-June 26, second measurements from Sept. 27-Oct. 12, third measurements from Jan. 10-Jan. 31 and fourth measurements from Mar. 16-May 31.

Table 10. Relationships between pump discharge and soil type by pump size, Batangas and Quezon, crop year 1971-72.

Soil type	Pump discharge (lit/sec) 4-inch	5-inch	All pumps
Light	12.92	8.13	10.57
Medium	7.69	8.39	8.07
Heavy	8.39	6.81	7.57
Average	9.65	8.01	8.70

Costs and returns

There are positive revenues for both seasons (Table 12), although the wet season return is slightly greater than that of the dry season. Dry season yield may have been affected by severe incidence of rice blast, tungro, and bacterial leaf blight, and a relatively inadequate water supply. The pump operating cost (Table 13) in the wet season is less than that of the dry season, because pumps are more frequently used during the dry season. Operating costs for 5-inch pumps are greater than those of 4-inch pumps for both seasons. This is brought about by greater depreciation and interest costs for operating and maintaining 5-inch pumps, and by their greater costs of operation. It is also interesting to note that actual pump operating cost is greater than the irrigation fee (Table 12) in both seasons. Thus, the pump owners lose about P153/ha in the wet season and P404/ha in the dry season in supplying water to pump users.

Economic-physical relationships

To determine the influence of depth of water table and soil type on yield and on pump discharge, analysis of variance was employed. F-values were insignificant at the 5 percent level suggesting that depth of water table did not influence the availability of water enough to affect the yield level. There are also no significant differences in pump discharge among water table depths. This could perhaps be explained by the common practice in the study area of installing the pumps in excavations as the water table gets deeper, so that they can still operate at a reasonable suction head.

F-values were also insignificant at the 5 percent level indicating that there were no substantial differences in yields among different soil types. There are significant differences in pump discharge among different soil types, however. The logical reason is the presence of good aquifers in light soils due to their high water conductivity. The pattern shown in relating area served to depth of water table and soil type in Table 14 indicates that available irrigable land is limited.

Pump use efficiency

To evaluate the performance of pumps we compared potential or rated capacities with actual performance. We found that all pumps are discharging water at substantially lower amounts than ISU design estimates (Table 15). Similarly, the actual area served is considerably less than the potential serviceable areas, especially for 5-inch pumps (Table 16). Poor pump performance is also reflected in the fact that only 89 percent of the area served in the wet season is cropped in the dry season.

Water Management

In the farms visited, rice fields are continuously flooded from 4 to 5 days after transplanting until about 2 weeks before harvesting. Water is usually conveyed through earth canals, although 13 of the pump systems used pipes and cemented canals. We observed that most of the earth canals

Table 11. Relationship between pump output and depth of water table by pump size in Batangas and Quezon, crop year 1971-72.

Water table depth	Average pump output (lit/sec) 4-inch	5-inch	All pumps
Shallow	9.84	5.74	7.76
Medium	8.08	8.39	8.20
Deep	8.26	12.11	10.21
All	8.71	8.77	8.71

Table 12. Cost and returns per hectare for pump irrigated ricefields in Batangas and Quezon, crop year 1971-72. (Yields were 2.1 t/ha in both the wet season and the dry season.)

Item	Wet Season (P)	Dry Season (P)	Whole Year (P)
Production	1538	1533	3071
Cash costs:	279	292	572
Hired labor	107	110	217
Fertilizer 1/	98	101	200
Plant protection	14	13	27
Seeds	53	60	113
Others	7	8	15
Non-cash costs:	720	730	1451
Irrigation fee	227	225	452
Harvester and thresher share	270	275	545
Depreciation and interest 2/	104	104	209
Unpaid labor 3/	119	126	245
Total costs	999	1022	2023
Net revenue 4/	539	511	1048

1/ Includes costs of herbicides and insecticides. 2/ Assuming linear depreciation and 12 % interest on capital. 3/ Includes operator and family labor. Rate of P4.50 per manday was used. 4/ Returns to operator and family labor and management, capital, and landlord's equity.

Table 13. Pump operating cost per hectare by season and pump size, Batangas and Quezon, crop year 1971-72.

Item	Wet Season		Dry Season		Whole Year	
					4-inch pump 1/	
Cash costs	145		207		352	
Fuel		34		82		116
Oil and grease		7		13		19
Repairs and replacements		104		112		217
Non-cash costs	153		366		519	
Depreciation and interest 2/		139		338		477
Unpaid labor 3/		14		28		42
Total cost	298		573		871	
					5-inch pump 4/	
Cash costs	206		235		441	
Fuel		57		97		154
Oil and grease		13		18		31
Repairs and replacements		136		120		256
Non-cash costs	255		450		706	
Depreciation and interest 2/		241		422		664
Unpaid labor 3/		14		28		42
Total cost	461		685		1147	
Average cost 5/	380		629		1009	

1/ Avg. area served: wet season, 4.4 ha; dry season, 3.9 ha. 2/ Assuming linear depreciation rate plus 12% interest on undepreciated value of pump. 3/ Based on 100 irrigation days at 16 hours operation. 4/ Avg. area served: wet season, 4.6 ha; dry season, 4.0 ha. 5/ Average operating cost for both 4-inch and 5-inch pumps.

Table 14. Relationship between area served, depth of water table, and soil type, 52 pump units in Batangas and Quezon, crop year 1971-72.

Season	Area served per pump (ha)							
	Depth of water table				Soil type			
	Shallow	Medium	Deep	Avg.	Light	Medium	Heavy	Avg.
				4-inch pumps				
Wet season	4.1	5.5	2.8	4.4	5.4	3.2	5.6	4.4
Dry season	3.9	4.4	2.7	3.9	5.2	2.8	4.4	3.9
Whole year	8.0	9.9	5.5	8.3	10.6	6.0	10.0	8.3
				5-inch pumps				
Wet season	4.3	5.5	3.2	4.6	2.3	3.4	6.8	4.8
Dry season	3.7	4.6	3.2	4.0	2.3	3.0	5.6	4.0
Whole year	8.0	10.1	6.4	8.6	4.6	6.4	12.4	8.8
				All pumps				
Wet season	4.2	5.5	3.0	4.5	3.8	3.3	6.2	4.6
Dry season	3.8	4.5	2.9	3.9	3.8	2.9	4.9	3.9
Whole year	8.0	10.0	5.9	8.4	7.6	6.2	11.1	8.5

Table 15. Relationship between actual pump performance and rated pump capacity by pump size, 41 pump units in Batangas and Quezon, 1971-72.

Pump size	Actual		Rated		Efficiency (%)
	Pump discharge (lit/sec)	RPM	Pump discharge 1/ (lit/sec)	RPM	
4-inch	8.9	1416	18.9	1800	47
5-inch	7.7	1425	37.8	1800	20

1/ Based on study of T.M. Mendoza on "Underground Water Development, Utilization and Conservation". (mimeo), Project Investigation and Development Division, ISU, Department of Public Works and Communications, Annex II.

Table 16. Relationship between actual area served and potential serviceable area by pump size, 41 pump units in Batangas and Quezon, crop year 1971-72.

Pump size	BHP	Actual area served 2/ (ha)	Potential serviceable area 1/ (ha)	Efficiency (%)
4-inch	8 - 12	4.4	9	49
5-inch	12 - 14	4.6	18	26

1/ Wet season. 2/ Computed by dividing rated pump discharge by 34 gal/min. (2.14 lit/sec). This was derived based on 1.22 meters of water required to grow a rice crop (Kung, 1964) and on 16 hours irrigation operation for 100 days.

Table 17. Reasons given by 52 pump owners as to why they charged certain irrigation fees, Batangas and Quezon, crop year 1971-72. 1/

Reason given	Number reporting	Percent
Rate prevails in the area	37	79
Think they can cover pump operating cost	8	17
Others 2/	2	4

1/ Five pump owners are the sole users of water from their pumps and therefore did not charge irrigation fees. 2/ Includes reasons like to give incentive to pump operator and costly to maintain a pump.

Table 18. Distribution of 65 pump users according to irrigation fee arrangement in Batangas and Quezon, crop year 1971-72.

Irrigation fee arrangement			Number reporting	Percent reporting
Wet season		Dry season		
20% NP	-	20% NP 2/	33	66
15% NP	-	15% NP	5	10
Others 3/			12	24

1/ Fifteen pump users did not pay irrigation fees for reasons like they own the pump, they are relatives or sons of pump owner, etc. 2/ Net products -- the gross product minus the seeds and harvester-thresher share. 3/ e.g. 10% NP - 10% NP, 10% NP-20% NP, 15% NP- 20% NP, 1/6 NP-1/6 NP 50% of fuel and repairs, etc.

Table 19. Distribution of 65 pump users according to satisfaction response to irrigation fee arrangement in Batangas and Quezon, crop year 1971-72.1/

Response	Number reporting	Percent reporting
Highly satisfied	4	8
Satisfied	33	66
Fairly satisfied	8	10
Not at all	5	10

1/ Fifteen pump users did not pay irrigation fees.

Table 20. Problems regarding pump use as reported by 23 pump owners, Batangas and Quezon, crop year 1971-72 1/

Problem reported	Number reporting 2/	Percent
Lack of cash for pump repairs	15	56
Availability of spare parts	6	22
Availability of skilled mechanic	5	18
Quality of repair services	1	4

1/ Twenty-nine pump owners reported to have no problem. 2/ Some pump owners reported more than one problem.

were poorly maintained, and that a lush growth of weeds thrived in them. This condition undoubtedly reduces the volume of water that reaches the paddies. Pump systems located in lower elevations relative to the rice fields are forced to use pipes and cemented canals to convey water to the higher portions of their farms.

Generally, farms adjacent to the pump system are irrigated first. For pump systems with several users, the users agree on who gets the water first, who gets it next, and so on. The agreement stipulates that each user will get enough water to meet his farm needs. During times when water is limited, the water is distributed in a manner that meets at least the minimum water requirements of all farms. Water distribution among users is thus quite successful because of its flexibility, a result of a strong spirit of cooperation among most pump users.

Cost of water

It is clear from Table 17 that pump owners have no systematic or sound basis for charging irrigation fees. Many pump owners charge for water cost at the rate prevailing in the area. The most common arrangement is for the pump user to pay half of the 20 percent of the net products (gross product minus seeds and harvester-thresher share) in both the wet and dry seasons (Table 18). Another typical arrangement was for the pump user to pay half of 15 percent of the net products in both seasons. There are other arrangements but all payments made are in kind. When asked whether they were satisfied with the irrigation fee arrangements, two-thirds of the pump users said yes (Table 19). Pump users seemed content with the irrigation fee arrangements, although we think that they responded favorably because they are so heavily dependent on the pump owners for their irrigation needs, especially during the dry season.

Problems regarding pump use

The major problem encountered by pump owners is the lack of cash for pump repairs (Table 20). This problem is due to expensive spare parts and costly repair services for major engine and pump breakdowns. The problem is aggravated by the difficulty in securing spare parts which have to be bought in Manila if not available in nearby cities. Another pressing problem was the dearth of skilled mechanics; this hampers farm operations by delaying the resumption of irrigation services. The least of the complaints aired by the pump owners is the poor quality of repair services. This can be attributed to repair jobs done by unskilled mechanics.

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Institutional and social organizational factors affecting irrigation: their application to a specific case

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ABSTRACT

Some concepts of organizational and social behavior are presented, and their application illustrated in a social study of three gravity irrigation systems in Southern Luzon, Philippines. The nature of interaction between the farmers and the administration of these systems is explored through the role played by the irrigation ditchtenders. Interpersonal relationships between the ditchtenders and the farmers are used to illustrate the importance of institutional factors in irrigation behavior.

INTRODUCTION

This paper examines the institutional and organization influences on water-use behavior in selected irrigation systems in the Southern Luzon region of the Philippines. While some of the forms of this influence may be specific to the Philippines, the more general condition of water-use behavior being influenced by institutional and organization factors is, of course, not unique to Philippine irrigation systems.

Since some ambiguity surrounds the concepts of institutional and organizational factors, the initial part of this paper is devoted to exploring these concepts.

BASIC CONCEPTS

Institutions and social organization

Let us begin with a basic distinction between institutions and social organization. This distinction derives from a more fundamental distinction in social life between what people believe should be done and what is actually done. Institution is a concept associated with ideal behavior and expectations and is a "generic concept for the variety of norms that govern social behavior: folkways, mores, customs, convention, fashion, etiquette, law" (Chinoy, 1967).

The concept of institutions is frequently used in the literature of economic and agricultural development. For example, in Institutions in Agricultural Development (Blase, 1971), the editor accepts the definition of institution provided by Schultz (1968): An institution is a behavioral rule. This definition of Schultz is consistent with the view of institutions being norms, or prescriptions, for preferred behavior. Blase goes on, however, to give the following examples of institutions: tenure institutions, extension programs, agricultural research institutions, legal systems, and national planning institutions.

In delineating these examples Blase reveals a basic confusion between institutions and social organization. Extension programs, agricultural research institutions, and national planning institutions are more than behavioral rules. They are, in addition, people behaving in patterns of interaction with other people. Social organization refers to those actual patterns of interaction that occur among a plurality of people. Such patterns are sometimes formal, purposive, and enduring enough to be given names: the Cruz family, the National Irrigation Administration, or the San Lorenzo Farmer's Irrigation Cooperative Association, Inc. Of course, social organization is also composed of patterns less formal, purposive, or enduring, such as a friendship clique, a patron-client relationship, a sari-sari conversion group, or a band of farmers from a common irrigation lateral.

Institutions and social organization are fused through the basic concept of role. Institutions converge and are organized around the performance of some function by one actor toward another actor or actors. This cluster of institutions associated with a given function is called a role. Roles enable men to better predict the action and re-action of others and thus for social relations and social organization to emerge. In an irrigation system the cluster of institutions around the function of water distribution--all ditchtender role -- and the cluster of institutions around the function of water use -- the irrigator role -- allow for the emergence of social organization in an irrigation system in the form of patterned relationships between and among irrigators and ditchtenders. These patterns of social organization vary between irrigation systems as suggested in the labeling of some irrigation systems as communal and others as NIA-operated systems. Some irrigation systems may exist in which irrigators' association are part of the social organization, while in others such formalized patterns are absent.

Finally, to understand the basic relationship between institutions and social organization requires recognition of the frequent inconsistency between what people believe should occur (the institutional element) and what actually occurs (the social organizational element). The basic "lack of close correspondence between the 'ideal' and the 'actual' in many and pervasive contexts of social behavior" (Moore, 1963) is one important force for change in either the institutional or social organizational patterns. A major reason for this inconsistency is that changes in the social or non-social environment either make it more difficult or impossible to act in certain established ways, or easier or possible to act in certain new ways. Whenever changes in environmental conditions occur and behavioral contingencies change, pressures arise to change either institutions or social organization. Change in either of these elements creates demand for change in the other.

Therefore, institutional and social organization influences on water management are two different, but related phenomena. On the one hand are those ideal and expected manners of doing things which may impinge on decisions and behavior regarding water use. On the other hand are those patterns of actually doing things that may influence water-use behavior.

Irrigation-specific institutions and roles

Human groups differ in the extent to which their institutions are specialized and applicable only to selected social contexts and behaviors. Likewise, human groups differ in the extent to which the roles in that group have a specialized or multi-purpose function.

In any case, not all the institutions of society will directly affect irrigation behavior since many norms are highly role-specific. Conceptually, the role of the irrigator is composed of a combination of irrigation-specific institutions and more general institutions that apply to a variety of social settings, including irrigation situations. For example, the Philippine irrigator interacts with other irrigators and with water authorities under the guidance of at least two norms. The first is the irrigation-specific norm that the field most needing water should receive it first. And the second is the more general norm, which also applies to irrigation systems, that one should avoid confrontation in dealing with others.

One important difference between irrigation settings is the extent to which the total bundle of institutions affecting irrigation behavior are irrigation-specific and differentiated from other role-specific institutions. In irrigation systems with a low proportion of irrigation-specific institutions the sources of institutional influences on water-use behavior are very diffuse.

This specialization of the institutional component has its counterpart in social organization. As mentioned, human groups differ in the extent to which roles are relatively undifferentiated. That is, each individual performs multiple roles similar to other individuals in the group. In some irrigation systems the role of water user, water distributor, and system maintainer may all be combined in each member of the irrigation system, while in other systems these roles may be separately assigned with no individual performing more than one of the roles.

There are two important ideas associated with role differentiation. First, whenever any one actor performs multiple roles his behavior in one role is likely to affect his behavior in another. As an example, consider the manner in which a landlord performs his role if the tenant is also a relative. Overlapping roles can of course have both positive and negative consequences. The positive consequences are suggested by the fact that a significant portion of social behavior is aimed at transforming single-purpose role dyads into multipurpose relationships, as evidenced in the compadrazco complex in Philippine society.

Second, when individuals are assigned increasingly specialized tasks in a human group they typically improve and refine the various behaviors and tasks associated with that role. For example, when the task of designing the irrigation system is shifted from the irrigator, with whom it lies in many primitive systems, to an engineer, the resulting physical system is typically more sophisticated and effective than formerly.

Whenever the roles in a human group become increasingly specialized and separated the problem of coordinating, or relating these specialities emerges. The problems is an obvious one. If the tasks of water distribution and water use are combined in the same role, as may occur in a small communal system, the problem of coordinating these activities is minimal. If, however, these two tasks are assigned to separate individuals, then clearly there must exist some procedure for integrating the behavior of these two separated but related tasks. The procedure may be oral communication, written notices, fixed water schedules, or some other means. Similarly, if the tasks of system design and system operation are the responsibilities of separate organizations, the resulting design may fail to take into account certain rules and patterns of behavior common to the water users. Such dysfunctional design rarely occurs in less complex systems where the water users themselves do the designing.

Consequently, institutional and role differentiation may have paradoxical results for the performance of any human group. The specification of institutions and the specialization of roles usually leads to improved performance of specific tasks. But, unless this increased division of activities can be managed and coordinated, undersirable consequences may also occur.

In irrigation systems a common form of differentiation is that noted by Pasteonack(1972): "There is a threshold of complexity in irrigation systems at which cooperation must give way to coordination; at which those served by the system relinquish their decision-making power and their direct role in settling disputes." Thus, a basic characteristic of irrigation systems, above a threshold of complexity, is the differentiation of tasks into two basic roles: water users and water authorities. Furthermore, this role differentiation is accompanied by various institutional and organizational procedures intended to integrate the two roles. One of the common difficulties in many complex irrigation systems is the inability to achieve a satisfactory level of integration. Water users do not feel that they are able to adequately "control" the behavior of the water authorities. Likewise, water authorities are frustrated in their attempts to obtain the "cooperation" of the water users. The problem of integrating differentiated roles is central to the problem that Levine (1971) has identified as "system-farmer interaction."

Tendencies to elaboration

In most modern irrigation systems two factors tend to cause further elaboration of irrigation-specific institutions and social organization. First, in most modern irrigation systems the water authority roles are performed by members of some government or quasi-government agency. The staff members of these agencies are part of, or linked with, a professional sub-culture that is concerned with the design of increasingly sophisticated physical structures and procedures for water use. Their concern is often translated into attempts to elaborate the social organization of the water users through irrigation associations, rotation groups, or lateral leaders. Likewise, they attempt to elaborate the institutional component by specifying new rules and regulations or introducing innovative rewards and punishments.

The tendencies to elaboration also arise from the needs and demands of the water users. As the untimely, unreliable, or inadequate delivery of water increasingly becomes a bottleneck in the water users' production process, there will emerge a demand for new institutional and organization forms to solve the problem. Farmers may increasingly value an irrigation association that will allow them to influence irrigation policy. Also, they may begin to favor new rules for dealing with their field neighbors that are more independent of the norms that apply when dealing with kinsmen, real or fictive, or barrio mates.

INSTITUTIONS AND SOCIAL ORGANIZATION IN PHILIPPINE IRRIGATION SYSTEMS

Having explored the basic concepts, institutions and social organization, the focus in this section will be the application of these concepts to concrete irrigation situations. In this application we can also illustrate the utility of this framework for understanding various modes of irrigation behavior.

Background of the data

This discussion is based on field observations and interviews made in three irrigation systems operated by the National Irrigation Association in the Southern Luzon region. The interview were made with all 22 ditchtenders employed in the three systems, seven individuals who either are or have recently been as water guards, all 27 farmers in two selected irrigation sections. The interviews were supplemented with information from the local office of the NIA. Important size characteristics of the three systems are presented in Table 1. System A has a considerably larger command area than the other two systems in both the wet and dry seasons. System B is difficult to manage because of the rolling terrain included in the system.

The irrigation systems serve small commercial rice farms. Data collected in nine of the barrios served by these systems indicate that 81 percent of the farmers sell some portion of their production. The use of technical inputs is also high -- 80 percent of the farmers interviewed use fertilizers. The data also show that 89.5 percent of the farmers were share tenants in 1970 (International Institute for Rural Reconstruction,1971). Farms are small, averaging 1.8 hectares. Only 3 percent of the farms are 4 hectares or more.

Linking differentiated roles: the ditchtender

NIA systems are characterized by a social organization in which the task of water distribution in the system is handled by a specialized group of water authorities. As mentioned previously, this form of differentiation requires procedures and patterns to integrate the water users with the water authorities. In NIA-operated systems, particularly those without any form of irrigators' association, much of the responsibility for this linkage is with the ditchtender. As reported by Wickham (1970), the ditchtender is the most available and visible representative of the water authority group. The major purpose of the system-farmer interaction is so that "farmer plans and system operation ... interact for successful production" (Levine, 1971). The interaction must facilitate the exchange of information between the water users and the water authorities so that decisions regarding water scheduling and use can be optimized. If either party is unaware or uncertain of the other's actions, planning is abandoned or follows a least-risk pattern. Neither of these solutions is satisfactory for modernizing agriculture.

This section of the paper focuses on selected aspects of the ditchtenders' performance in this integration role. It summarizes the nature of the ditchtenders' interaction with water users in the three systems mentioned perviously. The nature of the interaction is discussed in terms of the scale of his interaction, the form of his interaction, and the usual content of his interaction. This part of the discussion is based on an earlier paper describing system-farmer interaction (Coward, 1972a).

Scale of interaction. The successful integration of the irrigation system, in part, will depend upon the scale of interaction assigned to the ditchtender. How many farmers distributed over how much territory must the ditchtender deal with? The problem of scale is especially important in these systems because of the ditchtender's lack of modern communication and transportation technology.

Table 2 summarizes several characteristics of the scale of interaction assigned to each ditchtender. The ratio of concentration measures the extent to which the water users served by a ditchtender reside in a common barrio. The ratio is calculated by dividing the total number of water users served by the number of water users in the modal barrio. As can be seen, there is considerable variation between systems and among ditchtenders. At the upper limits, ditchtenders may be serving more tha 100 farmers who farm more than 200 hectares and live in 9 different barrios.

Form of interaction. Ditchtenders most frequently interact with farmers as individuals, or in small groups, and on a face-to-face basis. When larger groups meet it is almost always to discuss the water schedule or the payment of irrigation fees.

There is some written communication between the ditchtenders and water users. During the months of water scheduling, ditchtenders frequently issue notices to the water users explaining the days and hours during which water will be delivered to their farm ditch. Water users report that they sometimes use these written notices as proof of their turn to use the water and thus avoid conflict with other water users.

It is significant that few ditchtenders report having discussed irrigation problems with barrio captains even though barrio captains are typically a highly visible part of the barrio leadership. This situation might be related to the low concentration ratio mentioned previously. One local water authority suggested, however, that this is done to avoid unnecessary involvement with local political factions.

Content of interaction. The ditchtender spends much of his time cleaning the canals or collecting irrigation fees (Table 3). The activity of water scheduling and distribution has potential for meaningful interaction between ditchtender and water user, however, the activity is rarely done jointly. The basic contents of this interaction are farmer requests and ditchtender decisions, although the two components may be somewhat unrelated. Most decisions about water scheduling are made in weekly meetings involving the ditchtenders and the watermaster but neither water users nor their representatives participate in these meetings.

The frequent contact between the ditchtender and water user suggests the potential role of the ditchtender in the diffusion of information regarding technological innovations, including better water management practices. Twenty-seven water users were asked if ditchtenders ever provide information of this type to them. All but one replied, "no." They were also asked if they thought ditchtenders should provide such technical information as part of their job. Those who answered "yes" (59%) indicated that ditchtenders could help identify rice varieties suitable to the water conditions of their farms.

Some implications. The scope, form, and content of the interaction between ditchtenders and water users in these irrigation systems suggests a pattern of integration that is authoritarian, has minimal farmer participation, and in coincidental with high levels of uncertainty and frustration. It is a pattern of integration better suited for operating and maintaining the system at some present level than for developing the system and improving efficiency and equity in operation. So long as the water user is inhibited from being more directly involved in water ditribution decisions the system will lack feedback information for improvement and development.

If irrigation systems are going to be part of a dynamic and changing agricultural production system, new institutions and organizations for integrating the specialized roles of the water authorities and water users must emerge that are more open to water user participation.

A major institutional factor: smooth interpersonal relations

In irrigation systems in Southern Luzon irrigation-specific norms do not appear to be highly developed. An indication of this is the extent to which the Philippine value of getting along smoothly with others permeates the relationships between ditchtenders and water users. For this part of the discussion I have drawn on a previous paper dealing with values and irrigation behavior (Coward, 1972c).

Table 1. Size characteristics of three irrigation systems, 1971.

Irrigation system	Area irrigated (ha) Wet season	Dry season	Farmers served (no.)	Sections (no.)	Ditch-tenders (no.)
A	1849	1230	903	17	12
B	650	341	379	10	7
C	504	272	272	9	3

Table 2. Characteristics of the scale of interaction of ditchtender by irrigation system.

Characteristics	Irrigation Systems A Ave.	A Range	B Ave.	B Range	C Ave.	C Range	All systems Ave.	All systems Range
Farmers served 1971 wet season (no.)	75	(35-122)	54	(35-76)	91	(84-96)	73	(35-122)
Farmers served 1971 dry season (no.)	48	(0-91)	34	(0-58)	43	(0-84)	42	(0-91)
Area served in 1971 wet season (ha)	152	(64-206)	93	(69-121)	168	(151-189)	137	(64-206)
Area served 1971 dry season (ha)	102	(0-206)	48	(0-121)	91	(0-164)	84	(0-206)
Ratio of concentration (%)	54	(33-87)	71	(42-98)	61	(27-100)	62	(27-100)
Length of canal maintained (km)	4.1	(2.4 to 5.7)	4.5	(2.5 to 8.8)	5.2	(3.6 to 7.7)	4.6	(2.4 to 7.7)

Table 3. Self-reported activities of ditchtenders.

Activity	Number reporting this activity requires: Most amount of time	Second most amount of time	Third most amount of time
Cleaning the canals	14	6	1
Scheduling and distributing water	7	10	5
Collecting irrigation fees	1	2	13
Recording harvest yields	0	0	2
Supervising other ditchtenders	0	3	0
None	0	1	1

In Philippine society, smooth interpersonal relations (SIR), or getting along with others in a respectful manner, is a highly preferred style of interaction (Lynch and de Guzman, 1970). In situations where it is, or may become, difficult for two or more people to attain smooth interaction, someone will engage in one or more of the following actions to preserve or achieve SIR: concession, euphemism, employment of a go-between or gift-giving (either anticipatory or reciprocal).

The interaction between ditchtenders and water users is influenced by this pervasive institution. Ditchtenders attempt to create SIR with water users so they will follow his directives (see Table 4). The uncertainty of the farmers' response appears to derive from the absence of rules for distributing water that are well enforced either by socialization or punishment of offenses and the general inadequate physical condition of the system which make it nearly impossible to provide reliable service to the water user. In this situation the ditchtender is left with the use of SIR as a means to achieve conformity to his orders.

The use of SIR by the water users may be seen as an attempt to reduce uncertainty in decision-making (see Table 5). In these systems there is considerable uncertainty about how much water will be available during any crop period and a seeming absence of a well understood policy for distributing water in times of scarcity. Both of these conditions emphasize the need for the water user to have SIR with the ditchtender so as to be able to positively influence his water distribution decisions.

Thus, in Philippine irrigation systems smooth interpersonal relations are important mechanisms for the management of conflict. From this it follows that in changing the operation of irrigation systems, attention must be given to the effect of rules and roles on the ability of water users and water authorities to have smooth interpersonal relations.

Two generalizations emerge from this analysis. First, the ideal role of the ditchtender should be designed so that performance will permit creation and maintenance of smooth interpersonal relations with water users. If this is not done it is likely that the actual performance of the ditchtender will deviate from the ideal in a manner that will incorporate SIR. This is especially important in water scheduling. The procedures for scheduling the delivery of water should enhance the ability of the ditchtender both to get along well with the water users and to efficiently allocate the water. Adopting more standard procedures and policies for decision-making and increasing communication between water authorities and water users should contribute to this.

Second, water users should be permitted, and encouraged, to evolve informal irrigation roles that will create smooth internpersonal relations between water authorities and water users. This integration is likely to have positive consequences for water management. An example of an informal irrigation role is the water guard which I have discussed elsewhere (Coward, 1972 b).

Table 4. Summary of actions used by ditchtenders to achieve SIR with farmers.

Response	General category
Provides water when asked	Concession
Participation in farmers recreational activities when invited	Concession
Donates money for alms and civic affairs when requested	Gift-giving
Invites farmers to his house for food and drinks	Gift-giving
Give cigarettes to farmers	Gift-giving
Does not speak like a boss	Euphemism
Helps in work other than just irrigation	Positive service
Wakes farmers when water is to be delivered to their place	Positive service
Rearranges water schedules from night to day, if possible	Positive service

Table 5. Summary of actions used by farmers to achieve SIR with ditchtenders.*

Response	General category
Follow the requests and directives of the ditchtender	Concession
Provide snacks and cigarettes to the ditchtender	Gift-giving
Pay a larger share to members of the ditchtenders family who harvest palay	Gift-giving
Act respectfully toward the ditchtender	Euphemism
Provide companionship to the ditchtender when he is working at night	Job assistance
Speak to their landlords and other farmers about the need to pay irrigation fees	Job assistance
Help cut the grass on the canal	Job assistance

* An interesting comment not summarized in Table 5 was made by one ditchtender who reported that he felt the farmers maintained SIR with him by reporting the ditchtender's mistakes directly to him rather than to his supervisor.

CONCLUSION

Changes in water-use behavior that will result in improved water management will require a variety of changes in existing institutional and organizational patterns. Just which patterns will need modification will be location-specific. Likewise, the range of institutional and organizational patterns that will be affected will depend on the extent to which irrigation-specific institutions and organizations have been differentiated in that social context.

Existing institutional and organizational patterns have been established because of their previous (and probably, current) utility in meeting the needs of both water users and water authorities in the context of their social and nonsocial environment. They represent a response or adaptation to that complex and multifaceted behavioral context called the irrigation system.

To modify these existing patterns will require various situational (or environmental) changes which have two consequences. First, the new conditions reduce or reverse the utility of following the former patterns. And, second, they increase the benefits of the new patterns of behavior and prescriptions for behavior. This is a very difficult task to accomplish since most behavior has a variety of consequences, only some of which may be controllable by the change agent. In any case, one must begin with a thorough examination of the conditions and consequences that reinforce existing institutional and organizational patterns. To illustrate, as discussed previously, one consequence of the water users' efforts to establish smooth interpersonal relations with the ditchtender can be to reduce uncertainty about the delivery of water to his farm. Unless this consequence is changed (for example, by reducing uncertainty throughout the system with new rules of distribution or changes in the physical structures) it will be very difficult to modify the existing pattern of smooth interpersonal relations.

To modify existing patterns, a program of activities is needed to design and test new institutional and organizational forms for improving water management. Such a program should involve field testing of new approaches.

In any such program both water users and local water authorities should be closely involved at all stages. Too much separation of the functions of design and use can lead to a situation in which new forms are either "discovered" in an outside group or "invented" by a social planner and then presented to the ultimate users for their adoption. The success of institutional and organizational innovations can be highly dependent upon location-specific variables thus requiring the involvement of local people in their design or adaptation.

A thorough understanding of the contingencies of current behavior is a necessary condition for systematically shaping behavior in new ways. The contingencies of behavior in specific irrigation systems are relatively unknown to us at this time and deserve major attention by social scientists.

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Farmer attitudes towards irrigation and farmer potential for cooperation

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ABSTRACT

Farmer attitudes in five systems of the National Irrigation Administration were explored. The majority of farmers felt that they had adequate water, but that their water distribution could be improved. Farmers in water-short areas acknowledged the limited supply of water in their irrigation systems. These two groups exhibited contrasting attitudes, with the former tending to be relatively less cooperative and placing less value on irrigation. In terms of water distribution, farms served by the first half of the irrigation canal generally seemed better located than those served by the second half.

The contribution of irrigation to increases in rice production in the Philippines since 1960 has been analyzed by Crisostomo and Barker (1971). They showed that in the early 1960's rice production grew mainly because of increases in yield per hectare and in the late 1960's mainly because of expansion of irrigation systems which permitted increases in the harvested crop area. Against this background, case studies and other micro-level studies serve to highlight the problems and possibilities of irrigation as a vehicle for development. This paper is based on a study carried out in 1970 in five gravity systems of the National Irrigation Administration (NIA). Each provincial office of NIA is directly responsible for the routine management of one or more irrigation systems. An irrigation system has a dam (usually formed by a low barrage) serving a limited area known as the "command area." In this paper, the "NIA" refers primarily to the NIA provincial level office.

The general objectives of the paper are to describe farmers' attitudes toward irrigation, examine farmer potential for cooperation, and discuss ways of achieving better relationships between farmers and the irrigation system.

THE STUDY

The study was conducted at the farm level in three provinces, Nueva Ecija and Bulacan in Central Luzon, and Laguna in Southern Luzon. Central Luzon generally has two pronounced seasons, the wet season from June to October, and the dry season from November to May. Southern Luzon has a less pronounced dry season, lasting from January or February to May.

The five NIA irrigation systems covered are the Pampanga River Irrigation System, the Pampanga-Bongabon Rivers Irrigation System and the Peñaranda River Irrigation System in Nueva Ecija; the Angat River Irrigation System in Bulacan, and the Santa Cruz River Irrigation System in Laguna.

Eight research sites averaging about 30 ha. each were delineated from within these systems with the help of aerial photographs, maps and visits to the sites prior to the survey. A complete enumeration of farmers within the sites was made (N=133), with a map identifying the paddies farmed by each respondent.

The study was conducted jointly with an agricultural engineering project (Wickham, 1971) which measured daily water flows, monitored soil-water conditions, and collected other agronomic data. The two projects combined the disciplines of sociology and agricultural engineering, although each study was reported separately.

The sample was limited in that the farms covered were in irrigated double-cropped areas. In addition, sampling was purposive in the selection of the areas to enable the feasible measurement of water use. The sample therefore, does not represent a random selection of irrigation systems, or of areas within systems. The areas were carefully chosen, however, to include a wide range of irrigation conditions.

FARMERS' ATTITUDES TOWARDS IRRIGATION

By farm location

Farmers' attitudes towards irrigation may be related to the location of their farms relative to their source of water. Figure 1 separates farms into four groups, A, B, C or D, according to location on each side of the canal or lateral. Farms in location A are closer to the source of water coming into the canal and are higher in elevation than farms in location B; they are also higher than farms in locations C and D. Farms in location A first receive water flowing by gravity. Those in location B are also closer to the source of water in the canal, but receive water after it has flowed through the first half of the canal.

A vertical cross-section of Figure 1 (Figure 2) reveals that farms in location C are closer to the water table than farms in location A, although further from the source of water in the canal (Wickham, 1972). Their soils are usually more clayey than those in location A. A similar comparison can be made between farms in locations B and D. How, then, should farms be delineated for water distribution: farms in location A and B versus those in C and D, or those in locations A and C versus those in B and D. Or in Figure 1, does the line xy represent a stronger delineation than do the lines pq or p'q? The answer bears on policy decisions about the distribution of water to farms. The following sections discuss findings relating to these farm locations.

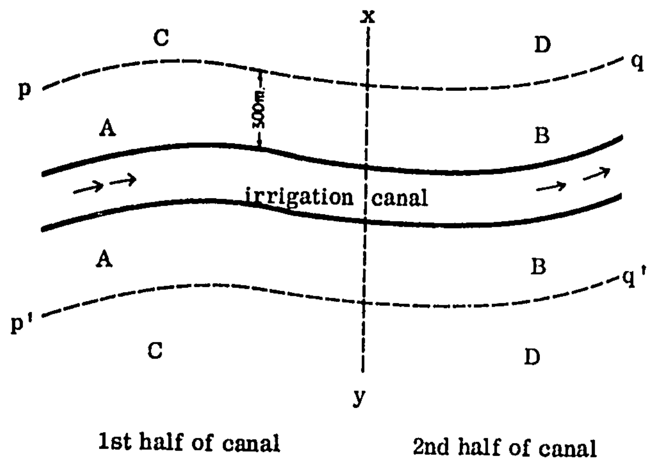

Fig. 1. Location Classifications
A = 1st half of canal, within 300 m of canal
B = 2nd half of canal, within 300 m of canal
C = 1st half of canal, more than 300 m of canal
D = 2nd half of canal, more than 300 m of canal

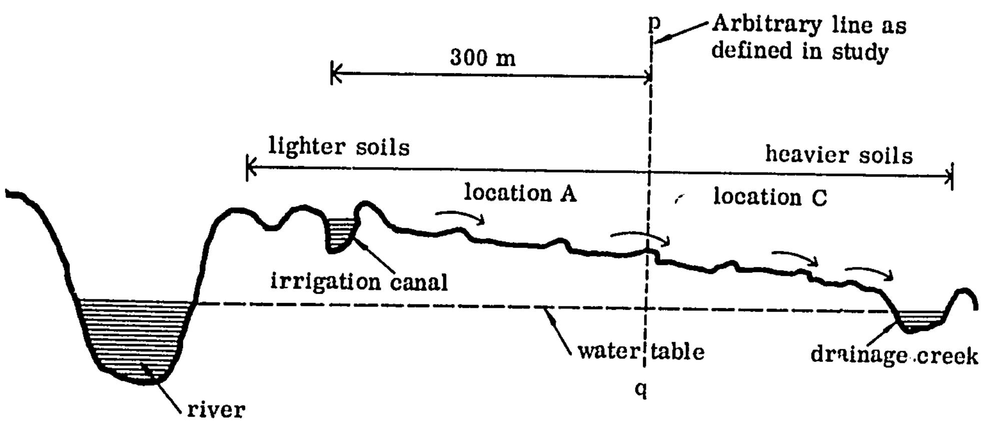

Fig. 2. Cross section of a typical lowland rice form, 1st half of lateral. Adapted from T. Wickham, IRRI Sat. Seminar, Nov. 18, 1972.

Seventy-three percent of all farmers acknowledged that irrigation enabled them to make a profit in rice farming in 1969 (Table 1). Of the farmers in the first half of the canal, 89 percent said that they were able to make a profit due to irrigation, compared with only 55 percent in the second half of the canal. When grouped by distance from the canal, 76 percent of those nearer the canal reported profits due to irrigation, compared with 69 percent of those beyond the 300 meter line.

Those in the first half of the canal appear to have less conflicts over irrigation (Table 2) than those in the second half of the canal. Eleven percent reported conflicts in the former, compared with 24 percent in the latter.

Asked how they judged irrigation fees, a higher proportion of those farmers in the first half of the canal felt that the fees charged were too large (54% compared with only 23% in the second half of the canal). When grouped the other way, the responses were not significantly different. This indicates that there was a greater appreciation of water among farmers in the lower reaches of the canal (Table 3).

Asked whether they were willing to participate in taking turns in getting water, a higher proportion of those in the lower reaches were willing to participate in such a scheme, 97 percent, compared with 86 percent in the upper reaches. When grouped lineally from the canal, the responses were not significantly different (Table 4).

In general, 71 percent of all farmers reported having at least enough irrigation water (Table 5). In comparing water adequacy between locations, a greater proportion in the first half of the canal (80%) reported adequacy compared with only 59 percent in the second half of the canal.

The pattern of fee payment was conditioned by the land tenure system, and by the general policy of the NIA to bill landowners and not the farmers in share-tenanted areas. When asked who usually paid the irrigation fees (Table 6), 36% of all farmers reported that they usually paid the fees to the landlord, 27% said the landlord was responsible for paying, 26% said that it was their own responsibility, and 11% did not know who usually paid.

When farmers were asked whether they were willing to pay more for pumps, 54 percent said they would. In this response, there was a sharp contrast between those in the first half of the canal and those in the second half, with farmers in the latter being more willing (73% compared with 38%, Table 7).

Asked how much they were willing to pay for an assured amount of water, the median was ₱35 per year, although where water was short, some farmers mentioned ₱60 to ₱100 per year. Propensity to pay, measured with

Table 1. Profit due to irrigation, by farm locations (percent based on column totals).

	1st half of canal (%)	2nd half of canal (%)	Total (%)
Yes, wet season only (2 crops/yr)	7	-	4
Yes, both seasons (2 crops/yr)	89	55	73
Yes, dry season only (1 crop/yr)	-	5	2
Yes, wet season only (1 crop/yr)	3	24	13
No profit	-	10	4
Don't know	1	6	4
Respondents (no.)	71	62	133

	Located within 300 m. of canal (%)	Located beyond 300 m. from the canal (%)	Total (%)
Yes, wet season only (2 crops/yr)	2	6	4
Yes, both seasons (2 crops/yr)	76	69	73
Yes, dry season only (1 crop/yr)	4	-	2
Yes, wet season only (1 crop/yr)	9	18	13
No profit	8	-	4
Don't know	1	7	4
Respondents (no.)	78	55	133

Table 2. Farmers reporting conflicts over water use in relation to farm locations.

	1st half of canal (%)	2nd half of canal (%)	Total (%)
No conflicts	89	76	83
Conflicts	11	24	17
Respondents (no.)	71	62	133
	$X^2 = 3.85$*	a = 0.05	d.f. = 1

	Located within 300 m. of canal	Located beyond 300 m. from canal	Total
No conflicts	85	80	83
Conflicts	15	20	17
Respondents (no.)	78	55	133

$X^2 = 0.5$ n.s.

Table 3. Farmers' response[1] to the amount of irrigation fees charged, in relation to farm locations.

	1st half of canal (%)	2nd half of canal (%)	Total (%)
Reasonable	22	48	34
Too high	78	52	66
Respondents (No.)	58	46	104
	$X^2 = 7.4$**	a = 0.01	d.f. = 1

	Located within 300 m. of canal	Located beyond 300 m. from canal	Total
Reasonable	42	23	34
Too high	58	77	66
Respondents (no.)	60	44	104
	$X^2 = 4.1$*	a = 0.05	d.f. = 1

[1] Twenty-nine farmers responding "don't know" dropped from sample.

Table 4. Farmers' willingness to participate in more intensive scheduling of water, in relation to farm locations.[1]

	1st half of canal (%)	2nd half of canal (%)	Total (%)
Willing	85	97	91
Not willing	15	3	9
Respondents (no.)	69	62	131

$X^2 = 5.0^*$ $a = 0.05$ d.f. = 1

	Located within 300 m. of canal	Located beyond 300 m. from canal	Total
Willing	95	86	91
Not willing	5	14	9
Respondents (no.)	76	55	131

$X^2 = 3.3^{n.s.}$

[1]One farmer responding "don't know" dropped from sample.

Table 5. Farmers' evaluation of the adequacy of water in relation to farm locations, combined wet and dry seasons.

	1st half of canal (%)	2nd half of canal (%)	Total (%)
Adequate or better	80	59	71
Highly or moderately inadequate	20	41	29
Respondents (no.)	137	94	231

$X^2 = 10.9^{**}$ $a = 0.01$ d.f. = 1

	Located within 300 m. of canal	Located beyond 300 m. from canal	Total
Adequate or better	70	74	71
Highly or moderately inadequate	30	26	29
Respondents (no.)	138	93	231

$X^2 = 0.6^{n.s.}$

Table 6. Pattern of fee payment, by site (percent based on row totals).

Location	Landlord pays NIA (%)	Farmer pays NIA (%)	Farmer pays landlord (%)	Don't know (%)	Respondents (no.)
Nueva Ecija					
San Ricardo	-	-	78	22	9
Bangad	-	52	21	27	33
Pulo	9	73	18	-	11
Bulacan					
Pulong Bayabas	8	33	59	-	13
Agnaya	29	12	59	-	16
Laguna					
San Juan	40	5	55	-	22
Victoria	54	23	23	-	13
Pinagbayanan-Linga	75	6	-	19	16
All sites	26	27	36	11	133

Table 7. Farmers' willingness to pay higher fees for supplemental irrigation in relation to farm locations.

	1st half of canal (%)	2nd half of canal (%)	Total (%)
Willing	38	73	54
Not willing	62	27	46
Respondents (no.)	71	62	133

$X^2 = 15.9^{**}$ a = 0.01 d.f. = 1

	Located within 300 m. of canal	Located beyond 300 m. from canal	Total
Willing	56	51	54
Not willing	44	49	46
Respondents (no.)	78	55	133

$X^2 = 0.4^{n.s.}$

a composite scoring system, showed that farmers in water-short areas had a higher propensity to pay fees than those in non-short areas.

By Stated Water Adequacy

Farmers were asked to evaluate whether they had adequate water, using a five-point scale. The scale ranged from "highly inadequate" to "more than necessary". The responses were later regrouped into "highly inadequate," "moderately inadequate," and "adequate" (which includes "better than adequate").

One question put to farmers, if it applied to them, was whether they thought their water shortages were due to lack of water in the whole irrigation system, to poor distribution, or to both (Table 8). Most farmers in the "highly inadequate" group attributed their water shortage to insufficient water in the whole irrigation system (55% of farmers in the wet season and 78% in the dry). Farmers in this group therefore acknowledged the limited capacity of the diversion systems which have essentially no storage capability. In contrast, farmers in the "moderately inadequate" and "adequate" groups attributed their water shortage mainly to poor distribution, especially during the dry season (63% and 57% of farmers, respectively).

In comparing yields obtained within each group over two seasons, there seemed to be a clear cut-off point at which yields were adversely affected (Table 9). The median yield of those in the "highly inadequate" group was only 2.2 t/ha compared with 3.6 t/ha and 2.8 t/ha of those in the "moderately inadequate" and "adequate" groups, respectively. The "moderately inadequate" group had better yields because it was associated with the use of more improved farm management practices than the other two groups (Table 10). In contrast, those in the "highly inadequate" group tended to have medium or low scores for the adoption of improved practices.

Summary of Attitudes

Thus the division of farms according to whether they are served by the first or the second half of the irrigation canal seems more meaningful than dividing them according to lateral distance from the canal. This has interesting implications for water management planning. In scheduling, water might be allocated to farmers in the lower reaches of the canal first to enable them to plant ahead. Or, those along the first half of the canal might be charged higher irrigation fees than those along the second half. Farmers in the latter half also seem keener to take part in schemes such as supplemental irrigation or more intensive scheduling. This implies that farmers in the first half of the canals probably take the situation for granted, and would tend to be less cooperative in schemes for reallocating water.

Although more than two-thirds of all farmers say they have at least adequate water, they nevertheless feel that water shortage in their areas was due more to poor distribution than to insufficient supply, implying dissatisfaction with the present method of water allocation.

Table 8. Stated water adequacy, reason for water shortage.

	Highly inadequate (%)	Moderately inadequate (%)	Adequate & up (%)	Total (%)
		WET SEASON		
Insufficient water in whole system	55	56	48	50
Poor distribution	45	44	48	47
Both	-	-	4	3
Respondents (no.)	11	9	44	64
		DRY SEASON		
Insufficient water in whole system	78	37	36	55
Poor distribution	15	63	57	40
Both	7	-	7	5
Respondents (no.)	27	19	14	60

Table 9. Stated water adequacy and yield obtained within each adequacy group, combined seasons.

Yield (t/ha)	Highly inadequate (%)	Moderately inadequate (%)	Adequate & up (%)	Total (%)
0 - 1.8	40	7	6	12
1.8 - 2.6	21	25	38	33
2.6 - 3.5	21	32	28	27
3.5 - 4.4	13	25	16	17
4.4 - 5.3	5	4	8	7
5.3 - 6.2	-	4	2	2
Over 6.2	-	4	2	2
Respondents (no.)	38	28	165	231
Median yield (t/ha)	2.2	3.6	2.8	2.8

FARMER POTENTIAL FOR COOPERATION

Farmers acknowledged that close cooperation was needed in irrigation activities. Most farmers reported having at least one farm ditch going through their farm, and said they helped to clean the ditches. Farm ditches are tertiary canals which lead away from branches of the main canal but NIA considers maintenance the farmers' responsibility. Asked whose responsibility it was to clean these farm ditches, about two-thirds (64%) said it was NIA's responsibility. In this respect, farmers in low adequacy areas had a different response from those in the medium and high adequacy groups (Table 11). Where there is low water adequacy farmers tend to be more cooperative in cleaning farm ditches.

Farmers' attitudes towards working in groups were explored (Table 12). In general, only pump use was a preferred (54%) group activity and even then those who preferred this on an individual basis were a sizable proportion (44%). It is notable that in water scheduling, farmers in all areas except Pulo (where there was an irrigation association) preferred to do it individually. Most sites also preferred that water control be done individually. These findings indicate that farmers tend to be individualistic, although they can change as in Pulo.

In cooperation scores (which are made from composite variables) farmers in the areas with highly inadequate water supplies showed higher potential for cooperation (Table 13). Their cooperation scores were at least double those in the adequate areas.

Cooperation among farmers seemed to be more at the informal than formal level. Few joined outside associations (Table 14). When asked if they would join an irrigators' association, many of them said they would, giving reasons such as, "If everyone joins and I don't, it would look bad," suggesting some kind of social pressure, or, "If it's for the good of all, why not?" These responses suggest that farmers need an outside stimulus before they would form groups. In the area where there was an irrigators' association, those who did not join it gave reasons such as "I was not asked," or "I was not around when they had the meeting," suggesting that the personal approach is essential in the formation of a group.

In assessing farmer potential for cooperation, one has to assess both the physical aspects such as farm location, topography, and other environmental constraints, as well as the social situation in the area. There is an apparent vicious circle in the oft-heard complaint that farmers do not get enough water and therefore do not pay irrigation fees, and that when they do not pay their fees, then they do not get the water. Within the context of this study, these statements do not appear valid, since the majority of farmers do acknowledge having at least adequate water (71%). Further, the irrigation systems, for various reasons, are not able to cut off the water supply to those who do not pay their irrigation fees.

Table 10. Score for improved practices within each stated adequacy group, combined seasons.

	Highly inadequate (%)	Moderately inadequate (%)	Adequate & up (%)	Total (%)
High	39	64	47	47
Medium	45	25	39	39
Low	16	11	14	14
Respondents (no.)	38	28	165	231

Table 11. Water adequacy throughout the year and farmers' attitudes towards cleaning farm ditches.

	Low adequacy	Medium adequacy	High adequacy	Total
NIA responsibility	38	63	71	64
Farmer responsibility	25	33	23	27
Both	37	4	6	9
Respondents (no.)	16	54	63	133

Table 12. Farmers' attitudes towards selected group-oriented activities.

	FARMERS* (%)								
	Nueva Ecija			Bulacan		Laguna			Total
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
Ditch clearing									
Individually	22	100	91	92	53	18	19	19	56
Group	78	-	9	8	41	82	77	81	42
Unwilling to do	-	-	-	-	6	-	8	-	2
Respondents (no.)	9	33	11	13	16	22	13	16	133
	$X^2 = 78.84^{**}$			a = 0.01			df = 14		
Water Scheduling									
Individually	67	81	36	83	71	59	62	94	71
Group	33	19	64	17	29	36	23	6	27
Unwilling to do	-	-	-	-	-	5	15	-	2
Respondents (no.)	9	33	11	13	16	22	13	16	133
	$X^2 = 27.38^{*}$			a = 0.05			df = 14		
Water Control									
Individually	11	67	64	67	47	68	43	81	60
Group	89	33	36	33	47	18	31	-	32
Unwilling to do	-	-	-	-	6	14	23	19	8
Respondents (no.)	9	33	11	13	16	22	13	16	133
	$X^2 = 35.82^{**}$			a=0.01			df = 14		
Fee payment									
Individually	100	97	100	100	94	86	85	87	93
Group	-	3	-	-	-	14	8	13	5
Unwilling to do	-	-	-	-	6	-	7	-	2
Respondents (no.)	9	33	11	13	16	22	13	16	133
	$X^2 = 15.07^{n.s.}$			a = 0.05			df = 14		
Pump use									
Individually	56	21	64	42	6	45	54	100	44
Group	44	76	36	58	76	41	33	-	50
Unwilling to do	-	3	-	-	18	14	8	-	6
Respondents (no.)	9	33	11	13	16	22	13	16	133
	$X^2 = 48.02^{**}$			a = 0.01			df = 14		

*1. San Ricardo 2. Bangad 3. Pulo 4. Pulong Bayabas
5. Agnaya 6. San Juan 7. Victoria 8. Pinagbayanan & Linga

Table 13. Cooperation score for each stated water adequacy group, wet and dry seasons combined.

	Highly inadequate (%)	Moderately inadequate (%)	Adequate (%)	Total (%)
High cooperation	60	47	32	39
Medium cooperation	8	21	31	26
Low cooperation	32	32	37	35
Respondents (no.)	36	28	165	231

Table 14. Farmer membership in associations other than irrigators' associations.[1] (Percent based on row totals)

Sites	None	One	Two	Three	Respondents (no.)
Nueva Ecija					
San Ricardo	33	44	23	-	9
Bangad	30	49	15	6	33
Pulo	73	27	-	-	11
Bulacan					
Pulong Bayabas	92	8	-	-	13
Agnaya	100	-	-	-	16
Laguna					
San Juan	77	18	5	-	22
Victoria	62	38	-	-	13
Pinagbayanan & Linga	75	25	-	-	16
Total	65	29	6	2	133

[1]Only one site, Pulo, had an irrigators' association. Of all farmers interviewed, 6% were members of an irrigation association.

In areas that are extremely short of water, there is greater potential for farmer cooperation. In the other areas, however, there is a need for stricter water control to better distribute the water, which requires both technical and social inputs. Tehcnical inputs require more irrigation hardware such as turnouts and control gates, as well technical skill in water management tied to knowledge of the agronomic needs of the rice plant. Social inputs include more communication between the NIA and farmers, and farmer organizations and cooperation in irrigation activities. Although the social inputs are easily theorized, they are more difficult than technical inputs to put into practice and often are more expensive, in terms of personnel and time, and in training programs for technicians and farmers. Other social inputs include studies into different alternatives for fee payments, revising the land tax criteria, and exploring various water distribution techniques.

ACHIEVING BETTER RELATIONSHIPS BETWEEN FARMERS AND THE NIA

Farmers generally have good relations and communication with the ditchtender. Paradoxically, while the ditchtender is theoretically part of the NIA personnel, he is frequently also in fact a farmer. Over half the respondents preferred the ditchtender to be involved with farming, and farmers perceived him as one of them. This somewhat removed the "NIA office" link between the irrigation system and the farmers. Farmers were also asked whom they preferred to see should they have an irrigation problem. Many preferred the ditchtender. Nevertheless, although many farmers saw the ditchtender quite often, it was more in a social context, so their communication was seldom about "irrigation." In this sphere therefore, there is a need for the NIA's higher-level personnel to increase their communication with farmers. Alternatively, the position of the ditchtender could be upgraded, and his responsibilities increased to cover water distribution within a limited area, and possibly the collection of fees. Many farmers were unaware of water scheduling dates, or that they could be exempted from paying fees under certain conditions. Some farmers suggested that the NIA personnel should come to the field to collect their fees rather than having the farmers go to the office. Apparently, there is a conventional rule of "first-come, first-paid", and the NIA fee collection loses out under this system.

In assessing the sociological aspects of fee payment, pertinent technical factors must be weighed. At the present, since the flow of water is governed largely by the topography of the area, and since some farmers inevitably are better served by irrigation than others, it seems unreasonable to charge a blanket irrigation fee for the use of water. The problem is whether farms nearer the source of water should be charged higher fees since they have better access to the water, or should they pay lower fees, since it is simpler to deliver the water to them. Or should irrigation fees be charged at all? Concurrently, the question of a meaningful increased land tax for farms better served by irrigation could be considered.

CONCLUSION

In the majority of the double-cropped areas covered by this study, the NIA has provided adequate water. Even in severely water-short areas, farmers realize there is not enough water in the whole irrigation system. Under moderately inadequate or adequate conditions, however, there seems to be a potential for better water distribution and a challenge to NIA personnel to gain the cooperation of farmers. Moreover, although farmers in the water-short areas tend to be more cooperative, they often suffer the consequences of acute lack of water, low yields. Thus, on the one hand, farmers in areas of assured water adequacy tend to be less cooperative since they already have free access to water. Farmers in water-short areas, on the other hand, exhibit a greater degree of cooperation in hope that it will improve their water supplies. The challenge is for both engineers and others involved in irrigation, including social scientists, to manipulate the physical and social environment to bring about better water supply to those areas difficult to irrigate, and more farmer cooperation in the well irrigated areas.

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Organization and operation of 15 communal irrigation systems in the Philippines

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ABSTRACT

Fifteen communal, or village, irrigation systems in Laguna Province were surveyed in 1969. The organization and operation of these systems is described, together with the farmers' evaluation of their irrigation, and estimates of their rice yields.

Almost 30 percent of the more than 1 million hectares of irrigated land in the Philippines is served by communal or private systems (Juinio, 1971). But because little information is available about communal irrigation systems (Christe, 1914; de Guzman, 1961; Ongkingco, 1972), experience valuable to the evolution of irrigation organizations in the Philippines is not being used.

There are at the present time about 16 communal systems in Laguna which are assisted by the National Irrigation Administration (NIA), and perhaps half that number sponsored by the Presidential Assistance on Community Development (PACD). Their sizes range from 14 to 1300 hectares, for a total of 4570 hectares throughout the province. In 1969 I surveyed 18 of these systems to gather information about their organization structure and operation. Interviews were held with farmers, mayors, municipal councilors, barrio captains, and even policemen. The results of the survey are reported in this paper for 15 systems (several smaller systems have been combined and are considered as one).

Figure 1 indicates on a map of Laguna the location of the systems, and the towns for which rainfall data are available. These data are summarized in Table 1, and reveal considerable variation within the province.

Prinza Irrigation Dam, Calauan

The Prinza Irrigation Dam in Calauan is the largest communal system in the province. It covers about 1300 hectares. The water comes from a lake in San Pablo and operates a hydroelectric plant servicing towns as far away as Los Baños and Pila. In addition to the usual seasonal problem common to most irrigation systems drawing water from rivers, there is a diurnal fluctuation in water flow due to the operation schedule of the power plant.

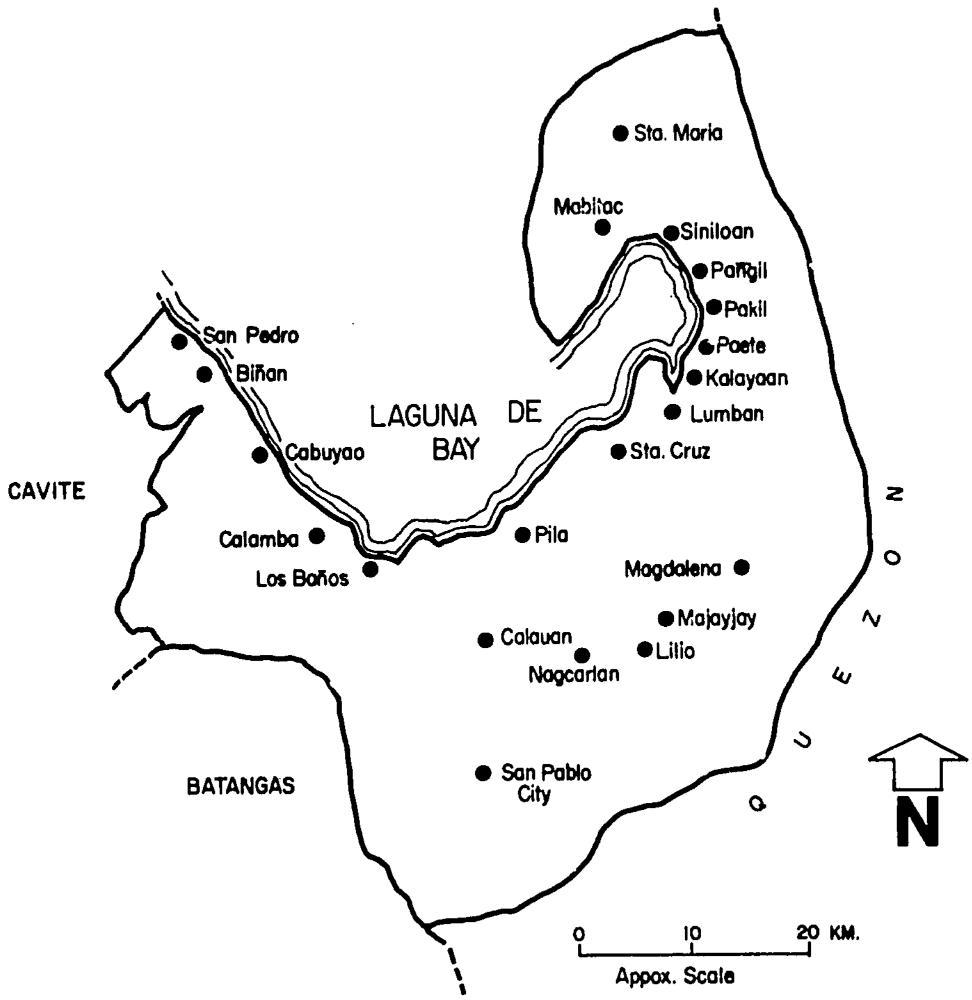

Figure 1. Map of Laguna Province

Table 1. Average monthly precipitation in centimeters for selected stations in Laguna, Philippines.

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	No. of years
UPCA, Los Baños	5.0	2.4	3.0	3.0	14.6	22.6	22.0	24.4	23.8	23.4	24.8	15.8	25-yr. average
Canlubang, Calamba	0.5	1.1	1.6	2.1	7.5	24.4	30.1	26.8	35.3	11.6	17.3	5.6	5-yr. average
Baybay, Siniloan	3.5	3.4	2.5	4.8	13.1	34.8	32.5	25.6	36.8	22.9	26.5	9.8	5-yr. average
Caliraya, Lumban	11.6	12.7	7.0	8.5	12.3	37.3	37.6	28.2	52.9	26.2	47.6	29.9	3-yr. average
Majayjay	12.0	9.7	7.3	11.9	11.8	35.6	33.7	36.8	47.6	33.5	44.6	30.5	5-yr. average
Pugadlawin, Mabitac	2.4	2.3	2.1	5.5	12.6	40.1	35.0	37.6	52.2	13.9	19.8	11.1	4-yr. average
Villa Escudero, San Pablo City	2.6	1.3	1.0	3.9	10.8	27.2	27.3	30.7	36.1	13.8	20.3	11.1	4-yr. average
Calumpang, Lilio	4.0	4.0	3.0	7.8	11.8	32.2	33.7	32.3	43.4	18.7	26.8	13.7	4-yr. average

A few farmers with fields close to the canals are satisfied with the operation of the system, but those whose farms are farther away complain about the inefficiency of the ditch tender. The deficient and irregular water supply makes weed control difficult which pulls down the rice harvest.

The whole system has only one ditch tender but he attends to only about 200 hectares. His responsibility includes weeding canals and repairing turnouts. He cannot do this alone so he hires labor on his own account. He estimates that this costs him about P100 per year. For his own services he gets one sack (44 kg) of rough rice per year from each of the 51 farmers served. In 1972 this would be worth about P1200.

His 12 years of service as a ditch tender provide him with the necessary experience to give advice to the farmers about the times to spray for pest control and the time to apply fertilizer. The farmers whom he serves also come to him regarding their problems in water delivery and schedule. His decisions are respected because he was appointed by the mayor to be the ditch tender.

The rest of the system has no ditch tender and the farmers themselves attend to water distribution and cleaning of canals.

Probably because of nearness to the University of the Philippines College of Agriculture and the International Rice Research Institute, and the effectiveness of government extension agents, the farmers are quite familiar with high yielding varieties, and with pest and disease control techniques. The farmers interviewed reported yields ranging from 3 to 4.5 t/ha.

Niugan System, Cabuyao

According to the farmers the Niugan system serves about 500 hectares during the rainy season but only 10 to 20 hectares are irrigated during the dry season due to low water supply. There are three locations along the river where temporary brush dams can be installed to raise the water level for conveyance to the fields. These locations are rotated each year so that the limited area served in the dry season does not always benefit the same farmers.

Some enterprising farmers have installed tube wells to assure a water supply in both seasons of the year. Some even provide water to nearby farms for a fee of 66 kg of rough rice per hectare per crop.

San Pedro System, San Pedro

The San Pedro system nominally irrigates more than 200 hectares but most of the farmers interviewed claim to have difficulty in getting enough water even during the rainy season. The dam is low so the water level cannot reach many farms. A suggestion was made that either the dam should be improved or, preferably, pumps should be installed to lift the water to the farms.

As a result of repeated water deficiency, yields were 1.7 t/ha or lower.

Magdalena and Mainpez Systems, Magdalena

The Magdalena and Mainpez communal irrigation systems are both within the town of Magdalena and irrigate about 170 hectares.

Unlike previous years when water was enough for everyone, the 1969 dry season placed many farmers in a tight situation. The town mayor, anticipating conflict between farmers in drawing water from the system, assigned a policeman to help distribute the meager supply. Occasionally the mayor himself went out with the policeman to watch over the water distribution. The farmers appreciated this act from the mayor even if they got water only 2 days a week. They said that they would vote for him in the next election.

Santo Angel System, San Pablo City

In 1968 PACD financed the cement and steel bars for the 120-hectare Santo Angel irrigation system. Members of the farmers' association constructed the system under the technical supervision of the NIA engineer. The farmers are now happy because they do not have to repair the dam every time there is a flood. Besides, all fields can now be well irrigated since leaks at the original brush dam have been eliminated. The good water supply assures the farmers of a twice-a-year harvest of 3.2 to 3.5 t/ha.

However, the interviews revealed that the farmers' association has become inactive since the construction of the dam. Farmers pay no fee and the association has no funds. Funds coming from farmers' irrigation fees are supposed to be used to hire a water tender to distribute the water equitably and to repair and maintain the system.

Pakil System, Pakil

The Pakil system was assisted by PACD in 1960 and now provides water to about 100 hectares. Members of the farmers' association pay 20 kilograms of rough rice per season for the use of water. This rice is used to pay the water master and labor hired when there is more work than the water master can do alone.

Like most rice fields along the lake, Pakil farms are invaded by rats. In this area, water lilies are abundant and they serve as hiding places for the rats which attack the rice plants at night.

Tubigan Farmers' Association, Biñan

The Tubigan system was assisted by PACD; it serves about 69 hectares. A pump was installed and the farmers claim to have doubled the yield to 3.2 t/ha because of better water supply. For the water the farmers pay 44 kilograms of rough rice per hectare planted.

Pangil System, Pangil

The 60-hectare Pangil system has no water supply problem in either season of the year and the farmers get yields between 3.5 and 4.5 t/ha. Although formerly assisted by the PACD, no formal organization of the farmers exists. Nevertheless, all activities are done properly. The vice mayor who is a farmer-land owner in the system, provides the leadership that ensures that the operation and maintenance of the systems is done properly. If work such as the repair and cleaning of the irrigation canal is needed the vice mayor informs the farmers and the work is done right away. The vice mayor also leads the campaign to kill rats.

Dalitiwan System, Majayjay

There are 40 farmers in the Dalitiwan system and all of them are under one water master, called a cabisilya. The water master directs the activities of the farmers in maintaining the system. When repairs of canals and checks are needed the water master tells the farmers where and at what time to report to do the job.

The water master gets nothing for performing his duties. He became the water master not by choice but because his father and his grandfather occupied the position and served the farmers of Dalitiwan for free.

According to the water master, who has occupied the position for more than 10 years, the position was given to his family because they owned the largest rice farm (3 hectares), and their land was nearest to the irrigation canal. He confidentially admitted that he would like to relinquish the position because he doesn't get anything out of it, but he could not do so because of community tradition.

Paete and Longos Systems, Paete and Kalayaan

The Paete and Longos systems are along the shoreline of Laguna de Bay and have the same problems. Few farmers plant during the wet season because the lake water inundates most of their fields. In addition, rats flock to the limited areas planted during wet season.

During the dry season the whole area is planted. There is not much problem in water supply and because of the rich soil few farmers apply fertilizer. With the high yielding varieties the farmers get as much as 4 to 5.2 t/ha.

The Paete system was improved in 1964, with assistance from the PACD, which brought the irrigated area to 30 hectares.

Romilo System, Siniloan

The Romilo system has no problem in water supply in either season of the year except in some higher portions which cannot be planted during the dry months. Yields are as much as 6 t/ha. Most farmers use new varieties and apply good techniques in rice production.

Lumban System, Lumban

A small river provides water to the Lumban system. Because the flow decreases during the dry season, farmers built a small dam to conserve rainwater for use in the dry season. Whatever is available during the dry season is divided by the farmers among their farms. During the wet season, the whole area has enough water.

Cortadilla and Mayputat Systems, Santa Maria

Farmers from the Cortadilla and Mayputat systems complain of watershed destruction which considerably reduces their flow of water during the dry season. Water is sufficient during the rainy season. During the dry season a limited area is planted and the water available is distributed among the farmers on a rotation basis. Many of the farmers whose land is far from the canal say that water distribution is unfair.

Taytay System, Nagcarlan

Water is sufficient both seasoms of the year in the Taytay system, and apparently the farmers do not encounter any irrigation problem. The barrio captain organizes the farmers to work on the system as needed. The area of the system is only 14 hectares and there are not many farmers to deal with.

In 1960 PACD spent more than ₱2000 on this system.

Balanga System, San Pablo City

The Balanga system is older than the farmers can remember yet there is no organization or procedure for the distribution of water. Farmers upstream and closer to the river are happy about the system and apparently do not realize that the downstream farmers barely get enough water especially during the dry season. Downstream farmers claim that if the dikes upstream were better maintained the water would reach them instead of returning to the river. The shortage of water has prompted these farmers to diversify their cropping system to include some eggplants. When asked if they would be willing to pay someone to maintain the system and distribute the water to the farms the replies were almost unanimous. They are willing to pay one sack of rough rice per year or the equivalent in cash, if they can be assured of water during the dry months.

Conclusions

Most systems studied have insufficient water supply during the dry season. The problem is aggravated when nobody is authorized to distribute the water among the farmers.

Even in systems with assigned water tenders, some farmers with areas farther away from the water sources express dissatisfaction over the equity of water allocation. To some extent this is the result of water shortage in the system which makes equitable water distribution even more difficult.

It is striking to note the satisfaction of farmers when somebody in authority, like a policeman or a mayor, attends to water distribution problems. Under these circumstances, farmers even seem to be satisfied with reduced water supplies. In addition, when a local official calls on the farmers to report to work they respond more readily than when asked by an ordinary farmer.

On the whole, most of the systems surveyed need some form of physical and social development. It seems that there is potential which only needs to be developed.

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The Pinagbayanan Farmers' Association and its operation

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ABSTRACT

Barrio Pinagbayanan, Pila, Laguna is the site of a new farmers' association. Organized around the need for two irrigation pumps, 19 rice farmers have joined together to make the purchase and improve their incomes. The role of the change agent is described in this paper, along with many of the details crucial to the effective functioning of the association. The associations' financial resources, its organizational structure, and its broader purposes are discussed.

Barrio Pinagbayanan is one of the pilot barrios in the Social Laboratory, a joint project of UPCA and SEARCA in Pila, Laguna. The Social Laboratory adopts an institutional approach to agricultural and rural development, aiming at building up an effective partnership between the government and the local people.

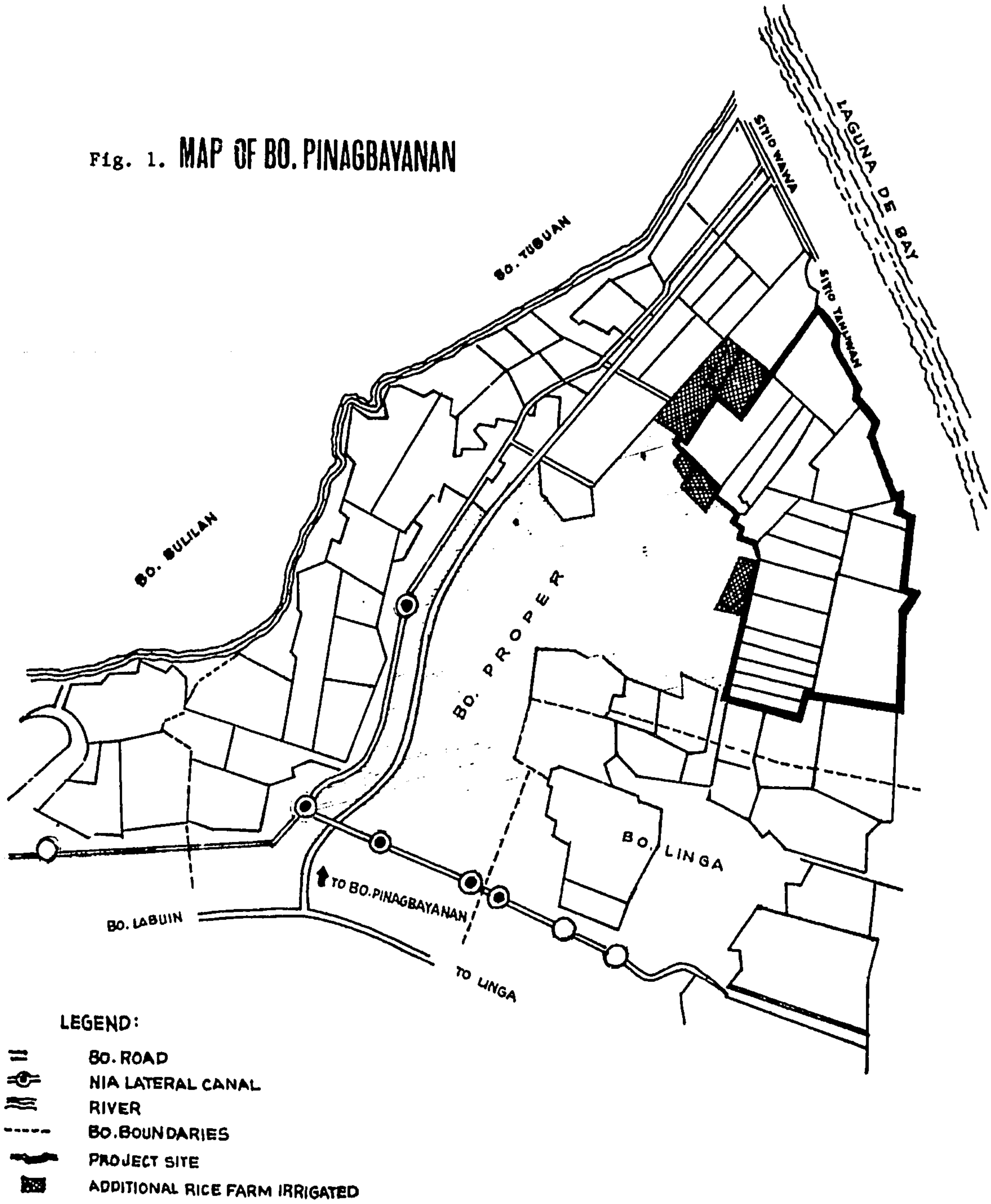
Like any other barrio, Pinagbayanan has numerous problems concerning agriculture, the foremost of which is irrigation water. Because of scarcity of water, farmers have organized themselves into a farmers' association. This cooperative undertaking seeks to solve the problem of inadequate irrigation supply by installing two pumps to irrigate 22 hectares of riceland.

BACKGROUND INFORMATION

In 1970, the barrio of Pinagbayanan (Fig.1) had a population of 1434 with an average household of six members. The heads of families had an average of 4 years of education while the housewives had an average of 3.5 years. Of 237 families in the barrio, only 24 percent were engaged in rice farming. The rest were fishermen, poultry and livestock raisers, employees, workers, and others engaged in various occupations.

Agriculturally, Barrio Pinagbayanan is basically a rice producing area. It has 67 hectares of riceland with 57 farmers who cultivate an average of 1.3 hectares each. A gravity irrigation system under the National Irrigation Administration covers the barrio, but only one-third of the area is adequately served. Inadequate irrigation supply prevents many of the farmers from fully using their land for optimum production. Thirty-three farmers, cultivating an area of 45 hectares, are adversely affected by the

Fig. 1. **MAP OF BO. PINAGBAYANAN**



lack of adequate irrigation. Their farms are located at the end of the main distribution canal of the irrigation system. Some of the farms are situated at higher elevations which makes water distribution more difficult (Fig.1).

During 1969, the average yields in the wet season were 2.14 t/ha (48.5 cavans) and in the dry season, 2.16 t/ha (49.0 cavans). Farmers use recommended cultural practices to some extent and extension workers from several government agencies are assigned to the barrio. The International Rice Research Institute (IRRI) and the University of the Philippines College of Agriculture (UPCA) have also been conducting field experiments through farmer cooperators.

Share tenancy is common. Forty-two percent of the rice farmers are share tenants, 32 percent are owner-operators, and only 9 percent are leaseholders (Table 1). Of the 57 farmers, 81 percent borrowed money for farm production or family purposes. The loans were obtained from relatives and friends, rural banks, private money-lenders, merchants, government institutions and landlords.

STEPS TAKEN TO ORGANIZE AN ASSOCIATION

In July 1970, a technician from the Social Laboratory paid a courtesy call on the barrio captain to explain the objectives of the laboratory and to notify the captain that the technician planned to live in the barrio with one of the farm families.

The technician's first activity was to map the houses in the barrio and to identify the heads of families. The technician visited farmers at work and at home which provided him ample knowledge of farm locations, conditions of the crops, and problems associated with local rice farming. He established rapport with the barrio people by attending social gatherings, joining informal discussion groups, and befriending the youth. He also helped local school authorities with a project on rice and vegetable production. In doing so, his role as a change agent was well understood by the barrio people. The close association with farm families greatly helped him to understand their values and ways of life. The technician did not rush headlong into the organization of farmers. Not until the barrio people recognized his role and developed confidence in him did he suggest the need for group action.

To identify the farmers who share common problems and interest in group action, farm and home visits as well as informal group discussions were conducted with the assistance of a farmer leader.

Farmers expressed numerous needs. The predominant one (cited by 28 farmers) was a better supply of irrigation water. They claimed the national irrigation system did not meet the water requirements of their farms especially during the dry season. The idea of organized group action to solve irrigation problems and increase rice production was emphasized during the discussions. The farmers became interested and asked how it could be done.

The informal discussions led to an organized meeting in September 1970 with 25 farmers attending. The farmers were informed of the nature of the project which involved their cooperation. A plan to install a 6-inch pump with a rated capacity of 900 gpm (56.6 lit/sec) that would cover a contiguous area of 20 to 30 hectares was discussed. Some wanted to expand the area of coverage to all the affected farmland.

Thereafter, weekly meetings followed. Nineteen out of 25 farmers returned to analyze the merits and benefits they could derive from the proposal. The topics discussed during these meetings were area of coverage and participation of farmers concerned, location of pump and willingness of landowners to participate, mechanics of repayment and financing, and capital investment required for the installation.

The initial setback

Financing the pump was the chief problem. The 19 farmers could not provide the P900 needed as a 10 percent downpayment for the pump. The pump was to be acquired from the Irrigation Service Unit. Only five could give their contribution of P50 each.

It was suggested that the landlords provide the initial investment an the farmers could pay it back after harvest. The landlords, however, did not support the idea and kept silent. Credit assistance from a rural bank was not feasible because the majority of farmers were afraid to borrow and did not have the necessary collateral. It was also felt that there were too many requirements imposed by the rural bank. The technician explained that by organizing themselves into an association, collateral would not be a problem, the association could act as the co-maker since it would have legal personality. In spite of this, the interest of some farmers sagged and three withdrew, breaking the contiguity of the proposed area of coverage. The possibility of forming a farmers' association with this group failed.

The breakthrough

The challenge of continuing the project and organizing an association was thrown back to the rmaining interested farmers. The farmers suggested meeting with other neighboring farmers. This group cultivates rice farms which were supposed to be covered later. Nineteen farmers attended this meeting and agreed to form a farmers' association, to be called the Pinagbayanan Farmers' Association.

Registration with the Government

After the farmers decided to form the association, six meetings were conducted to discuss and fulfill the requirements for registration with the Securities and Exchange Commission. The requirements were five copies of articles of incorporation and by-laws, a list of members and corresponding signatures, explanation of how the association objectives would be met, and a board resolution regarding compliance of a non-stock corporation.

The formulation of by-laws and the constitution was done before election of officers. This gave everybody a basic idea of the functions and responsibilities of the members and officiers who were to be elected. The by-laws were translated to local dialect (Tagalog) and made available to the members. They were patterned on the by-laws of the Farmers' Association for Commodity Exchange and Services in Santa Maria, Laguna, and the Santo Angel Irrigation Association in San Pablo City. The technician provided the leadership during the writing and adopting of the by-laws. Everybody actively participated in the discussions. The members gave suggestions and comments on policies concerning attendance, discipline, and responsibilities.

Most of the farmers did not have residence certificates. Since the residence certificate was a requirement for the registration of the association, the technician helped the members in securing their certificates in town.

When the by-laws were completed, elections for president, vice-president, treasurer, secretary, and members of the board of directors were held.

After 3 months of preparation, when all the pertinent papers were completed, they were sent through the provincial agriculturist and the Agricultural Productivity Commission to the Securities Exchange Commission for approval. The association gained legal status in January 1971. It had taken 7 months before the farmers were finally registered with the government.

Organizational structure

The association is a non-profit, multi-purpose cooperative operating primarily for the mutual benefit of the members. Membership in the association is restricted to farmers. The association can market agricultural products and buy inputs for its members, acquire and operate facilties for its activities, help members get farming information, and act as a bridge between the members and government programs. The association's board of directors is composed of seven elected officers who hold office for 1 year.

The members

Not all members of the association are residents of barrio Pinagbayanan. Six are from the adjacent barrios, but their farms are located in Pinagbayanan. Aside from farming, 16 were engaged in other livelihoods such as duck raising, poultry and livestock raising, fishing, harvesting, rig driving and as hired laborers.

The average household size was 7.4 members, with a low of 2 and a high of 12. The average member is 51 years old, the youngest is 35 and the oldest is 72. Fifteen had formal education ranging from primary to secondary grades while four had not gone to school. Ten are owner-operators, six are share tenants, two are leasees and one is part-owner. Each farmer cultivates an average of 1.2 hectares.

During the 1970 wet season the average yield of the members was only 1.5 t/ha. Only four members were able to plant in the 1971 dry season. On a total of 4.5 hectares, their average yield was 2.0 t/ha. The members already were using some recommended practices such as application of fertilizer, seed selection, straight-row planting, insecticides, and high yielding varieties.

PROJECT ACTIVITIES

Installation of two water pumps

After the association gained legal personality, weekly meetings were held with the farmers to discuss the irrigation pump project. Only 17 members having an area of 19.5 hecatares were involved because the other two members could get water from the national irrigation system. At the meetings the purchase of pumps, site and size of pumps, cost of installation, financing and sharing of payment were discussed. Instead of a 6-inch pump, the members decided to install two 5-inch water pumps to ensure that the farms would be adequately served during the dry season.

Next, the landlords were contacted. The landlords liked the proposal and gave their approval. The plan to have farmers install irrigation pumps was also presented to the administrator of the National Irrigation Administration (NIA) system covering the locality. The NIA approved the idea since their irrigation system could not fully satisfy the water needs of the farmers, especially in the dry season.

Application for two water pumps under a 10-year installment plan was made through the field representative of the Irrigation Service Unit. The president of the association acted as the applicant. With the application, the association had to submit a sketched map of the area, a tax declaration copy of the land, a copy of the association's articles of incorporation and by-laws, and identification photograph of the applicant.

Financing the project. Inasmuch as the members of the association could not finance the pump project, the local rural bank was asked to extend a loan. A feasibility study was prepared to determine the profitability of the project. The manager of the rural bank was also invited to one of the meetings to discuss the policies of the bank in giving loans to farmers and associations. This meeting enlightened the farmers and reduced their fear of borrowing money from the rural bank. The bank granted the association ₱10000 without collateral, payable in 1 year at 12 percent interest per annum. The amount of ₱8760 was left to the association after the interest and filing fees were discounted. The funds were released in 1971 and were deposited in the savings account of the association. Ten members of the association acted as co-makers to guarantee the loan. The participating farmers were required to sign promisory notes so all of them will be involved.

Before the funds could be released, proper authorization was required from at least two of the three officers of the association, and in addition the releases had to be countersigned by the technician. The treasurer only kept petty cash for immediate use.

Construction. After the irrigation pumps arrived the materials needed for the installation and pump accessories were bought in Manila. The president, treasurer, and the technician worked together in purchasing these materials. The total cost breakdown is shown in Table 2.

The members contributed free labor for drilling, construction of the pump house, and laying of the foundation. It became a group activity. The members were anxious to finish the construction immediately because some of the crops were already in dire need of irrigation water. The construction was finished in April 1971 in time to serve the needs of the farmers. People in the community as well as the members were happy to see the fruits of their labor.

The project scheme. The irrigation pump project involves the cooperation of both the landlords and tenants. They share the payment by deducting the irrigation fee before dividing the harvest. Owner-operators and leaseholders pay on their own.

Payment for irrigation was set at 16 cavans (of 44 kg) per hectare per season or 32 cavans per year. This quantity was arrived at on the basis of a P16 price per cavan of palay in order to repay the P10000 borrowed from the rural bank. The price of rice was set at the government support price to give allowance in case of crop failure. However, this rate was only applicable in the first year. Table 3 shows each farmer's pro-rated fee. The irrigation fee will be adjusted after the initial investment has been paid.

If the price of rice is greater than the assumed price, the extra amount will become a part of the savings of the individual participant.

Role of members. All the members actively participated in the formulation of policies and regulations for an efficient management of their project. The members convened at least once a month to discuss the problems that were vital to the operation.

To properly maintain and operate the pumps, two members who are knowledgeable were assigned to be in charge.
In the meantime since the association had limited funds to pay the operators, it was agreed that they would be paid in kind. Each operator will receive 15 gantas (approximately 27 kg) of palay per hectare every season. The operators also record the fuel consumed and pro-rate it for each member using the water. In this way the water requirement of each

Table 1. The tenure situation of 57 farmers in Pinagbayanan.

Tenure status	Percent
Share tenant	42
Leasee	9
Owner-operator	32
Part-owner	5
Lease-share tenant	3
Not ascertained	5
Others a/	3

a/ Farmer use of the land for a number of years is agreed upon without a rental fee.

Table 2. Initial expenses in the installation of the irrigation pumps.

Iteminzed Expenses	Amount
10% down payment for the pumps and membership fee	₱ 1442
Purchase of pump accessories	2080
Purchase of construction materials	1636
Driller-contractor's fee	800
Purchase of storage tank and drums	727
Service fee	100
Wages for hired labor	456
Crude petroleum and gasoline	660
Food	408
Miscellaneous	100
T o t a l	8409

Table 3. Estimated irrigation fees in tons pro-rated according to size of farm of participants.

Farmer	Area of farm (has)	Irrigation fees 1/ Tons of palay per year	Peso equivalent per year
Biluan, Emilio	1.02	1.44	522.56
Campanero, Lorenzo	2.92	4.11	1,494.08
Castillo, Marcelino	1.43	2.01	732.80
Datay, Exequiel	1.75	2.46	896.00
Escasura, Antonio	1.75	2.46	896.00
Espinosa, Teodoro	1.38	1.94	705.60
Gutierrez, Felimon	0.29	0.41	149.44
Javier, Apolinario	0.26	0.36	132.16
Lopez, Pedro	0.29	0.41	149.44
Manangkil, Domingo	1.24	1.75	635.20
Palasin, Oesario	0.32	0.46	166.08
Pelasin, Ciriaco	0.29	0.41	149.44
Penuela, Placido	1.12	1.58	575.04
Prescilla, Maximo	1.50	2.11	768.00
Ravelas, Olympia	1.10	1.54	560.96
Tope, Nazario	1.14	1.61	586.56
Vergara, Jose	1.75	2.46	896.00
T O T A L	19.57	27.50	P 10,017.60

1/ Based at P16.00/cavan of 44 kg. per season.

farm served by the two pumps is also recorded.

The members are all responsible for the maintenance and repair of dikes to minimize losses from seepage and percolation. Before and after the planting seasons, all the members worked cooperatively in repairing the embankments of the irrigation canals.

The operators are responsible for the distribution of irrigation water over the whole area. Each member is given a water schedule according to which water will be available. This was done to avoid conflicts between farmers and to insure fair water distribution. Members found violating the regulations were to be fined heavily.

Each member is obliged to get his own fuel from the storage tank located in the yard of one of the members. The secretary records the amount taken and the members who use it. A member hauls the fuel only when the water is allocated to his fields.

Production loans

Aside from the loan granted to the association, eight members were also given production loans amounting to ₱9795. The average loan was ₱445 per hectare in the wet season and ₱442 per hectare in the dry season. The loans were without collateral and payable in 6 months (every cropping season). The individual member is responsible for repaying the loans with the rural bank. The members did not borrow large amounts because it was the first time they had borrowed from a bank. Also they feared that they might not be able to repay the loan.

A farm plan and budget prepared by the technician was the first requisite for a member who planned to apply for production loans. The borrower and his wife signed an application paper and a promissory note. A co-maker's statement signed by the president, treasurer, and a member recognized by the bank was also required. It takes about a week before the loans are approved and released so that a farmer must apply 2 weeks before the onset of the planting season.

To avoid diversion of loan funds, savings accounts were opened for each member. The amount loaned was deposited in their respective accounts, and were made available only for the scheduled loan releases indicated in the farm plan and budget. The technician also checked to make sure that funds were used appropriately. Operations involving fertilizer application, use of insecticides, and planting operations were supervised. The members were required to follow the recommended cultural practices indicated in the farm plan.

Partnership with government and private institutions

The association serves as a link between the government and private agencies in executing agricultural development programs, in conducting field experiments, and in training students of agricultural extension and social sciences. The technician represents the association in these activities. Before any activity is undertaken, however, the decision of the members concerned is sought. Some of the activities in which the association has been involved were a rat control program conducted by the Bureau of Plant Industry, a trial of an experimental drier and an irrigation planning and design project with UPCA, a water management study with IRRI, soil analysis by the Bureau of Soils, and construction of a multipurpose pavement with the Presidential Arm on Community Development supplying ₱1000 for materials and the members supplying the labor. A multiple cropping project assisted by IRRI was also conducted in the barrio.

THE OUTCOME

Increase in rice yield. The irrigation pumps installed by the association contributed greatly to an increase in rice yield. Without sufficient water, production inputs could not be properly used for optimum production. Harvesting of the first crop started in October 1971 and ended in December. The second crop was harvested in May and June 1972. Table 4 shows the net yield of two harvest seasons before and after the installation of water pumps.

Another factor that contributed to the increase was greater use by members of recommended cultural practices. Aside from the increase in yield per hectare, the members will be able to plant two crops a year or even five times in 2 years. A still better situation lies ahead if the members will go on with the same cooperative spirit. Input use is shown in Table 5.

Repayment of loans. Right after the harvest of the first wet season crop, the members delivered their irrigation fee in the form of rough rice to the house of the treasurer for safekeeping. The association, through its president and treasurer, looked for market outlets. Full discretion was given by the members to the officers in selling their rice contributions. This is an example of the trust and confidence exhibited by the members in the association. Before finally disposing of the rice, however, the members concerned were informed of the price set by the buyers.

By selling the rice in bulk, a better price, ₱30.22 per cavan (44 kg), was received for 186 cavans (8.2 t) that were collected than if the farmers had sold it individually. The total sales amounted to ₱5620. The money was immediately deposited in the savings account of the association. Depositing of money is usually done by the president, the treasurer, or the technician.

Table 4. Yields before (1970-71) and after (1971-72) installation of pumps.

Crop year	Yield (t/ha)	
	Wet season	Dry season
1970-71	1.5	2.0*
1971-72	2.6	3.3
Increase (%)	75	61

*Based on two members with an area of 2.3 ha.

Table 5. Use of recommended cultural practices of the 17 members of the Association before and after installation of the pumps.

Practices	Before	After
	Number of farmers	
Use of high-yielding rice varieties	5	17
Use of dapog	6	17
Straight-row planting	7	15
Application of fertilizer	15	17
Weed control (rotary, weedicide and hand weeding)	12	17
Use of insecticides	9	17
Seed selection	10	11
Germination test	8	12

In the dry season, the members paid their obligations in cash rather than in kind. They were given a free hand to sell their rice to relieve them of the burden of bringing it from the field to the house of the treasurer. Two members were designated to remind other members of their contributions and obligations. The members paid their obligations to the president or the treasurer who in turn issued receipts for the money received. The total collection amounted to ₱5971 and was also deposited in the savings account of the association.

The association was then able to repay its ₱10000 loan from the rural bank of Pila. This was a remarkable achievement and it attests to the members' concern for living up to their commitments in a cooperative way.

The production loans were 100 percent repaid by the eight members of the association who took out the loans. They paid back the loans even before the maturity date. The technician encouraged them to pay in advance to establish a reputation with the rural bank. It will be easier for the farmers to acquire subsequent loans in the future.

Expansion of area of coverage. Due to the availability of water, more land was cultivated and additional farms were served by the pumps. The rice land served by the pumps increased from 19.5 to 22 hectares. With this additional area, the association now charges the members an irrigation fee of 10% of their net harvest. The fee serves as an additional source of income for the association that can be used for maintaining the pumps.

Effect on other individuals. The association's novel idea of installing water pumps on a cooperative basis became an example for other farmers' associations. The association has also been instrumental in motivating five landowners to invest in water pumps for supplementary irrigation.

PROBLEMS ENCOUNTERED AND THEIR SOLUTIONS

Not many problems have been encountered in the organizational setup of the association. The members and the officers are aware of the policies and the responsibilties expected of them. Problems are threshed out during meetings with everybody actively participating by giving suggestions and recommendations. One problem occurred in the installation of the second pump. The drilling operation was unsuccessful. It was decided to relocate the pump site but the association lacked money to finance the job. Two members paid their irrigation fees in advance, however, and with the services of another driller the reconstruction and relocation of the pump was accomplished.

Another problem, at first, was the use of the pumps beyond the time alloted for each member. The problem was solved by laying down policies for the use of the pumps. A schedule of water distribution was made for the members to follow.

The association asked the help of the Department of Agricultural Engineering, UPCA to improve the performance of the two irrigation pumps. A test showed that the pumps were only delivering 480 gpm (30 lit/sec) at maximum speed. A change from direct coupling to a V-belt connection between the engine and the pump increased the water delivery.

To reduce water loss through seepage and percolation, an irrigation distribution lay-out was developed to widen and properly construct the canals.

One member became a problem to the association because, due to personal conflicts with some of the members, he sometimes did not want to follow the water distribution policies. The officers and the technician confronted him and he admitted his mistakes. The members could have dropped him from the membership but he was given the chance to change. Besides, his farm is situated at the center of the area served by the pumps, and dropping him from the membership would mean changing the canal layout or acquiring an additional pump so that the farming operations of other members would not be affected.

A few members have not paid the full amount of irrigation fees set by the association, but it has nevertheless been able to repay its obligations with the rural bank of Pila. The delinquent members were given time to pay their balance in the next season.

LOOKING AHEAD

Rural development is a slow process since it involves human and economic factors. Organizing farmers to work cooperatively to achieve a common goal is helpful in leading them towards rural uplift. The Pinagbayanan Farmers' Association, although young, has full confidence that its members' objectives can be realized.

There are still many things the association needs while continuing its plans. One of the big problems is lack of financing. The members of the association hope that government and private institutions will extend financial assistance to them, to speed the implementation of new plans.

To fully use the irrigation water from the pumps, the members plan to line the canals with concrete. It would make water distribution more efficient and minimize losses due to percolation and seepage. Some other plans are to: (a) Provide the members and officers of the association more training in management techniques such as keeping records and making business transactions, (b) Purchase farm equipment such as hand tractors and small farm implements for use in farming operations. This will enable the members to follow their calendar of operations smoothly. (c) Build a drying pavement and a warehouse to store the crop. Farm production inputs would be readily accessible to the members. (d) Undertake regular training on rice production to keep members informed of advances. (e) Encourage savings as a means of acquiring or forming capital. This would increase self-reliance.

CONCLUSION

Cooperative undertaking through farmers' organizations is not an easy task because human factors are involved. The situation, needs, and interests vary among individuals and places so that there is no stereotyped procedure to follow in forming a successful farmers' association. The objective must not merely be to organize, but to create leadership, and to hasten education and training for a viable and functional organization.

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Making an irrigation association a vehicle for development: preliminary observations on a group of Philippine rice farmers

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ABSTRACT

The history of a pump irrigation project in Catanduanes, Philippines, is traced. Three pumps were introduced to the area in 1969, and a farmers' association established. The problems of this association and its relationship with the man responsible for installation and operation of the pumps, are analyzed. In 1972, an additional project was initiated which attempted to strengthen the association. Its progress in dealing with problems of land reform, water distribution, and credit are assessed.

INTRODUCTION

This paper examines some of the possibilities and obstacles confronting a group of farmers in Catanduanes Province, Philippines. The most basic of the problems are the absence of reliable water distribution, a lack of credit, the absence of land reform, and the need for knowledge about modern cultural practices that have been associated with the high yielding rice varieties. To help them deal with these difficulties, the provincial rice specialist of the Agricultural Productivity Commission and I began a project in July 1972, with the assistance and financial support of Philippine Business for Social Progress (PBSP), a Manila foundation whose resources are supplied by most of the biggest firms in the Philippines.

Briefly, the project provides supervised credit (the supervision coming mostly from the provincial rice specialist) to farmers who are able to arrange a 70-30 sharing agreement with their landowners, and who meet other qualifications that are accepted by the existing farmers' irrigation association as being appropriate. The irrigation association served as the organizational and operational mechanism for the project.

This project has been the only organized exposure that farmers in the province have had to the principles of land reform and supervised credit. At present the province has only one representative of the Department of Agrarian Reform and he arrived in November 1972. Furthermore, there is no source of credit available for landless farmers (i.e., tenants): there is no Agricultural Credit Administration branch, and the local rural bank declined a suggestion that they participate in the Agricultural Guarantee Loan Fund program of the Central Bank.

As the first harvests begin to be taken from the fields, it is too early for broad conclusions based on empirical evidence, but problems in the organization and operation of the project can be delineated and some observations about the usefulness of this type of approach to development can be made.

BACKGROUND: THE ASSOCIATION

The project is situated in the barrio of Pajo San Isidro, about 4 kilometers from Virac, the capital city of Catanduanes Province. Pajo is a community of near subsistence farmers. Accurate figures for such items as average income, literacy, and population density (in fact, even for population) are unavailable, although in the near future, PBSP will sponsor a survey which will cover these and other parameters in detail. The rice tenants who are participating in the project exist in hand-to-mouth poverty. Besides rice farming, there is some corn, camote (sweet potato), and gabi (taro) production. Some people find casual work with the Provincial Government or elsewhere in Virac, especially when the Bureaus of Public Works and Public Highways have funds. Some of the farmers also fish part time.

Pajo, like the rest of the province, has no pronounced wet or dry season. The temperature and number of sunny days permit at least two rice crops per year, given good irrigation. But the island of Catanduanes is in the center of the typhoon belt. The typhoon season generally lasts from May to January. The storms vary in intensity from mild to violent and, as might be expected, the possibility of their occurrence causes much apprehension among the farmers.

In 1969, an irrigation association was started in Pajo. The National Irrigation Service Unit (ISU) provided three pumps to bring water from the Santo Domingo River to about 40 has. of rice fields in Pajo. A downpayment of 10 percent of the purchase price was advanced by the provincial government for the pumps and the irrigation association agreed to amortize the remaining cost in increments of 10 percent plus interest for 9 years.

The association's president played a crucial, if not indispensable, role during the formation and early organization of the association. Although the president is a landowner in the barrio, he had suggested to the farmers 5 years earlier that they form a group which would have as its major goal the introduction of irrigation to the barrio. At that time, much of the land was devoted to corn and rice was grown only once a year. By 1968, the president was able to use his influence with provincial politicians to arrange to buy the ISU pumps. The province provided the downpayment (which was to be repaid by the association), but the president mortgaged his own riceland as collateral to the province. When the pumps arrived they were situated on the president's property. The president was the only association member who knew how to operate, maintain, and repair the pumps. In addition to him, a vice president, secretary, treasurer, and auditor were elected by the approximately 80 landlords and tenants who composed the membership of the irrigation association. The president, however, had by far the most important position and actually performed all the functions of the treasurer and auditor. He also tried to teach the farmers modern techniques of rice production, and he brought "resource people" to Pajo from government extension agencies.

Before the pumps began operation, the association, led by the president and advised by some engineers, laid out the irrigation canals. The actual construction of the canals was done by the association members under the bayanihan (mutual help) system. Each farmer who dug 20 meters of canal was supposed to be credited with ₱20 worth of "stock" in the association. The irrigated area was divided into zones and a director was elected to supervise water distribution in his zone and to report complaints or irregularities to the president. An irrigation schedule was devised and, according to the president, all members were advised when each zone would receive water. An irrigation fee of 10 percent of the harvest after removing the harvesters' share was to be paid by each farmer. This amount would be collected by the directors and turned over to the president during harvest. The fee was supposed to cover the costs of operating, maintaining, and repairing the pumps as well as amortizing the ISU loan.

NEED FOR AN INTEGRATED PROJECT

Previous efforts in rice production in this province have been piecemeal, centering on extension work and, occasionally, availability of quality seed and free chemicals from the Agricultural Productivity Commission or the Bureau of Plant Industry. In addition, past projects seemed often to be one-shot affairs that left farmers with some knowledge of modern techniques but without the means to implement what they had learned. In the short run, yields might temporarily be increased but, when the free chemicals had been exhausted or the farmers' classes ceased, farm practices returned to what they had been and no lasting progress was made.

A key deficiency of the previous projects was that land tenure was ignored. Although in violation of existing laws, the system followed in Pajo as in much of the Philippines, is that the landowner and the tenant equally share the costs of production (but usually it seems that the tenant pays the bigger "half") and the fruits of the tenants' labor. Then at harvest time (in Pajo) the production is split between the landlord and the tenant after deducting the harvesters' share (about one-sixth of the harvest) and the irrigation fee. In the past, this system may have been adequate for both parties: the labor involved in rice production was dramatically less, and the sharecropping relationship provided security to both the landowner and the tenant. Now, however, the situation has changed and the demands, both for national production and individual (farm by farm) equity have also changed.

The absence of land reform and credit was taking its toll during the early stages of the irrigation association. The association president said that the association was not working out as originally planned. Not only were the irrigation fees not sufficient to pay for the amortization of the ISU loan, but often he had to pay for spare parts and fuel out of his own pocket. (This experience is far from unique. The ISU central office in Quezon City reported that its success in collecting amortization payments from farmers' associations was so poor that for a while it discontinued providing pumps to associations and only made arrangements with private individuals.) Furthermore, the president said he had to redeem his mortgaged land, which was used as collateral for the downpayment, with his own money. Even with irrigation, rough rice yields were only about 0.9 to 1.3 t/ha. When we suggested beginning a project with a few member farmers on a pilot basis, involving a new share rate, supervised credit, and possible modifications of association procedures, he agreed to the idea.

ORGANIZATION AND OPERATIONAL PROBLEMS

Intra-organizational obstructions

Strong differences of opinion existed within the association that threatened its disintegration. There seemed to be a wide credibility gap between the president and members. The president complained that the members were uninterested in helping themselves and were content to let him do all the work. He recited his efforts in forming the association, securing the pumps, keeping them operating, paying for maintenance from his personal funds, and in general assuming responsibility for running the organization. He said that the farmers did not pay enough dues to the organization to support it and that he had been forced to raise the irrigation fee to 15 percent of the harvest. Finally, he said that some farmers were "out to get him". Two complaints had been lodged with the Provincial Fiscal against him, one by an association director and one by a tenant who claimed that the president had influenced his landlord to eject him illegally and without cause from his ricefield. The president implied that he was fed up and was ready to resign.

The association members had their own accusations. They said that the water distribution was often inadequate and the operator of the pump, a tenant of the president, showed favoritism. Many times the president's work with the Bureau of Public Works caused him to be away from the barrio, and even away from the province. During his absences the pumps were not allowed to operate which created chaos in the fields. The farmers also claimed that the president had promised them "stock certificates" proving that they had contributed to the construction of the canals, and membership identification substantiating their belonging to an organized group. None of these certificates had been presented. In addition, the president had the only copies of the association constitution and by-laws; the members saw these only on the day that they were signed.

The president, they said, ran the whole show and refused to give receipts for irrigation fees collected, refused to let the treasurer see the account books, and refused to let the auditor perform his duties. The farmers suggested that the president's claims that the fees were not sufficient for the needs of the association were disingenuous. One of the members' worst fears was that if they confronted the president with their grievances, he would pull the pumps off his property, or otherwise dispose of them, which would be disastrous for the farmers. They were not even sure whether the association or the president was the real owner of the pumps. Some members wanted a new president, but were afraid that bringing up the subject would mean the end of the association and of the pumps.

The gap between the president and the members, in my opinion, stems from faulty communications. The president has indeed run a one-man operation. If it were not for his political influence with the late Governor, his leadership in the barrio community, and his mechanical knowledge, the association and the pumps would never have come into use at Pajo. In the early days of the association's existence, the members probably were reluctant to participate actively because they were used to the president's leadership, because they respected his political influence, and perhaps because they lacked confidence in their ability to do what he was able to accomplish. Both he and the association members may have simply become comfortable in this relationship.

Trouble began when the irrigation fees failed to reach expected levels. Partly, this failure was due to the low production and partly, according to scattered reports, because collection techniques were faulty. There was no accounting system for the fees. Some of the farmers whose fields lacked water at crucial times, or who claimed such a lack, refused to pay the required amount. It is also likely that some farmers incompletely understood their obligations to the association, since the by-laws and constitution seemed never to be available, and that their identification with the group was not strong. The charges of favoritism by the operator seem to be based on facts. Since receipts for fees were rarely issued to the farmers, and since the farmers never knew for sure what the income and expenses of the association were, suspicion developed. Outside sources (municipal councilors, fiscals, and others) agree that the financial papers of the association were inaccessible and that the president was very possessive in his management of the group. There have been many indirect suggestions, although no outright charges and no proof, that the president was using association funds for his private expenses.

As time went on, the two parties grew farther apart. In fact, without the intervention of the project the association probably would have dissolved. Clearly, the success of the project and the life of the association both depended on the president's participation and approval. The problem, then, was to attempt to reconcile the two parties. This was accomplished, at least temporarily, through the intervention of the provincial governor. After listening to the above analysis of the problem the governor spoke at length with the president and with the members. He convinced the president that it would be in everyone's best interest if certain reforms were made in association operations. Then new elections were held in which the president was re-elected, the financial records were turned over to the treasurer, the balance of the association's fund was deposited in a bank account, the association was registered with the Securities and Exchange Commission, and new directors were elected. New irrigation zones were formed, work began on a gutter that had been destroyed by a typhoon, and some of the members showed increased interest in the association. It seemed that a new start was being made.

Land tenure

Both at the beginning of the project and during its operation, landowners, as might be expected, had difficulty accepting the concept that their tenants would be allowed to keep more of the harvest than the usual 50 percent. This problem persisted even though it was possible to show that the landowners would receive the same number of sacks of rice, if not more, than they usually got under the 50-50 system, if the harvest reached its expected level. Many wondered why we would not agree to an equal responsibility for the costs of production, offer technical assistance, and then allow the 50-50 arrangement to continue. We refused to consider this arrangement. It had to be repeatedly explained that the only choices the landowners had were to accept 70-30 and the possibility of an increased income from their land (due to the introduction of chemical inputs and modern techniques) or to continue with the 50-50 sharing without any assistance. This dispute caused considerable discussion, but eventually many landowners agreed to try 70-30 for at least one cropping season.

Landlord cooperation was essential for the project since there was nothing to coerce them into following the Code of Agrarian Reforms (Republic Acts 3844 and 6389). To secure their cooperation, they had to be shown that if their net income from their land was affected at all, it would increase. At the same time, it had to be proved to the farmers that the approximately ₱600 per hectare that they would be spending (an almost inconceivably large sum) would not drive them hopelessly into debt, but would in fact raise their net income.

A questionnaire was distributed to a group of interested tenants and they were asked the name of their landlord, the size of the farm or the number of man-days it takes to transplant it, the average yields for the wet and dry seasons, average production costs for all inputs used, and the cash contributions for input purchases made by the landowner. For each questionnaire returned the following items were computed: the gross breakeven point, the net income of the landowner, and the net breakeven point.

The net breakeven point is defined as the minimum yield required in order that the 30 percent landowner's share would not result in less rice than the amount he previously received under the 50-50 sharing arrangement. As shown in Table 1, the net breakeven point for a typical farmer is 3.14 t/ha.

The gross breakeven point is based on the yield required to entirely repay a production loan of ₱600 per hectare (plus 10 percent interest) for the current crop, and in addition have adequate savings for the costs of the succeeding crop. Table 2 shows a gross breakeven point for 4.31 t/ha for farms with production costs of ₱600 per hectare. If this yield level is attained, the landlord's 30 percent share would be considerably larger than his previous 50 percent share of 1.39 t/ha. Yield levels over 4 t/ha demand a high level of management from the farmer. so the gross breakeven point represented a target, while the net breakeven point was a minimum requirement. It was also understood that the arrangements could be modified when necessary.

Working out the details of the agreement between the landlords and their respective tenants was difficult. Ultimately, however, owners and farmers verbally agreed that the harvest would be share 70-30. The farmers are solely responsible for the production loan. The situation is not ideal, but it was the best that could be attained at the time. The landowners are free to renege on the agreement unless they value the sanctity of their own promises or unless an outside authority forces compliance with the Code of Agrarian Reforms.

Another problem connected with the agreements between the landlords and tenants is that tenants often are relatives of the owners. As a result a desire for preserving a cordial relationship with a landlord can overcome the desire for land reform, especially when the outcome of land reform is by no means certain. This is an important consideration in our project because the association is composed of both landlords and tenants. Ideally, the membership probably should be restricted to tenants and owner-operators, but to attempt such a change at this time, given the delicate factor of consanguinity, would be precarious. Eventually, though, the change should be made, for then tenants would be better able to appreciate that they have economic interests which are legitimate and which clash with those of the landlords.

The operations of the project are also affected by the many lots that are mortgaged and re-mortgaged to such as extent that it is difficult to tell who, exactly, is the usufructuary. That, combined with the kinship problem, makes constructing viable contracts that will be honored by all parties concerned a demanding task.

Delayed implementation

The first plantings under the new project were supposed to begin in April 1972. Harvesting would thus have taken place in July and August before the worst part of the typhoon season (October-December). The funding was delayed until the middle of June however, mainly because of PBSP requirements which demanded the consultation of the president. From April to June, he was out of town on a private contract. His absence not only delayed fulfilling the PBSP requirements, but, since his presence was necessary so the pumps could operate, land preparation

Table 1. Calculation of net breakeven point.

Previous yield:	1.39 t/ha
Landowner's share @ 50%	0.69
Landowner's share under 70-30:	0.69
Based yield of which 30% is landowner's share:	2.30
Harvesters' share (16.7%) and irrigation fee (10%)	0.84
Net breakeven point:	3.14 t/ha

Table 2. Calculation of gross breakeven point.

Production loan	P600/ha	
Interest @ 10%	60	
Expense for succeeding crop	600	
Total expenses:	1260	
Yield required to meet total expenses: P1260 at P25/44kg		2.22t/ha
Landlord's share @ 30% of subtotal		0.94
Sub-total		3.16
Harvesters' share (16.7%) and Irrigation fee (10%)		1.15
Gross breakeven point!		4.31 t/ha

was also postponed. When he finally arrived and the pumps began to operate, the irrigation schedule was forgotten as farmers frantically raced to their fields and began plowing. As a consequence, farmers have complained during the cropping season that they do not get water when they need it. The pumps can adequately serve the irrigated land only if a schedule is followed. The water problem is probably not as bad as it has been in the past, but it is still serious. Every so often charges of favoritism arise, but so far these have been resolved.

Urea was supposed to be used for the basal application and was ordered from a local store. The Manila floods prevented its delivery and forced us to use urea for some farmers and ammonium sulfate for others. Some farmers would therefore have paid more for the same amount of elemental nitrogen. It was decided to pro-rate the cost of all fertilizer by dividing the total cost by the total number of transplant-man-days and have each farmer pay according to the size of his land. This solution required careful explanation to people whose grasp of mathematics is limited, who are skeptical of any change in plans that involves their money, and who have been cheated before.

The peripatetic pump

When the project was just beginning the rift between the president and the members was about at its widest. One of the three ISU pumps had been relocated to a new site not on the president's property. It had been moved because the typhoon had destroyed the gutter, a long, elevated conduit made of sheet metal to carry water from the pump to a point where it could irrigate the lower half of the project area. The new site was downstream and permitted in connection with the other pumps, the irrigation of all the land. The president, acceeding to the suggestions of the farmers, led by the barrio captain (a potential successor to the presidency of the association), said he was ready to turn the pump completely over to the Barrio Council for operation. After a few weeks of operation, during which farmers were using the water for land preparation, it seemed that the move might be permanent. When the first seedbeds were made and the rice sown, however, the farmers learned that during high tide the pump was irrigating their seedbeds and fields with salty water. They learned this only when some of the seedbeds were wiped out. The dilemma was whether to keep the pump at its new location, operating it only during low tide, or to move it back to the president's land and rebuild the destroyed gutter. Many farmers were strongly opposed to removing the pump since they were satisfied with the water distribution and feared that water would be inadequate if they lost control of the pump. But the river level dropped due to the lack of rain and the pump was able to operate only a few hours each day. It eventually was removed, the gutter was rebuilt, and the farmers in the lower area were able to get water from the main canal. But some bad feelings remain between farmers in the two geographic sections. This is partly because water passes through the higher section before reaching the lower and the opportunity for irregular or unscheduled diversion of water exists. It also seems that participation in group meetings is better with those farmers in the higher section. Moreover, there are more farmers participating in the project (and receiving financial assistance) in the higher group. During the next season, we will try actively to recruit farmers from the lower group for participation in the project.

Seepage

Another problem only recently discovered is that the soil in many rice fields is very porous. Some fields that are fully irrigated will dry and crack within one day of being drained. Much of the fertilizer probably is leaching away, although the farmers say there is a noticeable difference in the growth of the rice that has been fertilized. Granular lindane has been ineffective, though, in controlling "minor" rice pests such as armyworms, nymphalids, whorl maggots, leafhoppers, and leaf folders. Interestingly, there are few signs of stem borer damage but many signs of damage by the "minor" pests, regardless of whether insecticide has been applied. Since lindane is the most expensive chemical we asked the farmers to buy, they began to balk at further applications, especially when they realized we are having them spray for the "minor pests". Next time, we will probably alter fertilization, by splitting it into three doses instead of two, and perhaps not use granular insecticide until stem borer damage warrants it. Also, we would like to explore methods of reducing water losses into the soil, if this is possible.

Debts

Complicating the failure of lindane is the claim of many farmers that they are surprised at the amount of <u>utang</u> (debt) they have acquired during the cropping season. Their reaction was unexpected because expenses are actually below our estimates and the farmers were all told in advance that they could expect to spend ₱600 per hectare. Perhaps when they see their names on paper accompanied by bigger debts than they have ever before had, it hits them harder than merely having it explained at a meeting. The surprise has resulted in some reluctance to apply chemicals, especially insecticide.

The president and the pump

An interesting effect of this project is that, according to reports, the president and his family feel that the diffusion of his autocratic command of the association has somehow eroded his position in the barrio. When the association began to consider buying a small rice drier, if funds become available, he offered to buy it with his own money "for the benefit of the farmers," as if he wanted to continue the dependency relationship. In relation to this, the association members with one exception, are still unsure who owns the pumps, but they are now inclined to give themselves the benefit of the doubt. According to the office of the Provincial Fiscal, the president signed the downpayment agreement with the province not as an individual, but in his capacity as president of an organization; thus, when the payments are completed, the pumps belong to the association. The ISU central office has a different idea; according to their records, the pumps are in the president's name as a private individual and when the amortization has been paid completely, the pumps will legally be his. The association members, with the one exception (the present treasurer), do not know this. A way will have to be devised to transfer the ownership to the association without unduly antagonizing the president. The president's active participation in the association is still necessary, but eventually the members will have to learn to get along without relying so heavily on him.

CONCLUSIONS

The project has not been in existence long enough to determine its success or failure in reaching goals not directly related to irrigation, but dependent on it. These goals, as stated in the project proposal, were both specific and general: to increase rice production to a level that would permit the farmers to use tested cultural practices including the application of chemicals and fertilizers; to introduce land reform concepts to the farmers and to have them understand that the Code of Agrarian Reforms provides them with both rights and responsibilities; to enhance the farmers' awareness that cooperative effort can help solve their irrigation problems, and is indeed indispensible if they are to have effective irrigation; and that this communal effort can also be applied to other problems. A second group of goals included the positive consequences derived from having an increased income, however slight. The chance always exists that very poor rice farmers, no less than wealthy landowners, will spend their income on items that might be intoxicating but not very productive. An effective association which inspires the confidence of its members, and which is led by people who actively seek and suggest productive uses for both association and private funds, should be able to offset this tendency, however.

The Pajo association, in this respect, has numerous promising opportunities. We are exploring the idea of making the association a dealership for Planters Products. This would have at least three beneficial effects: it would help in the capital formation of the association, it would guarantee a reliable source of farm chemicals, and it could involve members more closely in the operation of association business and further develop an appreciation for the value of collective effort. Another suggestion is purchase of a rice drier. Such a purchase would be put to good use since it frequently rains during harvest time. The same possibilities for collective operation obtain here. In addition, with the proper leadership the association could expand its scope of operations (if it can first prove itself effective in supplying reliable irrigation to its members) and become a general consumers' cooperative. These possibilities should get careful attention at some future date.

What, then, has been accomplished? Unfortunately, the yields appear to be disappointing. This will certainly not support our efforts and may injure our credibility with some of the farmers. However, there seems to be more faith in the new leadership of the association than before, especially now that the financial records are no longer inaccessible. There have been farmers' classes and the farmers have probably learned some new facts. They also seem to recognize that they have an obligation to repay what they borrowed from the association, although we will not insist on full payment immediately. Many farmers are now aware that the land reform law exists and that it applies to them as much as it does to their colleagues in Central Luzon. In fact, the illegal ejection of one tenant was recently prevented (with the helpful intervention of the provincial governor) in observance of the Land Reform Proclamation. Still, because specific instructions from the Department of Agrarian Reform are vague, the overall land reform aspect remains questionable.

Since the project has been in operation for only one season (it is supposed to last until June 1975), and since it failed to achieve expected yield levels, we have to hope that real progress will be achieved in the next crop. Yields must be increased. We will try to find the correct fertilizer combination for the soil and we will improve the water distribution system. The irrigation zones will be supplied with water according to schedule and unlike the past, no individual requests for water will be honored. Only requests by zone will be approved and filled. We have all learned much about the kinds of problems to anticipate and, hopefully, we will be able to deal with them more competently when they occur again.

A sign that our approach to development is valid is the provincial governor's endorsement in principle of another similar project. It would be started in another location, but be funded by the provincial treasury. He made this decision because it seemed to him that channeling funds through an association would be more economical and effective than previous approaches which tended to spread limited financial resources too thinly. Furthermore, if the new project is financed by a loan to an association, perhaps there is a greater change that the money will be returned to the province and re-circulated to other projects.

With a group of small farmers who work on contiguous rice fields, solving irrigation problems must be cooperative effort. If each farmer looks out only for his own welfare, water distribution will be chaotic and all will suffer. On the other hand, cooperation in making and following distribution schedules, compliance with association regulations, presentation and elucidation of problems at meetings and solving them collectively, and necessary change of persons in positions of responsibility can all underscore the benefits to be derived from collective effort. If farmers see that difficulties in water distribution can be satisfactorily resolved through their association, they should readily grasp the advantages of acting collectively in other important, but perhaps less obvious areas such as the procurement of chemicals, marketing, and disputes relating to the conflict between farmers and landlords. The Philippine government is making cooperatives an integral part of its effort in land reform. What better way is there to prove to skeptical farmers that cooperatives can really benefit them, than by showing that at the most basic level, their rice can get the water it needs if they form themselves into an association and, as a group, take the necessary steps?