Irrigation Management for Rice-Based Farming Systems in Bangladesh, Indonesia and the Philippines

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Proceedings of the Tri-Country Workshop on Irrigation Management for Rice-Based Farming Systems held in Colombo, Sri Lanka from 12 to 14 November 1990.

Senen M. Miranda and Amado R. Maglinao, editors

IIMI

INTERNATIONAL IRRIGATION MANAGEMENT INSTITUTE

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Coverphotograph by Senen M. Miranda showing an irrigated rice-based farming system.

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Foreword

IRRIGATION IS A major strategy of developing countries to support agricultural production. However, the success in rice production which has enabled a number of countries in Asia to attain self-sufficiency has also resulted in a reduction in economic returns from irrigated ricelands.

There are at least three options by which this problem could be addressed: a) by increasing the economic yield of rice; b) by increasing the area served by scarce water resources through more effective and efficient irrigation system management: and c) by introducing crops of higher value than rice into the irrigated rice farming systems. The International Irrigation Management Institute (IIMI) and the International Rice Research Institute (IRRI), considering the complementary strengths of the three options, and through a grant from the Rockefeller Foundation, conducted a joint study of them. IRRI clearly has interest in the first option. The second is a part of IIMI's mandate to improve irrigation system management. Both institutes are concerned with the third option of getting higher economic and more equitable social returns from the water and its associated land.

In addressing the three options, the project attempts to look at the problem from a comprehensive point of view to include agronomic, socioeconomic and institutional issues related to rice and nonrice crops in irrigated rice-based farming systems.

The project was conducted in collaboration with national agencies and institutes and scientists in Bangladesh, Indonesia and the Philippines. The consultation meetings held with the national agencies began in October 1987 in the Philippines and Indonesia, and in a limited way, in Bangladesh in January 1988. The consultations facilitated the identification of the research areas and the formulation of a collaborative strategy to implement the project. The project had six broad objectives:

1. To characterize the factors influencing the options for changes in rice-based farming systems, and to identify the more important options in selected geographic locations:

2. To determine the degree to which different levels of irrigation system performance influence the ability to incorporate changes in the farming systems effectively;

3. To develop efficient and economical methods for managing irrigation water delivery and the use of postrice residual water for rice-based systems in which nonrice crops are grown, with special reference to implications for agronomic practice and for institutional performance and change;

4. To transmit and interpret the research findings to agricultural and irrigation system managers, planners and policymakers to encourage informed and better decision making;

5. To enhance the development of trained professionals in the area of irrigation problems through the provision of graduate research opportunities; and

6. To provide an opportunity for IRRI and IIMI staff to interact in a variety of collaborative activities which would permit the development of an effective and mutually supportive long-term relationship.

This volume documents the proceedings of the workshop organized to review the findings, recommendations, and other project accomplishments using, as a basis, the above broad objectives. The review not only consolidated and synthesized the findings and recommendations but also identified appropriate strategies to operationalize the recommendations.

The forty-two participants from the national agencies in Bangladesh, Indonesia, the Philippines and Sri Lanka, the International Rice Research Institute and the International Irrigation Management Institute strongly feel that the generated information and technologies should be further evaluated through some kind of piloting. A gradual internalization process is needed to really feel the impact of the recommended innovations.

An action plan is needed to implement the findings so far obtained. Stronger and more active participation of the irrigation agency and fanners is envisioned. Likewise other agencies involved in agriculture (from production to marketing) should be included. The involvement of the research group will become less and less as the recommendations are adopted and institutionalized.

The workshop also identified ideas or areas of work for further research. Provision of the basic drainage facilities is necessary, particularly for upland crops. Looking at the farmers' situation, their motivation to participate in irrigation management should be studied more deeply.

In implementing these recommendations, the role that IIMI and IRRI have to play is still apparent.

IIMI and IRRI wish to thank the Rockefeller Foundation for supporting the project and providing the opportunity for the two institutes to have a solid start toward a lasting collaborative relationship, while enabling the professional development of a number of national staff from the collaborating agencies.

IIMI and IRRI also extend their gratitude to the national agencies, research institutes and scientists in Bangladesh, Indonesia and the Philippines for their unstinted support and cooperation throughout the conduct of the various aspects of the project.

Thanks are also due to several colleagues, especially Drs. Donald Parker, Hammond Murray-Rust, Douglas Vermillion, Alfredo Valera and C. M. Wijayaratna of IIMI and Drs. Terence Woodhead and Prabhu Pingali of IRRI. who have shared their time and expertise to address the objectives of an interdisciplinary and multidisciplinary research.

Special thanks are due to Dr. Senen M. Miranda (Senior Irrigation Specialist, IIMI) and Dr. Sadiq I. Bhuiyan (Agricultural Engineer, IRRI) for coordinating the implementation of the project and for organizing the workshop and to Dr. Amado R. Maglinao (IIMI-IRRI Collaborative Project Researcher/Coordinator in the Philippines) for his assistance in the preparation of the workshop proceedings.

Khalid Mohtadullah
Director for Research
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Opening Addresses

Welcome Address

Roberto L. Lenton
Director General, International Irrigation Management Institute
Colombo, Sri Lanka

I DO INDEED want to extend a very special welcome to all of you here from the agricultural institutes, irrigation agencies and other organizations in Indonesia, the Philippines and Bangladesh, to our special invitees from Sri Lanka, to our colleagues from IRRI and to my colleagues from overseas offices of IIMI, Drs. Parker and Wijayaratna.

It is very fitting that IIMI's first workshop since the decision a week ago to incorporate IIMI into the CGIAR system is being held in cooperation with the International Rice Research Institute. I am sure all of us consider IRRI to be the flagship of the CGIAR system and we are very pleased to have this workshop in cooperation with IRRI. We are very pleased that Drs. Bernardo, Woodhead, Bhuiyan and Pingali are joining us on this occasion. One objective of the study being reported in this workshop was to foster an effective and mutually supportive relationship between IRRI and IIMI. I strongly believe that this objective has been very well achieved.

The subject of this workshop is exceptionally important to all the countries of this region. We all know that these countries are increasingly reaching self-sufficiency in rice. We know that the returns to rice production are decreasing, that we need to foster and encourage the production of nonrice crops in rice-based systems, and that we need to improve the management of imgation systems in order to foster the production of nonrice crops. I am sure that the results of this study will help in introducing measures for managing water effectively, in rice-based systems in which nonrice crops are to be grown.

I am particularly pleased that this study is addressing the issues of irrigation for nonrice cropping in rice-based systems from the broadest point of view, that the technical issues are looked at both from the on-farm and the main irrigation system levels, and that economic and institutional questions are also going to be addressed. Undoubtedly, it will be important to consider strategies to operationalize the recommendations and findings that have been developed through these studies. In this connection, the research network on irrigation management for rice-based farming systems that Dr. Miranda has introduced over the last few years will play a very useful role. For all these reasons, I am sure that the results of the studies and the proceedings of this workshop will be eagerly awaited by those concerned with irrigation management and agricultural production in the region.

Over and above the specific results of the studies, I personally believe that the IIMI-IRRI project has served as a very useful example of cooperation among two international institutes and many national agricultural research programs in several countries. It is a model of cooperation that I think should be emulated elsewhere. It is also an excellent example of the value of combining country-specific researches carried out in Bangladesh, Indonesia and the Philippines to arrive at a synthesis that is generalizable and useful in many different contexts. I believe this combination of field research and synthesis is what makes the study unique and valuable. I am sure this will foster cooperation in other areas that will yield equally productive results over time.

Once again, I would like to welcome you all to this workshop.

Opening Remarks

Fernando A. Bernardo
Deputy Director General, International Rice Research Institute
Los Banos, Laguna, Philippines

Thank you Dr. Miranda, and thank you Dr. Lenton for the warm welcome

IT IS INDEED my pleasure to be here to attend this workshop and see many familiar faces. We would like to congratulate IIMI for being among the four or five different research institutes that were recently accepted to the CGIAR. It is only IIMI that has been accepted without any condition at all. May I invite you to join me in giving IIMI a big applause.

In this workshop, you can see the cooperation not only among international agricultural research centers and the national agricultural research programs, but also the cooperation between the oldest member of the CGIAR which is IRRI, and the youngest member which is IIMI. This is not saying that IRRI is more important. Even before IIMI's acceptance to the CGIAR, IRRI had already recognized the importance of collaborating with IIMI. During the last four years, we had hoped that IIMI would eventually be accepted to the CGIAR system.

The importance of irrigation management for rice-based farming systems cannot be underestimated. Studies at IRRI have shown that increases in rice yield can be attributed to at least three major factors, namely, use of modem rice varieties, improved management of soil fertility, and of course, water management. This shows the importance of water management in the Green Revolution. In fact, our data also show that although irrigated rice occupies only about 40 percent of the total hectarage for rice, it produces about 72 percent of rice in the world.

I would like to mention a few things about IRRI's strategic plan as it has just celebrated its thirtieth anniversary this year. In other words, IRRI has been in existence for thirty years since 1960. The original idea was to have the institute for only twenty five years, as planned by the Rockefeller and the Ford Foundations. We are now thirty years old and we feel that we are on the crossroads. We believe that IRRI should continue for another thirty years, but many donors think otherwise. In fact, many donors feel that IRRI has done its job as rice production has increased tremendously. Even different countries feel that investment on rice research is now of low priority. We would like to disagree, not because we would like to continue in our employment, but because we feel that IRRI as an institution should point out the fallacy in the thinking of the policymakers.

If you look at the world population, you will note that it continues to increase. In fact, we were surprised last year when we were in China, and a Chinese scientist presented figures showing that even in China, which has been very successful in family planning, population will continue to grow and will not stabilize, perhaps, until the year 2025 or 2030 or even later. Because of the increased birth rate and life span of man, population growth will continue. However, our resources for production, particularly land resources, have been decreasing. If population continues to grow and land resources for rice production decrease, where are we going to get rice for the future generations to come? Thus, there is no alternative but to continue research to intensify production but when you intensify production, many problems will also arise.

IRRI has developed a strategy for the year 2000 and beyond to address the problem. We feel that we should address the problems of not only the irrigated rice lands, but also of the less favorable rice areas which may be more difficult to handle. IRRI is trying to work on rain-fed lowland rice, on deep water rice, on saline areas near seashores, and on upland rice where water management is also very important. We are also trying to adopt a strategy that will increase the yield potential of rice in favorable areas by producing new plant types of rice and associated technologies. We further hope to maintain yield gains. High productivity may be achieved but how to stabilize this for the future is important as well. Of course, low productivity is always sustainable, but if we are going to address the problem of increasing demand for rice, we must achieve high productivity and make sure that this is sustainable without degrading the environment, without soil degradation or pollution.

Intensification of production in rice lands will also receive our attention; that is, growing not only several crops of rice but also growing other crops before or after rice. Again, water management becomes important because the problem of using available moisture before or after rice is a technical concern as well as an area with social implications.

In view of all these, IRRI is happy to collaborate with IIMI and the national programs in the Philippines, Indonesia and Bangladesh and hopefully, with other national programs as well. I understand that this project, which comes to an end in December 1990, involves only the three countries because at the time of its inception, IIMI's presence in other countries was limited. Now that IIMI is a member of the CGIAR, we are sure that there will be more collaboration not only with other international agricultural research centers but also with other national programs. We, therefore, look forward to the continuing cooperation with IIMI as well as with other national programs. I am glad to be here and happy to partiapate in your workshop.

SECTION I

Technical Considerations

for

Rice-Based Farming Systems:

Irrigation System Management

Water Management for Improving Irrigation System Performance in Bangladesh

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INTRODUCTION

IRRIGATION WATER IS a critical factor in crop production in Bangladesh. Recently, much concern has been expressed about improving the performance of existing irrigation systems, as many have lower efficiencies and crop yields than their potential. Planners, administrators and donor agencies seem to be shifting attention from building new irrigation systems to improving the performance of the existing ones. To realize this goal, there is a need to develop and implement practical methodologies to upgrade the performance of the systems and allow farmers to achieve higher benefits from the use of irrigation water.

There are very few research studies to pinpoint the weaknesses in the major irrigation systems; fewer still are those that demonstrate how to effectively alleviate them (Wickham and Takase 1976). Field studies are needed to identify the nature and magnitude of water management problems and to develop methods of improving water management. The studies reported herein determined technical requirements for improving imgation system performance through better water management in the Ganges-Kobadak (G-K) Project, North Bangladesh Tubewell Project (NBTP) and some selected tubewells of Rajshahi District in Bangladesh.

The Ganges-Kobadak (G-K) is a lift-cum-gravity irrigation system which started operation in the mid-sixties. It is the first and still the largest of its kind in Bangladesh. In this system, water is lifted from the Ganges River by pumps and distributed by gravity canals. It is observed that the pump operation schedule in the past has been erratic. Records for the past 19 years (1971-1990) indicate that the pump operation was started at various times between the last week of December and the first week of March. Uncertainties in the schedule of irrigation water deliveries may lead to wasteful management of water and loss of time caused by unpreparedness of farmers for productive use of water.

The North Bangladesh Tubewell Project (NBTP) was established during 1962-64 and is operated by the Bangladesh Water Development Board (BWDB). There are 381 electrically driven tubewells to pump groundwater for dry-season crops and for supplementing rainfall for rice production in the wet season. Each tubewell has a discharge capacity ranging from 57 to 114 lps and a lined main canal whose length ranges from 290 to 670 meters. All tubewells operate as independent units. About 31,580 ha of land area in the districts of Thakurgaon, Panchagarh and Dinajpur were expected to be irrigated by the 381 deep tubewells in the project area giving an average area of 83 ha per tubewell. In practice, the extent of the actual irrigated areas is much lower. In addition, 960 more deep tubewells, supposed to be handed over to the Grameen Bank, have been installed in the project area.

In Rajshahi area, studies were initiated in fifteen selected tubewell areas in 1989 in cooperation with Bangladesh Agricultural Development Corporation (BADC) and Rajshahi Krishi Unnayan Bank (RKUB). BADC is implementing an integrated area development project in 15 *upazilas* of Rajshahi, Nawabgonj and Naogaon districts. The most important component of the project is to provide groundwater irrigation by installing 3,000 tubewells. So far, the project has been able to install about 2,400 tubewells. The tubewells have been distributed among informal groups of farmers for their use on what BADC calls an 'irrigation fee charge basis.'

This paper highlights the important findings of the collaborative research in Rajshahi, the Ganges-Kobadak and North Bangladesh Tubewell projects. The specific objectives in relation to the technical considerations for rice-based farming systems are:

1. To identify and analyze strategies and methods followed in the operation of the irrigation systems.
2. To suggest an optimal pump operation schedule for increasing water utilizatiorrand crop production.
3. To suggest improvement alternatives for increasing system efficiency.
4. To explore possibilities of reusing drainage water.
5. To minimize operational losses of irrigation water and increase irrigated area, crop yield and improve distribution equity.

METHODOLOGY AND MEASUREMENTS

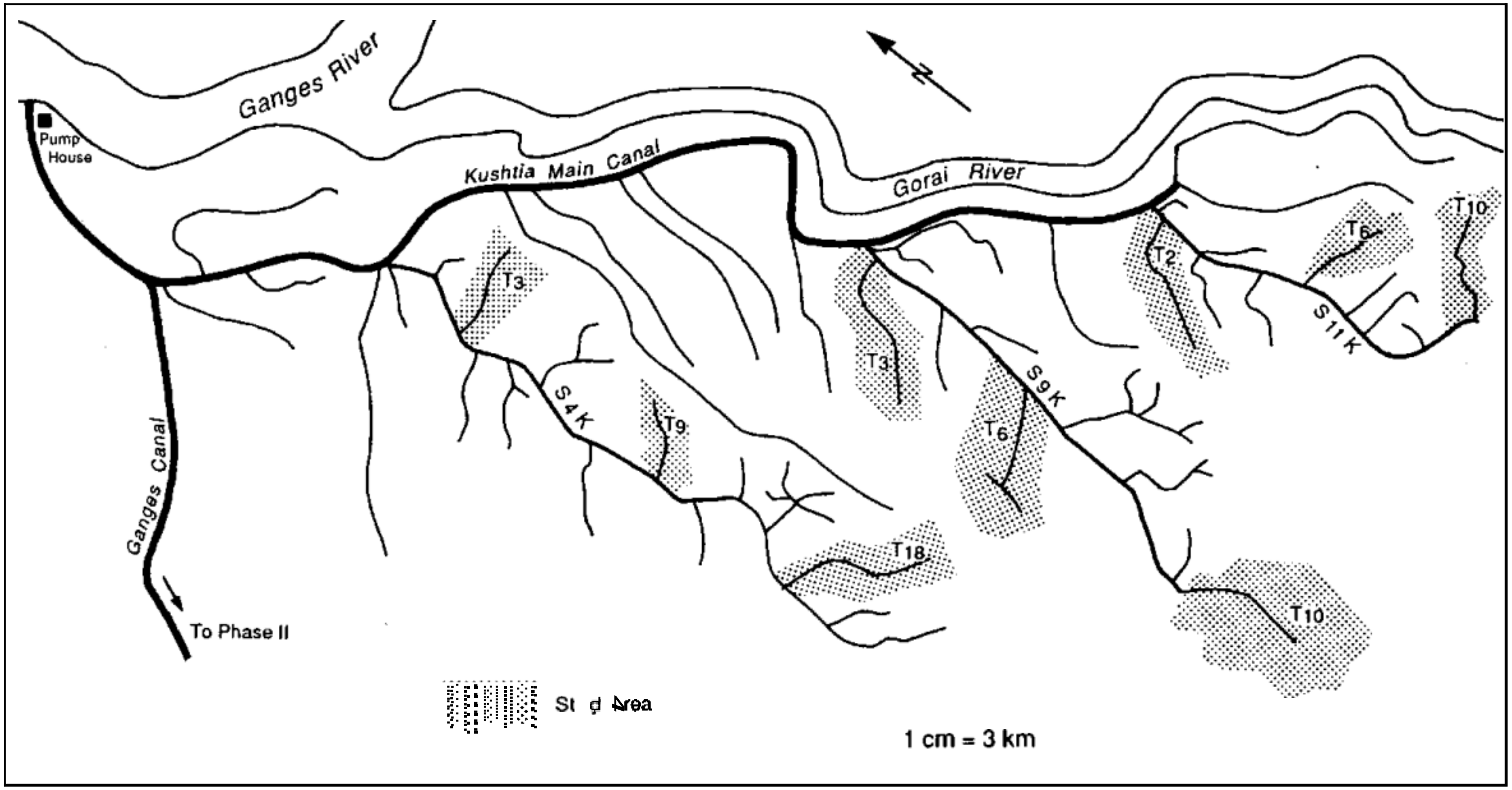
Research Sites

In the G-K Project (Phase I), the field research sites are in the service areas of nine tertiary canals belonging to three secondary canals: the fourth, ninth and eleventh secondary of Kushtia main canal (S4K, S9K and S11K). They represent the head, middle and tail reaches, respectively, of the main canal. Likewise, three tertiaries were selected from each secondary canal to represent the head, middle and tail reaches of the secondary. The tertiaries are: T3, T9, T18 of S4K; T3, T6, T10 of S9K; and T2, T6, T10 of S11K (Figure 1).

In the North Bangladesh Tubewell Project, field research was conducted mainly in 12 selected tubewells and their service areas which were chosen to represent the whole system. These pilot tubewells are: tubewell nos. 63, 77, 89, 93, 117, 118, 119, 120,125,126,138 and 142.

In Rajshahi area, a total of 15 tubewells have been selected randomly for the study. Among the 15 sample tubewells, 6 are from the irrigation fee charge based system (BIADP), 3 each from rental without RKUB support, rental with RKUB support and privately owned and managed systems.

Figure 1. Schematic diagram of Ganges-Kobadak Project, Bangladesh, showing selected secondary canals and tertiary canals and their service areas.



Field Observations and Measurements

Fifty observation **paddies** (bunded rice fields) were selected in each tertiary/ tubewell in G-K and NBTP and 20 paddies from Rajshahi area to represent the head, middle and tail reaches. Seasonal data on water and production status and discharge and daily data on rainfall, evaporation, seepage and percolation are recorded at each selected tertiary and tubewell.

Water ***use for land preparation.*** **Land preparation period** was considered as the period from seedbed preparation up to transplanting. Water use during land preparation was measured at the tertiary/tubewell headgate. Aggregate analysis for water use was made considering plot to plot irrigation distribution within and among farms. Land preparation period for Aus season was taken as the 40-day period prior to the date when 75 percent of the farmers have completed transplanting, or the seedling age used by 75 percent of the farmers plus 5 days, whichever was less. The period of additional five days was considered as the preparatory period for seedbed preparation and for arrangement of seeds by farmers.

In the *Aman* season (July-August to November-December), water use for land preparation was the amount computed for the period from 15 days prior to the date when 75 percent of the Aus rice (planted in March-April) fields were harvested to the date when 75 percent of the fields were transplanted to Aman rice.

Seasonal ***water use.*** Seasonal water use was assessed for the period from the beginning of land preparation to 15 days prior to the complete harvest in 75 percent of the plots of each tertiary/tubewell area.

Nonbeneficial water use. Irrigation water delivered in the tertiary/tubewell canals prior to the initiation of land preparation in Aus was considered nonbeneficial and unused. Unused water was measured for the years 1983-1990 for the selected tertiaries of G-K and was expressed in ha-cm.

Data analysis. Based on the collected data from the project, the present water use status in terms of water distribution, drainage reuse, pump operation and crop scheduling, among others, was assessed. Other available data from 1982 to 1989 were likewise used in the analysis.

RESULTS AND DISCUSSIONS

Ganges-Kobadak Project

Pump **operation.** The project has a designed total pumping capacity of 153 m^3/sec (CMS) (5,400 cusec) with three main pumps of 36.8 CMS (1,300 cusec) capacity each and 12 subsidiary pumps having a total capacity of 3.54 CMS (125 cusec) (synopsis

on G-K Project, Kushtia Unit, Phase I, March 1977). but the maximum actual discharge recorded was only 87.3 CMS (3,086 cusec) (NEDECO 1980). Records for the past 19 years (1971-1990) indicate that pump operation was started at various times between the last week of December and the first week of March (Table 1). In 1980, pump operation was begun in December (for 1981) and in 1978 it was begun in January. During 1982-1983, pump operation was started in the first week of February, whereas in 1984-1985 it was started in the latter part of February.

Table 1. Initiation and suspension dates of pump operation in Ganges-Kobadak Project, Kushtia, 1971-1990.

Year	Pump operation	
	Initiated	Suspended
1971	Feb 18	
1972	May 07	Nov 08
I973	Feb 15	Nov 12
1914	Feb 12	Nov 09
1975	Feb 01	Nov 07
1976	Feb 17	Nov 10
1977	Jan 06	Nov 10
1978	Jan 25	Nov 12
1979	Mar 03	Nov I5
1980	Mar 03	Nov 14
1981	Dec 23	Nov 14
1982	Feb 01	Nov 09
1983	Feb 03	Nov 18
1984	Feb 20	Nov 11
1985	Feb 25	Nov 14
1986	Feb 26	Nov 12
1987	Mar 10	Nov 21
1988	Mar 05	Nov 15
1989	Mar 07	Nov 15
1990	Fcb 23	

In 1979 and 1980, pump operation was not started until the first week of March. It is evident that the pump operation schedule in the past has been erratic. This may have led to the wastage of water as unused volume (Table 2). A timely and reliable water delivery schedule should be a major goal of the project to improve irrigation effectiveness and farmers' crop production. A proposal for shifting the operation schedule to February-October was considered recently but due to annual maintenance of pumps and desilting of the intake channel every year by dredging, the proposed schedule could not be implemented.

Early start of irrigation water delivery enables farmers to start their Aus rice crop earlier and harvest by July. This will also enable transplanting the Aman rice at the optimum time, i.e., by the middle of August. Delayed operation of pumps forces farmers to delay seeding and transplanting Aus rice, which adversely affects Aman rice production.

***Rainfall* distribution and evapotranspiration.** Average weekly total rainfall and evapotranspiration (ET) rates for the seven-year period 1983-1989 indicate that rainfall is higher than evapotranspiration for the months of May to September (Figure 2). Long-term rainfall and evaporation records at Amla (the nearest meteorological station for S4K area) and Jessore (which is the nearest for S9K and S11K areas) also show a similar relationship, except that in Amla the monthly ET is higher than rainfall in May (Ghani 1987).

It can be observed from Figure 2 that April (which is the driest month) and October are the critical months for Aus and Aman seasons, respectively. From long-term records and from the seven-year average data, it can be concluded that without irrigation, Aus rice crop will suffer severely in April (the crop is in its vegetative stage) as monthly evapotranspiration is much higher than monthly rainfall. Although that is not the case in October (when Aman rice is in its reproductive stage), a rainfall distribution and dependability analysis suggests that provision of irrigation is necessary to avoid crop damage (Figure 2) (Ghani, Bhuiyan & Islam 1981 and Saleh 1981).

Considering the variability in rainfall distribution and the S&P requirements, rainfall alone may not be enough to meet the crop water requirements. Irrigation water will be required during most of the months including those with monthly total rainfall greater than monthly total ET to meet potential requirements (i.e., ET + S&P both at potential rates).

Daily potential ET, which was considered equal to daily evaporation rate measured by the US. Bureau Class A pan method, varies widely. The average ET rate for the 1983-1989 period was 6.9 and 3.5 mm/day for Aus and Aman seasons, respectively, whereas the corresponding values from the long-term data from the adjacent meteorological stations are 4.2 and 2.8 mm/day. It is not clear why the 7-year values are higher than the long-term values. However, it was known from the elderly people of the area that weather has become relatively warmer.

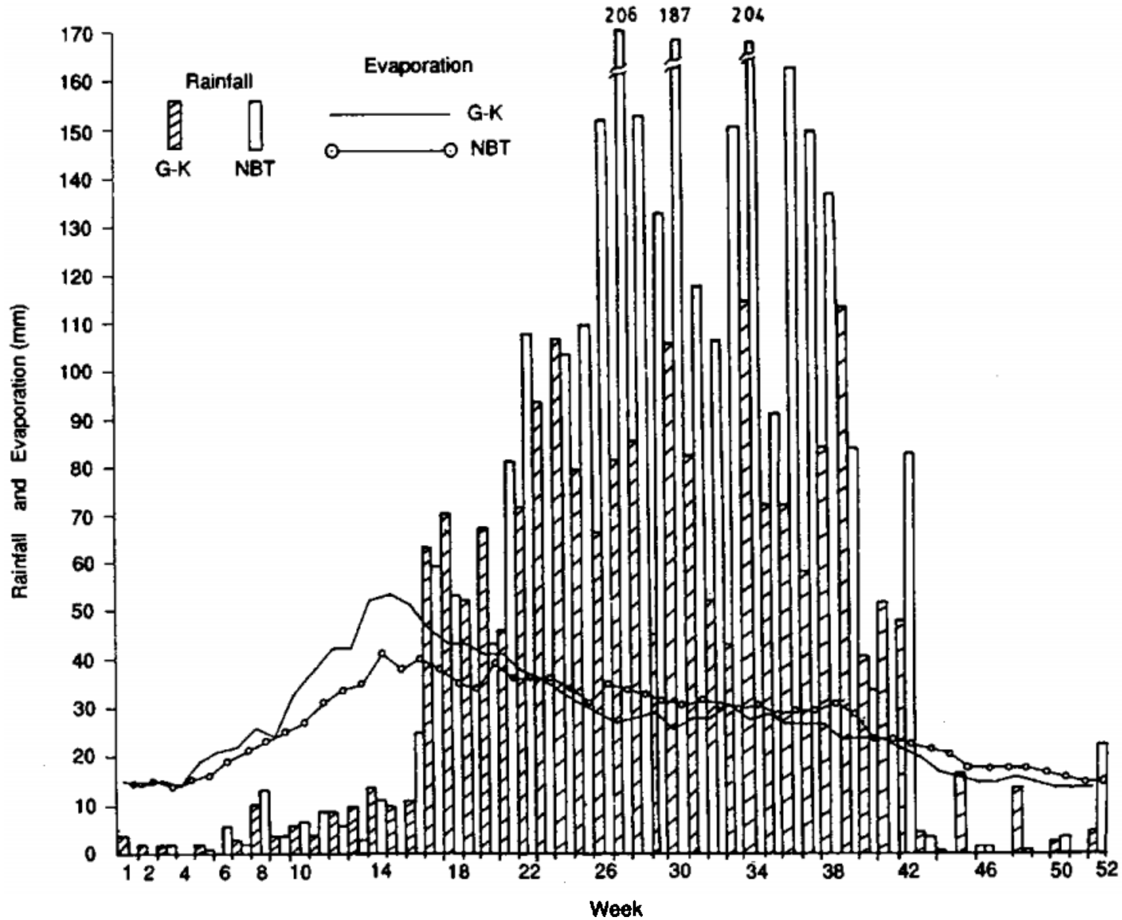
Water distribution status. Pumped irrigation water is distributed to the project area through a network of gravity canals consisting of the main, secondary and tertiary canals and field channels. The project was designed and constructed to operate initially as an automatic downstream control system.

Table 2. *Unused water volume (ha-cm) and period (days) at the beginning of* irrigation *water delivery* in *Ganges-Kobadak Project (Phase I), 1983 - 1990.*

Year	Period and volume	Location								Total
		S4K			S9K			S11K		
		T3	T9	T18	T3	T6	T10	T2	T6	(all ocations)
1983	Period	51	27		43	42	26	39	32	
	Volume	0,579	8,086	ND	4.724	5,689	115	1,329	58	**31,580**
1984	Period	10	13		43	18	24	20	6	
	Volume	1,264	1,003	NI	4.005	1.533	1,811	,006	301	10,923
1985	Period	20	25	20	35	21	48	21	4	
	Volume	4,607	2.029	*465*	1,414	1,899	2,748	233	694	16,089
1986	Period	14	9		6	4		12		
	Volume	1,400	2,511	NI	2,035	792	a/	1.980	NR	10,718
1987	Period	15	13		11	6	1			
	Volume	1.944	4,036	NI	2.105	1,238	11	a/	NR	9.334
1988	Period	10	7			3				
	Volume	919	1,236	NI	a/	368	a/	a/	a/	2,523
1989	Period	12			7	9			17	
	Volume	2.281	a/	NI	1.727	938	a/	NR	1,001	5,947
1990	Period	8	11		2	6		5		
	Volume	714	911	NI	487	509	b/	798	a/	3,419
Average volume		2,964	2,830	2,465	2,357	1.621	1,171	1.669	513	11.316

a/ = No **unused** period and volume.
b/ = No program.
ND = 'No delivery.
NU = No record.
NI = No irrigation.

Figure 2. Rainfall and evaporation values of G K and NBT projects (1983-1989).



In this system, the flow regulators should function automatically and the water level downstream of the regulators would control and operate them. Later, the system was converted to a manually operated upstream control type because of several problems encountered with the downstream control system. There are regulators in the main and secondary canals and check structures in the tertiary canals to control and regulate the flow of water. Project staff are assigned to operate the structures according to the direction of the higher authority for implementing the irrigation program. Most of the structures have graduated staff gauges but they are not calibrated; therefore, water flow is not measured at the headgates. However, flow depths are noted to estimate flow status in the downstream service area by making judgements from experience. Water allocation is scheduled by the project authority by fixing a seasonal imgation target and it has been implemented by adopting a rotational irrigation method since 1982.

Water *distribution* method. Fixed-interval rotation method of water distribution is planned for the project area, the schedule of which is prepared at the beginning of the season. A 9-day rotation has been in operation (since 1982) for the past several years in which all secondary canals except secondary S4K are to receive water on every ninth day and water flows continuously for 2 to 3 days depending on the service area. For secondary S4K, because of its great length (29 km), a continuous flow in the canal is allowed but rotation is planned among its tertiaries. Each of its tertiaries starts receiving water on every ninth day and its flow continues for 3 days. The planned rotational method is not properly implemented in the project area. The actual practice is one in which there is no fixed interval of the "no-irrigation period nor is there a fixed time of flow for the service area.

The present management has modified the 9-day rotation to a 10-day rotation schedule from 1989 so that the main canal is divided into two sections, head and tail. Each section would receive water for five days followed by a no-flow period of five days. However, there is rotation among the tertiaries of a secondary, for better distribution of water within a secondary area. The flow duration for a tertiary is fixed based on its irrigable area.

In 1990, an in-depth study on water rotation of the G-K Project was conducted in S8K which has four tertiary canals and a total of 44 outlets. The project management fiied the irrigation target considering areas under 37 outlets. For research on rotation, two outlets along each tertiary were randomly selected and from these 8 outlets, 78 farmers were selected based on head, middle and tail locations using a stratified random sampling procedure.

In the Aus seasons of 1983 to 1989 most of the middle and tail-end tertiaries received water deliveries for a lesser number of days than programmed. But in the head-end tertiaries water delivery was for a greater number of days than programmed (Table 3). Some head-end tertiaries, such as T3/S4K, received almost continuous water flow for the whole Aman season. On the other hand, tertiaries at the tail of the system suffered from inadequate and irregular water supplies up to 1989. Tertiary T2/S11K, which is also near the tail-end of the system, suffered from similar inadequacies during the study period.

Table 3. Duration of programmed and actual water deliveries (days) in Ganges-Kobadak Project (Phase-I), Bangladesh. Aus and Aman seasons of 1983-1989.

			LOCATION								
Year	Season	Pro/Act.	T3/S4K	T9/S4K	T1864K	T3/S9K	T6/S9K	T10/S9K	T2/S11K	T6/S11K	T10/S11
1983	Aus	Programmed	47	41	NR	45	40	44	35	40	NI
		Actual	112	95	NR	79	34	34	37	16	NI
	Aman	Programmed	34	35	42	32	39	40	40	49	NI
		Actual	69	101	103	62	63	36	109	47	NI
1984	Aus	Programmed	46	42	NI	45	43	41	41	44	NI
		Actual	64	122	NI	38	37	28	46	44	NI
	Aman	Programmed	35	40	38	40	34	33	32	36	NI
		Actual	70	111	98	85	42	28	72	52	NI
1985	Aus	Programmed	37	40	42	47	37	29	38	40	NI
		Actual	115	89	115	93	51	33	55	46	NI
	A M	Programmed	38	40	40	33	38	35	35	39	NI
		Acrual	117	110	93	75	91	40	77	68	NI
1986	Aus	Programmed	30	30	30	31	31	31	31	NI	NI
		Actual	12	44	74	26	34	22	44	NI	NI
	A M	Programmed	35	35	35	35	35	35	35	NI	NI
		Actual	67	41	25	18	44	25	76	NI	NI
1987	Aus	Programmed	30	30	NI	31	31	31	31	NI	NI
		Actual	70	35	NI	56	04	14	27	NI	NI
	A M	Programmed	35	35	35	35	35	35	35	NI	41
		Actual		56	19	19	33	27	13	78	NI
1988	Aus	Programmed	30	30	NI	31	31	31	31	30	NI
		Actual	68	26	NI	20	17	10	24	28	NI
	Aman	Programmed	35	35	35	35	35	35	35	35	40
		Actual	44	37	54	51	68	38	75	52	77
1989	Aus	Programmed	30	30	NI	31	31	31	NR	NI	NI
		Actual	44	37	NI	30	28	10	NR	NI	N
	Aman	Programmed	35	35	35	35	35	35	35	35	35
		Actual	58	42	29	70	42	45	45	77	44

NI = No irrigation.
Pro = Programmed.
NR = No record.
Act. = Actual.

From these figures, it can be concluded that the rotation method was not properly implemented and that there is a major scope for improvement in its implementation. A high priority should be given to improving this method.

Flow rates. Table 4 shows that all tertiaries except the first two of S4K received substantially lower flow rates than their design flow rates in each of the two seasons during 1983-1989. This may be one of the reasons for low irrigated area during the Aus season, especially in the tail-end tertiaries.

Water delivery, availability and flow rate for the S8K area are presented in Table 5. Actual flow duration in all four tertiaries is closer to the programmed period. Average available flow rates are also closer to the design flow rates for the tertiaries. This indicates the improvement potential of the rotational scheme. If project management gives more emphasis to the implementation of the nine-/ ten-day rotation, it can be implemented and farmers will be benefited.

Seasonal irrigation targets and achievemenfs. Seasonal irrigation targets are fixed at the beginning of the season by the project authority in consultation with relevant field officers. They review previous years' achievements and experience and based on that, prepare the current season's irrigation targets and schedules.

The extents of areas irrigated in Phase I and Phase II of the project in Aus and Aman seasons during 1978-1989 are presented in Table 6. The 1990 irrigated area in the Aus season was 12 percent and 59 percent higher in Phase I and Phase II, respectively, than the irrigation coverage of 1981 for the Aus season. The comparison is even more favorable for 1990 in relation to the records before 1981.

In the service areas of nine selected tertiaries, the irrigation achievements in the Aus seasons improved nominally during the 1982-1989 (Table 7) period. However, this improved significantly and consistently in the Aman seasons of the same period (Table 8). The achievement of the 1989 Aman season was about 20 percent higher than that of the 1981 Aman season. System level water use status in the selected tertiaries for land preparation and growing periods during Aus and Aman seasons are presented in Tables 9, 10, 11 and 12. Tables 9 and 10 show that water use varied largely during the Aus season both for land preparation (11-355 cm) and growing period (74-444 cm). In most cases, higher values were in the head tertiaries. The only exception was in T6/S11K area, maybe due to limited irrigated area and water supply. Variation in water use for land preparation and growing period during the Aman season was less as compared to the Aus season.

Pump *suspension.* In the study area, most rainfall occurs between June and July; in some years the high rainfall period extends up to mid-August. In the existing irrigation water delivery schedule and current farmers' crop production practices, the maximum rainfall period coincides with the harvesting time of Aus rice. Thus, rainwater is not properly utilized either by the crop or for land preparation for the succeeding crop. Therefore, the pump operation schedule must continue up to the middle of November irrespective of the initiation date of operation. If the pump operation period is shifted to February-October, it will allow a more effective

Table 4. Designed and measured discharges for 12 selected tubewells and 9 selected tertiaries in North Bangladesh Tubewell Project (NBTP) and Ganges-Kobadak Project (G-K), respectively.

NBT Project			G-K Project			
Tube-well no.	Design discharge (m^3/sec)	Average measured discharge (m^3/sec)	Tertiary no.	Design discharge (m^3/sec)	Aus season measured discharge (m^3/sec)	Aman season measured discharge (m^3/sec)
63	0.103	0.102	T3/S4K	0.159	0.230	0.273
77	0.053	0.053	T9/S4K	0.142	0.189	0.194
89	0.085	0.067	T18/S4K	0.292	0.103	0.241
93	0.111	0.099	T3/S9K	0.345	0.315	0.311
117	0.72	0.071	T6/S9K	0.354	0.195	0.235
118	0.057	0.057	T10/S9K	0.190	0.113	0.129
119	0.083	0.057	T2/S11K	0.207	0.154	0.180
120	0.083	0.072	T6/S11K	0.266	0.083	0.116
125	0.085	0.085	T10/S11K	0.207		0.112
126	0.106	0.078				
138	0.092	0.088				
142	0.085	0.085				

Table 5. Water ailabili status in the selected tertiaries of S8K, Ganges-Kobadak Project (Phase Aus S son, 1990.

Location	Irrigable area (ha)	Irrigated area (ha)	Depth of water (cm)			Rotation status (days)		Average seasonal flow (m^3/sec)	Design flow rate (m^3/sec)
			Irrigation	Rainfall	Total	Programme	Actual		
S8K	1038	528	49	68	114	-	-	0.70	0.76
T1/S8K	138	120	21	68	88	28	34	0.10	0.14
T2/S8K	381	179	28	68	95	18	14	0.52	0.45
T3/S8k	222	131	25	68	93	28	22	0.20	0.19
T4/S8k	297	97	72	68	140	18	22	0.37	0.35

Table 6. Area (ha) irrigated in Phase I and II of Ganges-Kobadak Project during Aus and Aman seasons, 1978-1990.

Year	Phase - I		Phase - II	
	Aus	Aman	Aus	Aman
1978	15.959	26.811	10.556	15.164
1919	11.469	29.014	7.372	25,254
1980	14,300	31,055	10,094	32,866
1981	16.672	33,242	12.452	38.565
1982	17.148	33,721	16,447	44,436
1983	19,870	34,538	15.739	40.435
1984	18.276	33.364	16,077	40.288
1985	18.637	36.495	19.426	46.559
1986	16,077	36,508	12,309	48,943
1987	16,652	37.054	13,806	48.954
1988	15,802	31.128	7.216	45,545
1989	16.856	M.793	7,807	45.055
1990	20.210		19.860	

Table 7. Irrigated area in the selected tertiaries of Ganges-Kobakak Project, (Phase I) Aus Season, 1982-1990.

Location	Irrigable area (ha)	IRRIGATION COVERAGE (ha)								
		1982	1983	1984	1985	1986	1987	1988	1989	1990
T3/S4K	112	62(55)a	94(84)	97(87)	83(74)	63(56)	69(62)	69(62)	67(60)	62(55)
T9/S4K	98	65(66)	81(83)	83(85)	67(68)	67(68)	67(68)	71(72)	61(62)	65(66)
T18/S4K	96	25(26)	25(26)	NID	10(10)	-	-	-	-	-
T3/S9K	428	146(34)	162(38)	102(24)	162(38)	162(38	136(32)	136(32)	62(14)	153(36)
T6/S9K	466	137(29)	142(30)	105(23)	142(30)	51(11)	138(30)	75(16)	22(5)	138(30)
T10/S9K	186	42(23)	55(30)	33(18)	50(27)	18(11)	40(22)	12(6)	10(5)	-
T2/S11K	216	93(43)	97(45)	101(47)	102(47)	66(31)	101(47)	140(65)	51(24)	105(49)
T6/S11K	285	4(1)	9(3)	9(3)	6(2)	-	-	75(26)	-	26(9)
T10/S11	241	13(5)	7(3)	NID	NID	-	-	-	-	-
Total	2128	587(28)	672(32)	531(25)	622(29)	427(20)	551(26)	578(27)	273(13)	549(26)

a. Figurer in parentheses indicate percent of irrigable area
NID = No irrigation delivery.

Table 8. *Irrigated* area in the selected tertiaries of *Ganges-Kobakak* Project, *(Phase I) Aman Season, 1982-1989.*

Location	Irrigable area (ha)	IRRIGATION COVERAGE (ha)							
		1982	1983	1984	1985	1986	1987	1988	1989
T3S4K	112	96(86)a	96(86)	104(93)	12(100	118(105	106(95)	96(96)	86(77)
T9/S4K	98	85(87)	85(87	87(89)	86(88)	86(88)	86(88)	98(100)	87(89)
T18/S4K	96	29(30)	35(36)	36(37)	38(40)	38(40)	36(38)	40(42)	30(31)
T3/S9K	428	264(62)	275(64)	276(64)	304(71)	304(71)	225(53)	276(64)	261(61)
T6/S9K	466	214(46)	241(52)	230(49)	245(53)	259(56)	134(29)	255(55)	243(53)
T10/S9K	186	98(53)	147(79)	136(73)	145(78)	162(87)	79(42)	148(80)	126(68)
T2/S11K	216	198(92)	195(90)	202(94)	202(94)	142(66)	205(95)	172(80)	126(58)
T6/S11K	285	93(33)	113(40)	121(42)	146(51)		113(40)	162(57)	162(57)
T10/S11	241	171(71)	235(98)	235(98)	211(88)		52(22)	131(54)	111(46)
Total	2128	1248(59)	1422(69)	427(67	489(70	109(52	1036(49)	1378(65)	1232(58)

a. Figures in parentheses indicate percent of irrigable area.

* New area was developed and included in the command area

Table 9. Average amounts of water (cm) used for land preparation in the selected tertiaries of Ganges-Kobadak Project (Phase-I), Aus Season, 1983 - 1989.

Year		T3/S4K	T9/S4K	T3/S9K	T6/S9	T10/S9I	2/S11K	6/S11K
1983	IR	73	48	23	26	2	I5	16
	RF	24	20	0	20	9	28	10
	Total	97	68	33	46	11	43	20
1984	IR	59	51	64	31	74	11	182
	RF	3	I	6	10	13	8	4
	Total	62	52	70	41	87	19	186
1985	IR	I07	31	27	15	50	7	344
	RF	2	23	2	9	14	14	11
	Total	109	54	29	24	64	21	355
1986	IR	25	22	27	24	21	23	21
	RF	3	3	2	2	2	5	5
	Total	28	25	29	26	23	28	26
1987	IR	25	26	23	23	18	12	17
	RF	1	I	2	0	6	10	6
	Total	26	27	25	23	24	22	23
1988	IR	27	23	21	20	20	13	NR
	RF	2	6	0	3	2	2	
	Total	29	29	21	23	22	15	
1989	IR	22	25	23	23	NR	20	
	RF	I	1	0	0		0	
	Total	23	26	23	23		20	

IR = Irrigation water
RF =Rainfall.
NR=No record.

Table 10. Average amounts of water (cm) used for growing period **in** *the selected tertiaries* **of** *Ganges-Kobadak Project (Phase-I), Aus Season, 1983-1989.*

		LOCATION						
Year		T3/S4K	**T9/S4K**	**r18/S4K**	T3/S9K	T6/S9K	'I 0/S9K	**'2/S11K**
1983	**IR**	230	187	**NR**	81	71	35	29
	RF	70	57		55	55	55	60
	Total	300	244		136	126	90	89
1984	**IR**	199	155		79	82	86	76
	RF	65	69		70	73	86	79
	Total	264	224		I49	I55	I72	155
1985	**IR**	389	%	898	117	83	77	41
	RF	55	47	68	67	47	43	33
	Total	444	143	966	184	I30	120	74
1986	**IR**	78	76	75	640	60	56	94
	RF	70	71	72	58	60	61	60
	Total	148	147	I47	122	120	I17	154
1987	**IR**	74	71	**NID**	68	60	62	61
	RF	45	50		60	58	63	61
	Total	119	I21		128	118	125	I22
1988	**IR**	79	60		39	37	37	54
	RF	%	111		119	121	I14	100
	Total	175	171		158	158	151	I54
1989	**IR**	79	67		53	60	**NR**	76
	RF	74	74		68	64		35
	Total	153	141		121	124		111

IR = gation water.
R F = nfall.
N R = record.
NID = **No irrigation delivery**

Table 11. Average amount of water (cm) used for land preparation in the selected tertiaries of Ganges-Kobadak Project (Phase-I), Aman Season, *1983-1989.*

Year		LOCATION								
		T3/S4K	T9/S4K	T18/S4K	T3/S9K	T6/S9K	T10/S9K	T2/S11K	T6/S11K	T10/S11
1983	IR	36	21	95	6	17	4	27	6	
	RF	16	17	13	9	40	32	39	24	
	Total	52	44	108	15	57	36	66	30	
1984	IR	37	38	50	20	17	3	20	16	0
	RF	21	27	20	12	16	17	20	53	18
	Total	58	65	70	32	33	20	40	69	18
1985	IR	98	19	38	13	19	10	8	26	
	RF	18	13	7	5	18	28	20	15	
	Total	116	32	45	18	37	38	28	41	
1986	IR	19	18	16	7	5	3	25	22	19
	RF	2	2	2	12	12	12	3	3	3
	Total	21	20	18	19	17	15	28	25	22
1987	IR	9			21	2	14	0	0	0
	RF	1			2	22	10	24	24	24
	Total	10			23	24	24	24	24	24
1988	IR	0	0	0	21	20	19	17	14	17
	RF	12	11	13	2	2	2	6	8	4
	Total	12	11	13	23	22	21	23	22	21
1989	IR	3	25		22	22	20	17	18	0
	RF	2	3		0	1	1	3	1	0
	Total	25	28		22	23	21	20	19	20

IR = Irrigation record
RF = Rainfall

Table 12. *Average* amounts *of water (cm)* used *for growing period* in the *selected* tertiaries *of Ganges-Kobadnk Project* (Phase *-I), Aman Season, 1983-1989.*

		LOCATION								
Year		3/S4K	9/S4K	18/S4K	3/S9K	6/S9K	10/S9I	2/S111	5/S11I	10/S111
1983	IR	130	I66	250	47	38	20	71	52	NR
	RF	I8	41	37	44	66	62	81	96	
	Total	178	207	287	91	I04	82	152	I48	
1984	IR	102	137	166	62	45	20	64	49	70
	RF	49	67	95	M	53	64	62	70	67
	Total	151	204	261	126	98	84	126	I19	137
1985	IR	361	117	117	48	93	34	31	82	98
	RF	46	36	30	39	SO	52	45	49	29
	Total	407	153	147	87	143	86	76	131	127
1986	IR	54	SO	46	58	53	48	74	70	66
	RF	I07	105	103	108	109	104	108	105	98
	Total	161	155	149	166	I62	152	182	175	I64
1987	IR	80	69	61	60	46	48	30	31	23
	RF	18	21	31	67	79	69	71	91	67
		98	90	92	127	125	117	101	122	90
1988	IR	78	72	64	63	55	M	73	62	67
	RF	29	60	56	68	69	56	41	49	42
	Total	107	132	110	131	I24	I20	114	111	I09
1989	IR	102	86	NR	70	73	70	66	77	70
	KF	30	35		41	36	39	49	35	41
	TOW	132	121		111	109	I09	115	I12	111

IR = Irrigation Water
NR = No record.
RF = Rainfall.

utilization of the rainfall for seedbed and land preparation of Aman rice which can be transplanted by the end of July and harvested by mid-November. Therefore, irrigation water delivery could be stopped by the end of October. The annual repair and maintenance of the pumps, the intake channel and irrigation canals could be conveniently completed during the November-January period.

In the current practice, pump operation is suspended partially or completely from time to time during the rainy season to avoid canal overtopping. Decisions on pump suspension are made by the Project Director on the basis of information received from the canal gatekeepers, through the canal telephone system or via personal visits. The scope for suspension of pump operation in June and July, when the **Aus** crop is in the maturing stage and land preparation for Aman is underway, is established and should be implemented. This will reduce operation cost and will encourage and influence farmers in the timely planting of rice.

The present management implemented the suggested strategy in the irrigation system during 1990. Pumping was started on the 23rd of February while the target was the 20th of February. Pumping suspension was also initiated and during the rainy season, pumps were suspended for 26 days, which is a significant improvement.

Cropping schedule. The system operational principle with regard to the third irrigated crop (wheat) has been clearly established. It was established that the old policy to support production of some irrigated wheat following harvest of Aman rice is not technically and operationally sound, because it interferes with the system's operational plan and also because the productivity of a wheat-rice-rice system is not sustainable in the long run. The suggested schedule of pump operation is February 01 through October 31. Implementation of this schedule will not require any additional resources, but should accrue significant additional benefits. Nonrice crops like gram, kheshari, onion and lentil are gaining popularity in the project area and the suggested schedule will be helpful. Extensive cultivation of these crops will generate more income for the farmers and will also help in maintaining land productivity.

Unused irrigation water. It can be observed from Table 2 that there is a lag period between the initiation of water flow in the tertiary canal and its utilization for **Aus** cultivation. The lag period varied from 2 to 51 days and as a result, every year a significant volume of water has been left unutilized at the beginning of the irrigation season. During 1983 to 1990, the average magnitude of yearly unused volume varied from 360 to 4,511 ha-cm among the tertiaries. The overall average yearly unused volume for the selected tertiaries for eight years was 1,668 ha-cm. In farmer plots which were under the management of the researchers, an average of 175 cm of total water (irrigation + rainfall) was used during the Aus season (BRRI 1985 and 1986). **Using** this amount as the basis, it can be concluded that the unused water volume could increase irrigation coverage in **Aus** by 10 hectares in each tertiary if it was properly used. Considering the high pump operation cost, a significant amount of operation cost could be saved if the period of nonutilization and underutilization of water could be avoided or reduced.

*Possible **reuse** of drainage water.* From the initial survey, it is observed that there is a strong potential for the storage of drainage water during the imgation period. It is found that more than 0.283 cms (10 cfs) water continuously flows through the drainage canal within 10 to 15 days after the irrigation schedule starts in the canal. It is possible to control the flow by constructing a check across the channel bed, which will allow the water level to rise so that water can be easily pumped into the irrigation canal. Depending on the basis of off take, farmers' behavior and water use practices, a volume of 0.28-.56 cms (10-20 cfs) of residual irrigation water may be used to irrigate part of S4K in the Aus season. For assured water supply at the study area, this residual irrigation water and continuous flow of drainage water should be used properly. Efficient utilization of this unused water in addition to pumped water and rainfall can help bring more areas under irrigation in Aus and Aman seasons. Moreover, it is also possible to divert water from Kumar River (main drainage canal) to the downstream of the siphon. In the Aman season, the water level of Kumar River rises by about 3.04 m (10 ft) higher than in the Aus season. So, the required amount of irrigation water can be partly supplied from Kumar River and from drainage water of D11K (secondary drainage canal). The combined utilization of the abovementioned two components will cover the risk in the dry season when there is a shortage of water at D11K canal.

To increase the system performance and irrigation water supply, additional excavation of canal or construction of any hydraulic structure will not be required. Only a pumping unit must be installed to feed the irrigation canal. By proper planning, it will be possible to irrigate about 809 ha in the Aus season and 1,417 ha in the Aman season (Table 13). From this area more than 5,000 tons of extra HYV rice can be produced yearly and about Taka 35 million (US$1.0 M) can be saved.

From this study it is observed that the water level rises up to 1.22 to 3.1 m in Kumar River within 10 days after the start of irrigation (Table 14). So, the required amount of irrigation water for that area can be made available by preventing the flow of drainage water from D11K and diverting water at the outlet of the siphon structure from Drainage Mara Kumar. In addition to this, a volume of 0.28 to 0.56 cms water flows continuously through S4K canal as residual irrigation water in the Aus season.

From the survey report, it is observed that S4BK and the tail end of S4K areas do not get irrigation water in either Aus or Aman seasons but that existing distribution facilities are good enough. The farmer groups of this area are interested in having a pumping plant for lifting water in the S4K canal. The study indicated that if 2 or 3 units of 0.28 cms (10 cusec) pumps are installed for lifting water into S4K canal in Aus and Aman seasons, this can bring 2,226 ha under irrigation. Operation and maintenance of these pumping units can be easily managed by farmer groups. As a result, job opportunities will be created for educated young people.

Table 13. *Comparison of irrigation coverage at* **present nnd proposed conditions reusing drainage** *water, Ganges-Kobadak* **Project,** *Kushtia.*

Location	Command area in (ha)	Present condition: Irrigation area in Aman 86 (ha)	Present condition: Irrigation area in Aman 87 (ha)	After implementation: Expected irrigable area in Aus season (ha)	After implementation: Expected irrigable area in Aman season (ha)
TI3/S4BK	113	10	10	35	61
T13/S4BK	127	9	9	17	61
D.F.C		72	28	24	60
T14/S4BK	158	12	12	36	81
TI5/S4BKT	253	23	24	70	121
T16/S4BK	338	NID	NID	103	202
T17/S4BK	522	8	NID	140	243
Subtotal S4BK	1583	90	79	160	838
T18/S4K	96	27	32	70	81
T19/S4K	225	19	20	104	I42
T20/S4K	232	21	21	35	I34
DFC	270	76	81	140	222
Subtotal S4K	823	143	154	349	579
Grand total	2406	233	233	809	1417

North Bangladesh Tubewell Project

Water availability and utilization. Earlier research established that the discharge capacities of the sample tubewells were on the average 91 percent of the original recorded discharge at the time of construction of the tubewells 17-18 years ago (Table 4). Furthermore, conveyance losses in the inadequately maintained lined main canals were found to be very high, causing major water wastage during irrigation (BRRI-BWDB-IRRI 1983). The main canal linings were repaired during 1982 and 1983 dry seasons mostly using an improved method in which the canal bed

Table 14. *River* stage, *rainfall and drainage flow of the* study *area, Ganges-Kobadak* Project *(Phase I), 1988-89.*

Month	10 days' average	1		I		Average water level in Kumar River (m)
		10 days' average drainage flow (cm)	Total 10 days' amount of rainfall (mm)	10 days' average drainage flow (cm)	Total 10 days' amount of rainfall (mm)	
	1	0	0	0	0	
March	2	0.24	39	0	0	3.12
	3	0.34	0	0	0	
	1	0.28	0	0	0	
April	2	0.27	4	0.65	0	4.26
	3	0.38	82	0.70	3.8	
	1	0.26	67	0.59	14.0	
May	2	0.40	123	0.79	168.7	
	3	0.66	81	0.73	0	
	1	0.51	5	0.59	73.7	
June	2	1.38	498	0.51	66.1	
	3	1.61	102	0.90	56.0	
	1	1.47	215	1.42	97.0	
July	2	1.37	25	1.42	76.0	
	3	1.01	102	1.42	0	
	1	1.02	39	1.42	55.0	
August	2	1.42	74	1.69	15.0	6.00
	3	1.37	40	1.69	28.0	
	1	1.01	99	1.42	23.0	
September	2	0.97	34	0.73	86.0	5.68
	3	0.90	0	0.48	104.0	
	1	0.97	104	0.59	37.0	
October	2	0.82	3	0.50	94.0	4.00
	3	0.39	0	0.57	5.0	
	1	0.22	0	0.42	0	
November	2	0.20	0	0.50	0	3.20
	3	0	0	0.51	0	

and about 30-cm height along the side slopes were plastered with rich cement mortar. This measure enabled an effective reduction of water conveyance losses by 66 percent (ibid.). The reduced conveyance losses not only improved the effective capacity of the tubewells to deliver water in a timely manner to different parts of the service areas but also reduced the problem of excessive water supply through seepage to areas where water was not needed.

Water availability is most crucial for crops in the Rabi season (November-March) because of very low rainfall. But tubewell water use during the Rabi seasons in the past was scanty. For example, on the average, only about 8 hectares were irrigated per sample tubewell during the 1982 Rabi season when benchmark information was collected (Table 15). On the average, tubewells were operated for about 6 hours per day (Table 16).

Table 15. Yield and area coverage of wheat in the selected pilot tubewells of North Bangladesh Tubewell Project, Thakurgaon, Rabi seasons, 1982-1989.

DTW No.	Discharge (lps)	Irrigable area (ha)	Area coverage (ha)							
			1982	1983	1984	1985	1986	1987	1988	1989
63	102	60	8.0	16.1	28.3	12.0	3.0	6.5	8.1	3.2
77	53	49	1.2	18.2	26.3	24.0	14.3	20.2	8.5	4.1
89	67	49	8.0	24.7	40.5	40.0	24.3	24.3	12.1	11.3
93	99	74	22.6	26.7	40.5	20.0	15.6	7.3	8.1	2.4
117	71	61	6.0	13.7	28.3	4.1	0.6	6.9	4.0	7.3
118	57	46	8.5	14.1	28.3	7.1	1.1	8.9	4.1	2.4
119	57	57	8.0	11.7	b/	b/	1.2	7.7	2.0	2.8
120	79	61	12.9	23.5	34.4	4.9	1.6	7.3	3.6	2.8
125	85	55	2.4	21.8	4.1	2.5	4.0	2.0	0.8	0.8
126	106	48	6.0	10.9	22.3	12.1	6.1	8.1	3.2	2.4
138	88	50	6.4	10.1	26.3	18.1	14.3	12.2	8.9	10.1
142	85	49	4.5	9.3	14.2	18.2	8.1	8.1	4.0	5.2
All DTWs		659	94.5 (0.10)	200.8 (0.21)	293.5 (0.36)	163.6 (0.20)	94.2 (0.09)	119.5 (0.17)	67.4 a/	54.8 (0.06)

a. Figures in parentheses indicate area irrigated per unit discharge
b. DTW was not operated due to sand gravel pumping problem.

Table 16. *Operating hours of* sample *deep tubewells under minimum irrigation coverage, North Bangaladesh Tubewell Project,* Aus *1990.*

DTW category		DTW No.	Totel operating days	Totel operating hours	Per day operaing hours
A.	Those fulfilling MICA target	5	91	378	4.15
		12	84	420	5.0
		15	98	489	4.98
		16	91	419	4.60
		133	168	1715	10.20
		135	168	1388	8.26
		156	77	522	6.77
		162	I33	769	6.78
		211	98	566	5.77
		212	77	565	7.33
		216	91	262	2.87
Average of A			106.90	681.18	5.79
B.	Those not fulfilling MICA target	89	140	1132	8.08
		90	98	197	2.01
		94	I33	1019	7.66
		214	63	295	4.68
Average of B			108.5	660.75	5.60

In the 1983 Rabi season, the irrigated area per tubewell increased by 104 percent over the area irrigated during the benchmark 1982 Rabi season. This positive gain could be attributed to the combined efforts of the research team.

Potential improvement. It is unfortunate that in most cases the wells are underutilized. The wells of the North Bangladesh Tubewell Project irrigate much less than their technically potential irrigable area. The average area irrigated per deep tubewell (DTW) is much below the potentially irrigable area (Tables 17 and 18). This situation exists for a variety of reasons, which have been identified and documented by present research. Prominent among those reasons are that:

a. High conveyance and operational losses are effectively reducing the proportion of pumped water that can reach the farmers' fields. The scattered demand for water is a major factor responsible for high operational losses. Field losses of water outside of the field channels are high in the light-textured soil when water has to pass through fallow or non-water-demanding plots.

b. Many farmers have suffered water shortage problems in the past and they are unsure of the system's ability to deliver the needed water in time.

c. Farmers' organizational problems create severe inequities in the access to reliable supplies of water.

Deep tubewell irrigation is the most costly method to convert a unit of land from rain-fed to irrigated status. In the NBT Project, BWDB has to pay an average of Taka 2,500/= (US$70) as minimum electricity bill per tubewell per month even if the tubewell is not operated.

The joint research project made a policy suggestion in 1988 that the Bangladesh Water Development Board attempt to solve the problems of suboptimal irrigated areas by requiring a minimum area of planned irrigated crops in any given season before a tubewell is put into operation for that season. The research team decided that the tubewell will not be put into operation in any season if the demanded irrigated area is less than 30 percent of the potential irrigable area which is equivalent to 0.09 ha/lit/sec (6 acres/cusec) of discharge.

The Minimum Irrigated Crop Acreage (MICA) Program was started from the Aus season 1988 to increase the irrigation service area. One field workshop of one-day duration was organized during 1990 in each research site to strengthen MICA activities and to communicate the concept of MICA to farmers and explain to them its rationale, usefulness and implementation mechanism. Each of the workshops was attended by farmer representatives, field- and project-level officials and research group members based at Thakurgaon. The policy of MICA was also communicated to farmers in the following ways:

a. Field-level extension staff were advised to make personal contacts with the Krishok Samobaya Samity (KSS) managers and farmers and explain MICA to them, and

b. In the training classes held in Central Association (of KSSs) office at upazila headquarters, KSS managers were informed of the policy and asked to communicate the idea to the farmers. But the most effective method was the field workshop organized by the project authority supported by the research group. The farmers of each tubewell were expected to organize themselves, form an irrigation committee to plan and implement an efficient and equitable water allocation distribution schedule with the assistance of the research group. The extension staff of the project supplied irrigation demand slips to a farmer group. The farmer group recorded in

Table 17. Comparison of potential and actual irrigation coverage (3 years' average) in selected pilot tubewells, before and after Minimum Acreage Programme in North Bangladesh Tubewell Project, 1984-1990.

'ubewell No.	'ischarge :apacity (lps)	'otentia rrigable rea (ha	irrigation coverage (ha)				Increaced irrigated area	
			Before minimum irrigation program		After minimum irrigatic :ogram			
			Actual rrigated area	% of potential irrigable area	Actual irrigated area	% of otential rigable area	ha	%
63	102.4	23.4	1.6	6.8	9.7	41.2	8.1	34.4
77	52.9	12.1	2.3	19.0	9.5	78.5	7.2	59.5
89	67.1	15.4	2.6	16.9	7.5	48.7	4.9	31.8
93	99.0	22.7	15.5	68.3	16.8	74.0	1.3	5.7
117	70.8	16.2	7.9	48.8	10.7	66.0	2.8	17.2
118	56.6	13.0	7.7	59.2	9.5	73.I	I.8	13.9
119	56.6	13.0	b		0.8	6.2	0.8	6.2
I20	79.2	18.1	c		9.7	53.6	9.7	53.6
125	84.9	19.4	30.0	154.6	25.7	132.4	-4.3	-22.0
I26	56.6	13.0	9.7	74.6	14.8	113.8	5.I	39.2
I38	88.3	20.2	4.8	23.8	13.3	65.8	8.5	42.0
I42	84.9	19.4	3.8	19.6	27.9	143.8	24.I	124.2
All ıbewells	899.3	205.9	85.9	491.6	155.9	897.I	70.0	405.7
Mean	74.9	17.2	8.6	19.2	13.0	74.8	5.8	33.8

b = Tubwell was not operated due to sand and gravel pumping problems.
c = There was irrigated crop (mostly nonrice crops).

the demand slip the extent of land they would imgate and submitted it to the extension staff. The the extension officials checked it to see if the minimum acreage had been shown in the demand slip. Once they were satisfied, they forwarded the information to the Engineering Division to operate the tubewells for the season.

Table 18. Comparison of potential and actual irrigation coverage (3 years' average) in selected satellite tubewells *before and after* Minimum Acreage Propramme in North Bangladesh *Tubewell* Project, 1985- 1990.

'uhewell no.	Discharge capacity (lps)	otential rigahle ea (ha)	Irrigation c :rage (ha)				ncreased irrigated area	
			Before minimum rrigatio rogram		After minimum rrigatio rogram			
			Actual Tigated area	% of 'otential rrigable area	Actual Tigated area	% of 'otentia rrigable area	ha	%
47	84.9	19.4	1.2	6.2	3.7	19.1	2.5	12.9
48	42.5	9.7	c		0.4	4.1	0.4	4.1
49	92.3	21.1	2.2	10.4	c		-2.2	-10.4
53	56.6	13.0	4.0	30.8	10.8	83.1	6.8	52.3
64	54.0	12.4	0.4	3.2	10.8	87.1	10.4	83.9
65	84.6	19.4	c		10.0	51.5	10.0	51.5
76	92.3	21.1	1.6	7.6	9.1	43.1	7.5	35.5
88	63.7	14.6	1.6	11.0	3.6	24.7	2.0	13.7
90	84.6	19.4	0.9	4.6	5.3	27.3	4.4	22.7
91	58.0	13.3	1.1	8.3	5.0	37.6	3.9	29.3
92	58.0	13.3	1.6	12.0	7.3	54.9	5.7	42.9
95	56.6	13.0	0.8	6.2	8.1	62.3	7.3	56.1
114	82.7	18.9	11.8	62.4	23.2	122.8	11.4	60.4
121	77.8	17.8	c		c			
122	53.4	12.2	4.0	32.8	1.4	11.5	-2.6	-21.3
123	63.6	14.6	16.6	113.7	6.2	42.5	-10.4	-71.2
124	83.8	19.2	11.7	60.9	8.8	45.8	-2.9	-15.1
127	113.2	25.9	6.3	24.3	9.3	35.9	3.0	11.6
128	65.1	14.9	1.2	8.1	15.2	102.0	14.0	93.9
129	106.1	24.3	12.9	53.1	21.2	87.2	8.3	34.1
131	56.6	13.0	5.8	44.6	6.3	48.5	0.5	3.9
139	137.3	31.4	4.2	13.4	12.1	38.5	7.9	25.1
141	61.1	14.0	11.9	85.0	21.8	155.7	9.9	70.7
347	88.3	20.2	c		9.7	48.0	9.7	48.0
All ubewells	1817.1	416.1	101.8	598.6	209.3	1232.7	107.5	634.6
Mean	75.7	17.3	5.1	29.9	9.5	56.0	4.5	27.6

c = **There was** no **irrigated crop (mostly nonrice crops).**

Imgated area per pilot tubewell in the Aus seasons increased from 8.6 ha during the pre-MICA period (1984-1987) to 13.0 ha during the post-MICA period (1988-1990) (Table 18). For the satellite tubewells, the area increased from 5.1 to 9.5 ha (Table 19).

Rajshahi Tubewell Sites

Tubewell discharge and irrigation coverage were measured in the selected fifteen tubewell sites in Rajshahi area during the 1990 dry season. Table 19 showed that actual discharge is much lower than the rated one. Water used for growing rice was less than that in the G-K and NBTP areas. However, the productivity of water was much higher in the Rajshahi area than in the other research sites (Table 20).

Productivity of water is highest in the Rajshahi area followed by G-K and NBTP areas. Rajshahi farmers are paying more for water than those in other locations which may influence them toward better utilization of water and other inputs. This indicates that realization of irrigation fees may help in improving irrigation system performance.

SUMMARY AND CONCLUSIONS

It is clear from the above discussion that some revision in the strategies and methods of allocating and distributing irrigation water would be useful. The following specific conclusions are drawn:

Ganges-Kobadak Project

Reliability of water supply. The reliability of water supply in the project is low and it should be improved. A reliable pump operation schedule, which will not change from year to year, should be immediately implemented. This schedule should be known to all farmers so that they can confidently plan their cropping activities.

Optimum pumping schedule. The schedule of pump operation should be advanced to February 1 through October 31. Implementation of this schedule will not require any additional resources, but should accrue significant additional benefits. If optimal timing is followed, farmers can conveniently grow a leguminous crop following the Aman rice harvest using the residual soil moisture. However, farmers' timing of crop establishment often cannot be advanced unless imgation water delivery is also on schedule.

Table 19. Tubewell discharge, irrigable area, water use yield and productivity of water in the selected tubewells of Rajshahi area, Boro Season, 1990.

Location	ischarg (lps)	rigable rea (ha	rrigated rea (ha)	Water used (mm) Land reparation	Growing period	Total	verage yield kg/ha)	roductivit of wale, kg/ha/mm
IFAD								
Shakua	52.1	24 3	13.5	288(12%)a	784(22%)	1072	3610	3.4
Durail-3	40 0	24.3	18.4	234115%)	788(22%)	1022	3610	3.5
Haridagachi	45.3	24.3	30 4	222(15%)	573(30%)	795	4590	5.8
RENTAL								
Mahabathpur-2	53.2	24.3	23.6	282(12%)	721(24%)	IW3	4450	4.4
Darshanpara	48.1	24.3	28.3	244(14%)	708(24%)	952	3000	3.1
Bakshemul	36.8	24.3	12.8	230115%)	651(26%)	881	3830	4.3
PRIVATE								
Palsa	49.3	24.3	27.1	192(18%)	568130%)	760	5230	6.9
Moheskondi	51.0	24.0	27.7	192(18%)	568(30%)	760	5230	6.9
Bakshail	41.6	24 3	16.2	184(18%)	717124%)	901	3450	3.8
Average		24.3	22.0	230115%)	681125%)	911	4148	4.7
IADP								
Sharangpur-1	27 0	24 3	176	150(23%)	711124%)	861	65W	7.5
Sharangpur-2	28 0	18.2	107	154(22%)	1216(14%)	1370	6940	5 1
Sharangpur-1	37 0	24.3	45	162121%)	1061(16%)	1223	6680	5.5
Fazilpur-2	34 0	24.3	148	180(19%)	1155(15%)	1335	6600	4.9
Amtoil	28 0	21.9	68	131(26%)	1109(15%)	1240	6710	5.4
Ramnagar-2	34 3	24.3	142	179(19%)	1160(15%)	1339	6550	4.9
Average		23.0	11.4	160(21%)	1069(16%)	1228	6663	5.5

a. **Figures in parentheses indicate the amount of rainfall.**

Water rotation schedule. **The 10-day rotation method is a technically sound and socially desirable method of water allocation and distribution for the project and should be implemented properly.**

Table 20. System-level water use, yield and productivity ɗ *water in the North Bangladesh Tuebwell Project, Ganges-Kobadak Project and Rajshahi tubewell sites* ɗ *Bangladesh, 1983-1990.*

Locatioı	Year	Rabi season			Aus season			Aman season		
		Vater sed mm)	Yield of wheat (kg/ha)	Produc-tivity of water (kg/ha-mm)	Water used (mm)	Yield of wheat (kg/ha)	Produc-tivity of water (kg/ha-mm)	Water used (mm)	Yield of wheat (kg/ha)	Produc-tivity of water (kg/ha-mm)
NBTP	1984	125	1860	14.88	1503	1785	1.19	1855	4156	2.25
	1985	696	1276	1.83	1909	3100	1.62	2109	4118	1.95
	1986	350	2496	7.13	2266	3608	1.59	2012	3655	1.82
	1987	432	1662	3.85	2988	4203	1.41	3146	3460	1.10
	1988	507	1394	2.75	2944	3932	1.34	2309	3442	1.49
	1989	1739	2124	1.22	2884	3663	1.27	2319	3615	1.56
	Mean	642	1802	2.81	2416	3382	1.40	2292	3741	1.63
G-K Project	1983	-	-	-	1930	3781	1.96	2071	4279	2.07
	1984	-	-	-	3134	3656	1.17	1970	4489	2.28
	1985	-	-	-	3440	3443	0.90	1902	4774	2.51
	1986	-	-	-	1633	3259	.00	1946	4033	2.07
	1987	-	-	-	1450	3280	2.26	1333	4050	3.04
	1988	-	-	-	1843	3047	1.65	1362	4392	3.22
	1989	-	-	-	1530	3412	2.23	1373	4524	3.29
	Mean	-	-	-	2194	3411	1.55	1708	4363	2.55
Rajshah Project	1990	1038	5154	4.97/a	-	-	-	-	-	-

a/ For Born Season rice.

Pumping suspension opportunities. From weekly total rainfall analysis, it is clear that for about 3040 days during June-July, when rainfall is high, water requirements for the maturing **Aus** crop or land preparation **for** the Aman crop under the recommended schedule could be largely met from rain water. Therefore, pump operation during this period should be suspended. Suspension of pumping is very important in terms of operation cost saving because presently it costs about Taka 4,00,000 (approximately US$ 11,500) per day to run the pumps.

Drainage water reuse. There is scope for reuse of drainage water especially in the tail-end areas. Few control structures will be required in the study area to facilitate the reuse of drainage water and this will bring significant benefit.

North Bangladesh Tubewell Project

Pump operation. Most of the tubewells are pumping about 90 percent of their rated capacity even after about **25** years of operation. The water table during the driest months remains within six meters of the soil surface and is fully recharged during the rainy season. Therefore, technical limitations in terms of water availability and pumping ability do not constrain water utilization. Yet, tubewell operating hours are very low compared with other locations in Bangladesh. Water utilization and irrigation coverage are also low and demand significant improvements.

Water distribution. The scattered demand for water in the dry season is inherently inefficient as far as the productive use of water is concerned because of associated losses in conveyance and operation. Optimum irrigable area in the dry season can be achieved if the rotational/blockwise water distribution is practiced through proper supervision.

Water productivity. Among the three study areas, NBTP has the lowest water productivity both in the Aus and Aman seasons. Higher productivity can be achieved through improved water management.

Minimum area coverage. The experience of the Minimum Irrigation Crop Acreage (MICA) Program shows that most of the tubewells are under suboptimal **use** and need further improvement for recovering operation costs and for increasing irrigation coverage.

Cropping plan. A diversified cropping plan should be adopted for maximizing the use of land and water resources. Cropping schedules should be adjusted so that Aman cultivation can take advantage of maximum rainfall periods and early harvest of the Aman crop will provide opportunity for cultivating other non-rice crops during the Rabi seasons since land and water resources are favorable. A systematic approach is needed to encourage farmers toward vegetable cultivation in the dry season.

Communication. Communication between the BWDB staff and end users (fanners) should be improved which will help in improving water delivery and utilization in the project area.

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Main Irrigation System Management for Rice-Based Farming Systems in Indonesia

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INTRODUCTION

FOR THE LAST ten years, the Government of Indonesia has bee promoting crop diversification in irrigated rice fields. Crop diversification (horizontal diversification) is a part of an integrated effort to achieve the objectives of

a. Sustaining and improving food self-sufficiency.

b. Increasing agricultural production to provide raw materials for industry and export.

c. Increasing farm productivity and value added of agricultural products.

d. Increasing farmers' income and improving their welfare.

The crop diversification program in irrigated rice fields also facilitates the operation and maintenance of irrigation structures according to the defined rules, especially in the main system. This is attained by:

a. Allowing the canals to dry up for maintenance work.

b. Decreasing the burden of operation and management during the dry season when normally there is a shortage of water.

c. Increasing the flexibility to allocate water for other uses which are steadily increasing and for supplemental irrigation of two rice crops and one upland crop (palawija) only. Therefore, the crop diversification program will restore the utilization of the irrigation network of Indonesia to its functional design.

Irrigation Management in the Main System

The main system in Indonesia is commonly associated with technical irrigation. These are the irrigation systems which have permanent structures and the distribution of water is fully controlled and measured.

The technical irrigation systems in Indonesia by 1988, covered an area of **2,534,613** ha, representing **57.8** percent of the total irrigated areas. About 1,934,387 ha **(76.3** percent) are located in Java. The general description of the irrigation system and the respective cropping intensity for rice are presented in Table 1.

Table 1. Irrigated area and rice cropping intensity, 1988.

Irrigation status	Areas (ha)		One rice crop percent	Two rice crops percent
	lava	Indonesia		
Technical irrigation	1,934,387	2,534,613	17.6	82.4
Semi-technical irrigation	415,244	1,180,716	29.1	70.3
Simple/village irrigation	376,621	612,432	43.0	57.0
Total	2,726,252	4,387,781		

2. The scope covers operation and maintenance of the irrigation networks together with their accessory structures from the intake to the tertiary canal, 50 meters downstream of the tertiary offtake.

3. The main system shall be responsible for distributing water from the intake structure down to the tertiary offtake according to the scheduled plan.

4. The operation and maintenance of the main system shall be the function and the responsibility of the Local Government.

5. Associated with irrigation water management as a whole, the Local Government (Local Irrigation Committee) makes a plan for the provision and allocation of irrigation water for different uses. This plan is decided by the Head of the Local Government on behalf of the Head of Local Irrigation Committee, at the latest, one month before the rainy season cropping begins.

The operation and maintenance of the imgation networks are also supervised by the Local Government. It establishes protection zones along and around canal bodies and irrigation structures, prohibits excavation in the protected zone to avoid water losses, and prohibits installation, modification or demolition of any structure which may disturb the main function of the irrigation network. The division of responsibility is shown in Figure 1.

SYSTEM MANAGEMENT FOR RICE-BASED FARMING

Management requires that there should be a set of objectives for which all subsequent activities must be oriented. Irrespective of the individual objectives of a particular irrigation system, the three major objectives of production, equity and sustainability should be considered. It is important that the three objectives must be achieved simultaneously.

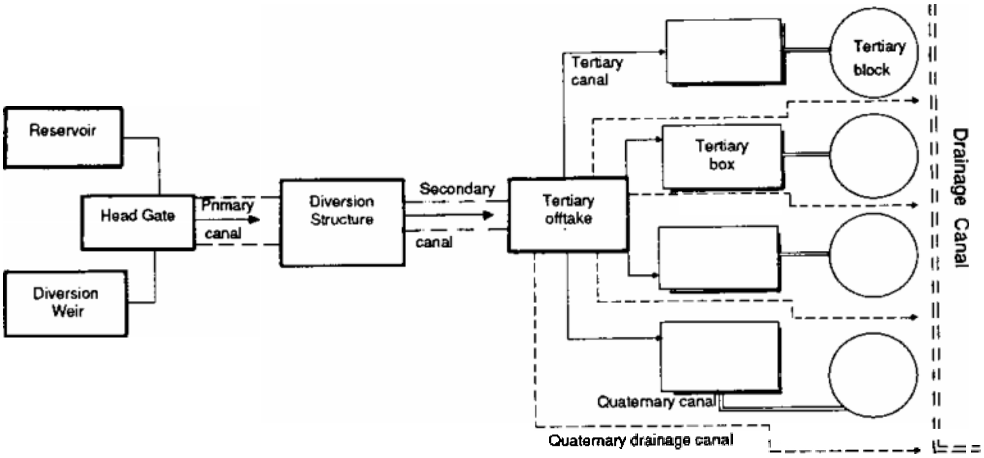
Equity in Water Distribution

Two sample case studies in the coastal plain of irrigated rice fields showed that inequity in water distribution resulted in a water shortage during the dry season and an excess water during the wet season in some parts of the command areas.

In the West Situbondo Irrigation Scheme, it has been observed that there is inequity of water distribution between the head and tail sections of the system. In terms of water sufficiency received by the farmers along the three sections of the secondary canal, head, middle and tail sections, it was shown that the head and middle sections received more water during the dry season than the tail section

(Table 2). However, this did not have much influence on the cropping pattern and the yield of rice (Table 3). Relative difficulties to obtain sufficient water in the middle and tail sections can be noticed from the area with cropping patterns R-U-U (one rice crop and two upland crops) and the lowest yield of the third crop in the tail section.

Figure 1. Delineation of responsibility on some activities of (technical) irrigation management.



Systematic name

Water resource — Main irrigation network |← 0 — Tertiary irrigation and drainage network

Managementaulhorily and regulation of irrigation water and irrigation network responsibility

Local Government (Irrigation Committee) — Water Users' Fanners Association (P3A), Subak. or owner → Government

Planning of inigalion water supply responsibility

Local Irrigation Committee proposes lo Local Government. Local Government adjudicates the plan. IC implements the plan → P3A, Village, Subak, other uses, submit applicalwn to IC

Operation and maintenance of irrigation network responsibility

Local Government → | ← P3A, Village, Subak, owners → | ← L G

Table 2. ***Water distribution performance of the secondary canal, West Situbondo Irrigation Scheme (WSIS).***

Sufficiency Level	First rice crop			Second rice crop		
	Head (N=270)	Middle N=266)	Tail (N=270)	Head (N=270)	Middle N=266)	Tail (N=270)
Water sufficient at all times	62.5	97.6	78.9	52.1	53.5	36.3
Water sufficient in 4 to 6 months	4.2	2.4	5.3	13.2	27.9	47.1
Water sufficient in 2 to 4 months	33.3	0.0	10.5	34.7	18.6	17.6
Water sufficient in less than 2 months	0.0	0.0	5.3	0.0	0.0	0.0

Table 3. ***Distubution of cropping pattern and rice yield along the secondary cannal of West Situbondu Irrigation Scheme.***

Location with respect to intake		Percent of sample				Yield of rice (t/ha)		
		R-R-R	**R-R-U**	**R-U-U**	**R-R-F**	I	**II**	**III**
Head	(n=270)	58.3	41.7	0.0	0.0	4.58	3.97	2.77
Middle	(n=266)	61.7	34.0	2.1	2.2	5.92	3.47	2.83
Tail	(n=270)	62.2	35.2	1.1	0.0	4.78	4.85	2.17

Using wetness index criteria (average soil moisture content in the command area), the study in the Cikeusik Irrigation Scheme indicated that the tail section of the command area also had drainage problems during the rainy season beside a water shortage during the dry season (Table 4). Rapid changes of water status in PB VII and VIII from wet to dry and wet again in accordance with the beginning of the rainy season give evidence to the inequity of water distribution along the main system. Further study indicated that based on soil moisture status, only 42 percent out of the 136-ha area could be grown to upland crops (Pusposutardjo and Arif **1990).** The potential area for upland crops in the tail-end portion of the system has decreased because of salt water intrusion during the dry season (Pusposutardjo and Arif **1990).**

Equity could also be influenced by the size of the irrigation system. **For** systems with smaller command areas (100-300 ha), inequity in water distribution along the main system is not significant. As a result, the influence of inequity in water distribution to the difference of cropping pattern in the whole command areas is also not pronounced (Anonymous 1988). Small irrigation schemes are usually located in the hilly areas and drainage may not be a problem. In this case, the willingness of farmers to grow upland crops depends much on the availability of water during the dry season and on economic considerations.

Accuracy in Annual Planning

The plan of the irrigation season is made by the Local Irrigation Committee (LIC) and approved by the Head of the Local Government. The plan for the season is then implemented by the LIC. Based on the plan, the LIC allocates water for different uses and distributes it according to the procedure of operation and maintenance. The irrigation plan also contains the schedule for routine maintenance by drying the canal (shutting the flow).

Vermillion et al. showed that enough information on previous experience is not used in the process of preparing the annual crop plan, and that the plan is not readily transformed into a set of operating rules. Thus, while the plan may call for a very limited area of rice in the first dry season, the system is actually operated in such a way as to encourage farmers to plant extra rice.

Since the irrigation season plan has to be made, at the latest, one month before the start of the planting season, the accuracy of planning with respect to the occurrence of rains or the availability of water in the main water course is very important. When the farmers deviate from the schedule, problems related to water supply and demand occur.

The use of 80 percent dependable rainfall in planning cannot reliably match the real condition. Studies conducted in three large irrigation schemes of Citagampor Project and in three small irrigation schemes in East Java indicated that farmers still rely more on their experience in predicting water based on the prevailing rainfall rather than on the planned irrigation schedule (Anonymous **1987;** Anonymous 1988). Normally, farmers start land preparation whenever the cumulative rainfall accounted from the latest minimum rainfall reaches 300-400 mm. The difference

between the irrigation plan and the existing activity in land preparation ranges from 10 to **14** days.

Table 4. ***Distribution of soil moisture status and the existing crop along Pabedilan Secondary Canal of Cikeusik Scheme during the dry season, 1989.***

Location of tertiary block	Month				
	July	August	September	October	November
lead (MTR V)					
a. Soil moisture status	(0,10,0)	(5,10,15)	(5,5,20)	(10,5,15)	(0,20,10)
b. Existing crop		Rice (D)	Rice		
		Corn	Corn (D)	Corn (D)	Corn
		Tobacco	Tobacco	Tobacco	
		Sugarcane	Sugarcane	Sugarcane	
ugarcane(D)					
		Mungbean	Mungbean	Mungbean	
		Onion	Onion	Onion	
liddle (SR 111)					
a. Soil moisture status	(10,0,0)	(10,15,5)	(0,5,25)	(0,15.15)	(10,5,15)
b. Existing crop		Rice (D)	Rice		
		Corn	Corn (D)	Corn (D)	
		Onion	Onion		
		Sugarcane	Sugarcane	Sugarcane	
ugarcane(D)					
			Chili	Chili	Chili
1iddle (PB III)	(0,0,10)	(0,0,30)	(0,0,30)	(10,5,15)	(5,20,5)
a. Soil moisture status	·	Onion(D)	Onion(D)	Onion(D)	Onion(D)
b. Existing crop		Sugarcane	Sugarcane	Sugarcane	Sugarcane
		Mungbean	Mungbean		
			Chili	Chili	Chili
'ail (PB VII & VIII)					
a. Soil moisture status	(5,5,0)	(10,20,0)	(0,0,30)	(10,0,20)	(25,5,0)
b. Existing crop	Rice(D)	Rice(D)			
		Onion(D)			Onion(D)
	Chili				
			Green manure	Green manure	Green manure

Source; Sukirno (1989).

Notes: (0,10,0) -number of days corresponding to wetness index (wet, moist and dry, respectively).
Wetness index: the average soil moisture in the area:
- wet - saturated or stagnant.
- moist - suitable for upland crop.
- dry - insufficient for any crop.
- D - dominant crop.

Since cropping is continuous, a delay of 10-14 days will shift the peak water demand to the land preparation period for the next (second) rice crop. When this occurs, maintenance of irrigation structures becomes a problem because the flow cannot be shut off since some farmers will still need water. Normally, the second season rice crop begins in the middle of the rainy season and farmers will not grow upland crops because the rice field is still too wet. Moreover, they expect to receive sufficient water from rainfall for growing a third rice crop.

In the implementation of the irrigation plan, several modifications or changes are commonly made. These are just based on experience and the accuracy of the plan is questionable. Farmers, therefore, do not rely on the irrigation schedule and oftentimes grow an unauthorized rice crop during the dry season. The ratio of unauthorized to authorized dry season rice crop is in the range of 50 to 100 percent.

Rotational Irrigation

When rotational irrigation is adopted, travel time of water is particularly important. Depending on the discharge being delivered, it may take a considerable time to fill the canal with sufficient water to generate a manageable stream size into each tertiary block scheduled for irrigation. If the stream size is too small to enable farmers to effectively distribute water within a tertiary block, the water has limited utility. Rotational schedules should thus be based not on the time of delivery at the head of the main or the secondary, but on the duration of useful discharges that can be guaranteed to be delivered to the head of each tertiary block.

Mawardi 1990 has demonstrated that in most of the canals studied, travel time is relatively easy to predict. The largest variation appears to result from the initial discharge at the head of the system, but even with this uncertainty, it appears feasible to design rotational irrigation schedules that make better allowance for travel time at the start of each rotation.

Rotational schedules have to be effectively implemented to meet equity objectives. If the schedule becomes erratic, farmers will lose confidence that their next turn will come when expected, and will probably either interfere with gate settings, thereby disrupting control over water distribution, or may as a last resort end up destroying structures.

IIMI's research has shown that rotational schedules are not rigidly adhered to (Murray Rust 1990). In 1988, part of the reason for this appeared to have been because the schedule was not very equitable. In 1989, the implementation was somehow improved, with most deviations being related to periods when supplies were greater than expected, and more farmers could obtain water than was initially planned.

TECHNICAL CONSTRAINTS IN MAIN IRRIGATION SYSTEM MANAGMENT

The last inventory conducted in 1988by the Directorate Irrigation I of the Directorate General of the Water Resources Development (DGWRD) showed that the quantity and diversity of the structures in Indonesian irrigation systems were enormous (Table 5). All these structures have to be managed under limited

Table 5. Physical infrastructure of the irrigation network **in** ***Indonesia.***

Item	Quantity
Number of irrigation schemes	6,731
Total command areas (ha)	4,819,470
Water resources: rivers. reservoirs, springs and others	14,859
Intake structures: pump. moving weir, fixed weir, free intake. etc	21,874
Structures in the delivery canal: sand trap, flushing gate, diversion structure, siphon, chute, drop structure, etc.	157,196
Structures in the drainage canal: bridges, culverts, spillway, etc.	10,968
Structures in the side canal: bridges, culverts, spillway, etc	688
Secondary canal (km)	62,823,680
Drainage canal (km)	19.582,I I2
Supply canal (km)	988.913,
Side canal (km)	623,286
Road inspection (km)	10,353,948
Cover dikes (km)	2,540,994

facilities, manpower and funds. Obviously, the operation and maintenance of the main irrigation system have already become a heavy burden on the government.

The limited facilities, manpower and funds also create related technical problems in the main system. These are:

1. ***Insufficient* hydrological** data. Hydrological data in terms of quantity, quality and time series are insufficient to back up the operation of the main system properly. Most irrigation schemes (especially out of Java) were designed and constructed using very limited hydrological data. These data have been collected for a few years (1-5 years), only during the implementation

of the imgation projects. Because of the very limited data, the operation of the irrigtion scheme is usually based on trial and error. Consequently, this affects the management of the system.

2. *Poor physical condition of the structures.* Results from several studies (Anonymous 1984; Anonymous 1987; Anonymous 1988; Susanto 1986) showed that most of the water measuring devices (especially the Romijn type) were not in good condition. The error of measurement may deviate from 30 to 105 percent of the standard reading. Very high variation between the actual and the estimated flow causes some parts of the areas to receive more water than the others as shown in Table 2. The error also results from improper construction (mostly with the Flume type), incorrect location, and poor maintenance. Poor canal maintenance causes considerable conveyance losses. These losses vary according to the length and condition of the canal, and discharge. A study on canal losses showed negative values possibly because the canal is located below the rice field areas. Conveyance losses of 5-10 percent are reasonable values for canals less that 2 km long. These increase to as much as 16-20 percent if the total length of the canal reaches 4-5 km.

3. *Insufficient drainage facilities.* Although in the design of irrigation systems the drainage requirement has been considered, drainage facilities deteriorate very fast. Farmers usually do not know the benefits of having good drainage facilities. They consider drainage facilities to be useless canals. The destruction of drainage canals at the tertiary level occurs mostly in the sugarcane areas. Considering that some upland crops are very sensitive to excess water, more attention has to be given to improving drainage facilities. Otherwise, the program on crop diversification in irrigated rice fields will not be very successful.

4. *Water resource.* More than *80* percent of the irrigation schemes in Indonesia are run-of-the-river type. These systems are very sensitive to the hydrological condition of the catchment area to store water from rainfall. As the condition of the catchment areas changes very rapidly due to deforestation, the river discharge also fluctuates very rapidly between peak flow and base flow. Evidently, it creates a problem in the management of the main system.

5. *Inadequate manpower and facilities.* The number of irrigation personnel with permanent status as government officials is still below the standard requirement (Djunaedi 1990). Most of those who are involved in operation and maintenance of the main system are monthly wage earners who are not motivated to achieve high quality of work. Besides inadequate manpower, in operation and maintenance of the main system there is also the problem of lack of transportation facilities to carry out field operations. A gatetender, for instance with a service area of 750 to 1,000 ha, is only provided with a

bicycle. With this transport, he has to monitor and record the daily flow and crop area, attend weekly meetings with water masters, supervise maintenance work, give guidance to water users' associations, and act as the irrigation extension officer. Similarly, the water masters who have service areas of more or less 5,000 ha are only provided with motorcycles for their transportation.

6. *Lack of a standard manual for operation and maintenance.* The gravity imgation system is influenced by topography. In the hilly areas, more structures are required to control the flow. In the flat areas, more check structures are required to obtain the needed head. These characteristics of the gravity irrigation system should be considered in the Manual for Operation and Maintenance. At present, however, this kind of manual is not yet available. A manual specifying the conditions of the area will facilitate the management of the system.

RECOMMENDATIONS FOR CHANGES IN IRRIGATION MANAGEMENT FOR RICE-BASED FARMING

Considering the objective of maximizing irrigation benefits in the dry season in the rice-based cropping system, Murray-Rust (1990) made an overall assessment of the results obtained from the component studies and indicated three main sets of tasks — rotational irrigation, continuous irrigation and planning for long-term objectives — where quick and effective progress can be made.

Rotational Irrigation

Rotational irrigation is a mechanism by which scarce water can be allocated to as many farmers as possible. It, therefore, requires greater top-down control over water than when water is relatively abundant. Given that rotations are almost inevitable in the dry season in the main and secondary canal systems, the following recommendations are presented

1. Rotational irrigation should be introduced when required for hydraulic reasons, and not based on values of factor-K because it is possible to have high factor-K values at low discharges.

2. The area planned for irrigation for each day has to take into account the ability of the irrigation agency staff to maintain proper control at the structures used to delimit rotational boundaries, and to minimize the number of gate operations required.

3. The size of rotational units should aim at maximizing equity by taking into account travel time, conveyance losses and other hydraulic conditions.

4. Within-season scheduling of rotational irrigation should be based on a priority system that guarantees water to a certain area, but specifying which areas would get additional irrigation water if supplies are greater than expected.

5. Once publicized, rotational schedules must be strictly adhered to so that farmers can have confidence in obtaining water according to the priorities already established. Failure to deliver water on schedule should be viewed as a serious mistake of the management.

6. The rotational schedule has to be agreed upon between farmers and irrigation staff well in advance of implementation and should, over time, following seasonal assessment of the benefits obtained, be modified to become an established and routine component of irrigation practices.

Continuous Imgation

From the perspective of improving dry-season irrigation performance, the focus of irrigation managers must be to manage excess water by reducing discharges at every opportunity, while still meeting the crop water requirements. Through good management, it is possible to move to a situation where farmers do not object to reduced deliveries because they are confident that the system will deliver water when needed. It should, therefore, consider the following:

1. During the wet season, delivering more water than required should be viewed as a management failure because it may have subsequent negative implications on the establishment of nonrice crops. This includes reducing discharges during periods of high rainfall or when crops are nearing harvest and have lower water requirements.

2. When supplies are greater than demand, more attention should be given to monitoring drainage conditions or water tables than to discharges entering tertiary blocks. In this way, it is possible to move towards a needs-based allocation of water under favorable water supply rather than relying on theoretical calculations of demand.

Planning for Long-Term Objectives

Most irrigation management strategies tend to concentrate on the short-term problems of matching available supplies to demand at field level. While this

achieves short-term production objectives it frequently leads to an inherently inequitable pattern of irrigation. Access to water is determined not by equity or the need to share benefits of irrigation water to as many people as possible, but by the ability of farmers to plant crops quickly. Once crops are planted, then demand-based water allocation principles no longer meet equity objectives.

This situation creates a genuine dilemma for those involved in the planning process because they have to decide whether equity is an important objective. For the irrigation manager, this is particularly difficult because achieving greater equity while maintaining production requires much greater managerial inputs than only meeting production goals. However, the combination of increasing pressure on land and water resources makes it imperative that equity is given as much importance as production, if the benefits of imgation investments are to be maintained. The following recommendations aim at ways of achieving these dual objectives.

1. The annual planning process should move towards allocation of water based on the area capable of being imgated to minimize discrepancies in cropping intensities between head-end and tail-end areas. This would result in allocation of water on a proportional basis using area as the primary determinant rather than the existing cropping pattern.

2. Where there are significant differences in soils or drainage conditions, the allocation should be modified to take into account the differences in water requirements. In such cases, there may also be merit in considering zoning, such as permitting poorly drained areas to obtain water for two rice crops instead of one because there is little opportunity for nonrice crop production.

3. In cases where water supplies in the peak of the dry season are very limiting, the annual plan should include a between season allocation, so that there is an overall level of equity developed over a period of two or three years.

4. There must be a clear linkage between the annual plan and the operational plan of the irrigation manager. An annual evaluation process should be done to determine whether deviations from the plan were the consequences of weaknesses in implementation or in planning.

5. It is particularly important that plans be properly followed in the transition period from the wet to the dry season to avoid too much area for more water-demanding crops which cannot be properly irrigated when water supplies begin to decline.

Complementing the above-cited strategies, several options have also been identified to address the problems in the operation and maintenance of the main system as a part of an integrated management activity. These are as follows:

1. Providing facilities and personnel to meet the minimum standard level.

2. Giving special attention to improve data-gathering and the processing technique to provide more reliable information.

3. Improving the information management system to minimize information losses and to maximize the use of information and data already gathered.

4. Providing different standard procedures of operation and maintenance according to the characteristics of the irrigation scheme, such as the elevation and topography of the command area. Developing a standard procedure of operation and maintenance (in the form of a manual) can be a long-term program.

5. Providing sufficient and reliable hydrological data, including the calibration of water-measuring devices.

6. Providing a simple but accurate method to estimate probable rainfall and river discharge. Related to this technique is the procedure to estimate the amount and distribution of available soil moisture over irrigated areas.

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Main Irrigation System Management for Rice-Based Farming Systems in the Philippines

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INTRODUCTION

MOST IRRIGATION SYSTEMS in the Philippines and in other developing countries of Asia have been designed for rice irrigation. The majority of such systems are run-of-the-river type, with fairly adequate water supply to irrigate their design areas during the wet season. However, during the dry season, they experience water scarcity so that only part of the design area could be served. This situation somehow encouraged the adoption of diversified crops in some of these systems.

While the need to produce more rice to support the demand of the increasing population is recognized, the production of nonrice crops during the dry season provides opportunities for increasing the productivity of irrigation systems. It could provide a means to optimally utilize the available land and scarce water resources for agricultural production.

The cultivation of upland crops in the dry season with or following lowland rice is not really a new practice in some irrigation systems. However, much more management inputs from both the irrigation agency and the farmers may be needed when nonrice crops are grown. Variability in demand in time throughout the season and at any moment of time within the system is expected. As most irrigation systems have been designed for rice cultivation, management modifications may have to be introduced.

This paper presents a synthesis of the results of the three-year study on irrigation management for rice-based cropping conducted by the International Irrigation Management Institute (IIMI) and the International Rice Research Institute (IRRI) in collaboration with national institutions in the Philippines. It was primarily based on the reports presented during the National Workshop on Irrigation Management for Rice-Based Farming Systems held from 10 to 11 September 1990 at the Continuing Education Center, University of the Philippines at Los Baiios, College, Laguna. It focuses on the system level considerations to improve the performance of irrigation systems for diversified cropping.

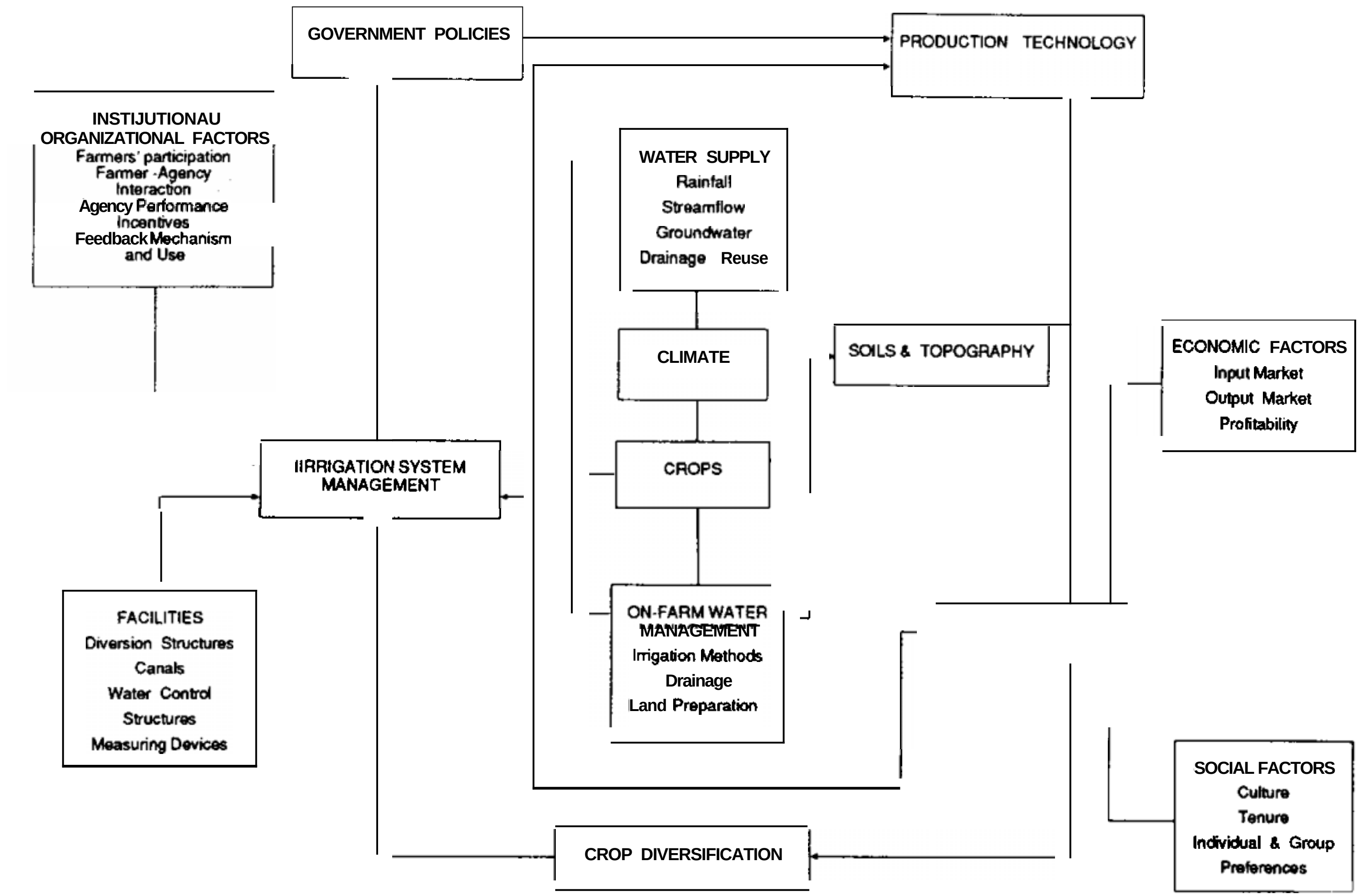
SCOPE AND OBJECTIVES

In accommodating nonrice crops during the dry season it is expected to address the three overall objectives of irrigation systems, namely; productivity, equity, and sustainability. By planting nonrice crops, larger areas can be served and made productive while improving equity **of** water distribution since more farmers will be benefitted. Through improved irrigation management, sustainable farming systems could ultimately be achieved. When farmers feel assured of receiving water deliveries that correspond in timing and quantity to the requirement of field crops, they will be more willing to take the risk of diversifying into new crops. The diversification of cropping systems reduces economic and biological risks associated with growing a single crop.

In addressing these overall objectives, each system has to develop its own set of specific objectives and plan out the processes that will be employed. Essential to these tasks is an assessment of the conditions of and the resources that may be tapped by the system (Figure 1). These resources include: 1) water source; **2)** land; **3)** crops; **4)** finances; 5) facilities; *6)* support services; and **7)** organizations. In one way or other, these are important considerations that have to be looked into. The project had given more emphasis on the aspects of management of water and management **of** organizations.

Management of **water.** Management of water concerns processes in the physical system. It encompasses the operation and maintenance of a canal system from the **source** down to the farm. **It** includes the delivery of water to farmers or farmer groups and the removal of the excess water not needed by the crops. Thus, it implies awareness of the water requirement of crops and of the constraints on water delivery that may be imposed by such aspects as soil type or land shaping.

Figure 1. Interrelationship of factors affecting crop diversification



Canal operations are still the predominant area of water management. Many of the present problems of canal operations result from the changing objectives of canal systems, like changes in cropping patterns as farmers adjust to economic changes.

The development and utilization of the groundwater resources could augment the surface water supply in most irrigation systems. The conjunctive use of groundwater and surface water resources may modify the seasonality of irrigation supplies.

Management of organizations. Institutional arrangement and organization and management changes that will facilitate the implementation of improved practices should go hand in hand with the aspect of management of water. Increased accountability of the irrigation agency, particularly to the farmers, and improved coordination among agencies should be looked into. Techniques to enhance communication and information management processes of the irrigation agency are also important. Thus, **management of organizations essentially** concerns people and includes information management.

Management should monitor not only the inputs but also the outputs, the process, and the feedback, and make necessary changes in real-time operations in response to such feedback. Enhancing the management capacity of the decision-making and operating personnel of irrigation agencies, is the key to achieving and sustaining high levels of irrigation system performance. If irrigation agencies are to adopt better canal operation practices and use them on a large-scale and sustained basis, profound changes in both their internal structures and processes and the policy environment influencing them will be required.

The relationship between the agency that manages irrigation and the users of water or the farmers must be given due attention. They are joint participants in the business of crop production, and irrigation cannot succeed without the best efforts of these two groups. The farm community, however, is not under the direct control of the managing organizations. But because the performance of the system is affected by those aspects that are outside an agency's direct control, it cannot ignore what happens in these sectors. It should be able to find ways of influencing them.

Objectives of the Project

In support of the overall goals of the IIMI-IRRI Project, the Philippine component aimed to: 1) document and analyze the planning and management procedures of irrigation systems with rice-based cropping; 2) explore strategies to efficiently and effectively manage irrigation systems for crop diversification; and 3) draw up recommendations for possible use by irrigation managers, farmers and policymakers.

IMPLEMENTATION ARRANGEMENTS

Study Sites

T [illegible] ducted in three operating irrigation systems in Luzon. [illegible] th [illegible] Talavera River Irrigation System (UTRIS) in Nueva Ecija, Laoag-Vintar River Irrigation System (LVRIS) in Ilocos Norte and the San Fabian River Irrigation [illegible] in Pangasinan (Figure [illegible] The criteria used in the [illegible] 1) irrigation system type and size; 2) presence [illegible]; 3) current activities of IIMI and IRRI; 4) presence of a variety of soil classes; 5) rainfall [illegible] 6) existence of farmers' [illegible] 7) location and environment (whether peaceful or not).

All three are run-of-the [illegible] November and dry the rest of the year, [illegible] 4,000 ha for UTRIS (including the San Agustin Extension area), LVRIS, and SFRIS, respectively [illegible] 1) Upland [illegible] diversified crops such as onion, tobacco, cotton, [illegible] etc., have been grown in portions of the service areas during

Talavera River Irrigation System. The UTRIS has two main [illegible] The left bank main canal (facing downstream) is called the San Agustin Extension (SAE) and the right bank main canal is called the UTRIS main (Figure 3). The SAE serves 750 ha (under one watermaster division) in the wet season and 150 [illegible] the dry season. It has one main lateral and three sub-laterals with a total canal length of 10 k

The UTRIS main serves 3,900 ha in the wet season and 500 to 750 ha [illegible] It has six main laterals and seven sub-laterals with [illegible]

Table 1. General description of study sites.

System	Dam type	[illegible] (h)	Soil type	Benefited area, crop year, 1989-90		
				Wet-season rice (ha)	Dry season	
					Rice (ha)	Other crops*(ha)
LVRIS	Ogee-dam	2,377	Silty clay loam to clay loam	2,377	700	700
UTRIS**	Ogee-dam	1,650	Silty clay loam to clay loam	3,900	1,150	500
SFRIS	Ogee-dam	4,000	Silty clay loam to clay	2,765	2,765	1 000

Notes:

* for LVRIS, predominantly garlic with tomato, mungbean and vegetables.
[illegible] predominantly [illegible] with some vegetables.

including San Agustin Extension area

Figure 2. Map of the Philippines showing location of study sites

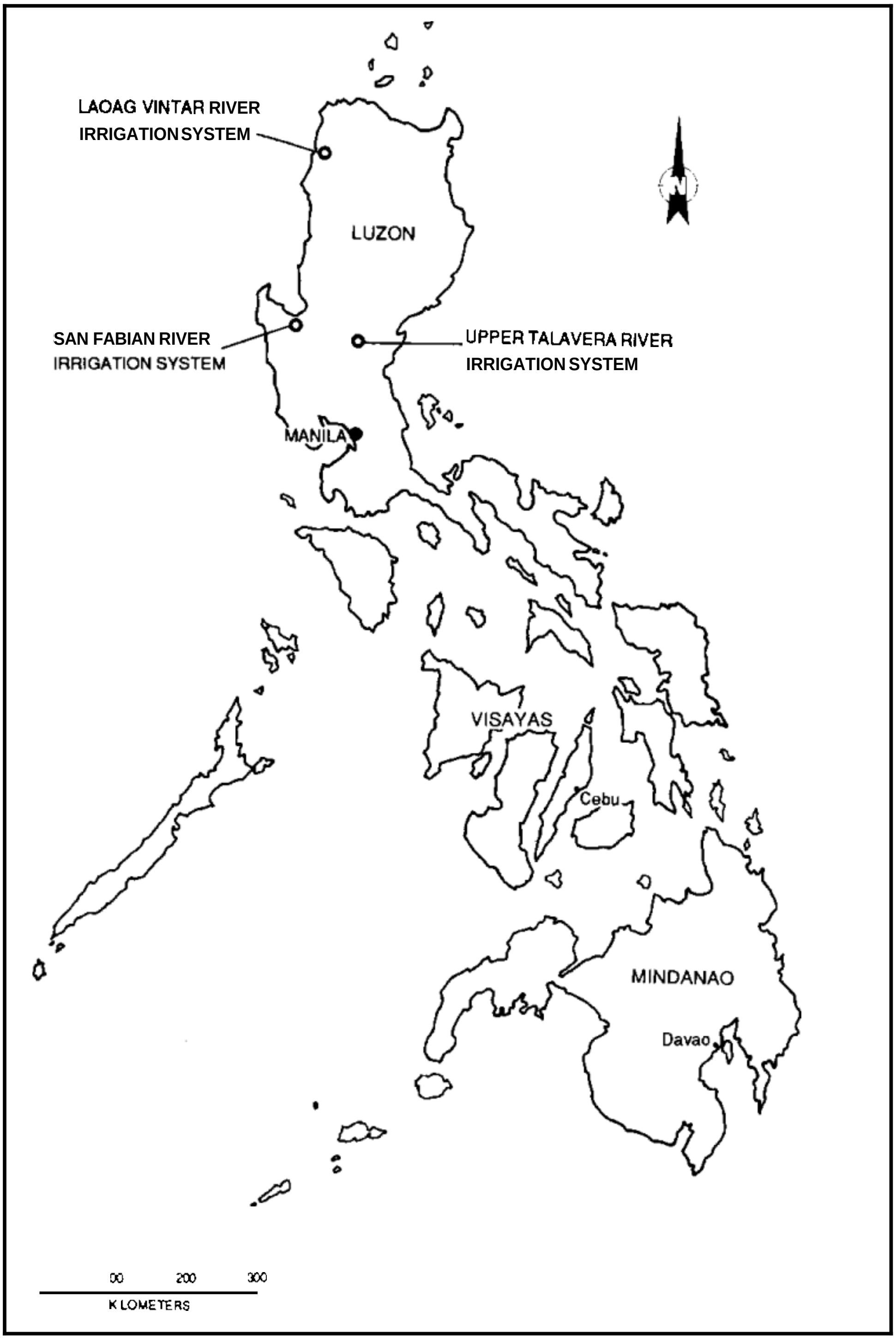
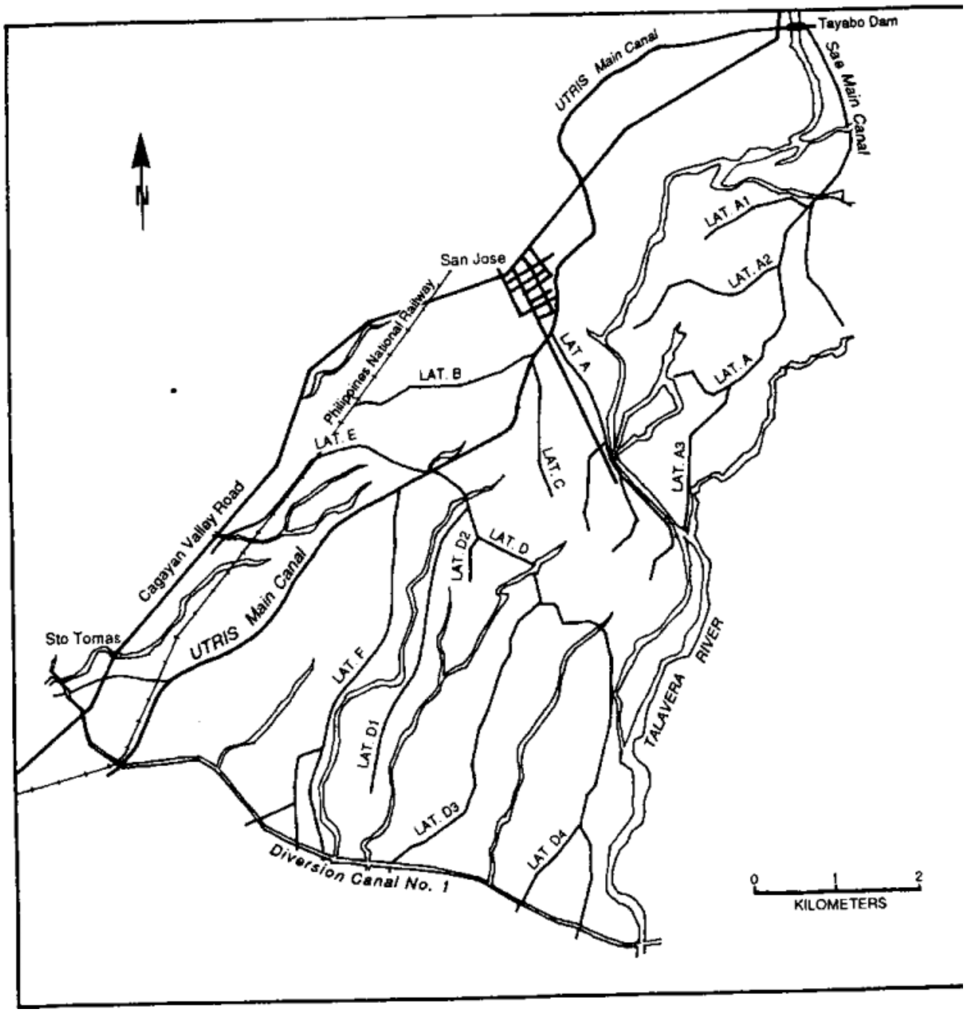


Figure 3. Map of **the** *Upper Talavera River Irrigation* **System.**



During the dry season, about 200 to 300 ha are planted to diversified crops, mostly onion. Besides the income from the crop, the physical characteristics of the soils in the area may have contributed to the practices of diversification. The agro-hydrological characterization conducted by the Bureau of Soils and Water Management (BSWM) showed that the system has generally lighter soils which suit upland crops (Figure 4). An earlier study by Cablayan and Pascual (1989) identified some 41 percent of the area as highly suitable for irrigated diversified crops, 54 percent as moderately suitable and only 5 percent as marginally suitable.

Laoag-Vintar River Irrigation System. The LVRIS has a total service area of 2,377 ha covering Laoag City, Vintar and some areas of Bacarra and Sarrat in the province of Ilocos Norte. It has a total canal length of 72.98 km composed of a 27.5-km main canal, seven laterals and five sub-laterals (Figure 5). Curved sections of the main canal which are susceptible to erosion are lined. It was recently rehabilitated through the National Irrigation Systems Improvement Project (NISIP).

The total area planted in the dry season is about 1,500 ha with about 800 ha planted to rice. Rice is generally planted in the upstream portion, near the main canal and in low elevation areas. Diversified crops, mainly garlic, are planted in well-drained light soils, mostly at the tail sections. More than 50 percent of the area of the system have been identified as highly suitable to diversified crops.

San Fabian River Irrigation System. The SFRIS also has two main canals on both banks of the Bued River. The left bank main canal (facing downstream) serves the San Jacinto area and the right bank main canal serves the San Fabian area (Figure 6). The San Fabian area has three main laterals and 5 sub-laterals.

The potential service area of the system is more than 4,000 ha but only half of it is served for the wet season rice. The water control system is only capable of irrigating 2,765 ha of rice in the wet season and 1,500 ha of rice and tobacco in the dry season. Tobacco and other upland crops are usually planted in the upstream laterals overlying alluvial fan terraces with soils of moderate to rapid internal drainage (Figures 7 and 8).

Research Implementation and Coordination

The different research studies were conducted primarily through contracts with national research institutions and by research scholars and fellows as part of the project's professional development objective. The National Irrigation Administration (NIA) was the primary collaborator. The other agencies involved were the Department of Agriculture (DA), Bureau of Soils and Water Management (BSWM), Central Luzon State University (CLSU) and the Mariano Marcos State University (MMSU). Coordination of the different activities was encouraged through regular meetings of the different researchers. Some of the studies were also included in the regular review and evaluation of researches conducted by the National Agriculture and Resources Research and Development System (NARRDS) through the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD).

Figure 4. Soil classification map of Upper Talavera River Irrigation System based on agro-hydrological soil characterization.

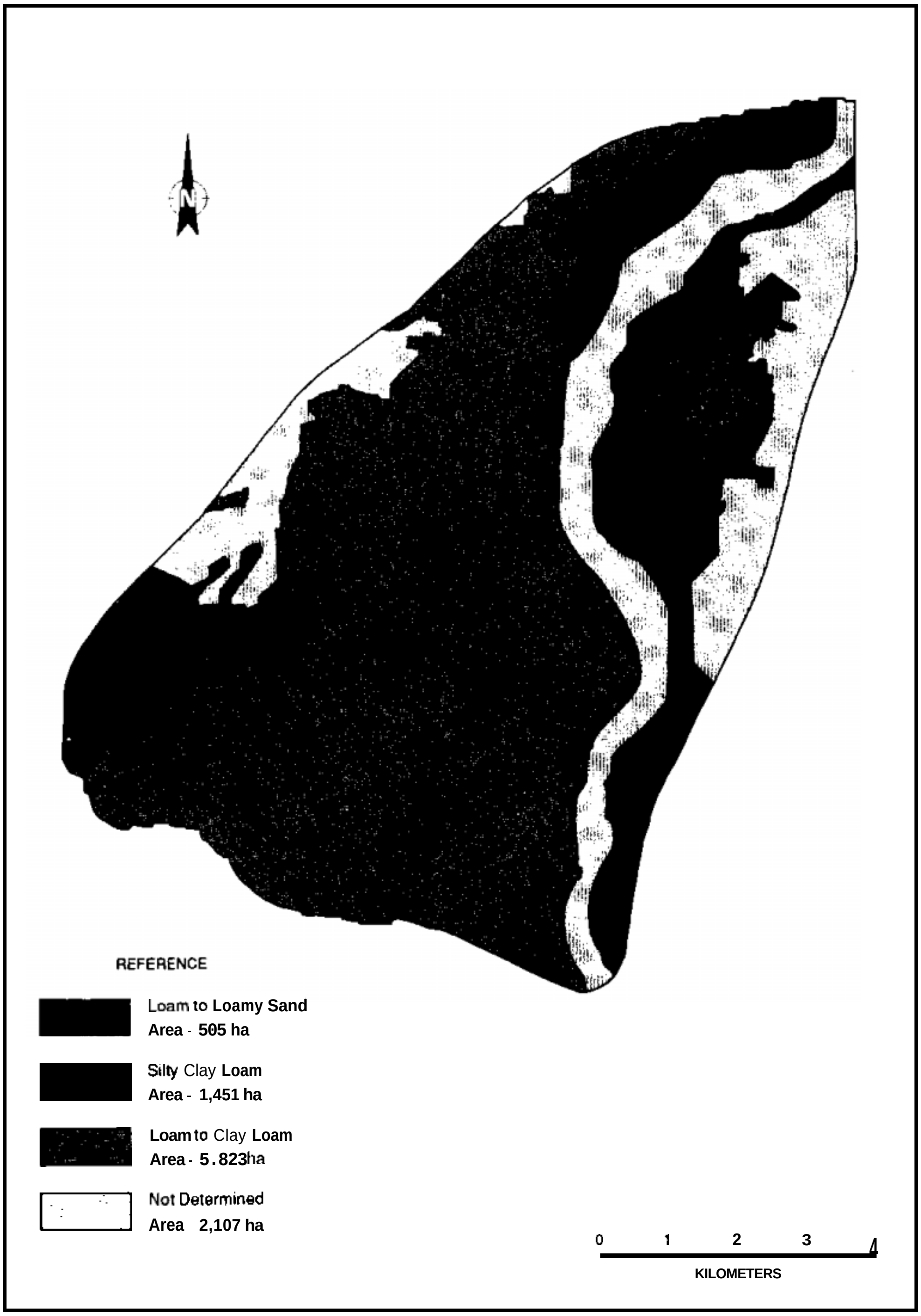


Figure 5. Map of the Laoag-Vintar River Irrigation System.

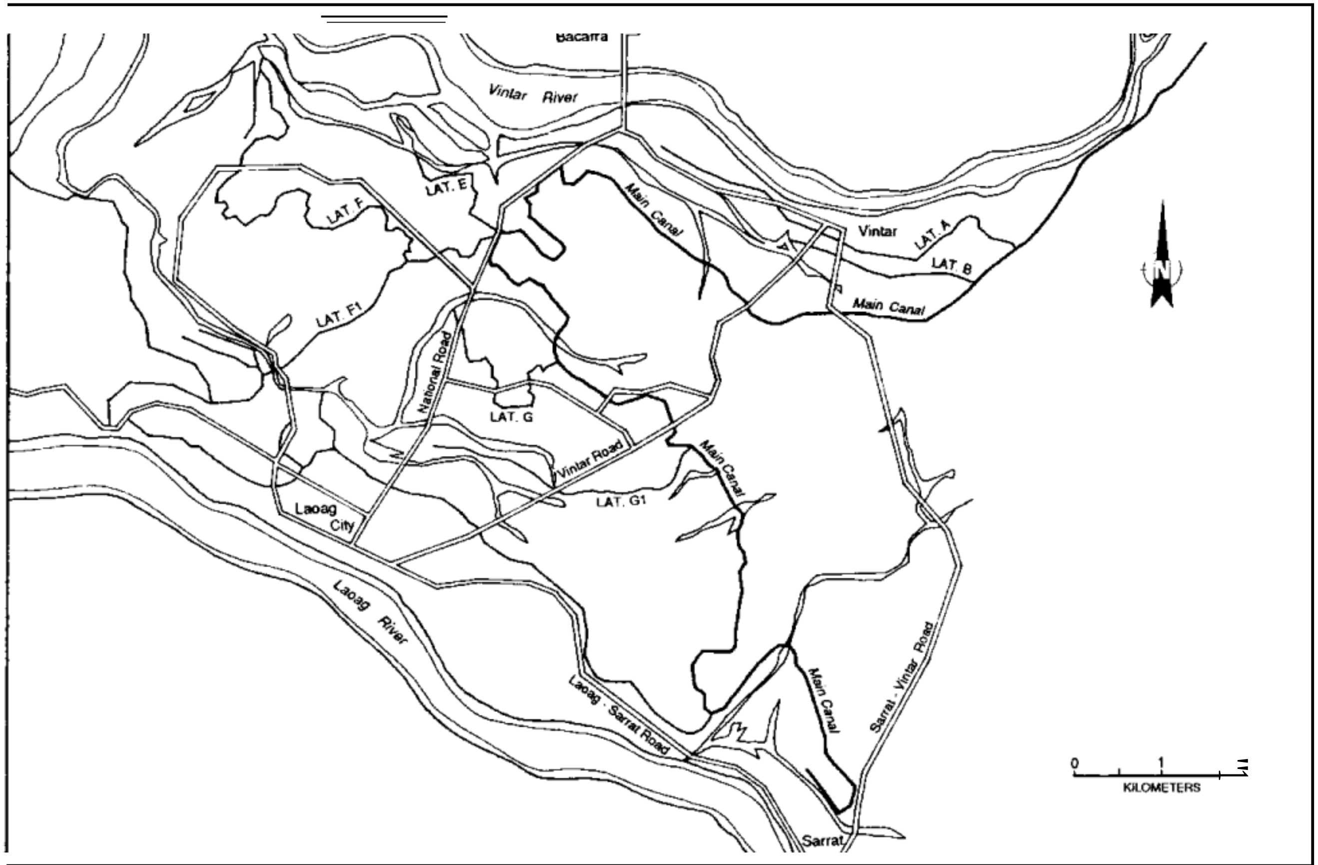


Figure 6. Map of the San Fabian River Irrigation System.

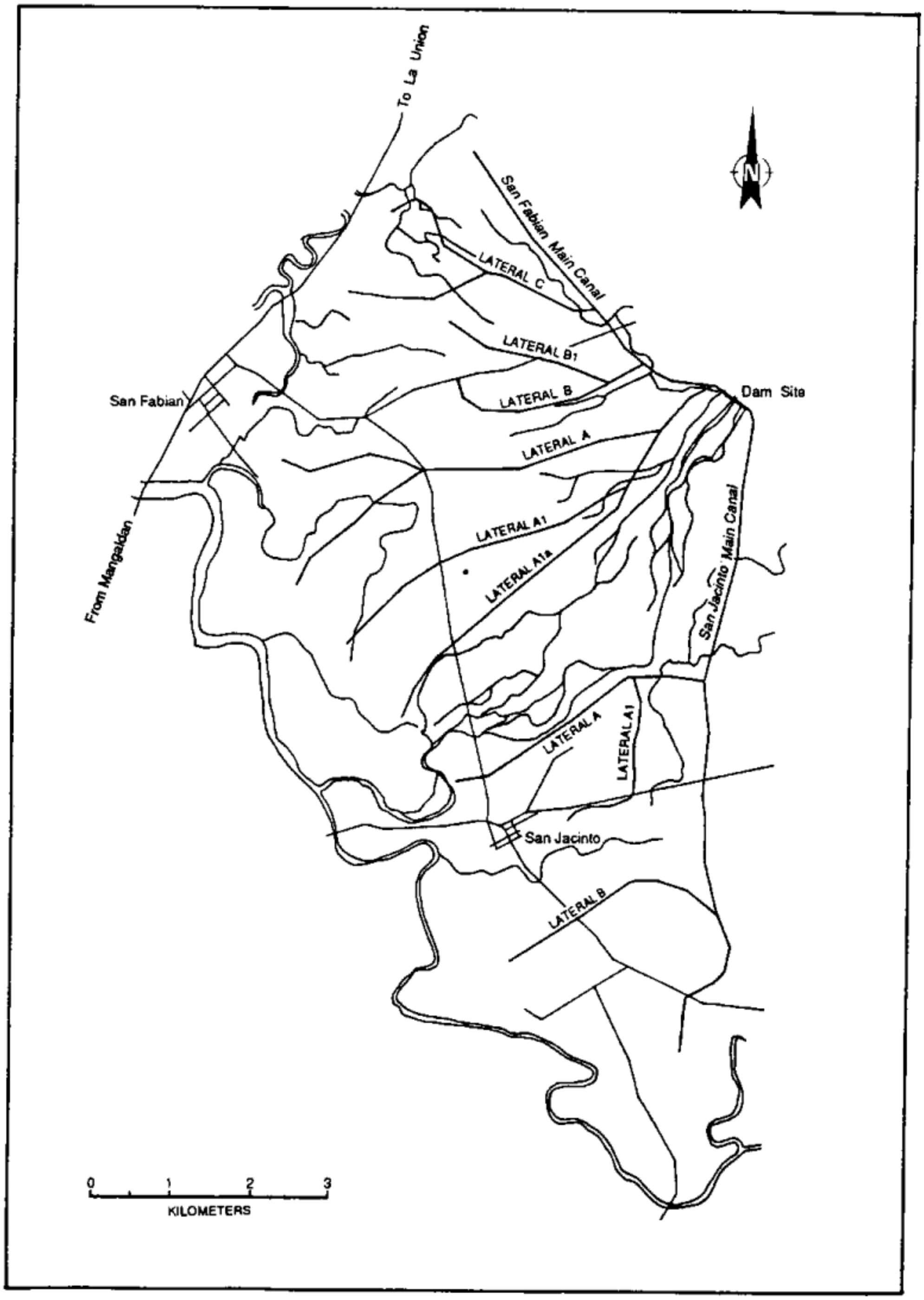


Figure 7. Agro-hydrological soil characterization map, San Fabian River.

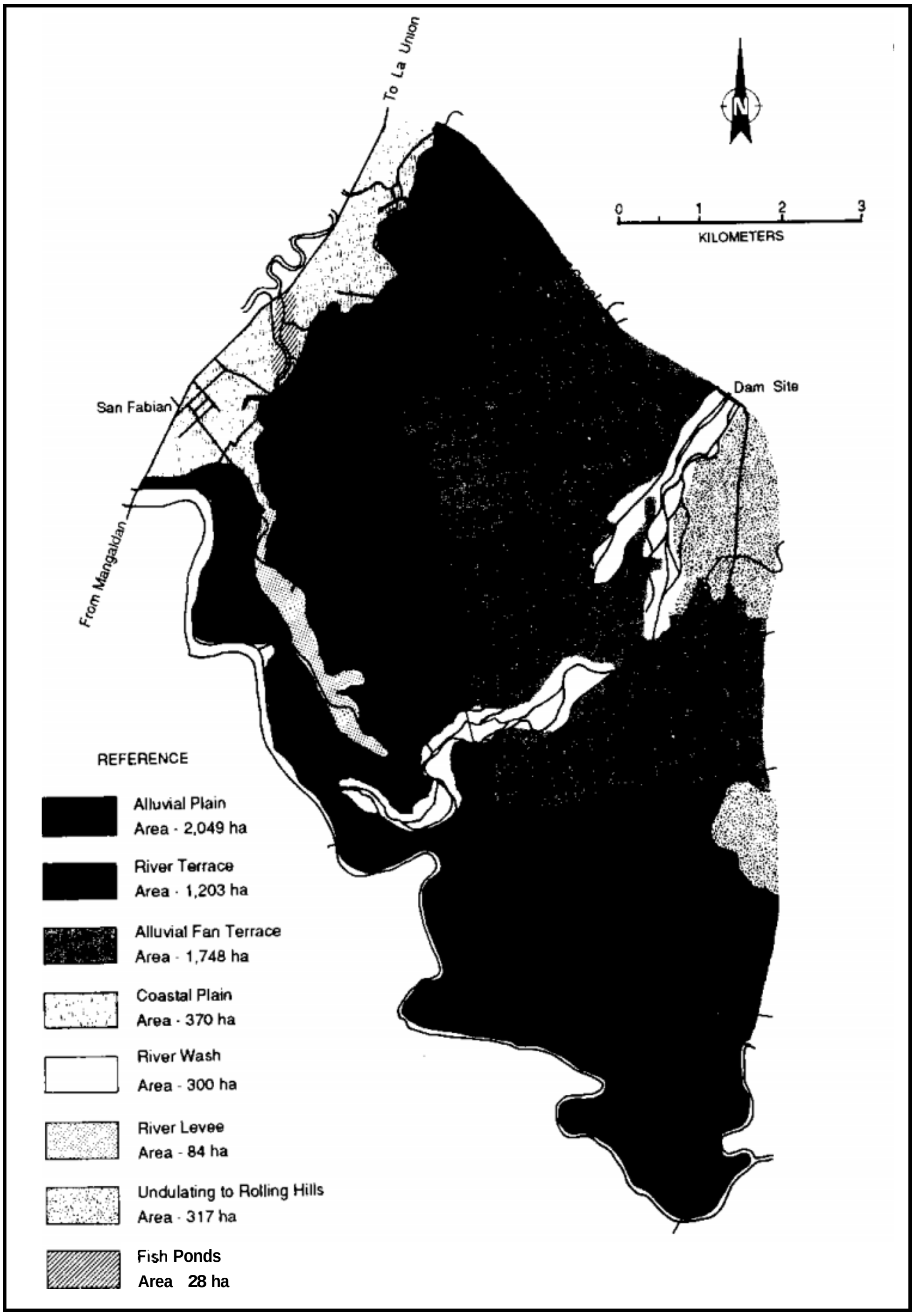
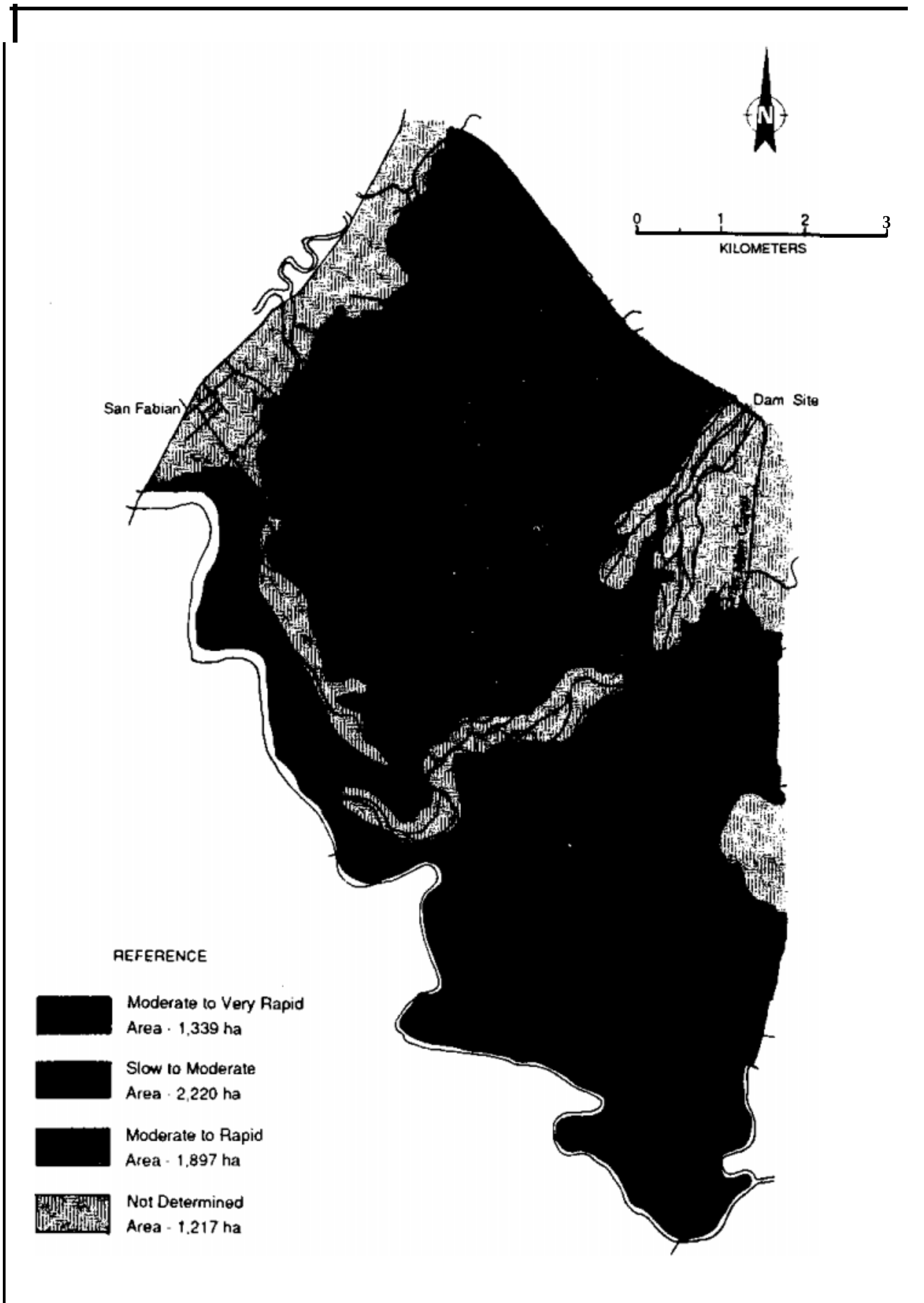


Figure 8. Soil permeability class map, San Fabian River Irrigation System, based on Agro-hydrological soil characterization.



RESULTS AND DISCUSSION

System Water Control

Given the water control setup, current farmer water application practices, and field physical configuration, a pressure energy two-thirds larger than that for rice should be developed for tobacco and other crops. This is needed to produce high flow rates to achieve a flash flooding effect such that water is applied quickly to a field and drained immediately to prevent waterlogging.

The higher flow rates required by nonrice crops further require higher water level in the supply canals. However, adequate mechanical control is usually absent in such supply canals. In UTRIS, steel gate turnouts and some check structures are already missing. Flashboards are sometimes used but these easily get lost and tree trunks and other debris are used. In such situations, adjustments in canal flows cannot be easily done. This induces the farmers to use debris on check structures which worsens canal maintenance problems.

The operating head requirement for nonrice crops likewise, results in the implementation of a rotational schedule not only by sections of the main canal system but even up to individual farmer level. As observed, however, not all areas in a certain section can be irrigated within the prescribed schedule. This results in sliding of the schedule, i.e., water is not diverted to the next area until all areas in the scheduled section are irrigated. Sometimes, areas unirrigated during the prescribed schedule have to wait for the next schedule.

Inadequate structural control facilities also hamper the implementation of the rotational schedule. If a turnout gate is missing in the upstream area, water supply remains continuous even when rotational distribution is implemented. Such an event causes problems in implementing an effective rotational distribution scheme.

Water Augmentation for Dry-Season Cropping

An inventory of shallow groundwater within UTRIS has shown the areas which have potential shallow groundwater even during the dry season which can be tapped particularly for upland crop production. Based on the persistence and depth of the water table, about four-tenths of the nonirrigated, non-waterlogged sites had usable resources of shallow groundwater early in the season and about one-fourth still had usable reserves at the end of the season. Early in the season, shallow water table was near the main canal and near areas irrigated for a second rice crop while at the peak of the dry season, shallow water table was found along the lower portion of the main canal.

Farmers, especially those owning farms located in the lower sections of the irrigation system where water is limited during the dry season, have been practicing water augmentation. The augmentation system consists of a centrifugal pump drawing groundwater either from open concrete-cased wells or drilled tubewells.

Monitoring of the water table depths, discharges and drawdowns indicated that there are reliable groundwater yields in the sites for augmenting water for irrigation systems for crop diversification. In the UTRIS, more or less 60 pump systems were observed operating within the service area in the 1989-90 dry season. Furthermore, there are farmers, observed to be constructing more new wells. It is important though to examine the effect of the increase in density of these systems on groundwater yield.

The conjunctive use of groundwater and surface water and even rainwater is worthwhile considering. Hence, managers of existing imgation systems in the country are encouraged to pilot test a water augmentation scheme, using shallow-well pump systems within their jurisdiction to determine the feasibility of adopting this system-wide.

Alternative Crops and Cropping Patterns

The results of simulation studies showed that diversified crops could result in higher total income for the farmers and higher collectible irrigation service fees for their irrigation agency (Table 2). Garlic was shown to be a very profitable crop in both UTRIS and LVRIS. Potato and onion have very high potential in LVRIS and UTRIS respectively. However, these crops have very volatile prices which could also cause losses to farmers.

Hybrid corn was shown to be the most viable crop compared to rice. Since the crop is to be produced only during the dry season, it would barely affect prices in other areas because corn is mostly raised as rain-fed during the wet season. The adoption of the crop will also reduce importation of the crop during the dry season. Field tests at UTRIS have shown that employing the present production technology coupled with supplemental irrigation, producing hybrid corn can be profitable. In San Manuel and Moncada towns in Tarlac Province, farmers have practiced the growing of hybrid corn with irhgation coming from shallow tubewells.

For leguminous crops and tropical wheat, there is still a need to improve technologies in growing these crops and the development of better varieties which could give higher yield to farmers comparable to rice production.

Irrigation Management at UTRIS

At UTRIS, the seasonal plan development starts with the submission by the Assistant Water Management Technicians (AWMTs) of their target imgable area, based on estimated available flow. It also includes weekly discharges necessary to support the programmed areas. These plans are submitted to the Zone Engineers (ZE) who consolidate them into the seasonal plan for the zone.

The zone plans are further consolidated into the district plan by the Operations Engineer (OE) which is then submitted to the Water Control Coordinating Council (WCCC) of the Upper Pampanga River Integrated Irrigation Systems (UPRIIS).

Table 2. ***Simulated crop areas, total production costs, gross production value, farm family income and collectible irrigation service fee,* LVRIS and UTRIS.**

crops	Crop area (ha)		Productio costs	Total gross productio value	Total farm family income	Collectibl irrigation service fee
	Rice	Nonrice	................thousand pesos..................			
Potato	690	1.254	35,820	423,546	387.726	1,082
Garlic	557	1,600	57,648	139,685	82,037	1,138
Tomato	557	1,600	15.258	90.725	17,792	1.138
Corn	557	1600	12.933	53,925	38,667	1,138
Peanut	690	1,254	12.721	46,970	34,667	1,082
Wheat	**551**	1.600	12,933	35,557	25,416	1,138
Rice	1,305	0	7,887	32,625	24,738	979
Mungbean	557	1,600	8,249	30,821	22,572	1,138
The Upper Talavera River Irrigation System						
Garlic	300	1,600	50,702	135.500	93,I89	1.103
Onion	300	1,600	42,312	115,500	64,798	1,103
Corn	300	1,352	11,776	41,300	29,525	912
Peanut	224	1,500	16,725	39.350	22,624	984
Mungbean	240	2,000	13,849	30,000	23,951	1,138
Rice	897	0	6,911	22,425	15,514	785
Soybean	368	1,580	18,635	30,530	11,895	1.152

Based on the OE district plans, the WCCC makes the plan for the entire UPRIIS, depending on the available water from all sources. The WCCC makes revision in the plan if the available water is not enough to support the program areas.

The entire plan for UPRIIS also includes that for the UTRIS even if it does not get water from the Pantabangan Reservoir. However, in a recent decision by the new Operations Manager of UPRIIS, the UTRIS management has been asked to treat the system separate from the reservoir-supported areas. Thus, a separate plan has to be prepared regardless of the plan for UPRIIS.

The UTRIS irrigation plan is prepared by NIA before the start of a season. This plan is disseminated to farmers through farmers' meetings, preseasonal trainings and *patalastas*. Sometimes, farmers do not understand the reasons behind the plan. Most of them do not know the specifics of the plans such as whether they are included in the program or not. The patalastas specify locations by watermaster division sometimes by laterals and villages. If only a part of such laterals or villages is programmed, the location of the area programmed is not specified. It is not uncommon to find farmers not knowing the Divisions to which they belong. Information dissemination seems to be a problem.

System operation in 1987-88 to 1989-90. At SAE, the Farmer Irrigators' Association (FIA) leaders helped in water distribution, taking full charge at night when the NIA personnel were not on duty. SAE can serve its whole service area during the wet season if the main canal is not silted. The main canal of SAE is built on the sideslopes of a hill and during heavy rainfall, runoff carrying large amounts of silt enters the main canal. These accumulate in canal bottoms and clog the canals. Removal of accumulated silt from canals requires the use of heavy machinery. SAE can only serve a limited part of the system during the dry season.

The UTRIS main canal can serve its whole service area during the wet season. Excess water flow was also diverted to the reservoir-supported area downstream of UTRIS. In the dry season, it can only serve 30 percent of the whole service area due to limited water supply. Low water supply usually started in late January to the beginning of the wet season. In the months of November to January, there was more than enough water to serve the programmed areas. This flow was used by downstream farmers who were not programmed to plant a second crop of rice, but they usually have shallow well pump systems to support their crop when water from canals becomes scarce. More often than not, farmers resorted to night irrigation. They walked along the canals during the night and removed checks in the main canal to divert water downstream. This deprived the programmed areas of night water supply.

In the past three years, the dry-season water supply of UTRIS was further reduced by illegal diversion of water from the Talavera River, by a log-dam upstream of the UTRIS Dam. There is a water right connected to this log-dam, but it is only for the wet season when the river flow is more than what UTRIS requires. However, it diverted water even during the dry season.

Water delivery to all sections of the system was continuous in the wet season until the beginning of the dry season (December to January). When water scarcity occurred in February until the end of the season, rotational water delivery was resorted to in the system. Areas under critical stages of crop growth were given priority to get water. The schedule was disseminated to the farmers before implementation. Rotational schedules in the past years, however, were not adhered to. Farmers did not follow the schedule especially during the night.

Progress of farming activities. Farming operations started earlier in 1989-90 than in the previous years. The cumulative land-soaked area showed that the start of operation for the 1989 wet season was two weeks earlier than in the previous years

(Figure 9). This is also shown in the cumulative planted area for the whole system during both the wet and dry seasons (Figure 10). It is worth noting that the area planted during the dry season of 1989-90 was almost twice that cropped during the previous years.

Somehow, these results showed a positive action on the recommendations given to both NIA and the farmers. Areas planted to two crops of rice (wet and dry seasons) in the downstream portion of the system had been recommended to plant early in the wet season. This would result in early planting of the dry season crop, and harvest of such crop in late February to early March. Water scarcity in the system usually starts in February and becomes extremely low in late March until the end of the dry season.

Analysis of the historical flow of the Talavera River showed that if the second crop is harvested in March, water scarcity could be avoided. This was explained to the NIA personnel and the farmers in a joint workshop in December 1988. It was then proposed that downstream areas mostly planted to rice start wet-season operation as early as possible. However, this will require extra effort by the NIA management to bring whatever flow available from the river during such period to the downstream area. During the last coordination meeting among the researchers, NIA and farmers, held in March 1990, this was agreed to be implemented during the 1990 wet season. However, repairs done in the system in May and June 1990 delayed this plan.

Water distribution. The system showed no improvement in dry-season water use efficiency (WUE) from 1987 to 1989 (Table 3). However, there was a clear improvement in water distribution. The water sharing was almost the same as the area ratio (60 percent upstream and 40 percent downstream) for the 1989-90 season. During the wet season, the downstream area was about 60 percent of the whole system in area irrigated. In other years, especially crop year 1987-88, inequitable distribution was prevalent.

Figure 11 shows that total system diversion in the wet season did not differ in different years. However, diversion in the dry season for the two later years was higher than in the first year of observation. Because of rainfall during the dry season 1988-89, there was higher diversion during February and March compared to 1989-90.

Figures 12, 13 and 14 show how the total diverted flow by the system was shared between the upstream and downstream sections of the system. In 1987-88 season, although the downstream section irrigated a larger area during the wet season, it was diverting much less water (Figure 12). The same situation was observed in 1988-89 except during the late wet and early dry seasons when diversion to the downstream area was greater than to the upstream area (Figure 13). In 1989-90, there was a marked improvement in terms of water sharing between upstream and downstream areas compared to previous years (Figure 14).

Figure 9. Cumulative land-soaked area, (started operation), crop years 1987-88, 1988-89, and 1989-90, whole system, Upper Talavera River Irrigafion System.

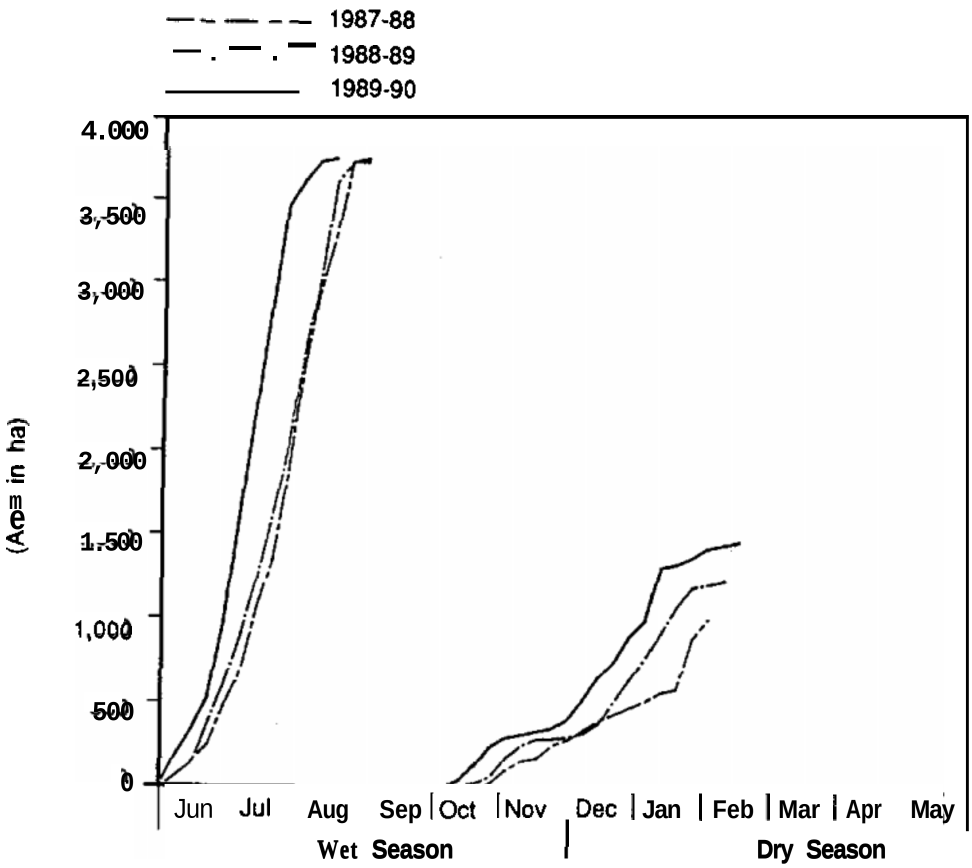
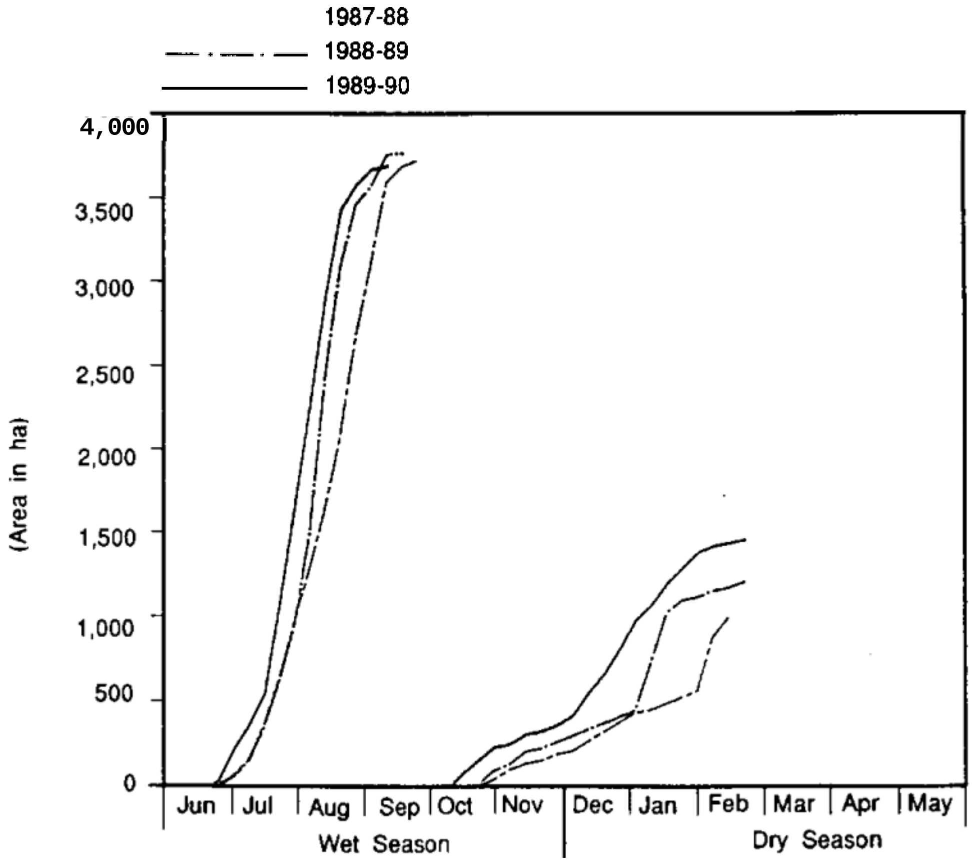


Figure 10. Cumulative planted area, crop years whole system, Upper Talavera River Irrigation System



Year	IDR	RF	AID	WUE	Water sharing. percent		
	.......(mm/wk)........			(percent)	Upstream	Downstream	System
1987-88	85	4	144	66	77	23	100
1988-89	70	6	219	42	49	51	100
1989-90	79	I	279	60	56	44	100

WUE = IDR/(AID + RF) X 100

Irrigation Management at LVRIS

Before the beginning of the dry-season cropping at LVRIS, NIA determines the area to be planted with rice, based on several criteria, foremost of which is the estimated available water supply. The area to be planted to nonrice crops is determined using the conversion factor based on the irrigation fee for nonrice crops which is 60 percent of the prevailing rate for rice.

The areas programmed for rice were mostly in the upstream and midstream portions, while those programmed for nonrice crops were in the downstream portion. Rice areas in the downstream portion are those not suited for nonrice crops because of their low elevation and the type of soil.

The plan of operation is discussed in several farmers' meetings either called by the NIA management or by the IA leadership in coordination with the LVRIS field staff. The farmers are given the option to decide on the kind of crops they wish to grow in their areas. The NIA management recognizes that based on experience, the farmers know very well the kinds of crop they should grow in their farms.

In the early part of the cropping season, there is enough irrigation water and it flows continuously in the main canal. Rotation is resorted to when the supply becomes low.

System *operation from 1987-88* to *1989-90*. At the start of each crop year (June), a one-year cropping calendar was developed through a preseasonal meeting between the *cabecillas* (head of the IA at the district level) and NIA. Lectures on proper water management, operation and maintenance, and evaluation and assessment of system performances were conducted by NIA.

Farmers were given eight weeks to finish land-soaking and land preparation during the wet season and six weeks during the dry season. NIA programmed the tail section first during the wet season.

NIA's watermasters and ditchtenders informed farmers beforehand of the planned schedule of farming activities, water delivery and deadlines of transplanting and necessary maintenance work through the cabecillas. Water was generally

Figure 11. *Weekly diverted flow at main canal headgate for crop years 1987-88 and 1988-89, Upper Talauera River Irrigation System.*

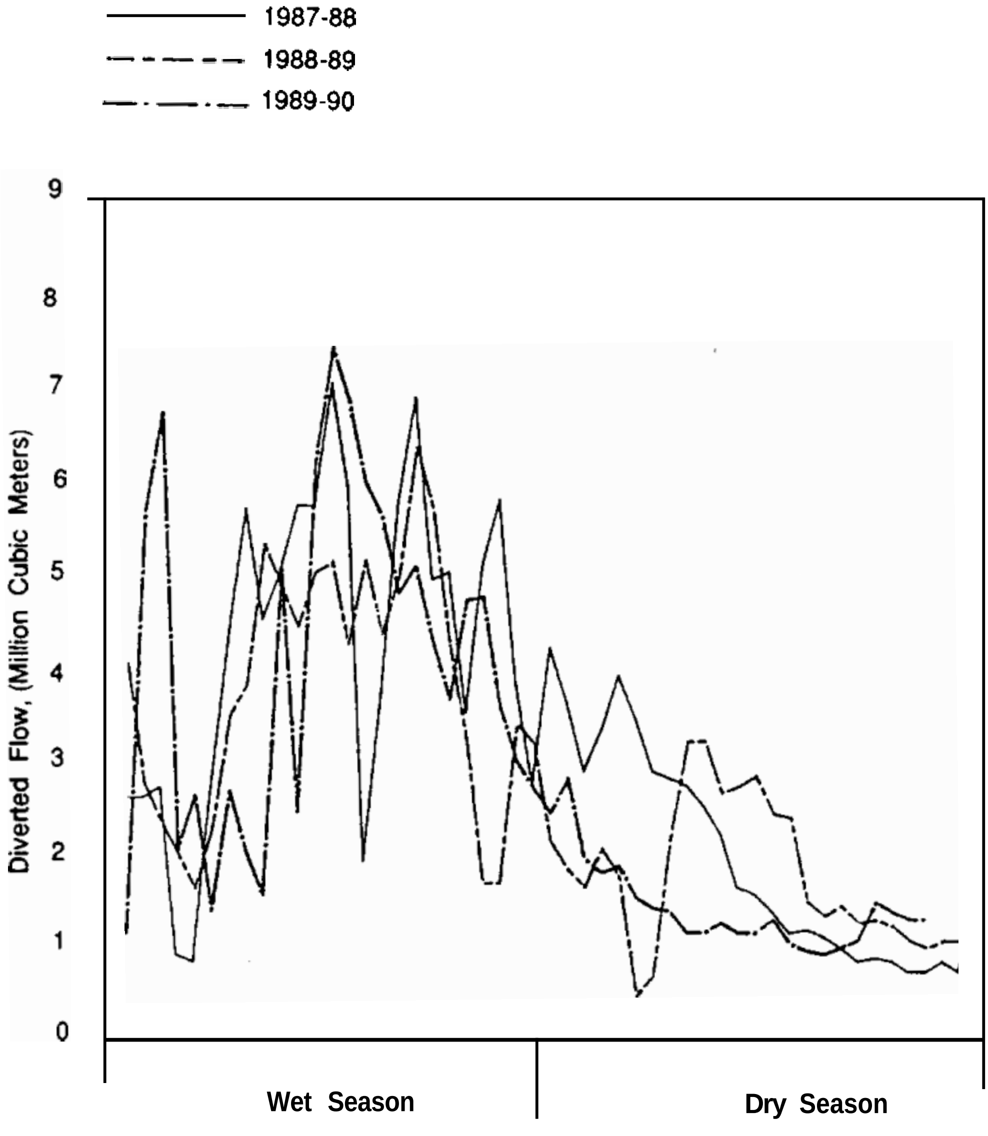


Figure 12. Weekly diverted flow at canal headgate, upstream and downstream areas for the crop yenr 1987-88, Upper Talavera River Irrigation System.

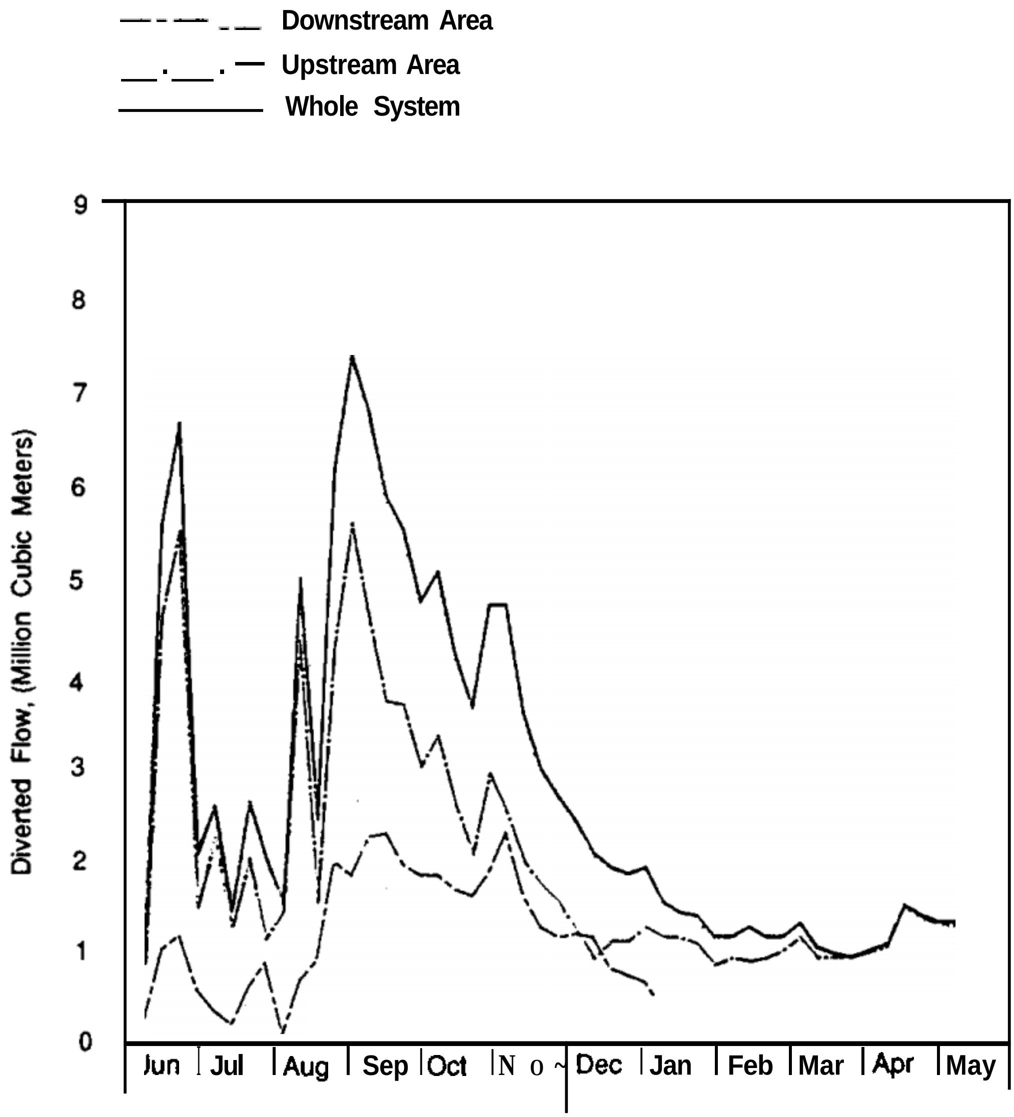


Figure 13. Weekly diverted flow at canal headgate, upstream and downstream areas for the crop year 1988-89, Upper Talavera River Irrigation System.

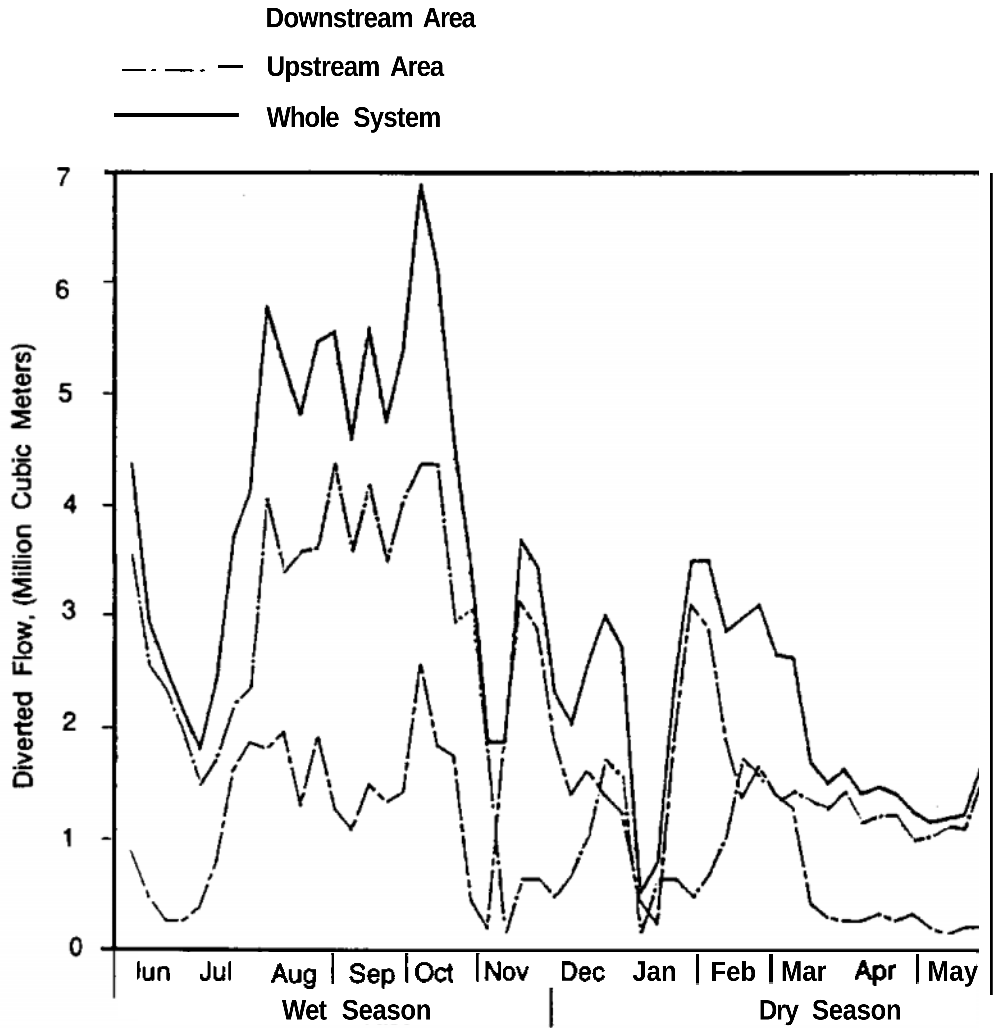
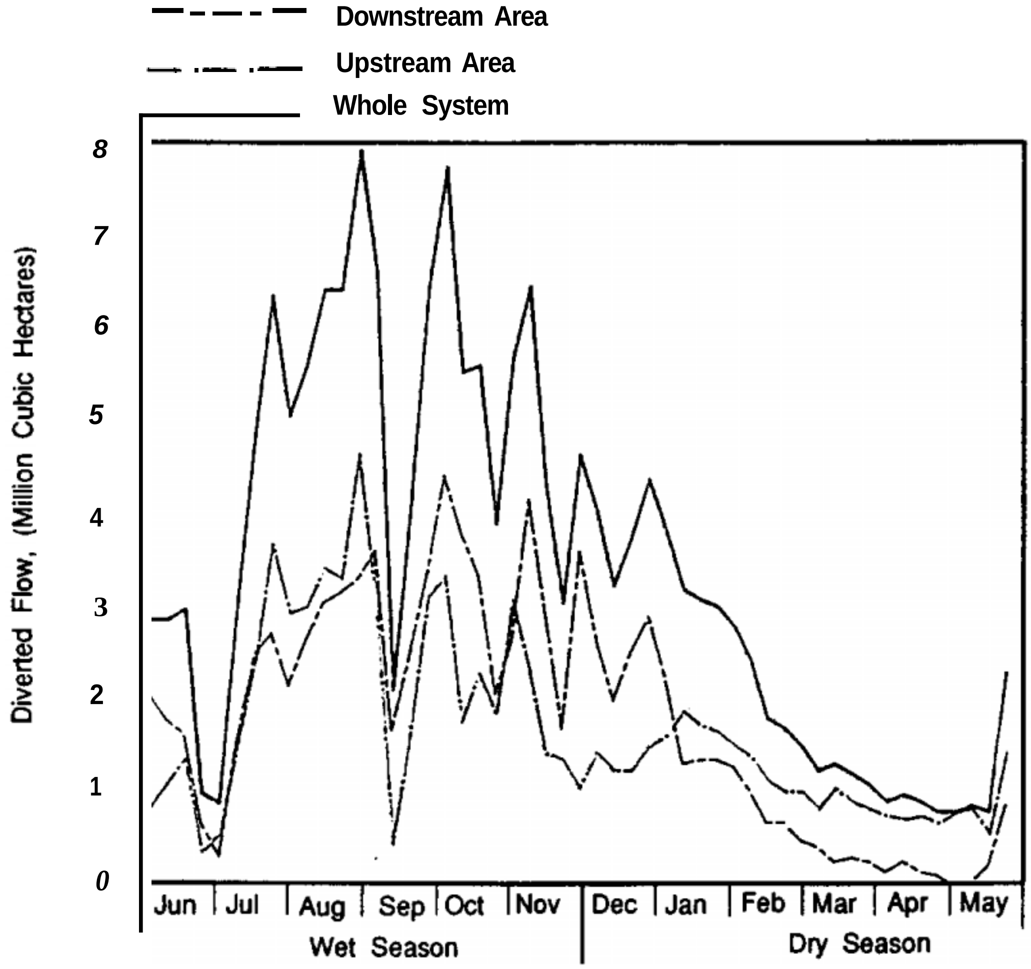


Figure 14. Weekly *diverted flow at canal headgate, upstream and downstream areas for the crop year 1989-90, Upper Talavera River Irrigation System.*



delivered continuously to all divisions; however, there was a fixed rotational schedule to irrigate areas which needed a large delivery in order to irrigate their service areas. During water shortage, rotational schedule was implemented throughout the system. The usual rotational schedule in a division was 1-2 days per district starting from the upstream to the downstream portion. Water delivery schedule was usually decided in situ by the watermasters, depending on the situation and status of water supply.

Progress of farming activities. Figure 15 shows the cumulative land-soaked areas (areas starting operation) for the crop years 1987-88 to 1989-90. In earlier years, some farmers started operation as late as February. In the preseasonal meetings for the dry season, 1989-90, the latest date of start of operation specified by the plan was mid-December. However, only about 30 percent of the farmers followed the plan. The main reason for the delay was the late release of certified rice seeds for the Rice Production Enhancement Program (RPEP) of the DA. This was solved by allowing the fanners to use their own seeds. However, it was already late when the farmers were informed of this decision.

There was not much difference in the cumulative land-soaked areas in the different years. However, in 1989-90, land-soaking was finished a month earlier than in the previous years. This was attributed to the vigorous campaign conducted to enforce the plan developed jointly by NIA and the farmer leaders.

Figure 16 shows the progress of planting for the system. A larger area was planted for the crop year 1988-89. This was due to the late rainfall during the wet season which made the farmers raise a second crop to offset the low wet-season production. In 1989-90, the planting date was earlier compared to the previous years due to the vigorous campaign to induce farmers to adhere to the schedule.

Water distribution. Figures 17 to 19 show the weekly water diversion of the system. Low water supply was observed earlier in the crop year 1989-90 compared to the other years. While low water supply occurred in mid-January in other years, it occurred as early as mid-December or a month earlier than usual in 1989-90. Water diversion to Division I was also reduced in 1989-90. This shows an improvement considering that in the other years, Division I had been diverting much water to the detriment of other divisions. This is considered an achievement for the system personnel and the farmers because water supply in 1989-90 was more critical.

There was no marked improvement during the years in terms of water use efficiency. However, there was an improvement in terms of water distribution (Table 4). In the earlier years, there was always a division getting less water than it required. In 1989-90, all divisions got more than what was required. This was due to the timely action on problems through monthly meetings. The weekly rotation schedule was not very effective because the desired critical flow diversion to the different sections of the system was not being met. This was recognized during the study and late in the season, for each week, and diversion was concentrated in one division only.

Figure 15. *Cumulative land-soaked area (started operation), Laoag-Vintar River Irrigation System, dry seasons, 1987-88, 1988-89 and 1989-90.*

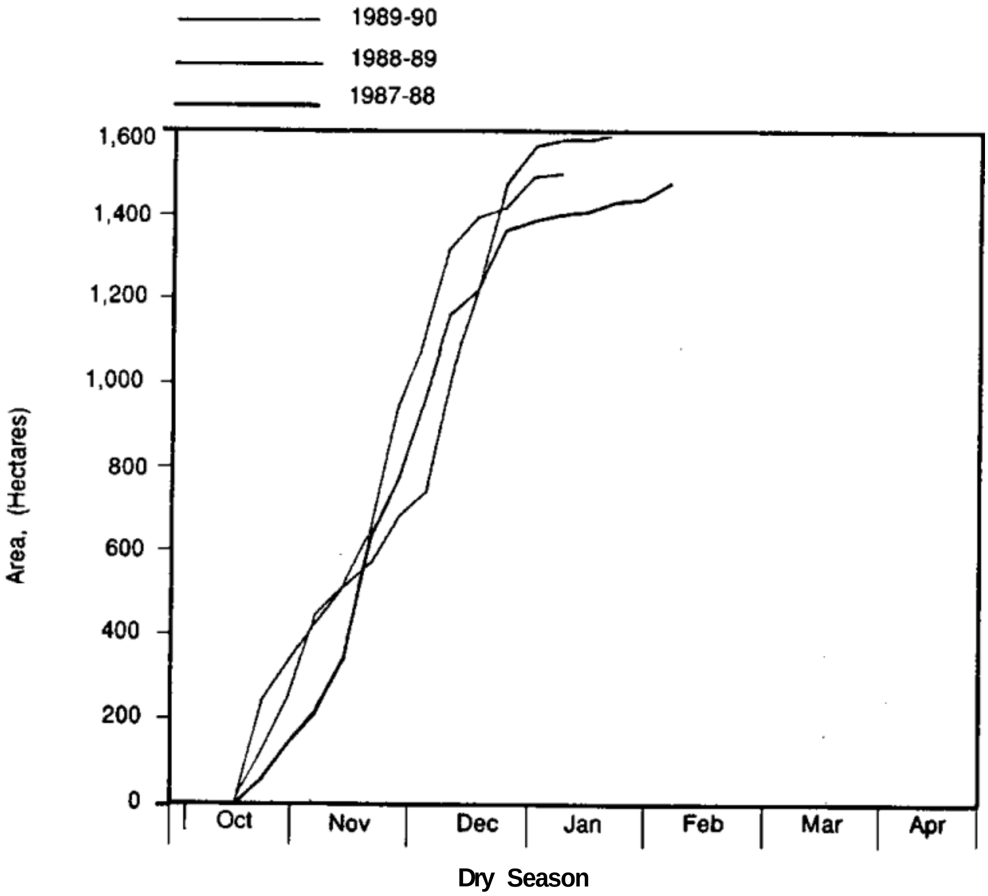


Figure 16. Cumulative planted area, Laoag-Vintar River Irrigation System, dry seasons 1987-88, 1988-89 and 1989-90.

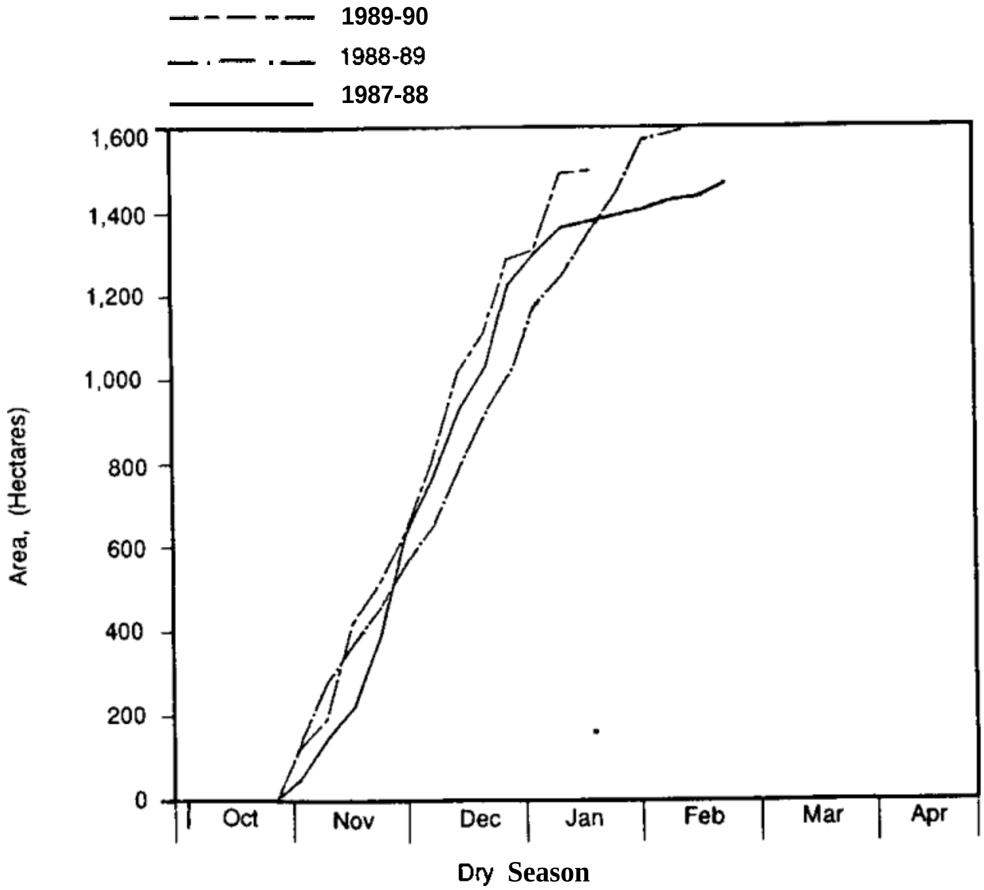


Figure 17. Weekly *diverted flows* at *main canal* and *divisional* kendgates, *Laoag-Vintar River* Irrigation System, *dry* season, *1987-88.*

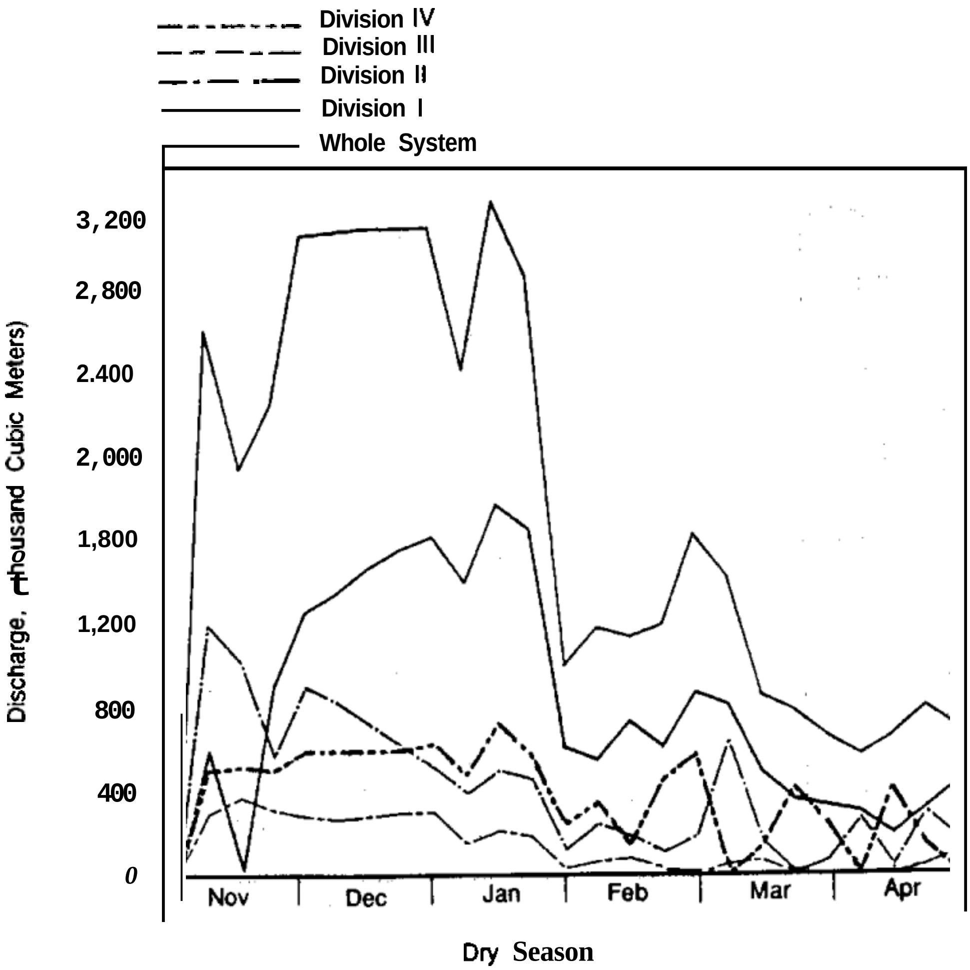


Figure 18. Weekly *diverted flows at main canal and division headgates, Laoag-Vintar Riwr Irrigation* System, *dry season, 1988-89.*

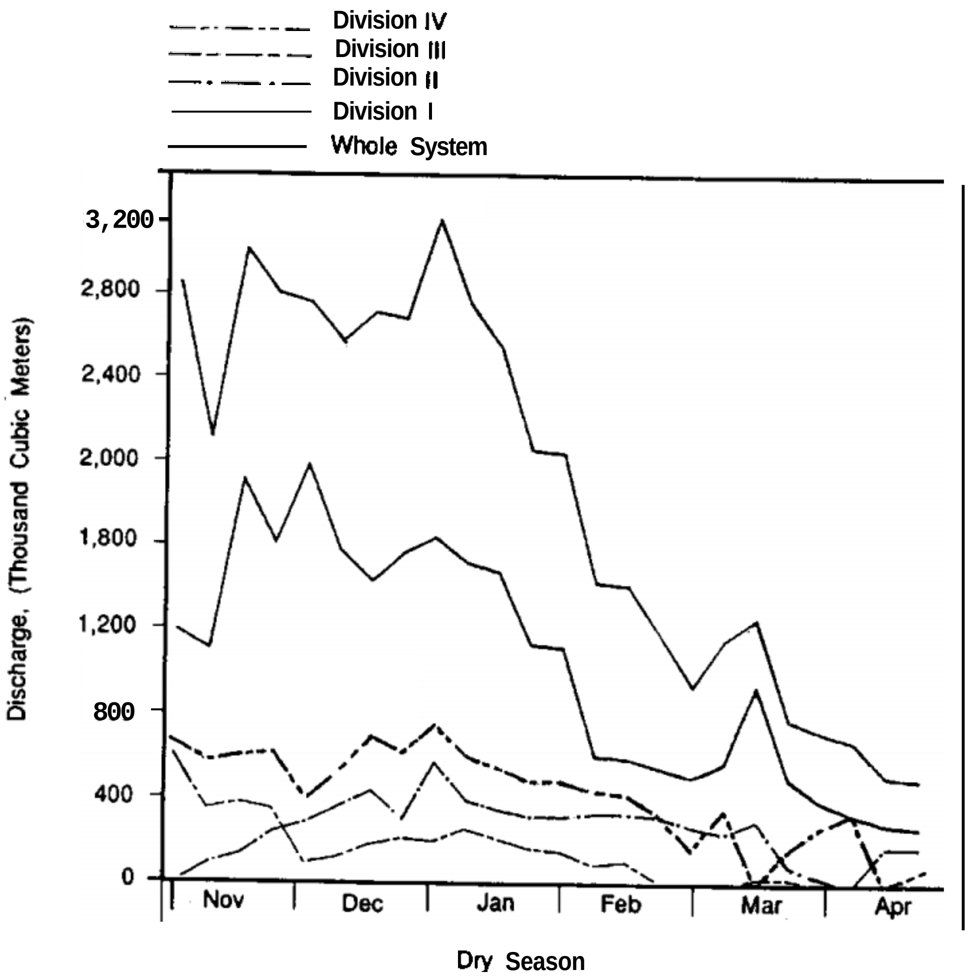


Figure 19. Weekly diverted flows at main canal and division headgates, Laoag-Vintar River Irrigation System, dry season, 1989-90.

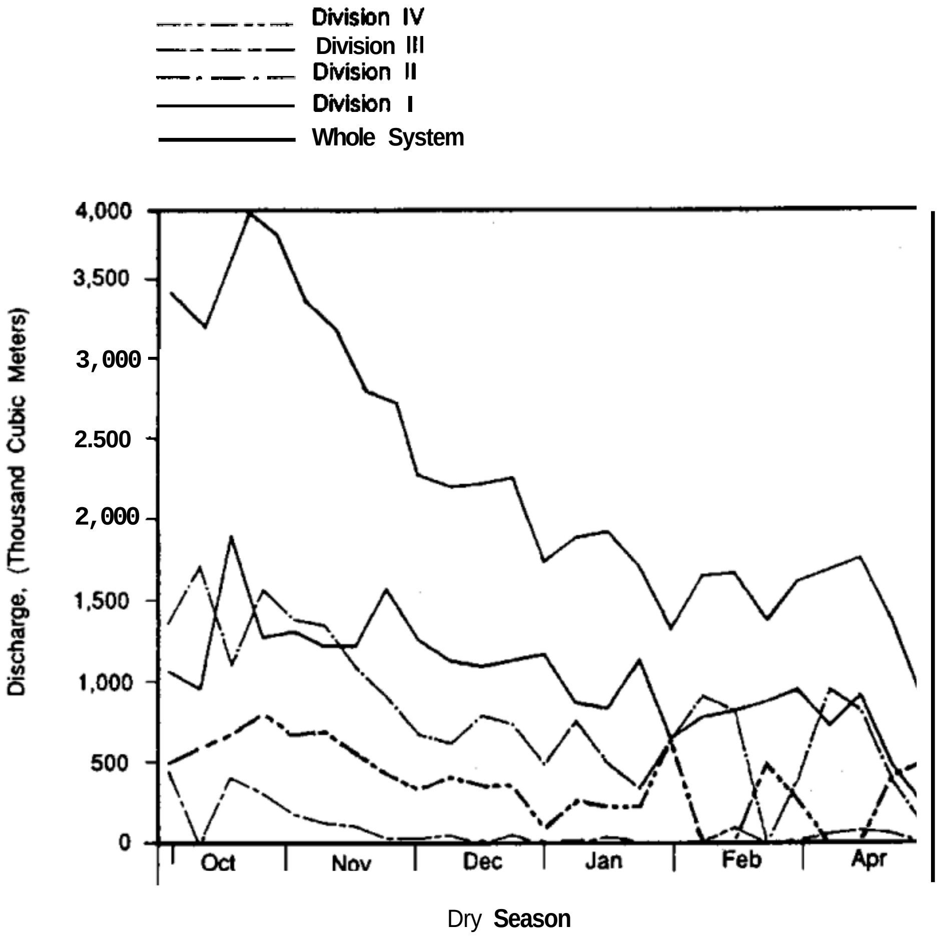


Table 4 seems to indicate that there was more water available in 1989-90. Considering the total diverted flow for the season, this is true, since the late season flow was quite larger compared to the other years. However, the early season flow in the previous years was larger compared to that in 1989-90.

Table 4 also shows that there should have been no problem in 1989-90. The total water supplied for the season was 2.3 times the required amount. However, the system was designed for rice at a value required for land-soaking. Diversified crops even need higher flows than these designed flows. Reduction in area irrigated compensated for the change in crops. However, the diverted flow could not be reduced, for it would have resulted in low turnout flows which would not satisfy the critical flows needed by the farmers. When the total supply is low, this is concentrated to a section to satisfy the critical flows. To compensate for individual farmers' critical flows, the flow diverted to each turnout is concentrated to a few individuals only. This is being followed in the system.

Table 4. Summary of water sharing (percent), by divisions for dry seasons 1987-88, 1988-89, 1989-90, Laoag-Vintar River Irrigation System.

Crop Year	Divisions				
	I	II	III	IV	System
1987-88					
IDR	8.6 (42)	5.7 (28)	4.9 (24)	5.4 (26)	24.6 (100)
AIF	22.6 (44)	13.7 (27)	4.1 (08)	11.8 (23)	52.2 (100)
IDR/AIF	2.6	2.4	0.8	2.2	2.2
1988-89					
IDR	10.4 (39)	5.9 (22)	3.3 (12)	8.1 (30)	27.7 (100)
AIF	24.0 (55)	5.9 (14)	3.4 (08)	9.7 (22)	41.0 (100)
IDR/AIF	2.3	1.0	1.0	1.2	1.5
1989-90					
IDR	10.9 (54)	4.1 (20)	1.8 (9)	7.6 (37)	24.4 (100)
AIF	25.0 (45)	19.0 (34)	2.1 (4)	9.2 (17)	55.3 (100)
IDR/AIF	2.3	4.7	1.2	1.2	2.3

IDR = Irrigation division requirement, total of the season in million cubic meters.
AIF = Actual irrigation flow, total for the season in million cubic meters.

Numbers in parentheses are ratios of the division share over the whole system in percent.

IMPROVED MANAGEMENT FOR DRY-SEASON IRRIGATION

The results of the different studies have identified a number of strategies and options which may be worth considering by the imgation managers, not only for irrigating nonrice crops during the dry season but also in the overall management of the systems. Some imgation procedures and practices can be further improved to effectively irrigate rice and nonrice crops or a mixed cropping system. The following suggested improvements focus on the existing planning, implementation, monitoring and evaluation procedures of NIA (Table 5).

Improved Physical Facilities and System Water Control

The physical condition of the irrigation system (e.g., canals and ditches, turnout structures, etc.) will have a direct bearing on the amount of water that will be required as it determines conveyance losses and consequently, efficiency of water delivery. Efficient control structures are not only necessary for imgation of upland crops but for rice as well. An efficient water distribution plan could be implemented, only with effective water control and measurement structures.

It is necessary to provide the needed volume of water to a certain section. Canal limitations should be considered in this aspect. Canals have critical flow limitations, that at a certain flow diverted to such canals, no flow occurs at turnouts unless excessive checking is done. At such low flows, farmers create their own checkpoints to divert water to their fields. Efficient operation of the system cannot be achieved in such situations. Canal flows should be maintained at a level where checking is done only at designed check structures.

System Characterization and Mapping

The agro-hydrological characterization of the system indicated the heterogeneity of the soils within the service areas of the irrigation systems. In UTRIS, six physiographic units had been identified while eight units were identified in SFRIS. These units showed variation in texture, infiltration rate and permeability. These characteristics have influence on the type of management that has to be employed.

A more detailed characterization of the system also provides more reliable data which could be input into a computer aided mapping program developed earlier. This program can be used as a tool for identifying parts of systems suitable for irrigated nonrice crop production and help improve the planning procedure in allocating water for rice and nonrice crop areas. Consequently, this will help in determining the demand for water. Since this technique requires reliable data inputs, it is necessary to have more detailed survey of the imgation systems. Updating existing maps will prove useful.

Table **5.** *Existing NIA procedures and recommended methodology/tools to further improve system management.*

Activity	Metho	ology/tools	Actual/recommended methodologies for UTRIS	
	Existing	Recommended	Existing	Recommended
Planting Estimation **of** Available Water **Supply**				
▪ Dependabl rainfall	5-year noving iverage	Incomplete gamma distributionanal Augment existing data and re-analyze annually	Veekly rainfall m a n based **n** 5-year previous data. Vhen Instrument for rainfall neasurement breaks down, o data is added and data ase is **not** updated and plan or last year is adopted	Veekly lependable **ainfall values to** e adjusted innually as data s added to **revious** ecords.
Stream **flow** (River discharge)	5-year noving iverage	**Lon-Normal/Low** Distribution Analysis augment existing data and re-analyze annually	itreamflow observations not sing done (stopped). data ase **on** out-dated **data** hence nnual program is inchanging and **personnel** cgards planning **as just** opying previous plans for ubmission **as** just copying revious plans for ubmission **as** requited.	Veekly lependable river low **values to** e adjusted innually **as** d a b s added to revious **ecords.**
· Other sources	isting drainage **re-use** dams, and private ' **shallow** well pumps	Identify other points where **re-use dams** could be constructed to fully utilize all possible water **sources.**		
3 Estimation **of** **Irrigation** Demand				
· crop water duty	Based *on* rice	Based **on** particular crop grown using crop coefficients and pan evaporation data. Existing data be verified during actual system operation.	Out-dated data **results** in inequal distribution of water n day **to** day operation of system due **to** incorrect assessment of water **needs**	Verified **dam** for **use** in planning and actual system operation.

Continued on ***page*** **93**

\ctivity	Methodology/tools		Actual/recommended methodologies for UTRIS	
	Existing	Recommended	Existing	Recommended
- **Soil** demand	Existing data but are they still in use or already lost in words?	Based on agro-hydrologic soil characterization.	Data may be outdated already, resulting in uneven distribution of water in daily system operation due to incorrect assessment of water needs	Verified data per area and crop for use in planning and actual system operation.
Efficiency distribution losses, application losses, system efficiency	Existing data but are they still in use or already lost in records?	Verification of data based on roil types, farmers practices, crops grown and existing structures and other irrigation facilities.	Data may be out-dated already resulting in same situation as above.	Verified data far use in planning and actual system operation.
Irrigators' Associations Involvement				
Planning	No or minimal involvemen	Active farmers involvement in decisions on which areas to be served, crops to be grown, operation dates and irrigation methods to be used.	Farmers not following plans resulting in inefficient performance due to disruption of planned activities thus no semblance of farmers' discipline in diverting water especially when there is no immediate water stortage.	Plans that M acceptable and followed by farmers.
Water distribution	No or minimal involvemen	Active involvement, in plan implementation. feed-back mechanism for evaluation of water distribution strategies.	It is only during critical water supply situation when: strict supervision is implemented where efficient operation is achieved.	Operation strategies responsive to farmers' needs and system limitation. efficient use of available water resources.

More Accurate Methods of Prediction

In determining water availability from river and rainfall, continuous data collection is recommended to account for climatic and terrestrial changes. More reliable analytical methods should be used in analyzing such data. The methods used in the simulation studies are recommended and considered as more reliable than the present analytical tools being used.

The probable amount of water that will be available is estimated primarily from the analysis of river and rainfall data. NIA presently uses the 5-year moving average to determine river discharge. However, streamflow observations are not being done and therefore outdated data are used. Hence, the annual program is unchanging and personnel regard planning as just copying previous plans for submission as required. Regular monitoring and calibration of the NIA systems diverting water for irrigation could provide weekly river flow values which could be adjusted as data are added to previous records.

The present five-year moving average method for determining rainfall probability is less reliable on the weekly prediction compared with the 50 percent probability level of the incomplete gamma function. It overestimates the actual rainfall and when measurement breaks down, the database is not updated and the previous year's plan is adopted.

The incomplete gamma distribution function (IGDF) is a hydrologic frequency analysis tool which is appropriate for analyzing daily, weekly or 10-day period rainfall data. It produces more reliable data than arithmetic means. For instance, in analyzing a five-year rainfall data for a certain week with four years when rainfall was zero and one year when rainfall was 50 mm, the arithmetic mean will say that 10 mm of rainfall can be expected while the IGDF will say that zero rainfall is expected once in four years, which best describes the probability.

Groundwater Utilization

The contribution of groundwater in upland crop production during the dry season can be tapped by planting in areas where the water table is shallow enough for the plants to use the water through capillarity. Existing drainage reuse dams and private shallow wells can provide supplemental water, particularly during scarce water supply situations. It was observed that farmers use these pumps even during the rainy season to be able to start their rice crops earlier when irrigation water is not available in the canal or when rainfall is very low. During the dry season, these pumps are the primary source of irrigation water although farmers still use water from the canal whenever it is available.

Crop Scheduling

In run-of-the-river type systems, cropping operations should be well-scheduled so that available water resources could be effectively used. Since water scarcity comes at the end of the dry season, earlier crop establishment would result in efficient use of available water supply and wider area planted. This aspect could also be useful in reservoir-supported systems, by timing operations requiring large volumes of water such as land-soaking in months with heavy rainfall to economize on water releases.

It was observed in UTRIS that in the past years, wide areas suffered from stress due to lack of water during the late dry season. This could be avoided by scheduling earlier planting than usual. Water supply situations in this system showed that harvest of the second crop of rice by late February to mid-March would result in a larger volume of available water to supply crop needs and may even enable planting in a larger area than usual. Analysis of the water supply graph for this system showed that this is possible.

Involvement of Farmers and Fanners' Organizations

Plans are usually developed by NIA for farmers. The main problems happen during implementation. Though farmers are informed of the plan, they do not understand well, the basis of such plans. Thus, many violations are committed.

The involvement of farmers and farmers' organizations as early as the planning stage may reduce the problems during implementation. In systems with active Irrigators' Associations (IAs), the determination of the program area is facilitated through the participation of the IA. Involvement of farmers during planning does not necessarily mean teaching them to plan for themselves, but to explain to them the necessity of the plan and the reasons for the actions taken. This ensures farmers' commitment to abide by the plan. This also gives a feeling of importance to the farmers.

The area served during the dry season at UTRIS has increased since 1987. Before 1987, the area served by the system ranged from only 500 to 700 ha. At present, it is more than 1,000 ha. Active participation of the farmers in decision making and managing the system, growing farmers' awareness of the systems capabilities, increasing rice prices, and government support programs to produce more rice have contributed to this endeavor. The study conducted in the system has helped in better management of the system, despite increased cropped areas.

Information Control and Use

Information should be considered important for making decisions pertaining to the management and operation of the imgation system. The status of farming activities, flows or discharges at critical points and amount of rainfall are important

variables to be monitored. Farming activities should be noted on a weekly basis so as to provide enough data to base decisions as to which sections of the system will need water. Flows on the critical points in the system should likewise be used for making decisions and not for recordkeeping only.

A regular meeting between the IA and the NIA field staff during the cropping season is an effective means of monitoring the operations of the system. The meeting could provide the feedback mechanism to make the schedule realistic and the opportunity to revise the schedule and settle conflicts in water distribution.

SUMMARY

The production of nonrice crops in some irrigation systems in the Philippines could be a promising alternative to increase the productivity of these systems, particularly during the dry season. Based on the studies conducted in three systems practicing diversified cropping, a number of options and strategies are recommended which may help improve system performance not only for rice irrigation but for considering nonrice crops during the dry season. Implementing these recommendations necessarily requires some modification in the existing physical facilities and management procedures of the system. It is thus necessary to further field-test these recommendations for ultimate institutionalization.

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Summary/Highlights of Discussions: Technical Issues on Main Irrigation System Management

THE TECHNICAL CONSIDERATIONS for rice-based farming systems as these relate to main irrigation system management were presented and discussed for Bangladesh, Indonesia and the Philippines by Drs. Ghani, Suprodjo and Maglinao. Dr. Ghani discussed the results of studies conducted primarily in the Ganges-Kabodak and the North Bangladesh Tubewell projects. In Indonesia, Dr. Suprodjo cited the findings from the West Situbondo and Cikeusik Imgation schemes. The results from the Upper Taiavera River Irrigation System, San Fabian River Irrigation System and the Laoag-Vintar River Irrigation System in the Philippines were presented by Dr. Maglinao.

The presentation and discussion elicited further questions, clarifications, comments and observations from the participants. These are highlighted as follows:

Rice Yields

Dr. Pingali asked why particularly for the second rice crop in Indonesia, the tail-end section yields 1 ton more than in the upper and middle sections of the irrigation system. Dr. Suprodjo explained that the second season is the most favorable time for rice cultivation in the tail-end section. During the rainy season (first rice crop), there is the problem of drainage while during the third cropping, there is water shortage. After 1986/1987, rice yields seem to stabilize at an average of 4.7 t/ha.

Policy on Self-sufficiency in Rice

Over the last few years, Indonesia has made a fairly significant move towards diversifying its export base to include the export of other high-value crops. However, this does not mean that the country has dropped its policy of self-sufficiency in rice. On the contrary, Indonesia still aims for rice self-sufficiency but it also has to consider the possibility of growing other crops in rice fields.

Another policy of the government at present is to plant sugarcane in unirrigated areas. Sugarcane occupies about one-third of the total irrigated area especially in Java. With this move, a potential of at least one-third of the irrigated area could be increased for rice culture.

Water Use Efficiency

Water use efficiency as indicated in the Philippines Report does not seem to reflect the actual data. Also related to water sharing, it does not seem that the tail-end areas have problems possibly because of an increasing water availability over the duration of the study. Water use efficiency was calculated using averages. The data seem to be misleading, but looking at the Occurrence of water scarcity, it was observed that it happened very much later in 1987-1988 and 1988-1989. In 1989-1990, this problem occurred as early as December. It was not really the lack of water to satisfy the demand but more of the required volume of canal flow to attain a canal head to deliver the right amount of water to the fields. Apparently, management was needed more during the study year than in earlier years.

Diversity of Soil Types

To address the physical diversity particularly of soils within the irrigation system, more checks are needed to raise the head. In hilly areas, more structures should be installed to better control water. In UTRIS, physical characterization indicated that only a small portion of the area is marginally suitable for diversified crops. The farmers themselves generally adjust to the availability of water.

Cost of Pump Operation

The price of diesel in Bangladesh has increased from 6.7 to 14.7 taka per liter and this may seriously affect rice irrigation. To benefit both the farmers and the government, management has to improve water use efficiency and decrease water losses. This could be partly addressed by a more coordinated effort between the researchers and the irrigation managers, and through proper data monitoring and communication.

Adoption of diversified crops which could make use of residual soil moisture, could also address the high cost of pump irrigation. However, proper timing has to be considered. Crops planted have to be harvested by December to free the land in time for the next rice crop.

Constraints to Crop Diversification

From a system management point of view, Dr. Pingali feels that there is no overriding constraint to shifting from the traditional monoculture rice to diversified cropping. In response, Dr. Ghani cited Dr. Pingali's statement that fanners could adopt any type of diversification if they are ready to pay for it. A case in point is the diversification in Thailand where vegetables and other crops are grown. It depends on how much the farmers are ready to pay and also on the expected return

from the additional expenditure. The cost of the management innovation should likewise be considered.

For Indonesia, Dr. Suprodjo said that it is not really correct that main system management does not have to be changed in response to crop diversification. From the technical point of view, because the areas of the farmers are small, more adjustments are needed to have more accurate water distribution. Secondly, the drainage problem should be addressed. With crop diversification, there is also a need to distribute water more equally in the field, which needs more control. These changes in the main system should, however, consider some changes in the management in the tertiary.

According to Dr. Maglinao, there seems to be no serious constraints in existing systems already practicing crop diversification as these may have been already addressed. However, the existing practices could still be improved.

Significant Research Findings

A number of significant findings could be further looked into or tested for further verification. For Bangladesh, system improvement could be achieved by looking at reliability of water supply, optimum pumping schedule, suspension of pumping operation, drainage water reuse and residual soil moisture utilization. For Indonesia, system characterization and mapping, groundwater utilization, and improvement of data-gathering were identified as priority areas. The Philippines emphasized better coordination between farmers and irrigation agency with due recognition of the support of other agencies concerned with crop production.

SECTION II

Technical Considerations

for

Rice-Based Farming Systems:

Farm-Level Water Management

On-Farm Water Management for Rice-Based Farming Systems in Bangladesh

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INTRODUCTION

THE OPTIMUM USE of irrigation water should be an important strategy for increasing agricultural production in Bangladesh. The overall development of the country's agriculture sector will require year-round use of the irrigation facilities for productive use of water. The country will realize substantial benefits if the allocation and distribution of the available water are improved. Field studies are needed to identify the nature and magnitude of water management problems and to develop methods of improving water management, which would help achieve higher crop yields, higher irrigation efficiency and greater water distribution equity.

Research, conducted by the Bangladesh Rice Research Institute (BRRI) and the Bangladesh Water Development Board (BWDB) in collaboration with the International Rice Research Institute (IRRI), was started in November 1981 in two irrigation projects in Bangladesh-the Ganges-Kobadak (GK) Project (Phase I) and the North Bangladesh Tubewell Project (BTP). The International Irrigation Management Institute (IIMI) joined the collaborative project in 1988.

This paper highlights the results of the collaborative research, with the following objectives:

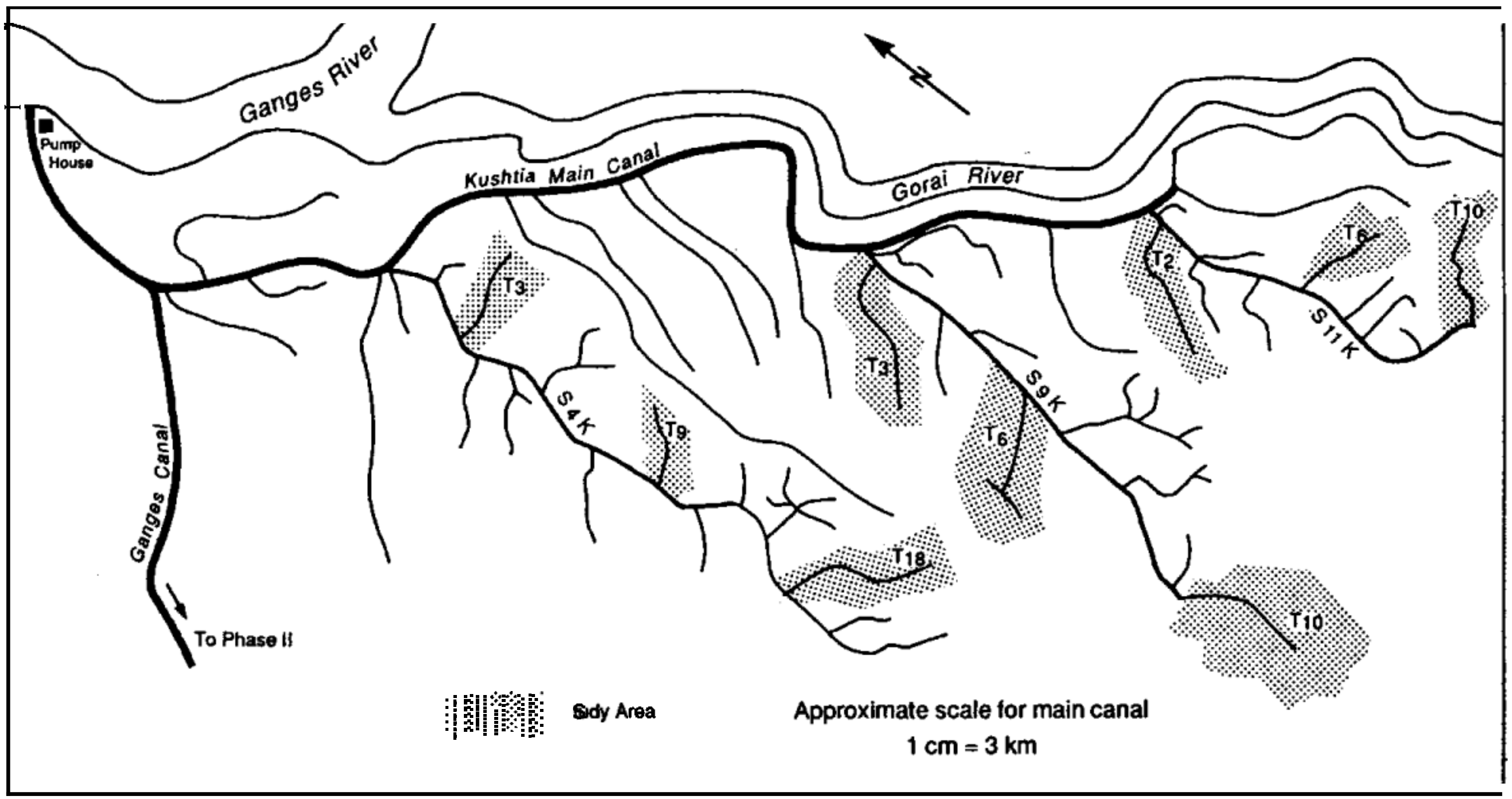
1. To establish the status of water utilization and crop production.
2. To identify and analyze strategies and methods followed in project operation and their effect on crop production.
3. To suggest improvement alternatives for increasing water use efficiency and crop production.

METHODOLOGY AND MEASUREMENTS

Research Sites

In the G-K Project (Phase I), the field-research sites are in the service areas of nine tertiary canals belonging to three secondary canals-the fourth, ninth and eleventh, respectively, representing the head, middle and tail reaches of the main canal. Three tertiaries were selected from each secondary to represent the head, middle and tail reaches of the secondary. The tertiaries are: T3, T9, T18 of S4K; T3, T6, T10 of S9K; and T2, T6, T10 of S11K (Figure 1).

Figure 1. chema Kobadak Bangladesh, showing selected secondary and



In the North Bangladesh Tubewell Project, field research was conducted mainly in 12 selected tubewells and their service areas which were chosen to represent the whole system. These "pilot" tubewells are: tubewell nos. 63, 77, 89, 93, 117, 118, 119, 120, 125, 126, 138 and 142. After the first phase of research in 1983, a pair of tubewells called "Satellit" was selected adjacent to each pilot tubewell for monitoring water- and crop-related parameters. Thus, 24 satellite tubewells (nos. 47, 48, 49, 53, 64, 65, 76, 88, 90, 91, 92, 95, 114, 121, 122, 123, 124, 127, 128, 129, 131, 133, 141 and 347) were included in the study.

Observation and Measurements

Fifty observation paddies were selected in each tertiary pilot tubewell area to represent the head, middle and tail reaches. Seasonal data on production status, use of inputs, and crop varieties were collected and analyzed.

Yields were assessed on the basis of crop-cuts taken in each season from the 50 selected plots of each of the nine tertiary/tubewell areas. A five-square-meter sample area was harvested from each plot, taking one square meter harvest each from five different locations of the plot. The harvest was threshed and grain yield measured. Moisture content of the grain was determined by a moisture meter. Yield was adjusted to 14 percent moisture content and expressed in kg/ha or ton/ha.

RESULTS AND DISCUSSION

The Ganges-Kobadak Project

Water *utilization*. The average rainfall recorded during land preparation vaned from 0.5 to 3.8 cm for the Aus and 1.2 to 15.2 cm for the Aman seasons (Tables 1, 2.3 and 4). The average irrigation delivery under research management was about 22 and 14 cm, for the Aus and Aman seasons, respectively. Under farmers' management, this corresponds to 24 and 15 cm, respectively. During the growing period (after seedling establishment prior to harvesting), rainfall was 69 and 58 cm in the Aus and Aman seasons, respectively. Irrigation delivery was 68 and 69 cm under research management and 83 and 81 under farmers' management in the Aus and Aman seasons, respectively. Water application values were higher for farmers' management as farmers did not maintain field levees properly which favored water loss.

Water use efficiency at field level varied from 36 to 69 percent in the Aus season and from 55 to 100 percent in the Aman season (Table 5). Low efficiency was observed near the head ends, possibly due to misuse of irrigation water. Water application values were higher for farmers' management as farmers did not maintain field areas properly. Average productivity of water during Aus was 2.86

Table 1. *Water used (mm) by farmers for land preparation and crop growth period in the selected* **locations of** *the Ganges-Kobadak Project (Phase 1)* **the *Aus* seasons, *1985-89*.**

Location	1985			1986			1987			1988			1989		
	IR	RF	Total	IR	RF	Total	IR	RF	Total	IR	RF	Total	IR	RF	Total
	Land preparation														
T3/S4K							330	11	341	276	25	301	234	13	247
T0/S4K	262	08	270	231	30	261	327	07	334	290	00	290	273	10	283
T3/S9K							236	19	255	217	25	242	236	00	236
T6/S9K	315	00	315	282	23	305	262	00	262	198	42	240	240	00	240
T10/S9K							190	63	253	212	20	232			-
T2/S11K							127	105	232	133	21	154	213	00	213
T6/S11K	240	36	276	234	*46*	280	184	58	242	-	-				-
Mean	272	15	287	249	33	282	237	37	274	221	22	243	239	05	244
Location	Growing season														
T3/S4K							821	453	1,274	828	961	1,789	827	738	1,565
T9/S4K	828	496	1324	835	708	1,543	791	504	1,295	752	1,110	1,862	844	737	1,581
T3/S9K							705	604	1,309	376	1,273	1,649	605	678	1,283
T6/S9K	1,096	509	1,605	749	596	1,345	686	582	1,268	418	1,209	1,627	65	640	1,292
T10/S9K							666	628	1,294	606	1,141	1,547	-	-	-
T2/S11K							630	609	1,239	552	998	1,550	781	350	1,131
T6/S11K	1,651	379	2,306	1,299	603	1,902	476	802	1,278	-	-	-	-	-	-
Mean	1,192	461	1,653	961	636	1,579	682	597	1,280	555	1,115	1,670	742	629	1,371

Table 2. Water used (mm) for land preparation and crop growth period under recommended management in the selected locations of the Ganges-Kobadak Project (Phase I), the Aus seasons, 1985-89.

Location	1985			1986			1987			1988			1989		
	IR	RF	Total	IR	RF	Total	IR	RF	Total	IR	RF	Total	IR	RF	Total
	Land preparation														
T3/S4K		-		-	-	-	248	11	259	268	25	293	223	13	236
T9/S4K	222	08	230	215	30	245	260	07	267	225	61	286	248	10	258
T3/S9K		-		-	-	-	226	19	245	208	03	211	230	00	230
T6/S9K	251	00	251	238	23	261	226	W	226	202	30	232	229	00	229
T10/S9K		-		-	-	-	181	63	244	199	19	218	-	-	-
T2/S11K		-		-	-	-	I23	105	228	I27	21	148	-	-	-
T6/S11K	227	36	263	207	46	253	167	,58	225			-	203	00	203
Mean	233	15	248	220	33	253	204	38	242	[illegible]	26	231	227	05	232
Location	Growing season														
T3/S4K		-		-	-	-	744	453	1,197	792	961	1,753	794	738	1,532
59/S4K	721	496	1.217	762	708	1,470	708	504	1,212	602	1,110	1,712	670	737	1,407
T3/S9K						677	604	1,281	387	1.190	1,577	529	678	1,207	
T6/S9K	772	509	1.281	600	596	1,196	602	582	1,184	372	1,211	1,583	600	640	1,240
T10/S9K		-		-	-	-	624	628	1,252	367	1,142	1,509	-	-	-
T2/S11K		-		-	-	-	612	609	1,221	540	998	1,538	760	350	1,110
T6/S11K	992	379	1.371	906	603	1.509	420	802	1.222	-	·	-	-	-	
Mean	828	461	1,289	756	636	1.392	627	597	1,224	510	1,102	1.612	671	629	1,300

Table 3. Water *used (mm) by farmers for* land preparation and *crop growth period in* the selected *locations of the Ganges-Kobadak* Project *(Phase I),* the *Aman seasons, 1985-89.*

Location	1985			1986			1987			1988			1989		
	IR	RF	Total	IR	RF	Total	IR	RF	Total	IR	RF	Total	IR	RQ	Total
T3/S4K							185	05	190	00	120	120	244	19	263
T9/S4K	236	29	265	203	21	224	167	00	167	00	112	112	271	28	299
T18/S4K							-	-		00	133	133	-	-	
T3/S9K							233	20	253	198	34	232	230	06	236
T6/S9K	117	52	169	50	120	170	23	215	231	210	37	247	234	09	243
T10/S9K							149	102	251	204	20	224	208	15	223
T2/S11K							00	241	241	177	56	233	180	25	205
T6/S11K	137	22	159	237	40	277	00	243	243	140	79	219	199	12	211
T10/S11K							00	240	243	168	47	215	212	03	215
Mean	163	34	197	163	60	223	95	133	221	122	71	193	222	15	237
Location	Growing season														
T3/S4K							811	184	995	857	288	1,145	1,246	302	1,54[illegible]
T9/S4K	1,013	234	1,247	538	1,053	1,591	-	-	-	900	600	1,500	996	345	1,34[illegible]
T18/S4K							709	307	1,016	902	561	1,463	-	-	-
T3/S9K							633	670	1,303	686	629	1,315	770	402	1,17[illegible]
T6/S9K	873	499	1,372	633	1,052	1,685	503	789	1,292	610	671	1,281	768	353	1,12[illegible]
T10/S9K							515	694	1,209	675	563	1,238	748	375	1,12[illegible]
T2/S11K							336	710	1,046	737	411	1,148	662	493	1,15[illegible]
T6/S11K	2,054	291	2,345	791	1,052	1,843	339	910	1,249	635	488	1,123	777	349	1,12[illegible]
T10/S11K							265	586	851	755	350	1,105	707	408	1,11[illegible]
Mean	1,313	341	1,654	654	1,052	1,706	514	606	1,102	751	507	1,258	834	378	1,21[illegible]

Table 4. Water used (mm) for land preparation and crop growth period under recommended management in theselected locations of the Ganges-Kobadak Project (Phase I), the Aman seasons, 1984-89.

Location	1985			1986			1987			1988			1989		
	IR	RF	Total	IR	RF	Total	IR	RF	Total	IR	RF	Total	IR	RF	Total
T3/S4K							89	05	94	00	120	120	231	19	250
T9/S4K	213	45	258	175	21	196	-	-		00	112	112	250	28	278
T18/S4K							-	-		00	133	133	-	-	
T3/S9K							206	20	226	208	17	225	224	00	224
T6/S9K	117	52	169	50	120	170	19	215	234	204	19	223	224	09	233
T10/S9K							138	102	240	187	20	207	203	03	206
T2/S11K							00	241	241	170	56	226	168	25	193
T6/S11K	195	22	217	220	28	248	00	243	243	136	79	215	182	12	194
T10/S11K						00	240	240	168	36	204	196	03	199	215
Mean	175	40	215	148	56	204	66	152	217	119	66	185	210	12	222
Location															
T3/S4K							796	184	980	776	288	1,064	1,02(	302	1.322
T9/S4K	936	258	1,194	497	1,053	1,550	688	209	897	722	600	1,322	859	345	1.204
T18/S4K							612	307	919	644	561	1,205	-		
T3/S9K							604	670	1,274	633	675	1,308	704	408	1,112
T6/S9K	839	499	1.33	527	1,065	1,592	462	789	1,251	553	689	1.242	730	362	1,092
T10/S9K							480	694	1,174	641	563	1,204	697	385	1.082
T2/S11K							304	710	1,014	733	411	1.144	657	493	1,150
T6/S11K	1,070	291	1.36	696	1,038	1,734	314	910	1,224	624	488	1,112	771	349	1.120
T10/S11K							232	666	898	672	418	1,090	702	408	1.110
Mean	948	349	129	573	1,052	1,625	499	571	1,070	666	521	1,188	767	382	1,149

Table 5. Average field level water use efficiency in the Ganges-Kobadak Project (Phase I), the Aus and Aman seasons, 1985-1989.

	Aus season			Aman season		
	applied	Water required (mm)	Water use efficiency %	Water applied (mm)	Water required (mm)	Water use efficiency %
	1,632	1.126	69	1,511	1,022	68
		1,190	59	1,975	1,082	55
	3,111	1.122	36	1.783	1,783	69
	1,726	1,083	63	1,356	1,141	84
1989	1,728	1.037	60	948	1,035	100
Mean		1,112	54	1.522	1.101	72

and 2.51 kg/ha-mm for research and farmers' management, respectively. The corresponding figures for Aman were 3.75 and 3.17 kg/ha-mm (Tables 6, 7, 8 & 9).

Table 6. Water use, yield and productivity of water under recommended management level in the selected tertiaries of the Ganges-Kobadak Project (Phase 1), the Aus seasons, 1985-89.

Location	1985			1986			1987			1988			1989		
	Water used (mm)	Yield (kg/ha	Water productivity (kg/ha-mm)	Water used (mm)	Yield (kg/ha	Water productivity (kg/ha-mm)	Water used (mm)	Yield (kg/ha	Water productivity (kg/ha-mm)	Water used (mm)	Yield (kg/ha	Water productivity (kg/ha-mm)	Water used (mm)	Yield (kg/ha	Water productivity (kg/ha-mm)
T3/S4	1,859	5,167	2.78	-	-	-	1,556	5,010	3.22	2,046	4,640	2.27	1,768	5,220	2.95
T9/S4	1,938	5,267	2.72	1,715	3,910	2.66	1,479	3,910	2.64	1,998	4,160	2.08	1,665	5,110	3.01
T3/S9	-	-	-	-	-	-	1,526	5,210	3.41	1,788	5,050	2.82	1,437	4,950	3.44
T6/S9	1,922	5,057	2.63	1,459	5,170	3.82	1,410	4,930	3.50	1,815	3,920	2.16	1,469	4,630	3.15
T10/S	2,109	3,697	1.75	-	-	-	1,496	3,840	2.57	1,727	4,620	2.68	-	-	-
T2/S1	-	-	-	-	-	-	1,449	5,050	3.49	1,686	5,050	3.00	1,313	4,920	3.75
T6/S1	2,830	4,127	1.46	1,762	4,890	3.27	1,447	4.280	2.96	-	-	-	-	-	-
Mean	2,132	4,663	2.27	1,645	4,610	3.17	1,466	4,600	3.14	1,843	4,750	2.48	1,532	4,966	3,26

Table 7. Water use, yield and productivity of water under recommended management level in the selected tertiaries of the Ganges-Kobadak Project (Phase I), the Aman seasons, 1984-89.

Location	1985			1986			1987			1988			1989		
	Water used (mm)	Yield (kg/ha)	Water productivity (kg/ha-mm)	Water used (mm)	Yield (kg/ha)	Water productivity (kg/ha-mm)	Water used (mm)	Yield (kg/ha)	Water productivity (kg/ha-mm)	Water used (mm)	Yield (kg/ha)	Water productivity (kg/ha-mm)	Water used (mm)	Yield (kg/ha)	Water productivity (kg/ha-mm)
T3/S4	1,851	4,953	2.68	-	-	-	1,074	4,980	4.64	1,184	5,730	4.84	1,572	5,640	3.59
T9/S4	1,767	5,403	3.06	1,746	5,033	2.88	897	4,400	4.91	1,434	4,767	3.32	1,482	4,450	3.00
T18/S	1,757	6,823	3.88	-	-	-	919	6,570	7.15	1,338	6,610	4.94	-	-	-
T3/S9	-	-	-	-	-	-	1,500	5,710	3.8	1,533	4,855	3.17	1,336	5,640	4.22
T6/S9	1,452	5,787	3.99	1,762	6,320	3.59	1,485	5,220	3.52	1,465	5,340	3.64	1,325	6,010	4.54
T10/S	1,290	6,213	4.82	-	-	-	1,414	6,040	4.27	1,411	5,970	4.23	1,288	5,220	4.05
T2/S1	-	-	-	-	-	-	1,255	5,440	4.33	1,370	5,555	4.05	1,343	5,963	4.44
T6/S1	1,692	6,287	3.72	1,982	3,897	1.97	1,467	5,600	3.82	1,327	5,405	4.07	1,314	6,080	4.63
T10/S	6,220	4.02	-	-	-	1,156	4,510	3.90	1,294	4,900	3.79	1,309	5,260	4.02	
Mean	1,622	5,955	3.74	1,830	5,090	2.78	1,289	5,390	4.18	1,370	5,459	4.00	1,371	5,533	4.06

Table 8. Water use, yield and productivity of water under farmers' management level in the selected tertiaries of the Ganges-Kobadak Project (Phase I), the Aus seasons, 1986-89.

Location	1986			1987			1988			1989		
	Water used (mm)	Yield (kg/ha)	Water productivity (kg/ha-mm)	Water used (mm)	Yield (kg/ha)	Water productivity (kg/ha-mm)	Water used (mm)	Yield (kg/ha)	Water productivity (kg/ha-mm)	Water used (mm)	Yield (kg/ha)	Water productivity (kg/ha-mm)
T3/S4K	-	-	-	1,615	4,810	2.98	2,090	4,270	2.04	1,812	4,920	2.72
T9/S4K	1,804	3,910	2.17	1,629	3,660	2.25	2,152	3,610	1.68	1,864	3,380	1.81
T3/S9K	-	-	-	1,564	4,880	3.12	1,891	4,920	2.60	1,519	4,730	3.11
T6/S9K	1,650	5,170	3.13	1,530	4,590	3.00	1,867	3,310	1.77	1,532	4,270	2.79
T10/S9	-	-	-	1,547	3,610	2.33	1,779	4,400	2.47	-	-	-
T2/S11	-	-	-	1,471	4,040	2.75	1,704	3,450	2.02	1,344	4,800	3.57
T6/S11	2,182	4,890	2.24	1,520	3,710	2.44	-	-	-	-	-	-
Mean	1,879	4,610	2.45	1,554	4,180	2.69	1,913	3,900	2.09	1,615	4,420	2.80

Table 9. Water use, yield and productivity of water under farmers' management level in the selected tertiaries of the Ganges-Kobndak Project (Phase I), the Aman seasons, 1986-89.

Loca-tion	1986			1987			1988			1989		
	Water used (mm)	Yield (kg/ha)	Water produc-tivity (kg/ha-mm)	Water used (mm)	Yield (kg/ha)	Water produc-tivity kg/ha-mm)	Water used (mm)	Yield kg/ha)	Water produc tivity (kg/ha mm)	Water used (mm)	Yield kg/ha)	Water produc tivity (kg/ha mm)
3/S4K		-	-	1,185	4,750	4.00	1,265	5,320	4.21	1,811	5,480	3.03
9/S4K	1,815	4,333	2.39	-		-	1,612	4,187	2.60	1,640	4,190	2.55
T18/S4	-	-	-	1,016	6,030	5.90	1,596	5,970	3.74		-	-
3/S9K	-	-	-	1,552	5,000	3.22	1,547	4,560	2.95	1,408	5,190	3.69
6/S9K	1,855	5,850	3.15	1,526	4,400	2.88	1,528	5,055	3.31	1.364	5,650	4.14
T10/S	-	-	1,460	5,380	3.68	1,462	5,590	3.82	1,346	4.470	3.32	
T2/S11	-	-	-	1,287	4.140	3.22	1,381	5,050	3.66	1.360	4,937	3.63
T6/S11	2,120	3,150	1.49	1,492	4.980	3.34	1,342	4,820	3.59	1.337	5,720	4.28
T10/S1	-	-	1,191	4,060	3.41	1,320	4,020	3.05	1,330	4.120	3.10	
Mean	1,930	4,440	2.30	1,360	4,750	3.49	1,451	4,952	3.41	1,450	4,970	3.47

Water Adequacy

Clearly, farmers are growing rice in both the Aus and Aman seasons with less water supply than required for maintaining continuous standing water in the field. While all known research indicates that continuous shallow ponding is needed to obtain maximum rice yield, it is not clear yet how much yield reduction is actually taking place in farmers' fields which is attributable to the water shortage induced by the rotational method of water distribution. Analysis of some field-level water-status records indicates that the perched water table fluctuates between a level above soil surface to about 30 cm below for most of the days in the Aman season. Field water level, measured in PVC pipes installed at 50 farmer plots in each selected tertiary/tubewell, dropped below 50-cm depth from the soil surface during about 10 percent of the Aman crop growth period. In the Aus season, field water table fluctuated between a level above the soil surface to about 45 cm below it during most of the season. In certain areas, the water table was found to drop below 80 cm on some days before irrigation water delivery was made. An in-depth study of the field water table fluctuations and their relationship to rice yields showed that yield reduction was not significant due to fluctuation of the water table (Ghani 1987).

Fertilizer Use and Rice Yield

Fertilizer (NPK) applied and rice yield obtained at the head, middle and tail reaches of the Kushtia main canal are presented in Table 10.

Fertilizer use decreased from head- to tail-end areas of the main canal. Rice yields obtained from head reaches were higher than those from tail reaches. Differences in rice yields from head to the tail ends of the main canal were higher in the Aus season than in the Aman season. Farmers generally used more fertilizer in Aman than in Aus. Higher fertilizer use in the *Aman* season may have been due to adequate and relatively assured water supply from the beginning of the crop season. However, farmers in the study areas applied relatively higher amounts of fertilizer N than the recommended rate in the Aman season.

Farmers along the head tertiaries generally applied higher amounts of fertilizer and obtained higher rice yields than those in the tail-end areas. The tertiary T9/S4K (middle) is an exception where the average fertilizer use rate was much lower in the head section, even though rice yield was higher. Uncertain and scanty water supply in the Aus season at the tail ends of secondary canals may have been the major reasons for low fertilizer use.

Table 10. *Average* **yield and** *input* **used in the selected** ***tertiares of the Ganges-Kobadak Project (phase I),*** **the Aus and Aman Seasons, *1982-89.***

	Yield (kg/ha)		Nitrogen (kg/ha)		Phophorus (kg/ha)		Potassium (kg/ha)	
	Aus	Aman	Aus	Aman	Aus	Aman	Aus	Aman
T3/S4K	4.299	4.422	78	76	41	[illegible]	26	20
T9/S4K	3,721	4,167	118	115	47		31	31
T18/S4K	2.681	4.390	54	113	17	28	7	18
T3/S9K	4.290	4.592	101	106	47	46	30	28
T6/S9K	3,324	4.196	75	105	34	39	21	23
T10/S9K	3.134	4,614	54	86	27	46	14	28
T2/S11K	3,059	4.4%	59	83	33	[illegible]	20	28
T6/S11K	2.159	4.140	44	83	20		11	29
[10/S11K1,815	3.219	18	76	9	40	3	22	
Mean	3,240	4,250	67	94	31	41	18	25

Fertilizer N Efficiency

Fertilizer use efficiency is the output of any crop per unit of fertilizer applied under a set of environmental conditions. Though fertilizers N, P and K were applied, only fertilizer N was considered for calculation of its efficiency. This is because N is the most important nutrient for rice production and its deficiency occurs almost everywhere (Yoshida 1981). Rice responds better to the application of fertilizer N than to the application of P and K. Several factors determine fertilizer N efficiency for rice at the farm level (De Datta 1981). Among them are soil, rice variety, season, time of planting, water management, weed control, fertilizer source, time of application, pest control, and cropping sequence. Fertilizer N application under Recommended Management (R.M.) was fixed at 80 kg/ha but under Farmers' Management (F.M.) it varied from farmer to farmer. Mean rice yields in the Aus season of all tertiaries under R.M. and F.M. levels were 5,497 and 3,590 kg/ha, respectively (Table 11). So, there was a yield gap of 1,007.5 kg/ha between R.M. and F.M. levels. Farmers at the head and middle tertiaries (T3/S4K, T9/S4K, T3/S9K and T6/S9k) of the S4K and S9K applied relatively higher amounts of fertilizer N than those of the other tertiaries. However, average N use at F.M. level was 62.1 kg/ha. Average fertilizer N efficiency was 57.5 and 62.2 (kg rice/kg N applied) under R.M. and F.M. levels, respectively during the Aus season. Fertilizer use efficiency in the Aus season at F.M. level was higher than that at R.M. level. Barber (1977) and De Datta (1981) reported that fertilizer efficiency was high with the first increment of fertilizer at a relatively low rate. High fertilizer N efficiency with relatively low rates of fertilizer N application in tertiaries T18/S4K, T10/S9K, T2/S11K and T6/S11K during the Aus season under Farmers' Management level was consistent with literature.

Farmers generally applied a higher rate of fertilizer N in all tertiaries than that under R.M. level during Aman. Mean fertilizer N application during Aman under F.M. level was 98.0 kg/ha as against 80 kg/ha under R.M. level. Average rice yields during the Aman season were 5,462 and 4,927 kg/ha under R.M. and F.M. levels, respectively. Approximately 536 kg/ha of additional rice were produced under R.M. level over that under F.M. level. Fertilizer N efficiency under R.M. and F.M. levels was 68 and 51, respectively. Mean fertilizer N efficiency under R.M. was higher than that under F.M. level. The low fertilizer efficiency under FM. level during the Aman season may be attributed to relatively high rates of fertilizer N application. Results obtained on fertilizer N efficiency during the Aman season were also consistent with literature (Barber 1977; De Datta 1981).

Water Fertilizer Interaction

Field experiments were conducted in the G.K. Project area during Aman 1988 and Aus and Aman 1989 to determine a suitable time of fertilizer N and irrigation water application. Fertilizer and water management treatments were: fertilizer N application one day before irrigation (T1), fertilizer N application after completion

Table 11. **Fertilizer N use, rice yield and *efficiency of fertilizer* N use under recommended *(R.M.)* and farmers' management *(F.M)* practices *at* the selected *locations* of the *Ganges-Kobadak* Project (Phase *I*), the *Aus* and *Aman seasons, 1987-1989*.**

Location	R.M.			F.M.		
		Yield	N-efficiency	N	Yield	N.efficiency
	Aus season					
T3/S4K	80	5.030	62.9	75	4,670	62.3
T9/S4K	80	4,040	50.5	125	4,680	37.4
T3/S9K	80	5,070	63.4	102	4,840	47.5
T6/S9K	80	4,530	56.6	67	4,060	60.6
T10/S9K	80	4,230	52.9	32	2,007	62.7
T2/S11K	80	5 . m	62.5	44	4.130	93.9
T6/S11K	80	4.280	53.5	30	2.140	71.3
Mean	80	4,597.1	57.47	62.1	3,589.6	66.9
Location	Aman season					
T3/S4K	80	5,560	69.5	75	5.240	69.9
T9/S4K	80	4.630	57.9	134	4,160	31.0
T18/S4K	80	6,600	82.5	108	6,030	55.8
T3/S9K	80	5,270	65.8	99	4.830	48.8
T6/S9K	80	5.480	68.5	108	5,040	46.7
T10/S9K	80	5,740	71.7	I03	5,150	50.0
T2/S11K	80	5,520	69.0	87	4,750	54.6
T6/S11K	80	5,470	68.4	89	5,080	57.1
T10/S11K80	4.890	61.1	89	4,060	45.6	
Mean	80	5,462.2	68.27	98	4,926.67	51.05

of irrigation (T2) **and** fertilizer N application after completion of irrigation followed by **soil** incorporation on the following day (T3). Yield responses of MV rice to fertilizer N application at different times of irrigation are presented in Table **12.**

Fertilizer N application followed by soil incorporation (T3) produced the highest rice yield during the three seasons in both locations excepting Swastipur **(T3/S4k)**

area, where rice yields were statistically identical at all levels of treatment during the 1989 Aman season only. However, substantial increase in yield was recorded in all seasons under treatment T3. Additional yield obtained from T3 over the control (Tl) ranged from 0.46 to 1.41 t/ha. Similarly, treatment T2 produced an additional yield of 0.21 to 0.90 t/ha over the control. Rice yield increased by 11 to 38 percent under T3 as compared to the control. On the other hand, treatment T2 resulted in a 5 - 29 percent additional yield over the control.

The low yield of rice obtained from the application of fertilizer N one day before application of irrigation water (T1) may be attributed to denitrification loss of N and washing out of N with surface run-off. On the other hand, fertilizer N application followed by soil incorporation (T3) may have minimized such loss of N, and therefore, yield was higher than that from other treatments. This suggests that in the rotational irrigation system, fertilizer N should be applied at the end of irrigation and should be incorporated for higher yield. Application of Zn and S at the rate of 10 and 20 kg/ha with NPK resulted in a higher yield than with NPK only.

bl 12. Yield respones of MV rice to fertilizer N application at different times of irragtion in the Ganges-Kobaduak Project (Phase I), the Aus and Aman Seasons, 1988-1989.

Treatments	Swastipur			Shailkupa		
	Additional yield (t/ha)	Percent yield oover TI	Mean increase over TI	Additional yield (t/ha)	Percent yield oover TI	Mean increase over TI
	Aman 1988					
TI	4.4c			3.7c		
T2	5.0b	0.65	14.94	4.5b	0.80	21.91
T3	5.5a	1.10	25.29	4.8a	1.19	32.60
	Aus 1889					
TI	3.4b			3.9b		
T2	4.3a	0.84	29.32	4.4b	0.42	10.65
T3	4.6a	1.14	33.43	5.5a	1.51	38.32
	Aman 1989					
TI	4.2			4.9b		
T2	4.5	0.21	4.95	5.8a	0.90	18.44
T3	4.1	0.46	10.84	6.3a	1.41	28.89

Numerical values followed by similar letters in columns do not vary significantly.

T1 = N fertilizer application one day before irrigation.
T2 = N fertilizer application after completion of irrigation.
T3 = N fertilizer application after completion of irrigation followed by soil incorporation on the following day.

Table 13. Average annualgrain yield (t/ha) for selected cropping pattern in the Ganges-Kobadak Project (phase I), Bangladesh, 1982-1989.

Cropping pattern	Total yield under recommended management	Total yield under farmers' management
Wheat-BR1-BR4[a]	11.41 (8.93[b])	10.06 (7.63)
Wheat-BR1-BR11	11.80 (10.34)	10.41 (9.09)
Gram-BR3-BR11	11.77 (10.56)	9.94 (8.8)
Gram-BR1-BR10	11.81 (9.81)	10.44 (8.93)
Lentil-BR1-BR4	10.61 (9.88)	8.14 (7.76)
Kheshari-BR1-BR11	11.36 (10.15)	10.28 (9.23)
Dhaincha-BR3-BR10	10.26 (10.26)	8.53 (8.53)
Dhaincha-BR3-BR11	11.64 (11.64)	10.17 (10.17)
Sunhemp-BR1-BR11	11.65 (11.65)	9.25 (9.25)
Wheat-BR6-BR10	10.50 (9.50)	9.24 (8.14)
Wheat-BR1-BR10	11.25 (10.30)	10.65 (9.40)
Gram-BR1-BR11	10.47 (9.36)	9.54 (8.46)
Cowpea-BR1-BR11	11.51 (9.99)	10.80 (9.56)
Kheshari-BR1-BR10	10.84 (9.95)	9.52 (8.69)
Kheshari-BR1-BR4	10.85 (9.78)	9.74 (8.72)
Kheshari-BR14-BR11	10.21 (9.56)	8.07 (7.57)
Average	11.12 (10.10)	9.63 (8.75)

a Crops grown in the Rabi (winter), Aus and Aman seasons, respectively, i.e., wheat is grown in Rabi, BR1 in Aus and BR4 in Aman.

b Figures in parentheses are the rice yields (t/ha) for the pattern.

Cropping Pattern

Cropping pattern trials were conducted in the project area during the years 1983 to 1989 under recommended and farmers' management of inputs, with a view to maximizing farmers' economic return from available land and water resources.

Some tested cropping patterns, along with yields obtained under recommended and farmers' management levels are presented in Table 13. It can be concluded that two H W rice and a legume or green manure crop may be the best combination for areas where water availability permits two rice crops annually. Such combination produced about 12 tons/ha grain yield in the experimental fields, out of which about 10 tom were obtained from the Aus and Aman harvests. These patterns yielded about one ton less under farmers' management than under recommended management. Replicated trials in farmers' fields of T10/S11K produced over 6.0 ton/ha when BR11 was grown after green manuring (Sesbania), which is higher than the two rice crops grown under inadequate water conditions in the tail-end tertiary area prior to 1984. It provided an altemative for the tail-end farmers to grow one assured HYV Aman rice by transplanting at the recommended time in place of two rice crops under delayed and inadequate water supply conditions.

Therefore, production of a suitable non-rice crop during the Aus season as an alternative to rice should be emphasized in the tail-end areas. (BRRI-BWDB-IRRI 1986).

Among all the Rabi crops grown within the G-K Project, kheshari occupies the maximum area. In the project area, farmers generally cultivate kheshari as a relay crop. It was observed that the majority of the farmers (about 80 percent) broadcasted kheshari seeds between November 15 and 30. Some farmers broadcast pregerminated kheshari seeds if the moisture is not sufficient in the rice field. Average yield varies from 190 to 1,180 kg/ha (Table 14) depending upon the soil moisture, weather and farmers' practices (some farmers used green kheshari plants as fodder).

Wheat was the second most popular Rabi crop in the G-K area before 1987-88 because there was an initiative to popularize rain-fed wheat within the project area. Some farmers adopted this cereal crop and usually cultivated in low pockets of the G-K Project.

In the G-K area, yield of wheat was 1,510-2,326 kg/ha under nonimgated conditions. At the very beginning of the on-farm research in 1981, trials were conducted with wheat in 1981-82 and 1982-83 Rabi seasons and average yields of about 1987 and 1,750 kg/ha under RM and FM levels were obtained (Table 14). About 13.5 percent higher yield of wheat was obtained under RM level which may be due to the higher amount of fertilizer used in RM plots. Wheat trials were discontinued after the 1982-83 Rabi season as rice-rice-wheat is not sustainable (Bhuiyan and Gwnasekera 1988) and after that farmers were discouraged to grow wheat in the Rabi season. Yet some farmers within the project area practice wheat cultivation in some low pockets where mostly local Aman rice is cultivated in the wet season.

Gram is another popular Rabi crop in the G-K Project area. The sowing and harvesting dates are almost similar to those of wheat. Most of the farmers broadcasted gram between mid-November through mid-December and harvested by the end of March. Average yield of gram varies considerably from year to year depending on the soil moisture and rainfall. Average yield of gram over the years 1983-84 through 1989-90 was about 1.0 t/ha without fertilizer (Table 14).

Tabl 14. 'eld (Kg/) oj populara rabi crops in the selected tertiaries of the Ganges-Kobadak 'oject (Phase I), Rabi seasons, 1981-82 to 1989-90

Year	Kheshari		Gram		Wheat		Onion		Garlic		Lentil	
	RMa	FM	RM	FM	RM	FM	RM	FM	RM	FM	RM	FM
1981-82	-	-	-	-	2477	2390	-			-		-
1982-83	-	-	1930	1510	1497	1110	-			-	280	180
1983-84	1320	1180	1280	1020	-	-	-			-		-
1987-88	990	760	450	400	-	-	8210	8280		-		-
1988-89	650	500	2030	1820	-	-	6450	6340	1830	-		-
1989-90	200	190	600	560	-	-	7676	6986		-		-
Mean	790	658	1258	1082	1987	1750	7445	7205	1830	-	280	180
Ferti-	N				80	30	45	33			20	
lizer use	P				60	34	44	46			60	
(kg/ha)	K				40	19	29	30			40	

• RM = Recommended Management. FM = Farmers' Management.

Onion is the second most popular non-rice crop grown in the project area. Popularity of onion increased after the 1986-87 Rabi season, when demonstration with onion started under RM level in different locations of the project (Table **15).** Onion is very sensitive to moisture stress and also to excess moisture levels. Under irrigated conditions, yield of onion may *go* up to 20 t/ha with proper fertilizer management (Mondal 1988). In comparison to that, yield of onion is much lower in the study area. It was observed that yield of onion varied from **6.3** to **8.3** t/ha. Fertilizer application level was very low and only about 50-60 percent of the farmers used fertilizer in growing onion, which may be the major cause for the lower yield. It is also indicated that the majority of the farmers used "cowdung" (about 10t/ha) in their onion field.

About 1 to 3 percent of the farmers in the G-K area grew pea, oil seeds and lentil during the Rabi season (Table 15).

North Bangladesh Tubewell Project

Improvements in the use of HYV rice. As in the case of irrigation water use, emphasis was given by the project management and research group from the 1982 Aman season to increase the use of high-yielding rice varieties by farmers. The following specific activities underscored the effort in this direction: (a) identification of target fallow farms and those planted to Aus rice which are on time for HYV rice in the

Table 15. Adoption of different rabi crops in the Ganges-Kobadak Project (Phase I), the Rabi seasons. 1983-84 to 1989-90.

Year	Adoption of crops (percent)							
	Kheshari	Wheat	Gram	Onion	Pea	Lentil	Oil seeds	Total
1983-84	7.3	3.8	0.7	8.4	-	-	1.6	21.8
1984-85	27.8	11.1	5.3	8.2	0.9	-	0.7	54.0
1985-86	22.9	11.1	11.1	8.7	3.3	-	-	57.1
1986-87	9.1	13.6	19.8	8.4	4.2	1.1	-	56.2
1987-88	18.7	5.3	7.3	15.3	2.2	1.8	-	50.6
1988-89	21.0	3.3	16.0	6.9	4.7	-	2.4	54.3
1989-90	13.0	12.3	3.8	15.8	2.3	0.8	2.0	50.0
Mean	17.	8.6	9.1	10.2	2.9	1.2	1.7	41.9

succeeding season, (b) information drive to familiarize farmers with recommended high-yielding varieties which are suitable for transplanting in the early, middle or late Aman season; and (c) better supervision of irrigation facilities and greater field inspection by the irrigation project staff to solve technical irrigation problems and thereby creating confidence in the farmers' minds about the reliability of water supply.

In the 1988 Aman season, the use of HYV increased to 74 percent of total rice area in the pilot tubewells compared to 36 percent for the 1982 Aman season. However, the HYV rice hectarage grew by more than 70 percent during the one-year period in 1982-83. During the benchmark period, only about 15 percent of all rice planted used HYV, whereas in the subsequent Aman seasons, in addition to high increase in area grown to H W rice, the percentage of HYV to all rice grown increased highly and consistently (Table 16).

Cropping pattern trials during the years 1984, 1987, 1988, and 1989 indicate prospects of diversified crops in the project area (Table 17). Crop diversification should be an important strategy for effective utilization of tubewells.

In the project, wheat coverage during 1983-84 was 68 percent and gradually decreased in the following years (Table 18). In the North Bangladesh Tubewell Project deep tubewells are highly underutilized in the Rabi season. In was observed from a study that only 0.16 ha/lit/sec were irrigated in the Rabi season as against the potential of 0.65 ha/lit/sec for rice. The potential for non-rice crops might be higher than the above figure. The soil is sandy loam and with high potential for growing non-rice crops. The lower wheat coverage may be due to the high price of seed and fertilizer and the late harvest of Aman. The low market price of wheat as compared to that of rice also affected wheat coverage. Moreover, the project authority allowed farmers to grow rice instead of wheat which was not allowed

Table 16. Irrigated area and MV coverage in the selected pilot tubewells of the North Bangaladesh Tubewell Project, Thakurgaon, Aman seasons, 1982-89.

DTW N".	Irrigable area (ha)	Irrigated area (ha)								MV coverage (ha)						
		1982	1983	19Y	1985	1986	1987	1988	1989	1982	1983	1984	1985	1987	1988	1989
63	60	120	55.5	59.5	59.5	58.7	56.7	59.5	55.5	15.0	30.4	39.3	38.5	41.1	45.3	34.4
77	49	10 8	46.6	49.0	47.8	44.5	45 1	47.8	44.9	24.3	17.9	36.8	38.5	15.2	34.4	27.1
89	49	32.9	46 0	49.0	48.6	46.2	46.6	48.6	38.9	30.4	35.2	40.1	41.7	39.3	38.9	11.9
91	74	34.0	14.4	62.6	11.7	72.9	48.2	16.7	48.2	24.1	41.3	50.0	51.4	41.3	42.5	34.4
117	61	28.7	61 5	60.7	62.8	58.7	60.7	61 8	59.9	19.4	11.1	44.2	38.5	14.4	30.4	28.3
118	46	18 Y	47.8	46.2	55.7	44.5	46.2	M.%	46.2	14.2	15.6	411	42 5	1 6	16,	1.1
I19	57	16.1	72.8	a/	a/	52.6	56.7	61.9	56.7	12.1	11.1	21.1	24.3	34.8	11.1	11.1
120	61	16.1	64.8	60.7	61.R	58 7	60.7	66.4	50.6	17.4	19.1	4.f	466	14.5	40.5	12.1
125	55	50.6	51.4	55.5	55.1	58.8	55.5	91.1	607	8.1	17.0	30.4	31.6	16.8	44.5	42.5
126	48	41.3	46.6	47.8	47 4	50.6	47.8	46.6	18.7	25 I	39.1	45.3	45.3	296	40.5	44.5
138	50	48.6	50.2	50.5	43 3	41.1	50.0	83.4	84.3	24.3	19.6	4.1	54.8	25.1	32.5	48.1
142	49	16.0	48.2	62.8	48.6	46.1	49.0	73.3	60.7	10.1	23.1	38.5	34 4	36.8	40.9	54.7

a/ Tubewell was not operated due to sand and gravel pumping problem.

during the previous years. Therefore, fanners preferred to grow rice which is the main staple and the return from rice is higher than that from wheat. In can be observed from the Table that potato and mustard are gaining popularity. There is no technical problem in terms of irrigation water availability and drainage in this area for crop diversification.

Yield and input use. The levels of fertilizer use in the Rabi, Aus and Aman seasons were lower than the recommended rate (Table 19). Farmers used a lower rate of NPK fertilizers in the NBTP area than in the G-K area and obtained lower rice yields though water was not a limiting factor in the tubewell area.

Table 17. Average annual grain yield (t/ha) for the selected cropping pattern in the North Bangladesh Tubewell Project, Thakurgaon.

Year	DTW NO.	Cropping pattern	Yield (t/ha)	
1984	63	Sonalika-Sunhemp-BR11	8.08(5.28)	7.40(4.70)
		Sonalika-Millet-BR 11	8.08(5.28)	7.40(4.70)
		Balaka-Mungbean-BRIO	8.48(5.28)	7.79(4.79)
		Pavon-Dhaincha-BR4	7.38(5.00)	6.27(3.77)
	118	Sonalika-Sunhemp-BR11	8.30(5.60)	8.33(5.43)
		Sonalika-Millet-BR11	9.30(5.60)	9.43(5.43)
		Balaka-Mungbean-BR10	8.07(5.80)	7.08(4.12)
		Pavon-Dhaincha-BR4	7.78(5.58)	6.45(4.45)
	126	Sonalika-Sunhemp-BRII	9.18(5.78)	8.78578)
		Balaka-Mungbean-BR10	8.00(5.00)	8.01(4.81)
		Pavon-Dhaincha-BR4	8.02(5.02)	7.04(4.64)
1987	I26	Sonalika-Purbachi-BR11	12.21(10.33)	11.09(9.21)
1988	89	Kanchan-Millet-BR11	8.34(5.52)	7.71(4.89)
	118	Kanchan-Sesame-BRI0	7.33(4.89)	5.30(3.96)
		Fallow-Purbachi-local rice	7.95(7.95)	7.40(7.40)
	120	Sonalika-Sesame-BR11	6.64(4.59)	5.20(3.IS)
	I26	Fallow-purbachi-BRI1	I1.44(11.44)	10.89(10.89)
		Kanchan-Millet-Pajam	8.44(3.67)	7.21(3.67)
	142	Fallow-Purbachi-BRIl	9.90(9.90)	8.83(8.83)
1989	89	Kanchan-Millet-BR11	10.02(6.91)	8.46(5.35)
	118	Kanchan-Sesame-BRI1	6.63(4.64)	6.39(4.40)
	126	Mustard-Fallow-BRII	6.61(6.04)	5.66(5.09)

Note: Sonalika, Balaka, Pavon and Kanchan are wheat varieties.
BR stands for rice variety.

Table 18. Adoption of different Rabi crops in the North Bangladesh Tubewell Project, the Rabi season 1982-83 to 1989-90.

Year	Adoption of crops (percent)			Total
	Wheat	Mustard	Potato	
1982-83	38.3	-		38.3
1983-84	68.3	-		68.3
1984-85	43.3	-		43.3
1985-86	33.3	-		33.3
1986-87	37.2	-		31.2
1987-88	23.0	-		23.0
1988-89	21.7	2.2		23.9
1989-90	29.2	0.8	3.8	33.8
Mean	36.8	1.5	3.8	40.6

Table 19. ***Average yield and input use in the North Bangaladesh Tubewell Project, Thakurgaon,*** *1983 - 1989.*

Year	Rabi season				Aus season				Aman season			
	Wheat yield (kg/ha)	Nitrog (kg/ha)	Phosphc rus (kg/ha)	'otash (g/ha	Ria (kg/ha)	itroge :g/ha)	ospho- rus (g/ha)	Potash (kg/ha)	Rice (kg/ha)	Nitroge (kg/ha)	iospho rus kg/ha)	otash :g/ha)
1983	2,380	66	64	40	3,539	52	46	35	3,973	45	43	29
1984	1,860	44	55	31	1,785	31	24	16	1,655	36	39	24
1985	1,276	43	24	17	3,100	45	49	25	2,109	32	35	30
1986	2,496	49	48	28	3,608	44	36	23	2,012	33	33	24
1987	1,662	47	44	28	4,203	51	51	31	3,146	38	37	23
1988	1,394	60	50	30	3,932	79	51	32	2,309	43	42	26
1989	2,124	62	51	30	3.663	75	48	27	2,319	37	31	18
Mean	1,884	53	48	29	3,404	53	43	27	2,503	37	37	24

SUGGESTED STRATEGIES FOR IMPROVED WATER MANAGEMENT

Ganges-Kobadak Project

Adjustment in riceproduction schedules. In theexistingcondition, the Aus and Aman rice is transplanted mostly in the second half of April/May and August/ September, respectively. Transplanting of Aus rice should be completed in March which will allow for better use of available rain in June-Julyand for use of HYVs both in the Aus and Aman seasons, leading to more irrigationcoverage and higher annual rice production.

Soil moisture utilization. Means to produce profitable legume crops using the residual moisture after the harvest of Aman rice should be accelerated to utilize the period between the end of Aman and the beginning of Aus in the project area.

North Bangladesh Tubewell Project

1. ***Water delivery schedule.*** Farmers prefer a water delivery schedule which will allocate and distribute water to different areas or blocks of the service area

in a fixed or predetermined schedule. Blockwise rotational schedule of water delivery will improve the water distribution system.

2. *Cropping plan.* The diversified cropping plan should be adopted for maximizing use of land and water resources. The cropping schedule should be adjusted so that Aman cultivation can take advantage of the maximum rainfall period.

3. *Communication.* Communication between the BWDB staff and the water **users** (farmers) should be strengthened which will help in improving the water delivery schedule in the project.

4. *Socioeconomic factors.* Timely input and credit support and assurance of fair price for the products will encourage farmers to adopt diversified cropping.

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On-Farm Water Management for Rice-Based Farming Systems in Indonesia

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INTRODUCTION

As in most countries which have attained self-sufficiency in rice, Indonesia is paying increasingly more attention to diversification in association with rice in the irrigated areas. This approach is to provide fanners with better cropping options and greater opportunities to generate higher farm income. However, the success of this endeavor would largely depend on various hydrologic, agronomic, economic and socio-institutional factors or constraints that would influence a wide-scale diversification program.

Water is a critical input in crop production. In the dry season, when water supply in the irrigation system declines, the availability of water for crop production becomes a crucial factor for cropping as well as for crop choice. Farmers usually achieve a o p intensification diversification and income by growing nonrice crops

such as legumes (particularly soybean and mungbean) or maize or in some small regions, chili or onion which may be grown after the harvest of one or two rice crops.

The relationships between irrigation-water-related factors such as availability, reliability and distribution, and farmers' cropping and crop choices should be better understood by planners and implemmtors of agricultural development programs. This paper focuses on the selected water and crop-related issues to better understand the on-farm level water management for rice-based cropping.

METHODOLOGY

The Study Area

Different component studies were conducted at the Cikeusik (also called Manuengteung) Imgation System located at Cirebon, West Java. The system has a command area of about 7,511 ha and has 114 tertiary blocks. The average annual rainfall in the area is about 1,600 mm (1984-1988 average).

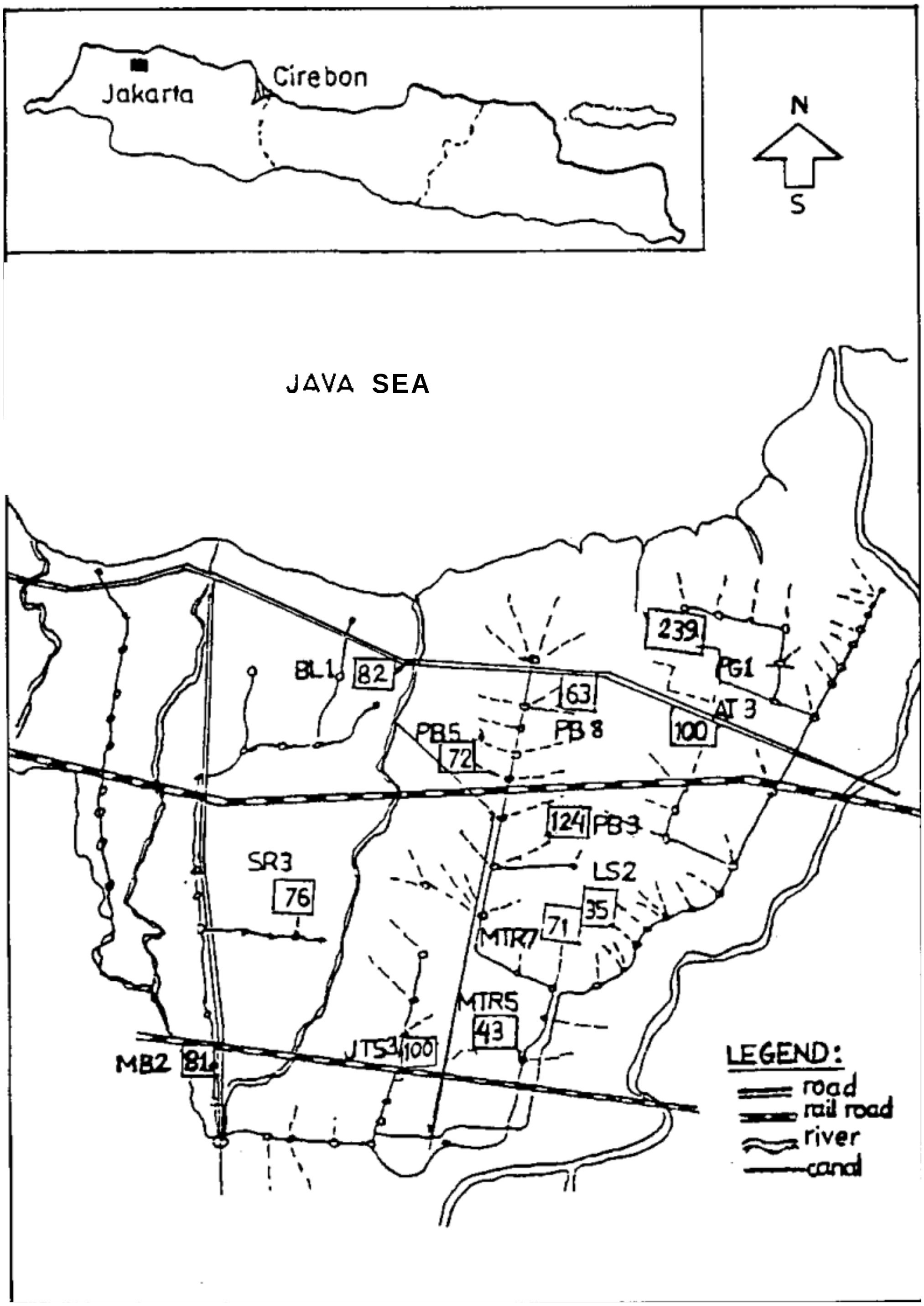
Rice is the principal crop grown, particularly in areas with sufficient water supply. Some areas even have three rice crops a year. However, in areas where imgation water supply is scarce, nonrice crops such as onion, chili, stringbean, mungbean, corn and others are mostly grown during the dry season. Rice is the dominant crop during the wet season which starts in December and ends in April. The first dry season (DS I) is from May to July and the second (DSII) from August to October.

Data Collection and Analysis

To determine water relations to dry-season crop choice and profitability, 12 tertiary blocks were selected within the irrigation system, 4 each at the head, middle, and tail sections of the system (Figure 1) (Wardana et al. 1990). Seventy nine sample farms were randomly selected from these tertiary service areas. Information on canal water availability, groundwater use, crop choices, relevant agronomic practices, yield, farm receipts and expenditures, and farmer background were obtained from the sample farmers through farm surveys. For certain water-related information, the *ulu-ulu* (water tender) was interviewed. Tertiary level water discharge data were collected daily.

The effects on the growth and yield of maize and mungbean of farmer-acceptable tillage practices and of realistic irrigation regimes defined in relation to soil-water holding capacity and ongoing crop-water usage were determined at three toposequence elevations (representing the irrigation system's head, middle, and tail regions, and drainage hydrologies), two crop sequences, maize-mungbean and mungbean-maize grown from May to October 1989 comprising Dry Seasons I and II (Juliardi et al. 1990). Mungbean cultivar No. 129 and maize hybrid cultivar C-1 were used in the study.

Figure 1. *Map* showing *the location of the* 12 sample *tertiary blocks, Cikeusik Irrigation System, Cirebon, West Java, Indonesia.*



Three tillage systems, zero tillage (To), strip tillage (Ts), and maximum tillage (Tm) were compared. For both maize and mungbean, seeds were sown by hand into manually dibbled holes at a spacing of 40 x 50 cm and 40 x 10 cm for maize and mungbean, respectively. Maize was fertilized with 120:90:60 kg/ha N:P:K applied in portions at 7, 30 and 45 days after seeding (DAS).

For mungbean, 45:45:45 kg/ha N:P:K was divided between application at 7 and 21 DAS, the first in combination with Furadan (17 kg/ha) to combat soil-bome insects. Hand weeding was made every 10-14 days from seedling emergence to flowering, and insecticidal sprays were applied every 7-10 days during 10-40 DAS.

Three irrigation regimes were investigated at each elevation and for each crop sequence. The least-irrigated plots (I-S) received a single irrigation of 20 mm the day before seeding. An intermediate level of irrigation (I-80) comprised a 20-mm pre-seeding watering, together with reirrigation to field capacity within the root zone whenever its water content was depleted of 80 percent of its available water. The most-irrigated treatment (I-40) involved a 20-mm pre-seeding watering together with reirrigation to field capacity whenever 40 percent of available water had been used.

Regular measurements were made for all plots (and for each crop elevation). Rainfall, depth to groundwater table, soil water content and bulk density and soil strength throughout the crop rooting zone, seedling emergence percentage and time of emergence, plant height and rooting depth and density, yields of grain and total dry matter, and components of grain yield were regularly measured.

At the Kuningan Experimental Farm in West Java, the effect of population density on the irrigation use efficiency of mungbean in addition to tillage and imgation was also studied (Abas et al. 1990).

RESULTS

Water Availability, Crop Choice and Cropped Area

About 41 percent of middle- and 79 percent of tail-section farmers considered the supplies of water insufficient (Table 1). More than 50 percent of the head section farmers were of the same opinion. Inequity problems resulted from the inappropriate system of water rotation and the "water-grab" mentality of upstream farmers who have more access to the limited canal supplies.

Figures 2a to 2c show the declining tertiary canal supplies with the advance of the 1988 dry season in the head, middle and tail tertiaries. The first and second 15-day average discharge values for each month illustrate the canal supply behavior as the seasons progressed. The decreasing water supplies in the tertiary canals from April to September are evident.

The head section had greater discharge per unit area than the lower sections. Most farmers would plant *palawija* crops in May if they are supplied with adequate water to establish the crops. To supplement the low discharge during the middle

Table 1. Factors contributing to water shortage and inequity problems, Cikeusik Irrigation System, Cirebon, West Java, Indonesia, 1988 DS I[a].

Item	Head	Middle	Tail	All farms
No. of samples	26			79
Irrigation water supply insufficient (percent)	58			59
Rotation is not appropriate (percent)	19			27
"Water-grab" mentality of upstream farmers (Percent)	35			30

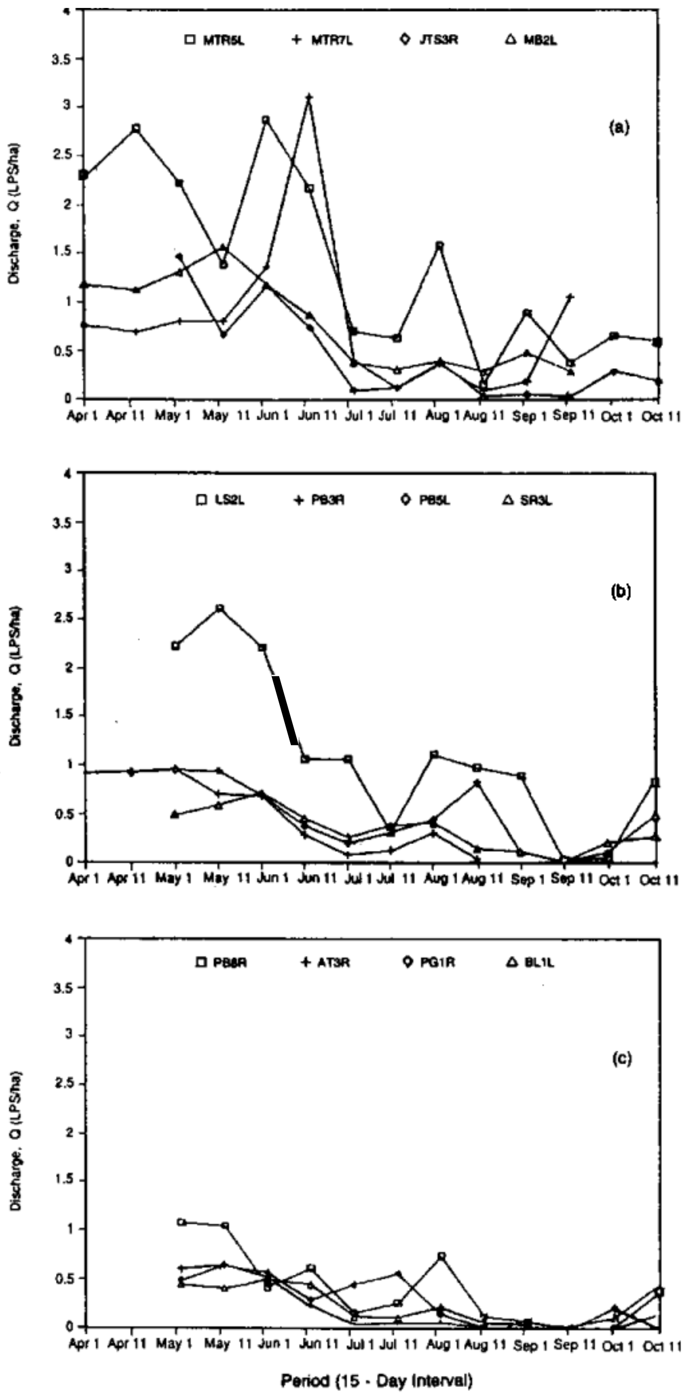
[a] *Some farmers gave more than one answer.*

and later part of the season, some farmers used dugwells. It should be noted that larger areas in three tertiary blocks of the section were planted to sugarcane (Table 2). It could be that the head section was scheduled to be planted with the mandatory sugarcane crop during that year.

Table 2. Extent of rice and nonrice crops grown in Cikeusik lmgation System, Cirebon, West Jaw, Indonesia, 1988 DS I and DS II.

Tertiary	DS I					DS II		
	Area (ha)	Rice	P.wija	S.cane	Fallow	P. wija	S. cane	Fallow
Head								
MTR5L	43	8	20	9	6	10	17	16
MTR7L	71	0	29	22	20	6	22	43
JTS3R	100	12	27	56	5	5	61	34
MB2L	81	0	34	44	0	3	44	34
Middle								
LS2L	35	0	8	27	0	5	27	3
PB3R	124	0	45	54	25	20	54	50
PB5L	72	0	30	29	13	24	29	19
SR3L	76	35	2	39	0	0	39	37
Tail								
PB8R	63	11	30	0	22	30	0	33
AT3R	100	70	30	0	0	30	0	70
PG1R	239	0	17	0	222	7	0	232
BL1L	82	6	12	0	64	0	0	82

Figure 2. Discharge (Q) per unit area for 4 tertiaries of the head section (a), middle section (b), and tail section (c), Cikeusik Irrigation System, Cirebon, West Java, Indonesia, 1988 DS I and DS II.



For the middle farms, only tertiary block LSZL had a discharge greater than the rice crop water requirement (Figure 2b). Like the head section, it also had large areas planted to sugarcane. In one tertiary block, SR3L, about 50 percent of the area was planted to rice in DS I despite a relatively low canal discharge. In this tertiary, the farmers used groundwater during the season to supplement the canal water supply. The other tertiary blocks planted all or most of their areas to nonrice crops since the canal discharge was not enough to meet the rice crop water requirement in DS I. Although tertiary LSZL had a higher discharge rate for most of the May to September period, no rice was grown, with over **75** percent of the area grown to sugarcane. The rest of the area was grown to palawija crops. Like tertiary MTR5L of the head section, this tertiary had a relatively higher discharge rate because of its smaller area.

The canal discharge in the tail section was lower than in the upstream section (Figure 2c). Yet **two** of the sample tertiary blocks (PBER and AT3R) planted rice in DS I. Tertiary block AT3R planted 70 percent of its area to rice with supplemental water pumped from the drainage canal serving several upstream tertiaries. Furthermore, over 90 percent of the area of tertiary PG1R had no crop (fallow) in either both DSI or DS II. This is because since the second week of June, the canal discharge, which was very low from the beginning of DS I, started to decline and reached virtually zero flow towards the end of DS I. Moreover, this section received no water in DS II.

Comparing tertiary MTR5L in the head section and LS2L in the middle section, which are the **only two** tertiaries with a discharge high enough to grow rice in DS 1, it was observed that sugarcane and palawija were the dominant crops grown. Tertiary LSZL area had no rice at all. Clearly, farmers' crop choice was influenced not by water availability alone. In general, farmers in the head reaches, who have more access to adequate canal water supplies, can exercise their crop choice considering the other important factors such as economic returns and income stability. For middle and tail-end farmers, alternative sources of water had to be tapped to have this flexibility.

Groundwater Use

To supplement canal water during the dry months, some farmers utilized groundwater and some others pumped water from drainage canals. Dugwells were common in the head-end area while tubewells of about 10-30 m depth were common in the middle and tail areas. Shallower tubewells in the tail areas would yield salty water from the sea.

More than 50 percent of the head and middle section farmers used groundwater in DS II (Table 3). Because of salt problems, **tail farmers used less groundwater.** The farmers utilized groundwater mostly to supplement canal supply, as pointed out by 100 percent of the groundwater **users** in the head and middle sections in DS I and 75 percent of the groundwater users at the tail area. During DS II, groundwater had been used to meet the full crop water requirement. This reflects the greater scarcity of canal supplies in DS II relative to DS I.

Table 3. Groundwater use by section and by season, Cikeusik Irrigation System, Cirebon, West Jaw, Indonesia, 1988 DS I and II.

Item	Head n=26	Middle n=29	Tail n=24	All farms n=79
Perecent of farmers using groundwater (%)				
DS I	23	3	17	14
DS II	58	52	4	38
Purpose of groundwater use:				
a. To supplement canal supply (%)				
DS I	100	100	75	92
DS II	20	27	0	16
b. For full crop water requirement (%)				
DS I	0	0	25	8
DS II	80	13	100	84
Percent of farmers owning the well (%)				
DS I	100	100	25	75
DS II	93	60	0	51
Cost of grounwater use US$ /ha per season				
DS I	69	45	53	56
DS II	51	58	100	69

US$1.00 = Rp.1,800. Only variable costs are included

The majority of the groundwater users in DS I and DS II in the head area owned the wells. Groundwater users in the tail section, on the other hand, paid rents for the use of wells in DS 11. The average cost of groundwater use ranged from US$45 to US$69 per hectare per season in DS I, and from US$51 to US$100 per hectare in DS II.

Table 4 shows significantly higher mean yield per hectare of onion (10.74 t/ha) in DS II for the groundwater users. Thus, even if they incurred higher cost of production, it could be compensated for by the significantly higher returns above paid-out costs and gross margin per hectare than the nonusers. In fact, the average nonuser incurred a net loss of about US$100 per hectare.

The use of groundwater to alleviate canal water shortages and increase the cropping intensity and farm income should be highly encouraged. However, studies to establish the availability of groundwater in space and over time should be conducted.

Table 4. Comparative costs of and returns from onion, groundwater users versus nonusers, Cikeusik Irrigation System, Cirebon, West Java, Indonesia, 1988 DS II.

Item	Users	Nonusers	Difference
No. of samples	15	24	
Mean yield (t/ha)	10.74	6.02	4.72***
Total value of production (US$/ha)	2,129	1,020	1,109***
Costs of production (US$/ha)			
Seeds	499	404	95
Fertilizer	144	90	54**
Insecticide	220	113	107***
Labor			
Hired	375	283	92*
Family	207	141	66*
Other costs	107	91	16
Total paid-out costs of production (US$/ha)	1,345	981	364**
Total variable costs of production (US$/ha)	1,552	1.122	430***
Returns above paid-out costs (US$/ha)	784	39	745***
Gross margin (US$/ha)	577	(102)	679**

US$1.00 = Rp.1,800.
***,**,*, significant at 1 percent, 5 percent and 10 percent, respectively.

Fertilizer Use

The level of N fertilizer use in DS I was high, with an average of **212** and **209** kg/ha for the sample farms for rice and onion, respectively (Table 5). However, it was observed that the farmers at the head section used less N-fertilizer for rice than those in the other two sections. In contrast, the head-end farmers used more N and P fertilizers for onion, i.e., **224** and **94** kg/ha, respectively.

Table 5. Fertilizer use by crop and by section of the Cikeusik Irrigation System, Cirebon, West Java, Indonesia, 1988 DS 1.

Crop/fertilizer	Head	Middle	Tail	All farms
Rice				
No. of samples	5	6	I	12
N (kg/ha)	157	245	295	212
P (kg/ha)	27	39	95	39
K (kg/ha)	20	45	71	37
Onion				
No. of samples	18	19	23	60
N (kg/ha)	224	212	195	209
P (kg/ha)	94	85	57	77
K (kg/ha)	93	120	48	a4
Chili				
No. of samples	1	0	0	1
N (kg/ha)	347	-	-	341
P (kg/ha)	57	-	-	57
K (kg/ha)	66	-	-	66

In DS 11, the head farmers used a higher level of N fertilizer **(246** kg/ha) for onion (Table 6). On the other hand, an average farmer in the middle section used more P and K fertilizers for onion, i.e., 87 and 117 kg/ha, respectively. The highest level of K fertilizer was for chili in the middle farms. It must be mentioned that to benefit from high doses of fertilizer, appropriate crop and water management practices and good timing of application must be adopted.

Table 6. Fertilizer use by crop and by section, Cikeusik Irrigation System, Cirebon, West Java, Indonesia, 1988 DS II.

Crop/fertilizer	Head	Middle	Tail	All farms
Onion				
No. of samples	12	16	11	39
N (kg/ha)	246	194	36	65
P (kg/ha)	63	87	36	65
K (kg/ha)	85	117	29	82
Chili				
No. of samples	13	2	1	16
N (kg/ha)	183	201	360	196
P (kg/ha)	65	57	108	63
K (kg/ha)	44	129	28	54

Profitability and Land Tenure

Table 7 shows the costs and returns per hectare of onion by land tenure in DS I. Although the mean yield per hectare of onion was similar for both owner-operators and leaseholders, the value of production of the leaseholders was higher by US$126 per hectare. This can be attributed to the variations in the prices received by the farmers. Leaseholders, however, incurred higher production costs, mostly land rents, as well as total variable costs which resulted in a net loss of about US$39 per hectare.

A similar trend was also observed for rice farmers. Leaseholders spent more in seed and fertilizer than the owner-operators (Table 8). Despite the higher input use of the leaseholders, however, their mean rice yield was about 0.9 t/ha lower.

Profitability and Area Location

In DS I, the mean yield per hectare of rice did not vary much between the head and middle farms (Table 9). However, in a farm in the tail section, where only one farmer planted rice, the yield was very low (2.43 t/ha). Thus, the total value of production per hectare for this section was also very low, only about 40 percent of what the head and middle farms obtained.

Table 7. Comparative costs and returns of onion by land tenure, Cikeusik Irrigation System, Cirebon, West lava, Indonesia, 1988 DS J

Item	Owner-Operator	Leaseholder	Difference
No. of samples	29	31	
Mean yield (t/ha)	9.61	9.33	0.28
Mean price of onion (US$/kg)	0.16	0.17	(0.01)
Total value of production (US$/ha)	1.525	1.651	(126)
Costs of production (US$/ha)			
Seeds	421	374	47
Fertilizer	121	112	9
Insecticide	207	156	51
Labor			
Hired	495	461	34
Family	231	333	(102)
Other costs	5	254	(249)
Total paid-out costs of production (US$/ha)	1,249	1.357	(108)
Total variable costs of production (US$/ha)	1,480	1.690	(210)
Returns above paid-out costs (US$/ha)	216	294	(18)
Gross margin (US$/ha)	45	(39)	(39)

US$ 1.00 = Rp. 1,800

Table 8. Comparative costs and returns of rice by land tenure, Cikeusik Irrigation System, Cirebon, West Java, Indonesia, 1988 DS I.

Item	Owner-operator	Leaseholder	Difference
No. of samples	6	6	
Mean yield (t/ha)	4.65	3.78	0.87
Total value of production (US$/ha)	595	475	120
Costs of production (US$/ha)			
Seeds	10	17	(7)
Fertilizer	42	131	(89)
Insecticide	16	21	(5)
Labor			
Hired	147	264	(177)
Family	34	I12	78
Other costs	3	230	(277)
Total paid-out costs of production (US$/ha)	218	663	(445)
Total variable costs of production (US$/ha)	252	775	(523)
Returns above paid-out costs (US$/ha)	377	(188)	(565)
Grass margin (US$/ha)	343	(300)	643

US$1.00 = Rp.1,800

Table 9. Cost and returns of rice by section, Cikeusik Irrigation System Cirebon, West Java, Indonesia, 1988 DS (Gadu) I.

Item	Head	Middle	Tail	All farm
No. of samples	5	6	I	12
Mean yield (t/ha)	4.4	4.36	2 43	3.73
Total value of production (US$/ha)	550	574	229	535
Costs of production (US$/ha)				
Seeds	14	14	16	14
Fertilizer	44	46	16	73
Insecticide	18	19	18	18
Labor				
Hired	151	244	129	206
Family	116	46	16	13
Other costs	122	95	265	166
Total paid-out costs of production (US$/ha)	339	495	628	440
Total variable costs of production (US$/ha)	455	541	644	513
Returns above paid-out costs (US$/ha)	211	19	(399)	95
Gross margin (US$/ha)	95	33	(415)	22

S$1.00 = Rp.1,800

The head farmers spent less for fertilizer (since they applied less fertilizer), insecticides and hired labor, but utilized more family labor as manifested by the higher average imputed cost. Still, the head farmers incurred lower total paid-out and total variable costs per hectare compared to farmers in the other sections. As expected, the head farmers produced higher returns above paid-out costs and gross margin, US$211 and US$95 per hectare. In contrast, farmers in the tail section incurred a net loss of about US$415 per hectare for rice.

For onion, the middle farmers had a slightly higher yield than the head farmers, 10.5 and 9.7 t/ha, respectively (Table 10). However, the price of onion received by the farmers in all sections (US$0.16 per kg on the average), was much lower than the normal price range of US$0.28 - US$0.55/kg. Since the total paid-out and totalvariable costs did not vary much among the secrions, the deficit (net **loss)** in gross margin for both head and tail farmers can be attributed to low output prices.

Table 10. *Costs* and *returns of onion by section, Cikeusik Irrigation System, Cirebon,* West *Java,* Indonesia, 1988 DS I.

Item	Head	Middle	Tail	All farms
	26	29	24	79
No. of samples	9.7	10.5	8.4	9.5
Mean yield (t/ha)	0.16	0.17	0.16	0.16
Total value of production (US$/ha)	1616	1822	1332	1590
Costs of production (US$/ha)				
Seeds	494	421	301	396
Fertilizer	137	134	89	116
Insecticide	177	231	143	181
Labor				
Hired	556	468	423	411
Family	150	16	168	134
Other costs	150	16	168	134
Total paid-out costs of production (US$/ha)	1514	1330	1121	1304
Total variable costs of production (US$/ha)	1928	1545	1360	1588
Returns above paid-out costs (US$/ha)	162	496	211	286
Gross margin (US$/ha)	(252)	211	(28)	2

US$1.00 = Rp.1,800.

With regard to other crops grown in DS II, chili gave greater returns per hectare in the different sections (Table 11). Despite a lower yield for the tail section, chili still gave a higher total value of production than in the middle farms, which could be due to price variations between sections. Similarly, the tail section produced the highest gross margin from chili, US$1,688 per hectare while the middle farms had an average of US$912 per hectare.

Mungbean'gave positive returns in all sections in DS II. The returns about paid-out costs ranged from US$95 to US$149 per hectare in the head and tail sections, respectively, while the gross margin ranged from US$30 to US$96 per hectare.

Table I1. *Costs and returns* of chili, corn *and mungbean by section, Cikeusion Imgation System, Cirebon, West Java, Indonesia, 1988, DS II.*

Item	Head	Middle	Tail	All farms
Chill				
No. of samples	13	2	I	16
Mean yield (t/ha)	8.87	6.52	4.00	8.27
Total value of production (US$/ha)	2,564	1,507	2,222	2,41 I
Total paid-out costs (US$/ha)	738	505	531	696
Total variable costs (US$/ha)	849	534	595	924
Returns above paid-out costs (US$/ha)	1.826	1,002	1.691	1.715
Gross margin (US$/ha)	1,640	912	1,688	1,562
Corn				
No. of samples	1	5	1	7
Mean yield (t/ha)	2.5	2.9	3.6	2.9
Total value of production (US$/ha)	111	I30	159	131
Total paid-out costs (US$/ha)	53	232	131	192
Total variable costs (US$/ha)	54	374	387	330
Returns above paid-out costs (US$/ha)	58	(102)	28	(61)
Gross margin (US$/ha)	57	(244)	(228)	(199)
Mungbean				
No. of samples	3	3	2	8
Mean yield (t/ha)	0.52	0.71	0.73	0.64
Total value of production (US$/ha)	225	306	303	275
Total paid-out costs (US$/ha)	130	190	154	I59
Total variable costs (US$/ha)	I36	276	207	206
Returns above paid-out costs (US$/ha)	95	I16	149	116
Gross margin (US$/ha)	89	30	96	69

S$1.00 = Rp.1,800.

Profitability and Land Size

In DS I, the mean rice yields per hectare of the four land size categories were very similar, about 4 t/ha (Table 12). However, Category I, which has the smallest farms, incurred the highest total paid-out cost of US$433 and total variable cost of US$502 per hectare. This resulted in a net loss of about US$11 per hectare. In contrast, the other three categories obtained a higher gross margin per hectare, ranging from US$181 to US$227 on the average.

Table 12. Costs and returns of rice and a w n by land size, Cikeusik Irrigation System, Cirebon, West Java, Indonesia, 1988 DS I.

Item	Land sire			
	I	II	III	IV
Rice				
No. of samples	4	3	4	I
Mean yield (t/ha)	4.09	4 10	4.50	4.00
Total value of production (US$/ha)	491	643	522	444
Total paid-out costs (US$/ha)	433	354	302	86
Total variable costs (US$/ha)	502	416	328	263
Returns above paid-out costs (US$/ha)	58	289	220	358
Gross margin (US$/ha)	(11)	227	194	181
Gross margin (US$/ha)	(11)	227	194	181
Onion				
No. of samples	I2	16	14	18
Mean yield (t/ha)	11.9	9.6	9.0	8.I
Total value of production (US$/ha)	2.029	1,740	1,235	1,441
Total paid-out costs (US$/ha)	1,617	1,408	1,160	1,120
Total variable costs (US$/ha)	2,222	1,634	1,507	1,191
Returns above paid-out costs (US$/ha)	412	332	75	321
Gross margin (US$/ha)	(193)	106	(272)	250

For onion, the lowest yield was in Category IV or those fanners larger than 0.74 ha. However, its value of production was higher than that of Category III lands, which could be attributed to output variations among farms. The returns above

paid-out costs ranged from US$75 to US$412 per hectare. Categories I and III had net losses which could have been avoided if farmers were able to sell their harvest at normal prices during the season.

Tillage, Irrigation and Crop Yields

In 1989, plant height of both maize and mungbean was affected more by season and elevation than by tillage or irrigation. At the head elevation, the plant height of maize reached about 2.7 m in DS I but only 2.0 m in DS II. On the other hand, mungbean plants in DS I were 0.49 m high and 0.53 m in DS II. At the tail elevation, maize was 2.3 m high in DS I while mungbean was 0.40 m.

Rooting depth of both crops and in both elevations was determined primarily by the depth to the water table. In DS I, at both head and tail elevations, the rooting depth of maize reached 35 cm and mungbean, 20 cm. In DS II, maize at the head elevation also reached 35 cm (but more quickly than in DS I because of the deeper water table). Similarly, mungbean at both elevations benefited from deeper water table to roots down to 29 cm depth.

Root mass density in the tilled zone (0-10 cm) responded slightly to tillage (especially intensive tillage), but more for maize than for mungbean, and more in DS II than in DS I. Root mass within the whole rooting zone responded to irrigation, at both elevations for both crops. These responses were consistent with the observed patterns of soil strength.

Grain yields for maize and mungbean as affected by tillage are presented in Table 13. Averaged over crops, season, and elevation, the benefit from maximum tillage (Tm) was higher than from strip tillage (Ts) and even much higher in the wetter than in the drier season. Maximum tillage gave slightly more benefit to the shallower-rooting mungbean than to the deeper-rooting maize.

Maize gave a lower yield/million plants with tillage (average of Ts and Tm) compared to no tillage (To). However, for the shallower-rooting mungbean, yield/plant with tillage was higher than without tillage.

Maize and mungbean responded to both I-80 and I-40 irrigation treatments (Table 14). For maize, the incremental efficiency indicates that incremental water could be used effectively as the total water uptake of 201 mm was substantially below the potential season crop water requirement of about 300 mm. For mungbean, however, total water use of 134 mm comprised a larger portion of the potential requirement of about 170 mm, and the incremental efficiency of irrigation was lower.

For both mungbean and maize, total water use was similar for I-80 and I-40 indicating that less irrigated plants have been able to take up additional soil matric water. Similarly, the least irrigated plants (I-S) made effective use of the postrice residual soil moisture and the pre-seeding 20 mm irrigation to produce almost 1 t/ha of mungbean grain and more than 4 t/ha of maize. For mungbean, tillage increased the effectiveness of using the postrice residual moisture.

Table 13. Effect of tillage on grain yield of mungbean and maize in various seasons and at various elevations at the Cikeusik Irrigation System, Cirebon, West Java, Indonesia.

Tillage	Head					Middle	Tail	
	1988/W	1989/I	1989/I	1989/II	1989/II	1988/I	1989/I	1989/I
	Mungbean							
	No. of reps included							
	5	5	5	5	3	5	5	3
	Grain yield (t/ha)							
None	0.95	1.19	-	-	0.98	0.73	-	0.95
Strip	-	0.98	-	-	1.06	0.85	-	1.01
Maximum	0.89	1.21	-	-	1.09	0.96	-	0.98
Std error	0.05	0.04	-	-	0.06	0.04	-	0.05
	Maize							
	No. of reps included							
	5	5	4	5	4	5	5	4
	Grain yield (t/ha)							
None	-	5.03	5.15	5.42	5.42	-	4.30	4.41
Strip	-	4.93	5.06	5.19	5.26	-	4.38	4.33
Maximum	-	5.10	5.13	4.57	4.79	-	5.07	5.32
Std. error	-	0.15	0.14	0.48	0.48	-	0.16	0.16

Notes: W = wet season.
I, II = DS I, DS II.
Experiments in 1988 DS I (head and tail), 1988 WS and 1989 DS 11 at tail elevation were destroyed by rats and viruses.
Std.= Standard

The economic value of the incremental yield gain from irrigation could correspond to irrigation deliveries of 10 mm every 5 days during 0-20 DAS and 20 mm every 7 days thereafter to 34 DAS. This would increase mungbean grain value from US$75 to US$100 and maize grain value from US$60 to US$90.

Elevations and Crop Sequences

Averaged over all tillage treatments, yields of mungbean and maize were higher at the head than at the tail elevation (Table 13). The lower yields at the tail may be due to the generally shallower water tables, higher plant population density for mungbean and partly to highest pest pressures.

Averaged over all tillage and irrigation treatments, grain yield of maize was higher in DS II than in DS I, while mungbean yield was higher in DS I than in DS II. Thus, the mungbean-maize sequence had higher productivity than the maize-mungbean sequence.

Table 14. Effect of irrigation on grain yield and grain yield per plant for mungbean and maize in 1989 DS II at the head elevation in Cikeusik Irrigation System, Cirebon, West Java, Indonesia.

Irrigation	Irrigation total (mm)	Total water use (mm)	Grain yield (t/ha) (kg/ha/mm)	Yield per mm total water (kg/Mp/mm)	Yield per plant (t/Mp)	Yield per plant per mm total water (kg/Mp/mm)
I-s	20	116	0.95	8.2	2.68	23
1-80	45	128	1.03	8.0	2.50	20
1-40	58	I34	1.15	8.6	3.12	23
Std. error	2	10	0.07	1.1	0.21	3
I-s	20	153	4.20	27.5	52	340
1-80	65	201	5.65	28.1	64	320
I-40	78	200	5.61	28.1	66	330
Std. error	3	15	0.22	1.8	3	20

Note: Std. = Standard
Mp = Million plants.

Growth of Mungbean at Kuningan Experimental Farm

Differences between crop growth at the two elevations were apparent both in terms of plant height and grain yield. Maximum plant height at 7 weeks after seeding (WAS) averaged 47 cm at the upper elevation and 35 cm at the lower. The differences are substantial and began to develop at 5 WAS. Mungbean grain yield was also higher at the upper elevation.

At either elevation, plants were highest on the most irrigated plots (I-40). At the upper location, plants were marginally higher with tillage than without tillage. Plant height was similar for all tillage treatments at the lower elevation.

The effect of irrigation was confounded by the variability of drainage of the experimental fields. After normalizing the grain yields relative to the yield of the least-irrigated treatment and averaged over both elevations for all three tillage/ plant population treatments, yield progressively increased as irrigation total increased to 120 mm. This amount of irrigation corresponds to reirrigation at the 1-40 criterion. Higher irrigation resulted in yield decline probably because of rainfall occurrence, wetting recently irrigated soil and reducing the aeration to a level too low for effective root metabolic activity. At either elevation, highest yield would be achieved with no tillage, the 35 X 10 cm spacing and reirrigation when about 40 percent of the plant available water had been used.

CONCLUSIONS AND RECOMMENDATIONS

During the dry season, beginning from DS I to the end of DS II, canal water supplies of the irrigation system consistently declined (Wardana et al. 1990). In almost all canal areas, these discharges were too small to meet rice crop water requirements. This problem was more pronounced in the tail section than in the head section of the system.

Farmers are able to better exercise their options for crop choice, if canal water supplies are adequate for various crops, or if they have alternative sources of water supply such as groundwater. The benefit from using groundwater mostly came from higher yields due to alleviation of water stress and the higher levels of material and labor inputs used.

With respect to the actual choice of crops, farmers have to consider other important factors such as higher and more stable net returns. With its more stable price, rice is often preferred. Onion and chili farmers usually suffered the consequences of unstable price. The price fluctuation problem should be appropriately addressed by the concerned agencies. Appropriate marketing infrastructure, postharvest facilities and market information systems should be introduced to establish price stability of crops, particularly certain palawija crops such as **onion** and chili.

Further research should be conducted to establish the role of water availability, price stability and profitability in farmers' decision-making process in irrigated crop production systems.

Irrigation is done to rewet soil to field capacity whenever the 40 percent of the available water in the root zone is used which gives worthwhile returns of 28 kg grain/ha/mm water for maize and 8 kg/ha/mm for mungbean (Juliardi et al. 1990 and Abas et al. 1990). This corresponds to irrigation application (during rainless periods on soils of 50-60 percent clay) of 10 mm every 4-5 days during 0-20 DAS, and 20 mm every 6-7 days thereafter. Analyses of irrigation responses in terms of yield per plant per mm water indicated that technologies that establish and sustain high plant population densities (0.10 Mp/ha for maize and 0.50 Mp/ha for mungbean [Mp = million plants]) are also likely to promote efficient use of irrigation water. Irrigation also gives benefit by maintaining soil strength below the limit that constrains root and plant growth.

Persistence of groundwater as shallow as 30 cm constrained rooting and crop productivity in DS I at all elevations, and in DS II at the tail elevation. Because of shallow water table, productivity of both maize and mungbean was about 10 percent higher at the head than at the tail elevation, and about 5 percent higher in DS I than in DS II.

Postrice soil matric water (particularly if supported by a single pre-seeding irrigation) without further irrigation had potential to support 1t/ha of mungbean grain or **4** t/ha of maize. These yields are worthwhile for smallholder farmers.

The availability of postrice soil matric water might be manipulated to the advantage of the palawija crops by appropriate scheduling of the rice-phase irrigation. For shallow rooting mungbean, yield of a residual moisture crop can be

increased by 33 percent by shallow tillage. And this tillage, and the subsequent seeding (for maize or mungbean), can be economically and effectively accomplished if the preceding rice is sown or transplanted in rows alternately spaced at 7 and 28 cm. The 28-cm spacing affords easy postrice access for operators and implements. Tillage also gives useful increases in mungbean emergence and helps ensure plant population densities sufficiently high that full benefit can be derived from irrigation.

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Farm-Level Water Management for Rice-Based Farming Systems in the Philippines

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INTRODUCTION

IRRIGATION SYSTEMS IN the Philippines and many other Asian countries have been developed essentially for rice-rice cropping systems. The scarcity of water supply in the dry season (DS) has, however, consistently caused low cropping intensities (average 126 percent) in most Philippine national irrigation systems (Rosegrant et al. 1987). The areas at the tail-end sections of most irrigation systems are predominantly deprived of DS crops because of scarcity in water supply. Furthermore, the riceland productivity under the rice-rice cropping is showing signs of either decline or stagnation. However, about 50-75 percent of irrigated ricelands in Asia are physically suited for growing nonrice crops (Ko 1987). In the Philippines, about 20 percent of the total irrigable areas of the National Imgation Systems are suitable for diversified cropping (Vergel 1987).

In recent years, there has been increasing concern on how the low levels of land utilization, cropping intensity, income from rice production and irrigation system performance could be improved, and how the favorable soil conditions could be fully utilized for sustaining productivity. Among the alternative approaches considered by irrigation authorities and planners are crop diversification, system rehabilitation, augmentation of the scarce water supply, efficient use of residual soil moisture after rice for growing nonrice crops, and improved water control and management. However, information on the requirements for farm-level water control and management, water augmentation and the use of residual soil moisture after rice for growing nonrice crops in the DS in typical irrigation systems is still inadequate.

This paper describes under four major issues the studies undertaken under the IIMI-IRRI project to evaluate alternative approaches for improving the productivity of land and scarce water supply and thus increase and sustain fanner's income in irrigated rice systems.

COMPONENT ON FARM-LEVEL WATER MANAGEMENT STUDIES

Compatibility and Adequacy of the Farm-Level Water Control Facilities in a Rice Irrigation System for Nonrice Crops

The existing irrigation infrastructures in rice irrigation systems has been reported as a major constraint to crop diversification (Miranda and Panabokke 1987). For this reason, some authors have indicated the need for rehabilitating or upgrading the irrigation hardware to introduce the flexibility needed to allow large-scale crop diversification within the system. But this requires a knowledge of how the canal network should be designed or modified to enable better control of the system and how the water should be managed and applied (Bhuiyan 1989).

During the 1988 to 1990 DS a study was undertaken to determine the needs for farm-level water control and management that would allow flexibility for farmers to exercise DS cropping options between rice and nonrice crops in areas served by typical irrigation systems.

The study was conducted in the Upper Talavera River Irrigation System (UTRIS) in Nueva Ecija during the 1988 and 1989 DS and in the San Fabian River Irrigation System (SFRIS) in Pangasinan during the 1990 DS to further evaluate the findings from UTRIS and its practical applicability for other nonrice crops not found in UTRIS (Figure 1). The selected systems have different soil classes, distinct wet and dry rainfall patterns and have diversified cropping.

During the DS, when water supply is generally low, only 20-25 percent and about 60 percent of the potential imgable areas of UTRIS and SFRIS, respectively, are grown to rice and nonrice crops. The major DS crops are rice and onion in UTRIS, and rice and tobacco in SFRIS. Soil in the top 45-cm depth in each system is clay loam.

Six turnout service areas (TSAs) were selected in UTRIS, and 5 TSAs were selected within SFRIS (Figure 1). Field data, collected at turnout and farm levels, included irrigation water flows, farm-level water control facilities, irrigation schedule, water allocation and distribution methods, soil water status, water conservation practices, crops and water use. The study revealed that additional water control facilities were constructed and maintained by the farmers on both individual farms and the TSA of both irrigation systems to support diversified cropping in the DS.

Farm-level facilities. Additional on-farm infrastructures were constructed by farmers during the DS, but the intensity varied between the two systems which grew two different nonrice crops. In UTRIS, the farmers divided and reshaped their original rice plots which are larger than 500 m² into two or more subplots to grow onion. In contrast, the SFRIS farmers (n=20), who grew tobacco after rice, maintained the original size and shape of the rice plots.

The average size of the onion plots in UTRIS ranged from 676 to 1,018 m², with an average of 850 m² (Table 1). However, only about 80 percent of the plot area is effectively used for growing onion and the remainder is used as buffer and for the construction of multipurpose ditches along the perimeter of each plot or subplot. These multipurpose ditches are used (i) to intercept seepage from adjacent rice or onion plots, and (ii) to facilitate irrigation water application and the removal of excess water. In SFRIS, the entire plot area (average = 880 m’) is generally utilized for growing tobacco. The difference in the farm-level facilities used in onion and tobacco plots could be attributed to the sensitivity of onion to waterlogging, particularly during the bulb formation period when surface water must not submerge the neck of the bulb or dumping off may occur.

Figure 1. General layout of the Upper Talavera River Irrigation System (UTRIS) in Nueva Ecija, the San Fabian Irrigation System (SFRIS) in Pangasinan showing the relative location of the study sites.

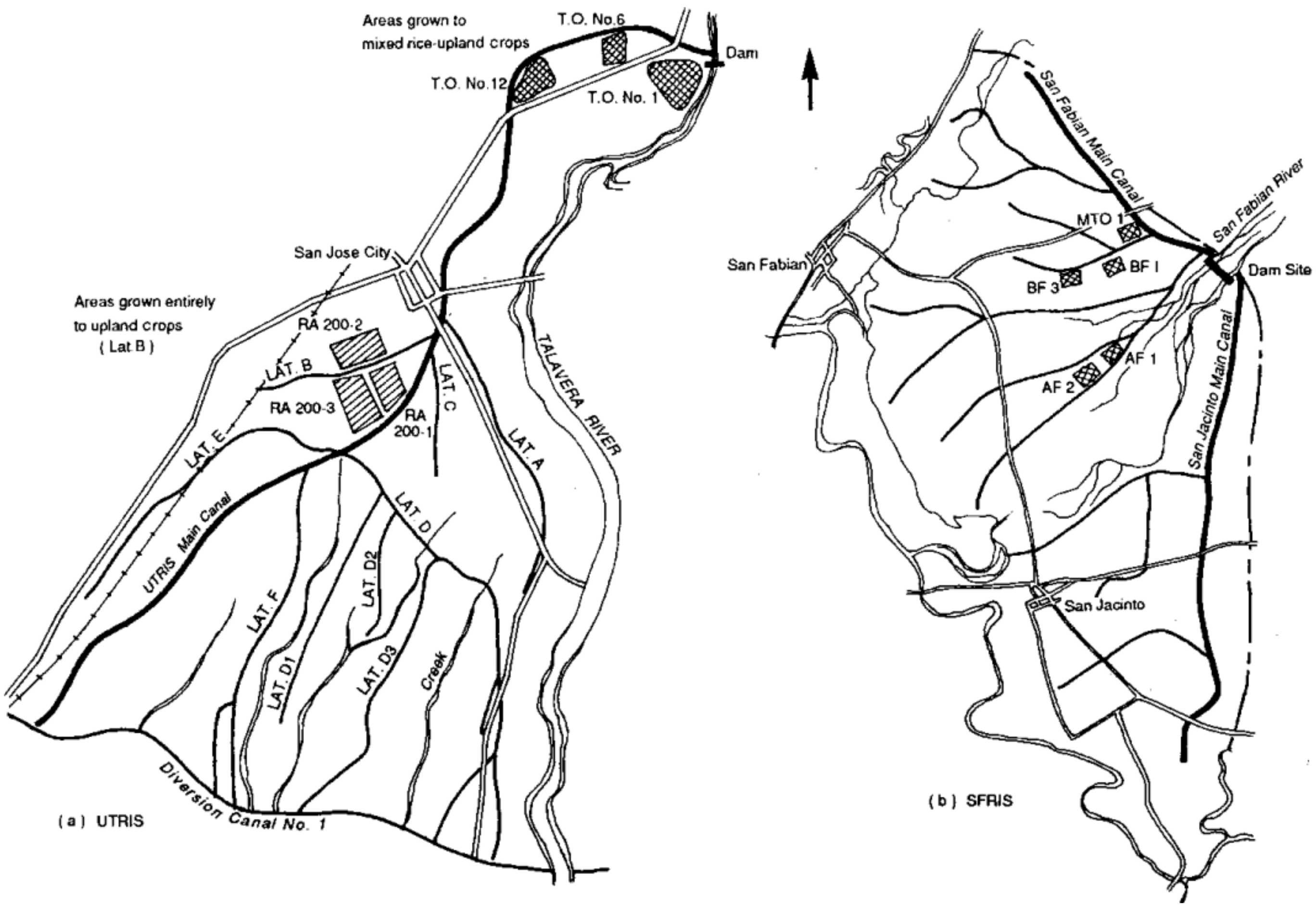


Table 1. Average plot size (m^2), net area planted to rice and upland (onion or tobacco) crops, and percent area used for on-farm water control in selected farms in UTRIS, Nueva Ecijaand SFRIS, Pangasinan, 1988, 1989, and 1990 DS.

Particulars	Rice	UTRIS		SFRIS
		Mulched onion	Unmulched onion	Unmulched tobacco
Plot area, m^2	1006	1018	676	879
Net cropped area				
· m^2	1006	834	549	879
. percent	100	82	81	100
Percent area used for water control	0	18	19	0

TSA-level facilities. Additional and temporary farm ditches and supplementary farm ditches are used by the farmers in conveying water from the supply (main or lateral) canal and the main farm ditch to their farms in the DS. The average farm ditch density (FDD) used during the WS for rice within UTRIS is about 70 m/ha (Table 2). In the DS, the average FDD in irrigating nonrice crops is 225 m/ha which is about 3.7 times more than the FDD in the WS. In SFRIS, only about 30 percent more farm ditches are used during the DS than during the WS when only rice is grown. The increase in FDD in the DS in both irrigation systems is caused by the construction of temporary farm ditches, which are removed together with the multipurpose ditches, during the WS and the area released is planted to rice. In general, only the main farm ditch is maintained during the WS to irrigate rice. The land area used for the construction of temporary farm ditches is 315 m^2/ha in UTRIS, but only 60 m^2/ha in SFRIS. The difference between the onion and tobacco plots is due to the different water application methods used for these crops.

It can thus be inferred that the main farm ditch and the essential water control structures such as turnouts with gates, division boxes and check drops (where necessary) which are maintained for WS rice are compatible and could adequately support the basic requirements of diversified cropping in the DS. Additional supplementary farm ditches required only for areas with topographic limitations must also be constructed. Farm ditches and other water control facilities needed for growing nonrice crops will vary, depending on the crop choice and these can be adequately handled by the farmers.

Table 2. Average potential irrigable area and density of farm-level facilities of selected TSA in UTRIS, Nueva Ecija, and SFRIS, Pangasinan. the Philippines, the WS rice and DS nonrice cropping.

Particulars	UTRIS	SFRIS
Potential irrigable area, ha	48	9
Farm ditch density, m/ha		
· WS	70	124
· DS	255	159
. Ratio, DS:WS	3.7	1.3
Area used for the conslruction of temporary farm ditches, m^2	316	60

Water Management Practices to Provide Flexibility of Fanners' Crop Choice, and to Improve the Water Use Efficiency and Land Productivity.

Potential nonrice crops are not readily accepted during the DS because of deficiencies in managing imgation systems (Miranda and Panabokke 1987). Water deliveries as required by intermittent water application for nonrice crops are rarely precise or reliable, particularly during the DS. Hence, to promote crop diversification, appropriate techniques of farm-level water management must be developed to promote reliable water deliveries.

Data were evaluated to ascertain the current water management practices and develop a model of improved water scheduling and distribution within the turnout service area of an imgation canal which would promote higher water use efficiency and provide farmers the flexibility of crop choice in the DS.

Water delivery and distribution. Water deliveries to the different TSAs varied between and within the two irrigation systems. In UTRIS, daily water deliveries were made to the different TSAs from January to April during the 1989 DS at an average flow of 2.8 lps/ha for about 6 days a week (Table **3).** In SFRIS, the average water deliveries to the different TSAs was **3.7** lps/ha **for** an average duration **of** 5 days/week. From February to April 1990, when water supply was low, high water flows (average **6.9** lps/ha) were delivered at least one day a week for a duration of 4-19 hours during the farmers' irrigation schedule.

Table 3. Average flow rates and duration of water deliveries to the different TSAs from January to April, UTRIS, Nueva Ecija and SFRIS, Pangasinan, Philippines, 1989 and 1990 DS.

Particulars	UTRIS	SFRIS
Average potential irrigable area, ha	36.0	9.3
Average flow rates		
. lps	101.0	34.3
. lps/ha	2.8	3.7
Duration of seasonal water deliveries		
. no. of weeks	17.0	16.0
. no. of days/week	6.4	4.9

In UTRIS, water was issued in rotational sequence among farmers from the upstream to the downstream areas of the main farm ditch. In SFRIS, the farmers within a TSA were generally divided into two groups and each group was given a schedule to imgate every week. If a farmer failed to irrigate his farm during the scheduled day(s), he was allowed to imgate the following day. The rotational schedule was more systematically and rigorously practiced in SFRIS than in UTRIS.

Water application and conservation. "Flush flooding" was practiced by both the onion and the tobacco farmers. The onion farmers in UTRIS applied irrigation water *plot-by-plot* in alternate sequence using the temporary farm ditch constructed for the purpose. In contrast, tobacco farmers in SFRIS applied water *plot-to-plot*. Farmers from both systems reported that they could manage excess water problems, if created.

Mulching with about 10-15 cm thick rice straw is the most common method of conserving water for onion. It was especially practiced by farmers in areas where water supply was scarce. Farmers' reasons for mulching onion plots are (i) to conserve water and thus allow a longer interval between irrigations, (ii) to control weed growth, and (iii) to produce shiny bulbs and create higher market value. Tobacco farmers in SFRIS, and onion farmers of UTRIS whose farms were near the source of irrigation, did not use mulch.

Water use, application and delivery efficiency. Farms in which mulching was practiced used about 50 percent less water than those where it was not practiced (Table 4). The amount of water used for rice was about 877 mm which is almost the same as that used for unmulched onion. Tobacco crops in SFRIS used an average of about 700 mm of water.

The average water application efficiency, defined as the ratio of the net water applied to the plot to the total water delivered to the plot, was 89 percent for the onion plots of UTRIS in 1988 and 1989 DS. (Net water applied is the difference between the amounts of water applied to and drained from the plot). The average

highest attained water storage efficiency, defined as the ratio of the amount of water stored in the soil after irrigation to the net water applied to the plot was about 54 percent. Mulched plots, however, had a slightly higher water application efficiency (average 90 percent) than the unmulched plots (88 percent) (Table 4). In SFRIS where tobacco plots were not drained, the water application efficiency was close to 100 percent.

The effectiveness of the water delivery mechanism within the different TSAs was evaluated in terms of the irrigation delivery efficiency (IDE) defined as the ratio of the total irrigation water delivered to the plots to the total water diverted from the turnout.

Table 4. **Average** *water* **use** of **rice,** ***onion and tobacco,*** *UTRIS,* ***Nueva Ecija and SFRIS, Pangasinan. 1988, 1989, 1990 DS.***

Particulars	Rice	UTRIS		SFRIS
		Unmulched onion	Mulched onion	Unmulched tobacco
Total water applied, mm	175	855	433	610
Total water drained, mm		103	48	0
Net water applied, mm	775	752	385	610
Effective rainfall, mm	102	83	56	82
Total water use, mm	877	834	442	692
Interval of irrigation, days	7	8	16	15
Rate of water application, lps	10	17	16	31
No. of irrigations	12	9	4	6
Average depth per water application, mm	62	95	101	102
Average duration of water application, minutes	106	55	86	43
Water application efficiency (%)	77	88	90	100
Seasonal irrigation period, days		78	63	71

The average irrigation delivery efficiency (IDE) at UTRIS was about 30 percent whereas at SFRIS it was about 70 percent (Table 5). The low IDE in UTRIS could be attributed to the continuous water deliveries made to the farm ditches in most head-end sites compared to the rotational deliveries in SFRIS.

Table 5. Average seasonal water delivered, water divertedand irrigation delivery efficiency at the TSA level, UTRIS, Nueva Ecija and SFRIS, Pangasinan, Philippines, 1989 and 1990 DS.

Particulars	UTRIS	SFRIS
Average water delivered, mm	497	610
Average water diverted. mm	1323	863
Irrigation delivery efficiency (%)	38	70

The regression model is significant at 1-percent level and it explained about 90 percent of the variations in plot area irrigated (Table 6). This model was then integrated into a water scheduling and distribution model (WASDMOD) which was developed to estimate the water diversion requirement at the turnout, the area that can be imgated per day, and irrigation delivery efficiency for upland crops, with a continuous or rotational water delivery within the main system. Rainfall during the DS was considered negligible.

The input variables for WASDMOD are selected soil parameters (field capacity, wilting point, bulk density, depth of root zone), TSA size, rate and duration of irrigation water application per plot, pan evaporation, duration of irrigation water delivery to the TSA, allowable soil water depletion, methods of water delivery, soil water conservation methods, seasonal irrigation period, and water application, storage and conveyance efficiencies.

Table 6. Estimated coefficients of the function[1] relating area of plot irrigated (Ar) to water flow (Qu), duration of irrigation (Du), irrigation interval (Ii), and dummy variable for mulched onion and unmulcked onion and tobacco plots (Dm), UTRIS, Nueva Ecija and SFRIS, Pangasinan, 1988, 1989 and 1990 DS.

Variables	Pooled regression	Standard
Constant	-180	
Qu (lps)	28.3**2	0.9
Du (min)	5.9**	0.2
Ii (days)	-2.9**	0.8
Dm	+8.4**	23.8
R-squared	0.9	
F-ratio	407.4**	
No. of observations	194.0	

Ap = f(Qu, Du, Ii, Dm); Dm = 1 for mulched; o for unmulched

[2] Coefficients with two asterisks (**) are significant at 0.01 level

WASDMOD was evaluated by substituting the average values of the above-mentioned parameters to one TSA (area = 53 ha) at the head-end section of UTRIS. The results are shown in Table 7. To increase the irrigation delivery efficiency from its low value of 29 percent to at least 75 percent, the following alternative options are given by the model

1. A continuous or 24-hour water delivery to the turnout at 164 lps for 3.5 days a week. This option could be adopted if water allocation in the main system is by section-wise rotation.

2. Water delivery of 155 lps for 10 hours per day. This could be employed for a continuous supply situation in the main system. The water saved by this method could be delivered to the downstream section of the system for night storage and/or use by other farmers.

3. A continuous water delivery of 65 lps each day. Although this option could increase the irrigation delivery efficiency, the low flow rate may not be practical and acceptable to the farmers because it will not be sufficient for their requirements.

Table 7. Current practice and corresponding alternative options d *water delivery to the TSA to increase irrigation delivery efficiency for diversified crops.*

Parameters	Current	Alternative Options		
	0	1	2	3
Duration of water delivery				
(hours)	24.0	24.0	10.0	24.0
(days/week)	7	3.5	7	7
Water delivery rate (Ips)	169	164	155	65
Turnout area, ha	58	53	53	53
Seasonal water delivered, m	6834	684	684	684
Seasonal water diverted, m	2366	912	922	912
Irrigation delivery efficiency, percent	29.0	75.0	75.0	75.0
Irrigation interval, days	9	9	9	9
Area irrigated per day, ha	16	15	6	6
Remarks	ontinuous ater deli- :ry at gh flow ites	.otational rater deli- ery at igh flow ıte for .5 days	)-hour ıily water :livery at gh flow ıte	:ontinuous rater deli- ery at low ow rate

Note: The average values used in the **WASDMOD** are as follows:

FC=23.75 percent, **PWP** = 9.66 percent, Drz = 30.00 cm, BD = **1.46 gm/cc**
Epan = 6.80 mm/day, **Qu** = **17.2** Ips, Turnout area = **53.3** ha, **Du** = **55.20** minutes
Es = 50.0 percent, Ea = **RR.2** percent and Ec = **75.0** percent for unmulched plots.

Option (1) is superior to the others; it can irrigate almost the same area of 15 ha, as currently imgated by the farmers, but with **a** 2.5-fold increase in irrigation delivery efficiency.

The foregoing results showed that:

The water application efficiency in each system is generally **high** (about 90 percent and above). However, the irrigation delivery efficiency is lower in UTRIS (38 percent) than in **SFRIS** (70 percent), because of the continuous delivery to farm ditches in most upstream sites in the former. In contrast, SFRIS deliveries were on intermittent schedules dictated by the rotational supply of water in the main system.

Based on the WASDMOD evaluation, the low irrigation delivery efficiency in UTRIS could be improved to at least 75 percent by reducing either the number of hours of water delivery to the turnout per day or the number of days of delivery in a week.

Control of Shallow Water Table in Irrigated Ricelands for Diversified Cropping

One of the physical constraints on the production of nonrice crops in irrigated riceland is the shallow water table that is created by seepage from canals, and/or adjacent flooded rice farms. However, if this could be effectively regulated, the shallow water table can be used for meeting part or all of the crop water requirement.

A field experiment was conducted at the Lower Talavera River Irrigation System (LTRIS) to address the problems encountered by the farmers in growing upland crops adjacent to irrigation canals or rice areas. The objective was to design and evaluate practical techniques of controlling shallow water table on farms adjacent to flooded imgated rice for growing nonrice crops and determine the relative costs of and returns from the use of the techniques.

An **RCB** design with five water table control treatments, each with **four** replications was used in the field experiment in which com was grown. The five treatments consisted of four (T1 to T4) different levels of drainage-cum-interceptor channels established strategically in relation to the source of excess water and one (T5) without a channel serving as a control.

The channels had nearly rectangular cross-sections and each was about **30** cm wide which drained to a main drain. Each treatment was applied on an area of 200 m^2 (10 m x 20 m) and was surrounded on two sides by imgated rice plots. The field had a slope of about 0.24 percent perpendicularly away from the canal bank and along the length of the experimental plots. Soil was silty clay loam.

Hybrid yellow corn, variety **SMC** 305, was seeded at 20 cm x **70** cm. Fertilizer was applied to all plots at the rate of **160-40-40 kg NPK/ha**. Other cultural practices were the same for all treatments.

The regression analysis showed that corn grain yield increased significantly with increasing water table depth (Figure 2). High yields were found at the middle of the plot and decreasing towards the drainage-cum-interceptor. The yield gradient was due to the relatively shallow water table near the drainage ditch and deeper water table at the middle. Among the different drainage ——-interceptor systems, treatment (T1) gave significantly higher yield of **7.3** t/ha compared to the other treatments (Table 8). The yields between (T2) and (T3) did not differ significantly but are significantly greater than the yields in (T4) and (T5). The slightly higher (but not sigruficant) yield in (T4) compared to (T5) was due to the drainage improvement made during the post-vegetative growth period of the crop.

Table 8. Average corn grain yield (t/ha), water table depth, plant height, and gross margin in each water control treatment, LTRIS, 1990 DS.

Water control treatment	Drainage cum-intemp-tor channel depth (cm)	No.	Average water table depth (cm)	Plant height (cm)	Average yield (t/ha[1])	Gross[2] margin US$/ha
1	50	2	15	139	7.3a	948
2	30	2	13	126	5.5b	644
3	30	3	12	123	5.6b	652
4	20	3	5	110	3.5c	320
5	0	0	5	111	3.3c	287
Rice from adjacent ria fields						754

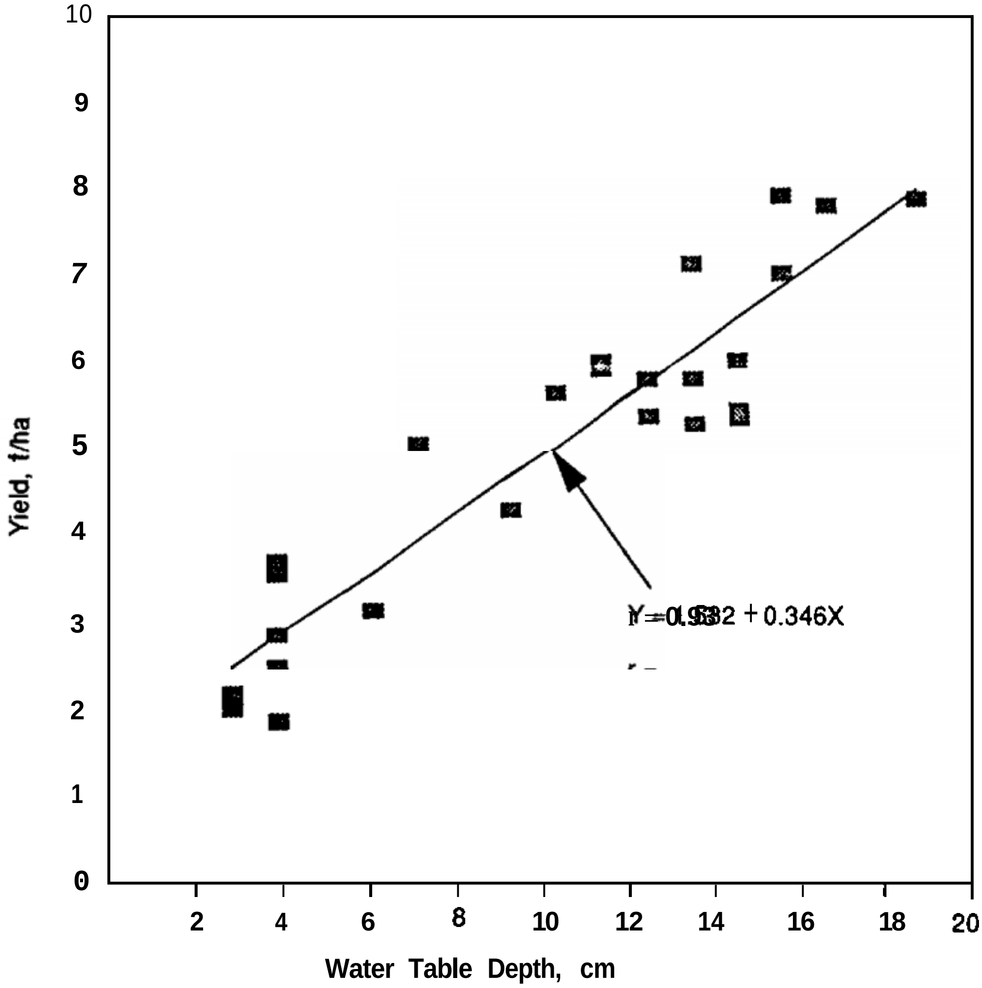
[1] Within column, numbers followed by a common letter are significantly different at 1 percent level. Th ir yi l l f i i th dja l t i 6 2 t/h ith a gross i f US$754/ha.

[2] Output prices used are government support prices of US$ 0.20 per kg of both rice and corn. US$1.00 = Pesos 25.00

In the experiment, the 50-cm deep drainage-cum-interceptor channel proved to be more effective in the water table control and more profitable than the other systems with shallower channels that were tried. The corn crop did not need any irrigation during its entire growth cycle because the soil moisture within the root zone was adequate to support its growth. Water stress was not observed in any of the treatment areas during the 1990 DS.

The experiment showed that shallow water tables on the farm created by canal seepage and excess water application to adjacent rice paddies can be effectively lowered by the use of well-designed drainage-cum-interceptor channels. Results also indicate that corn production with such seasonal investment is more profitable than rice production.

Figure 2. ***Relationship between corn grain yield and water table depth, Laoag-Vintar River Irrigation System, dry season, 1990.***



Agronomic and Irrigation Management Options to Increase DS Cropping Intensity, Yields and Income

What can be done in parts of imgation systems with inadequate irrigation supply to increase farmers' income? From 1987 to 1989 DS, two major research activities were undertaken in UTRIS and in other similar systems with the following objectives:

1. To develop appropriate techniques that would promote efficient use of post-rice residual water and limited irrigation water for growing nonrice crops.

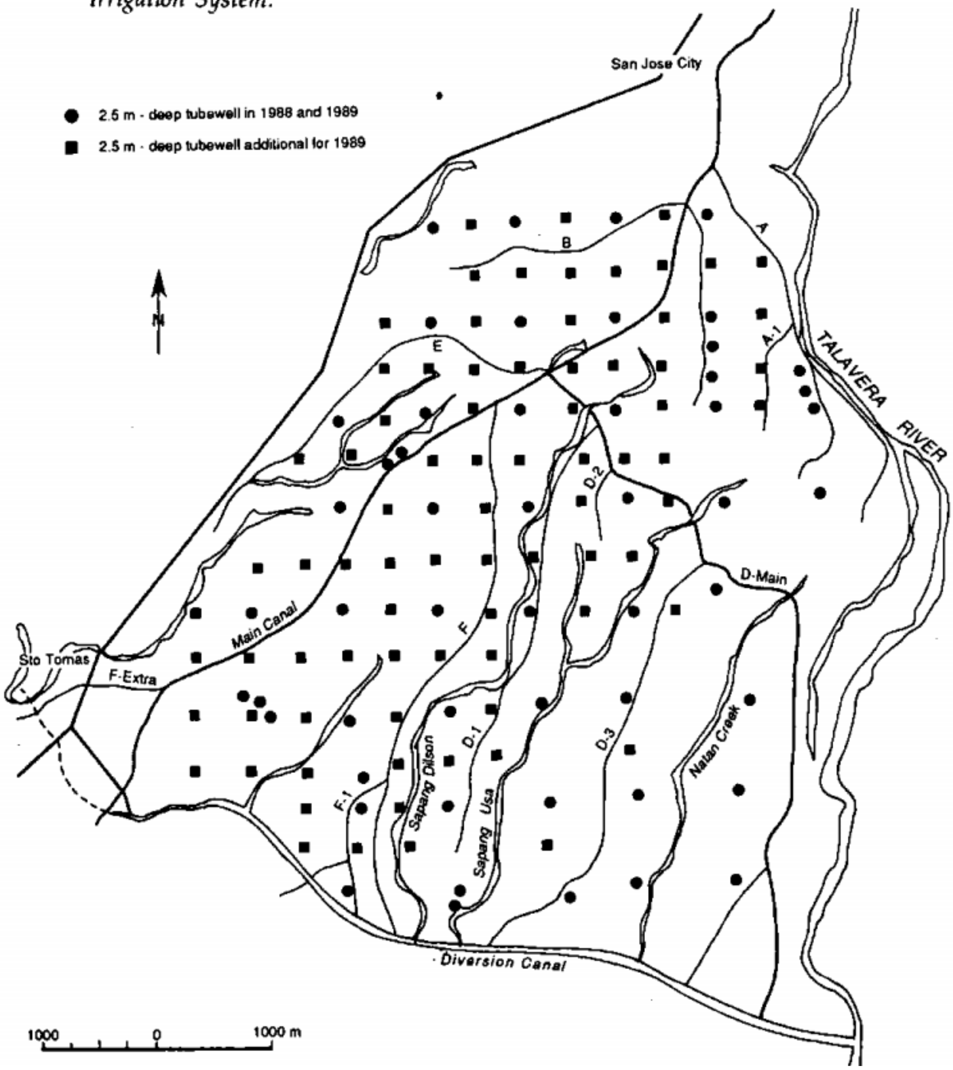
2. To document the nature and extent of water augmentation practices employed by farmers with limited irrigation water supply, and other information useful in policy formulation and decision making.

Use **of post-rice** *shallow* **water fable.** Soil-water persisting **during** the dry season after rice harvest can support legume crops by direct exploitation by legume roots, and farm pumps. This was explored in a survey of shallow water table using 2.5-m deep perforated tubewells located throughout UTRIS (Figure 3). During the 1988 DS, 52 sites on the non submerged fields were selected on rectangular grid basis for the monitoring of water table depths twice weekly. The additional 71 sites concentrated in the western areas were monitored in 1989 DS.

About 44 percent of the sites are irrigated **or** waterlogged riceland in December and 31 percent at the end of April. Among the nonirrigated/nonwaterlogged sampled sites, about **40** percent had usable resources of shallow water table early in the season in both 1988 and 1989, and about 25 percent still had usable resources at the end of the seasons in both years (Table **9).** Geographically, within the system and early in the season, shallow water table was found near the main canal and near areas irrigated for the second rice. **At** the peak of the DS, shallow water tables were found along the lower portion of the main canal where fields were mostly irrigated by water pumped from the diversion canal (outside UTRIS).

Tillage ***and*** **irrigation for** ***legumes*.** **During** the 1989 DS, a field experiment was undertaken to measure and interpret the effects and interactions of tillage and irrigation on the growth and yield of legume following rice in previously puddled soil, and to identify management technology and irrigation scheduling to enable production substantially to be higher than that of the farmers. **For** DS cropping, the persistence of shallow water table is equally important as water table depth. Table 10 shows that findings in the 1988 and 1989 seasons were consistent. On the average, 25 percent of the sites had shallow water table for more than **20** days; an additional **25** percent of the sites had shallow water for 1-20 days which could possibly be managed for the benefit of nonrice DS crops.

Figure 3. 1989 Survey of resources of dry-season shallow groundwater in Upper Talavera River Irrigation System.



Depth range (cm)	Potential for aiding DS cropping	Proportion of sites at:					
		Early sampling			Late sampling		
		1988 DS (Dec) (%)	1989 DS (Feb) (%)	Mean (%)	1988 DS (%)	1989 DS (%)	Mean (%)
20-90	High	36	12	24	0	10	5
90-150	Slight	10	24	17	16	20	18
>150	None	54	64	59	84	70	71

Table 10. Persistence of shallow groundwater at UTRIS in 1988 and 1989 DS. *Proportion of sample sites' (excluding irrigated and waterlogged) having water table persisting for various durations at depths 10-100 cm.*

Duration (days)	Proportion of sites in:		
	1988[a]	1989[b]	Mean
21-27	16	33	24.5
1-20	26	30	28.0
0	58	37	47.5

[1] Excluding irrigated or waterlogged areas

[a] 52 uniformly distributed sites.

[b] 123 sites with greater concentration.

Four tillage/seeding and four imgation treatments for mungbean were field-tested in UTRIS. The heat-tolerant Taiwan green mungbean cultivar was used and seeded (with inoculant, fungicide, insecticide) on 25 November 1989, two days after rice harvest. There was no rainfall; irrigation water was pumped from the main canal by a delivery system that allowed precise application; all plots received 3.2 t/ha rice straw mulch, and all treatments were confined in Latin Square (LS) design with 4 replications of each combination. Harvest of mungbean (in 4 primings) was done during 1-20 February 1989.

The results of the experiment reveal that:

1. Shallow tillage — provided 0.60 million plants/hectare (Mp/ha) are established (as achieved with no tillage) and survive to harvest — should promote 0.9 t/ha of mungbean grain.

2. If DS irrigation is available, then interrow deep + shallow tillage — provided *0.60* Mp/ha survive — should promote **1.5** t/ha of mungbean grain.

3. There were substantial benefits from irrigation of **20** mm at **3** weeks after sowing (WAS)plus **30** mm at **4** WAS. Additional irrigation was used less efficiently.

4. Supporting studies in less heat-stressed environment (Friar Lands River Irrigation System, Santa Cruz RIS and IRRI) achieved production of **2** t/ha mungbean grain, substantially higher than the Philippine average of **0.5** t/ ha.

Water augmentation schemes. A survey of **32 UTRIS** farmers in Nueva Ecija and **5** SFRIS farmers in Pangasinan was undertaken to document **the** nature and extent of groundwater use to augment canal supplies by these farmers.

Farmers located at the tail-end sections of irrigation systems where water is limited, especially during the later part of the DS, supported their (diversified) nonrice crops with the use of shallow groundwater drawn by centrifugal pumps through open wells. The open wells which were constructed with concrete casings havea diameter of **0.75** m to **1.0** m and a depth from **3.5** m to **7.5** m. Most of the wells **(78** percent) are about **5-7** m deep (Table **11).** About **62** percent of the wells were developed before **1980** and the remaining **(38** percent) after **1980.** All of the wells in SFRIS were developed after **1980.** The wells in UTNS and SFRIS were developed at a unit cost of US$25-US$150.

The pump size used is from **3** to **5** inches **(7.5** to **12.5** cm) but the size of **86** percent of the pumps is **4** inches **(10** cm) (Table 12). Most of the pumps **(89** percent) have a rated discharge capacity of **300** gallons per minute (gpm) (18.9 **Ips)** and the rest **(11** percent) have a capacity from 400 to 600 gpm, **(25** to **38** lps). Diesel engines of different brands are generally used as prime movers of the pumps. The engine capacity ratings range from 3 to **7.5** kw **(4** to **10** hp), but the most common (66 percent) are from 3-6 kw **(4.8** hp).

The average static water table depth in the wells at UTNS (Lateral B area) is about **1.8** m below the ground-surface from June to January and increased gradually from **2.3** m in February to **3.0** m in April. Similarly, in SFRIS, the water table depth ranges from less than **1.0** m in August to November but increases to about **4.0** m in April and May. The average drawdown of pump wells in **UTNS** is **0.9** m for average discharge of **18** Ips whereas in SFRIS, the average drawdown is **0.7** m with a discharge rate of about **16** lps.

The average area served by the pumps ranges from 2 to a little more than **5** ha cultivated by **3** to **6** farmers (Table **12).** The most common nonrice crops irrigated by the farmers practicing the water augmentation scheme are onion, tobacco, and corn. Water is generally pumped done from February to April when the water

Table 11. Profile of wells used by farmers practicing augmentation and diversified cropping, UTRIS and SFRIS, 1990 DS.

Items	UTRIS N=32	SFRIS n=5	Total n=37	%
Type of wells				
Open dug well with concrete casing	32	5	37	100
Depth of wells (m)				
n=35				
3-4	4	0	4	11.4
4-5	3	0	3	8.6
5-6	13	5	18	51.4
6-7	10	0	10	28.6
Year developed				
1960-1970	9	0	9	24.3
1970-1980	14	0	14	37.8
1980-1990	9	5	14	37.8
Cost of well development				
US$25 - 50	23	0	23	62.2
50 - 100	5	5	10	27.0
100 - 150	4	0	4	10.8

US$1.00 = Pesos 25.00

supply from both systems (UTRIS and SFRIS) is inadequate. The basin method of irrigation or "flush flooding" is used for onion and furrow irrigation for tobacco and corn. The average rates of water application are 18 lps, 8.3 lps, and 8.6 lps for onion, tobacco, and corn plots, respectively (Table 13). Data obtained in one irrigation application for each of these crops showed an average depth of 81 mm for onion, 90 mm for tobacco, and 50 mm for corn. These amounts are respectively 17 percent and 12 percent less than the amount applied for onion and tobacco in the gravity irrigated plots indicating that farmers using pumps for augmenting their irrigation needs are relatively more efficient in using water.

Table 12. Profile d **pumps** *used by* **farmers** *practicing augmentation* **and** *diversified* **cropping,** *UTRIS and SFRIS 1990* **DS.**

Items	UTRIS	SFRIS	T I	
	N=32	n=5	n=37	%
Diameter of pump (cm)				
7.5 x 7.5	3	0	3	8.3
10.0x 10.0	26	5	31	86.I
13.0 x 13.0	2	0	2	5.5
Capacity/discharge (Ips)				
19	20	5	25	89.3
25	1	0	I	3.6
32	1	0	1	3.6
38	I	0	I	3.6
Engine KW				
3-5	12	0	12	34.3
5-7	9	5	14	40.0
7-8	6	0	6	17.9
>8	3	0	3	8.6
Area served (ha)				
<2	10	0	10	28.6
2-3	5	0	5	14.3
3-4	7	0	7	20.0
4-5	4	3	7	20.0
>5	4	2	6	17.1
No. of farmers served				
<3	12	0	12	46.I
4-5	5	0	5	19.2
>6	4	5	9	34.6

Water augmentation through shallow well pumps was found beneficial to the downstream farmers with limited supply of irrigation water. Their crops are insured against drought during the latter part of the DS. Owners and users of the augmentation system do not compete anymore with the upstream farmers for irrigation water supply.

Crop planted	Average farm area (m^2)	Duration of irrigation (min)	Discharge (lps)	Depth of water applied (mm)	Method of water application
Onion	**2826**	**210**	**17.7**	**81**	Basin
Tobacco	**3049**	**512**	**8 3**	**90**	**Furrow**
Corn	**2793**	**335**	**8.6**	**50**	Furrow

CONCLUSIONS AND RECOMMENDATIONS

1. The basic and essential permanent farm-level facilities needed to support WS rice and DS diversified cropping are the main farm ditch and the water control structures such as turnouts with gates, diversion boxes and check drops (when necessary). Additional supplementary farm ditches required only for areas with topographic limitations must also be constructed. Farm ditches and other water control facilities needed for growing nonrice crops will vary depending on the crop choice and these can be adequately handled by the farmers.

2. Water application techniques of the farmers in both systems are "flush flooding." For onion, water is applied within a farm ***plot-by-plot*** whereas for tobacco water is applied ***plot-to-plot.*** In each case the adopted technique is suited to the water supply rate and the crops' tolerance to excess water.

3. Water application efficiency in onion as well as in tobacco was high. Mulched plots had a slightly higher water application efficiency (90 percent) than the unmulched plots (88 percent), but in SFRIS, where tobacco plots were not drained, the water application efficiency was close to 100 percent. However, the ***plot-to-plot*** water application method that was practiced in tobacco irrigation would result in a relatively low water distribution efficiency. The irrigation delivery efficiency is lower in **UTRIS** (38 percent) than in **SFRIS** (70 percent). The low efficiency in UTRIS is due to the continuous delivery of water to the farm ditches in most upstream sites. **SFNS** deliveries were on an intermittent schedule dictated by the rotational supply of water in the main system.

4. Based on the WASDMOD evaluation, the low irrigation delivery efficiency in UTRIS could be improved to at least 75 percent by reducing the number of hours of water delivery to the turnout per day or the number of days of water delivery in a week.

5. Corn grain yield can be significantly increased by lowering the shallow water table depth created by seepage and excess water application to neighboring rice paddies by a 50-cm depth drainage and interception channel.

6. Usable resources of the post-rice shallow water table persists on about 40 percent of **the** UTRIS area. Both the persistence and the area might be increased by rice irrigation management. Residual moisture with appropriate seeding and tillage has potential for 0.9 t/ha at UTRIS (less favorable environment), and 2.0 t/ha in more favorable environments.

7. Water augmentation utilizing shallow water table through open concrete cased-well and pump systems in the tail-end areas of irrigation systems is feasible and highly recommended for diversified crops.

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Summary/Highlights of Discussions: Technical Issues on On-Farm Level Irrigation Management

THE THREE PAPERS discussed in the Session focused on the technical considerations for rice-based fanning systems as these relate to on-farm irrigation management. Dr. Ghani highlighted the important findings on water utilization and crop production status in the Ganges-Kobadak and North Bangladesh Tubewell projects. Ms. Iis Syamsiah presented the selected water and crop-related issues, based on a study during the 1988-1989 dry seasons in the Cikeusik Irrigation Scheme. She was requested to incorporate the results of the other studies in the final report. Mr. Tabbal described the farm-level irrigation water control facilities essential to support diversified crops, in the dry season in typical rice irrigation systems in the Philippines. The highlights are given under the following five sections:

Farmer-Managed versus Researcher-Managed Fields

The results from Bangladesh showed that the number of water applications were lesser but that the yields were higher in the researcher-managed fields than in the farmer-managed fields. To ensure that there is no attribution problem, the analysis should consider any difference in the input levels and technologies used in the two sites. It was mentioned that the researcher-managed fields followed the BRRI-recommended fertilizer rate of 86-40-40 kg NPK per hectare. Some fanners even used higher rates. In terms of water inputs, both sites got the same irrigation water delivery and allocation. However, in the researcher-managed fields, the water level had been maintained and the water was contained within the paddy. This was not the case in the farmer-managed fields which allowed surface drainage or overflow from plot to plot. It was suggested to sort out the various factors influencing yield and consider not only nitrogen but also other factors like differences in land preparation, timing of fertilizer application, pesticide and herbicide use.

Wheat Crop in the Rabi Season in Bangladesh

There was some increase in the area grown to wheat in the rabi season but there were no data on wheat up to 1983. In the Ganges-Kabodak Project, irrigated wheat is not really recommended because from November to February or March there is no water delivery. If there is any wheat, it is nonirrigated and it depends on the farmer if he will plant wheat or not. Most farmers just leave their land fallow and wait for an optimum Aus rice cultivation.

In the North Bangladesh Tubewell Project area, wheat is a popular crop next to rice. It was picking up until **1983-1984** but declined after that due to the problem in price support. At the time of harvest, due to the Food for **Work** Program, wheat saturated the market and prices went down. This should be addressed by some policy of the government.

Reliability, Equity and Adequacy of Water Delivery and Supply

There should be a good measure of reliability. The Bangladesh paper mentioned low reliability but no concrete measure has been presented, except the start date of pump operation and rotational delivery. Reliability is more important for nonrice crops in rice irrigation systems. It is necessary to find ways of quantifying this parameter.

In response, Dr. Ghani referred to reliability under two aspects, first, in terms of water **supply,** whether the Project can supply the requirement of the system. **As** mentioned, the Project could supply water to only **70** percent of the irrigable area. The other aspect is on *water distribution,* in terms of amount and timing. **As** an example, the total available water is more than enough for the rice crop but in the tail-end area, there are times when there is water shortage. Furthermore, within the tertiary, the head section uses more water than the crop needs.

What was explained may have referred to adequacy of water supply and equity of distribution. Reliability could mean, knowing what is going to happen next week and how accurate it is. It may be worthwhile to ask the farmers to predict how much water they may get in a certain period but not how often they will not get water.

Dr. Murray-Rust related reliability to farmers' crop choice in the dry season in response to water availability. Observations in Indonesia showed that the irrigation agency experienced difficulty in the delivery of irrigation water to various crops grown in the area of the system. **A** recommendation could be to fix the volume of water supply and let the farmers decide.

Dr. Undan focused not so much on reliability but on the communication between the irrigation agency and the farmers. The farmers should be informed of the maximum water available to give them the option on what to plant and how much to plant.

Productive Technologies and Farmers' Choice

Dr. Pingali is inclined to conclude that systems which have been diversified historically will continue to be diversified and systems not diversified historically may not diversify at all because of soil/physical constraints. If this is true, then the net social benefit that a project like this could give to farmers is to provide technologies that can increase productivities of the systems.

Dr. Bhuiyan commented that it is very difficult to conclude that systems already diversified will remain diversified. The degree of diversification changes from year to year. During the September workshop in the Philippines, this issue was

discussed with farmer participants. The farmers clearly stated that they switched from onion to garlic to rice very quickly from year to year, so there is a shift from a monoculture rice to diversified cropping.

Farmers do choose between rice and nonrice crops depending on expected returns although some are actually mandated, like sugarcane in Indonesia which has to be grown every third year. The issue is to give the farmer a choice of crops so that he can grow what he thinks is best for that particular season. In areas with high water table, the technology is to use raised beds or to control the water by lowering the water table.

The major problem is the market tor the products and on this basis, it is difficult to really recommend what is best to produce. Sometimes, weather is a very important consideration. **Also,** farmers' attitudes are very difficult to change. In the Philippines, most farmers **are** used to rice culture and diversified cropping needs to be demonstrated.

Drs. Undan and Maglinao also argued that there are already available technologies applicable to various situations. What is necessary is to discuss these in greater detail to determine what specifically these technologies and the points of application are.

Crop Diversification Plan

The case of crop diversification in the Ganges-Kobadak Project was presented. The problem is, if diversified crops are planted in the dry season, there will still be standing nonrice crops when pump operation starts in February, causing seepage and possible drainage problem. Likewise, rice sowing will already have started, thereby having both rice and nonrice crops in the field. This being the case, additional work like supplementary farm ditches for seepage control or complete rehabilitation of the project may be needed.

If crop diversification is introduced in the GK Project, what may be done is to schedule pump operation to start in February and end in October 31. The optimum sowing time for the nonrice crops will be in the middle of November. These can then be harvested by the end of February, so there will be no problem of drainage.

In Indonesia, the government sets targets of how much rice and other crops will be grown each year, and every district will have to follow this cropping plan. In the wet season, all the areas are planted to rice. In the dry season, both rice and nonrice crops can be grown although with some say from the government. For example, because of large importation of soybean, the farmers are pushed to plant this crop. In Cikeusik Irrigation System where farmers are planting onion, the local regulation is to limit the area for onion. It means that the farmers cannot plant more than the area allocated. In terms of water delivery, rotation is done when the supply decreases.

SECTION III

Economics and Institutions in

Irrigation Management

for

Rice-Based Farming Systems

Socioeconomic and Institutional Issues in Irrigation Management for Rice-Based Farming Systems in Bangladesh

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INTRODUCTION

ALTHOUGH IN BANGLADESH the share of agriculture in the Gross Domestic Product (GNP) has been declining over the years, it still remains the largest sector of the economy (Table 1). This sector produces nearly 38 percent of the country's output and provides direct employment to three-fifths of its labor force. In order to realize the economic and social goals of achieving self-sufficiency in food grains, ensuring the supply of raw materials for the growing industrial sector, and generating employment and income for the burgeoning rural production, the rate of growth of the agricultural sector must be accelerated.

Any acceleration of the growth of agriculture in Bangladesh, however, is critically dependent on irrigation development which has great potential in the country. Actual area irrigated by different methods in 1987-88 was found to be 2.35 M ha or about 26 percent of cultivable area and about 35 percent of potentially irrigable land (Table 2). Irrigated area can be increased by both investing in new projects and improving the efficiency of the existing imgation systems. Since investment in new irrigation projects has become more expensive as a result of increasing capital costs per hectare, the government as well as the donor agencies are now putting greater emphasis on enhancing the performance of existing systems through improved irrigation management.

Table 1. Sectoral shares of the GDP (percent) at constant (1984-85) prices

	1985-86	1986-87	1987-88	1988-89
Agriculture	41.4	39.9	38.5	37.6
Crops	32.9	31.6	30.2	29.4
Forestry	2.7	2.5	2.5	2.5
Livestock	2.9	2.9	2.9	2.9
Fisheries	2.9	2.9	2.9	2.8
Mining and quarrying	0.001	0.001	0.001	0.001
Manufacturing	9.7	10.1	9.8	9.9
Large scale	5.2	5.7	5.5	5.5
Small scale	4.5	4.4	4.3	4.3
Construction	5.4	5.5	6.1	6.3
Power, gas, water and sanitary services	0.6	0.7	0.8	1.0
Transport, storage and communication	11.1	11.9	12.0	12.3
Trade services	9.1	9.0	89	8.7
Housing services	7.9	7.8	7.9	7.9
Public administration and defense	3.8	39	4.1	4.0
Banking and insurance	2.1	2.1	2.0	2.1
Professional and miscellaneous services	8.9	9.1	9.9	10.2
GDP at market prices	100.0	100.0	100.00	100.0

Source; Statistical Pocket Bwk of Bangladesh. Bangladesh Bureau of Statistics (BBS) 1990.

Table 2. *Total area* irrigated *by different* methods in Bangladesh in *1987-88*.

Methods	Actual area ha ('00000)	Irrigated percent
A. Surface water irrigation		
i. Gravity flow	1.15	4.90
ii. LLP	5.27	22.44
iii. Traditional methods	238	10.13
Subtotal	8.80	37.47
B. Groundwater irrigation		
i. STW	8.70	37.03
ii. DTW	5.55	23.63
iii. HTW	0.44	1.87
Subtotal	14.69	62.53
Total	23.49	100.00

LLP = Law lift pump.
STW = Shallow tubewell.
DTW = Deep tubewell.
HTW = Hand tubewell.

Sources: Planning Commission, Government of Bangladesh, 1990 Draft, Fourth - Five Year Plan, Dhaka.

Irrigation management can be defined as "the process in which institutions or individuals set objectives for irrigation systems, establish appropriate conditions, and identify, mobilize and use resources to attain these objectives — while ensuring these activities are performed without adverse effects (IIMI 1989). Objectives often adopted in the irrigation management process include (Uphoff 1986):

1. Greater production or productivity in terms of crop yield, area cultivated and/or cropping intensity;

2. Improved water distribution in terms of greater reliability, predictability and equity;

3. Reductions in conflict among water users and with government agencies;

4. Greater resource mobilization — both material and human;

5. Sustained system performance.

The realization of the above objectives depends, in large part, on a number of socioeconomic factors and issues. This paper aims at identifying some of these factors as they relate to the performance of irrigation system management in Bangladesh. It is based primarily on the findings of studies (Hakim et al. 1990a, b, c, d, e and Islam 1990) conducted under the IIMI-IRRI Project on Irrigation Management for Rice-Based Farming Systems. These studies were conducted in the north and northwest of Bangladesh and covered both gravity and groundwater irrigation (deep tubewell) systems. The gravity irrigation system studied is the Ganges-Kobadak (G-K) System – the largest irrigation system in the country and located in Kushtia District. The deep tubewell (DTW) irrigation systems include the North Bangladesh Tubewell Project (NBTP) in Thakurgaon; Bangladesh Agricultural Development Corporation (BADC) DTWs under direct and rental management (in the Rajshahi area); and private DTWs located also in Rajshahi District (Table 3).

Table 3. Location, ownership and mangement patterns of irrigation systems included in the study.

System and location	Ownership	Management
BADC Rental DTWs *with* RAKUB participation. Rajshahi	Public, BADC	Private. Farmer group
BADC Rental DTWs *without* RAKUE participation, Rajshahi	Public, BADC	Private. Farmer group
BADC, BIADP DTWs, Rajshahi	Public, BADC	Public, BADC + Private, Farmer group
Private DTWs. Rajshahi	Private (Farmers)	Private (Farmers)
G-K, Kushtia	Public. BWBD	Public. BWBD
NBTP, Thakurgaon	Public, BWBD	Public, BWBD

BADC = Bangladesh Agricultural Development Corporation
DTWs = Deep Tubewells.
RAKUB = Rajshahi Krishi Unnayan (Agricultural Development) Bank.
BIADP = Barind Integrated Area Development Project.
G-K = The Ganges-Kobadak. It is the largest gravity irrigation system in the country.
BWBD = Bangladesh Water Development Board.
NBTP = North Bangladesh Tubewell Project.

In addition to a number of cross-site issues, the studies included the results of two experiments, one dealing with water rotation in the G-K Irrigation System and the other on a method to increase irrigation coverage in the North Bangladesh Tubewell Project. The data utilized in all of the studies were collected through personal interviews with farmers, fanner leaders and agency managers using structured questionnaires, informal discussions and participant observation methods.

SOCIOECONOMIC FACTORS AFFECTING IRRIGATION MANAGEMENT

Mobilization of Internal Resources — The Irrigation Service Fee

In Bangladesh, it is the stated government intention to recover the entire Operation and Management (O&M) costs and as much of the capital costs as possible from irrigation systems developed and owned by the government. The underlying objective is to ease budgetary pressures and release funds for investment to create additional irrigation facilities and to undertake other development projects. In pursuance of this policy, the government has not been providing enough money out of its general budget to meet the O&M costs and, wherever possible, to realize capital costs from the beneficiaries. The present irrigation fee of some of the public systems, however, is much too low to cover O&M costs. **As** can be seen from Table **4**, in the G-K and NBT systems, irrigation fees cover only **16** and **6.5** percent, respectively, of O&M costs. **As** a result, these systems have been suffering from operational and maintenance problems (**Ali** 1989 and Hakim et al. 1990a). If one 'looks at O&M costs as a proportion of incremental benefits due to irrigation there would appear to be little economic justification for fixing irrigation **fees** at the low levels used in these two projects (Table **5**). **As** users of rental and private tubewells (systems that cover most irrigators in Bangladesh) pay fees and charges at least covering their full O&M costs, there seem to be few equity or social justice reasons for keeping the fees so low on a few public systems.

In addition to low fee rates, the collection efficiency of the fees is very low in these two public systems. While the collection efficiency in private and rental systems under study varies from 79 to 98 percent, it is only **1.13** percent in G-K and **23.55** percent in the NBT System (Table 6). The relatively high collection efficiency in the other systems can be explained by three major factors. First, sanctions against non-payment are strong and effective. If a farmer does not pay his fee in a particular season, water supply to his field is stopped in that season and he is denied water in the following year. Second, the incentive for collection is very strong. If the fee is not collected, the tubewell managers lose their formal and informal pecuniary benefits. Formal benefit is their honorarium and informal benefit is the excess of irrigation fees over O&M costs. Furthermore, *if* fees are not collected they cannot continue irrigation because they are totally dependent on irrigation fees in order to operate the system. Discontinuation will deprive them of the direct benefits of irrigation. Third, in one system (private), the fee is collected partly in kind.

Table 4. *Irrigation fee and O&M costs in* **irrigation** *systems* **under** *study (average* **per year per**

System and location	Year	Irrigation fees[a]	O&M costs[b]	Irrigation fees as % of O&M costs
BADC rental DTWs *with* RAKUB participation, Rajshahi	1989-90	2287[c]	2460[c]	93.66
BADC rental DTWs *without* RAKUB participation, Rajshahi	1989-90	3173[c]	2005[c]	163.24
BADC, BIADP DTWs, Rajshahi	1989-90	4810[c]	4442[c]	108.19
Private DTWs, Rajshahi	1989-90	3929[c]	1891[c]	207.77
G-K, Kushtia	1988-89	329[d]	2097[d]	16.06
NBTP, Thakurgaon	1988-89	289[d]	4426[d]	6.52

[a] ·igation fees are defined as payments by the farmers to the farmer group management in the case of all BADC DTWs systems, to the private owners in the case of Private DTWs system, and to the government in the cases of G-K and NBTP systems for the i[illegible] ig [illegible] receive. In the c[illegible]ses o[illegible] DTWs systems irrigation fees include the rental / irrigation [illegible] d by BADC on farmer groups. Average per year per hectare irrigation fees as shown in the table have been calculated by [illegible] gross i[illegible] area

[b] O&M costs include both direct and [illegible]

[c] For sample DTWs only.

[d] For entire project.

BADC = Bangladesh Agricultural Development Corporation
DTWs = Deep Tubewells.
RAKUB = Rajshahi Krishi Unnayan (Agricultural Development) Bank.
BIAI[illegible] = Barind Integrated Area Development Project.
G-K = The Ganges-Kobadak. It is the largest gravity irrigation system in the country.
BWHD = Bangl[illegible] W[illegible] D[illegible] B[illegible]d.
NBTP = North Bangladesh Tubewell Project.

Table 5. Incremental benefit and *O&M* cost (*in* Taka) in **G K** *and NBTP* (*1989-90* **prices)**

Season	Crop	Per hectare net return w/ irrig.	Per hectare net return w/out irrig.	Per hectare incremental benefit	Per hectare G-K Kushtia	O & M costs NBTP Thakurgaon	O & M as percent of incremental benefit	
							G-K Kushtia	NBTP Thakurgaon
Kharif -I	Aus	14,426	2,063	17,363	1,489	1,903	12.00	15.4
Kharif-II	Aman	11,230	6,783	4,446	608	620	13.60	14.0
Rabi	Wheat	4,079	1,377	2,702	-	1,903	-	70.3

Sources: For O&M cost same as stated in Table 4.

For net return, average of several field survey findings,

Per ha net return = total variable costs minus grass return. Gross return has two components: value of main product and value of by-prcduct.

Per ha total yearly costs have been distributed among the crops in proportion to the present irrigation fees for the crops.

G-K = Ganges Kobadak.
NBTP = North Bangladesh Tubewell Project.
Kharif-I = Pre-monsoon dry crop season.
Kharif-2 = Monsoon crop season.
Rabi = Dry crop season.
w = with.
w/out = without.
irri. = irrigation.

In the Public G-K and NBT systems, low collection efficiency is explained by a number of factors over which local agency officials often do not have much control. These factors may be enumerated as follows:

Table 6. Irrigation service fee collection efficiency.

ystem and location	Period	Collectible irrigation fee ('00000 taka)	Collection ('00000 taka)	Collection efficiency (%)
BADC rental DTWs *with* RAKUB participation, Rajshahi	1984-85 to 1988-89	56.88[a]	45.45	79
BADC rental DTWs *without* RAKUB participation, Rajshahi	1989-90	2.12[b]	2.03	96
BADC, BIADP DTWs, Rajshahi	1989-90	3.29[b]	3.16	96
Private DTWs, Rajshahi	1989-90	2.79[b]	2.73	98
G-K Kushtia	1984-85 to 1988-89	1872.50[a]	21.20	1.13
NBTP, Thakurgaon	1984-85 to 1988-89	85.47[a]	20.13	*13.55*

Sources: For G-K, Thakurgaon and rental with RAKUB official records and far the other three systems of the present field survey.

[a] For entire project.
[b] For sample DTWs only

BADC = Bangladesh Agricultural Development Corporation.
DTWs = Deep tubewells.
RAKUB = Rajshahi Krishi Unnayan (Agricultural Development) Bank.
BIADP = Barind Integrated Area Development Board.
G-K = "he Ganges-Kobadak which is the largest gravity irrigation system in the country.
BWBD = Bangladesh Water Development Board.
NBTP = North Bangladesh Tubewell Project.

Lack *of farmer participation/involvement.* Collection efficiency depends, to a large extent, on the ability and motivation of user-fanners to pay. As noted earlier, in terms of incremental benefits received from irrigation, farmers do have the ability to pay irrigation fees, yet they do not pay. One reason for this is their lack of motivation to pay which may be explained, partly, by their nonparticipation in any

aspect of irrigation management — including the determination of irrigation fee rates. One hundred percent of the Kushtia and Thakurgaon sample fanners reported that they were not involved in the fixation of rates (Table 7), 94 percent of Kushtia farmers and 40 percent of Thakurgaon farmers were ignorant of the criteria used for the determination of their present fees (Table 8) and 93 percent of Kushtia farmers did not know who decided the fee rates (Table 9). Farmers have not been convinced of why they should pay the fees. One hundred percent of the Kushtia sample farmers consider even the present low fee to be unreasonable (Table 10).

Table 7. **Sample farmers' responses as to whether they participated in deciding irrigation fees.**

System and location	Responses		
	Yes	No	Total
BADC rental DTWs *with* RAKUB participation, Rajshahi	19 (52.8)	17 (47.2)	36 (100)
BADC rental DTWs *without* RAKUB participation, Rajshahi	31 (96.9)	1 (3.1)	32 (100)
BADC, BIADP DTWs Rajshahi	53 (91.5)	5 (8.6)	58 (100)
Private DTWs Rajshahi	33 (84.6)	6 (15.4)	39 (100)
Total: Rajshahi	136 (82.4)	29 (17.6)	165 (100)
G-K Kushtia		89 (100)	89 (100)
NBTP Thakurgaon		160 (100)	160 (100)
Grand Total Rajshahi + Kushtia + Thakurgaon	136 (32.8)	278 (67.2)	414 (100)

Note: Figures in parentheses are row percentages.

BADC = Bangladesh Agricultural Development Corporation,
DTWs = Deep tubewells.
RAKUB = Rajshahi Krishi Unnayan (Agricultural Development) Bank.
BIADP = Barind Integrated Area Development Project.
G-K = The Ganges-Kobadak which is the largest gravity irrigation system in the country.
NBTP = North Bangladesh Tubewell Project.

Table 8. Sample farmers' awareness about the criteria for fixation of irrigation fees

System and location	Aware of criteria	Not aware of criteria	Total
BADC rental DTWs ***with*** RAKUB participation, Rajshahi	**34** **(94.5)**	**2** (5.5)	**36** (100)
BADC rental DTWs ***without*** RAKUB participation, Rajshahi	**31** **(96.8)**	I **(3.2)**	**32** (100)
BADC, BIADP DTWs Rajshahi	**58** (100)		**58** (100)
Private DTWs Rajshahi	**38** **(97.6)**	**1** (2.4)	**39** (100)
Total: Rajshahi	**161** **(97.6)**	**4** **(2.4)**	**165** (100)
G-K Kushtia	**5** (5.6)	**84** **(94.4)**	**89** (100)
NBTP Thakurgaon	***80*** (50)	***80*** (50)	160 (100)
Grand Total: Rajshahi + Kushtia + Thakurgaon	**246** **(59.4)**	**167** **(40.6)**	**414** (100)

Note: Figures in parentheses are ***row*** percentages.

BADC = Bangladesh Agricultural Development Corporation.
DTWs = Deep tubewells.
RAKUB = Rajshahi Krishi Unnayan (Agricultural Development) Bank.
BIADP = Barind Integrated **Area** Development Project.
G-K = The Ganges-Kobadak which is the largest gravity irrigation system in the **country.**
NBTP = North Bangladesh Tubewell Project.

Table 9. Sample fanners' *awareness* about who decides the *level of* irrigation *fees*.

System and location	Aware of who decides	Not aware of who deades	Total
BADC rental DTWs with RAKUB participation, Rajshahi	35 (97.2)	1 (2.8)	36 (100)
BADC rental DTWs without RAKUB participation, Rajshahi	32 (100)	-	32 (100)
BADC, BIADP DTWs Rajshahi	58 (100)	-	58 (100)
Private DTWs Rajshahi	39 (100)	-	39 (100)
Total Rajshahi	164 (99.4)	1 (0.6)	165 (100)
G-K Kushtia	6 (6.7)	83 (93.3)	89 (100)
NBTP Thakurgaon	151 (94.4)	9 (5.6)	160 (100)
Grand Total Rajshahi + Kushtia + Thakurgaon	321 (77.5)	93 (22.5)	414 (100)

Note: Figures in parentheses are row percentages.

BADC = Bangladesh Agricultural Development Corporation.
DTWs = Deep tubewells.
RAKUB = Rajshahi Krishi Unnayan (Agricultural Development) Bank.
BIADP = Barind Integrated Area Development Project.
G-K = The Ganges-Kabadak which is the largest gravity imgation system in the country.
NBTP = North Bangladesh Tubewell Project.

Table 10. Samplefarmers' *opinion* on the reasonableness of the *size* of irrigation *fees.*

System and location	Responses		
	Yes	No	Noopinion
BADC rental DTWs *with* RAKUB participation, Rajshahi	3 (97.2)	51 (2.8)	
BADC rental DTWs without RAKUB participation, Rajshahi	30 (93.75)	(6.25)	2
BADC. BIADP DTWs Rajshahi	54 (93.1)	4 (6.9)	
Private DTWs Rajshahi	31 (79.5)	8 (20.5)	
Total: Rajshahi	I50 (90.9)	13 (7.9)	2 (1.2)
G-K Kushtia		89 (100)	
NBTP Thakurgaon	148 (92.5)	12 (7.5)	
Grand Total: Rajshahi + Kushtia + Thakurgaon	298 (71.9)	I14 (27.61)	2 (0.5)

Note: Figures in parentheses are row percentages.

BADC = Bangladesh Agricultural Development Corporation.
DTWs = Deep tubewells.
RAKUB = Rajshahi Krishi Unnayan (Agricultural Development) Bank.
BIADP = Barind Integrated Area Development Project.
C-K = The Ganges-Kobadak which is the largest gravity irrigation system in the country
NBTP = North Bangladesh Tubewell Project.

KSS (cooperative) managers are involved in the collection of irrigation fees. These leaders, however, are not necessarily chosen representatively from the irrigators. In addition, cooperative discipline (as represented by the holding of regular member meetings) is low — resulting in reduced accountability of the KSS leaders. These leaders have little formal or informal authority to enforce any discipline. Under these circumstances, the involvement of KSS managers in fee collection cannot be considered as involving farmers.

Lack of financial autonomy. Financial autonomy here refers to "situations where an irrigation agency must rely on irrigation service fees for a significant portion of the resources needed for O&M, and where it has control over the expenditure of the funds collected from the fees" (ADB-IIMI 1986). In the G-K and NBT systems, whatever fees the agencies collect go to the government treasury. The agencies do not have any say on the use to which the irrigation fees are put and their annual (O&M) budget is independent of the amount of irrigation service fees collected. This lack of financial autonomy can be expected to affect collection efficiency in three ways. First, since collection does not affect their O&M budget directly, the agencies may not have a sufficiently strong material incentive to increase collection efficiency. Second, since the agencies do not have any say on the use of collected fees, they may feel unmotivated to increase fee collection efficiency. Third, without financial autonomy the quality of irrigation services may be adversely affected due to low accountability of the irrigation agencies. Farmers may resist paying fees if the quality of irrigation services is unsatisfactory.

Quality of services. Imgators in the G-K System, especially middle and tail users, express some dissatisfaction on the quality of services they receive in terms of the certainty, adequacy and timeliness of water deliveries. Users do not always know when the main pump will start and when they will get water. They are unable to predict pump starting time on the basis of past experiences because there is such a wide variation in the past start-up dates (Ghani 1987). An attempt is being made to regularize this start date.

Due to maintenance problems, the G-K canals — particularly tertiary and field channels — are often not in proper condition. In some places it has become very difficult to identify the original alignments of canals and channels. In some places a number of the hydraulic structures of the secondary and the tertiary canals are either inoperable or missing. As a result, whatever water is available cannot be distributed in an effective and timely manner to users, especially to the fields of tail-end farmers. The head-end and middle farmers, being in an advantageous position, are often able to meet their water needs through unauthorized cuts in the canals — a form of water stealing at further cost to the tail enders. The lack of sufficient canal maintenance is explained partly by (i) an inadequate number of agency staff, especially those at the field level, (ii) the absence of an appropriate mechanism for farmer participation in the operation and maintenance of the system at the secondary, tertiary, and field levels, and (iii) the shortage of funds for operation and maintenance. A rehabilitation scheme is presently being implemented in the G-K System, after the completion of which the quality of services is expected to improve.

In the NBT System, while farmers can generally be certain of their tubewell's start-up time, the irregular supply of water has been a major problem at times in the recent past. Due to electricity failures, the regularity and sufficiency of water supply cannot always be maintained. Electricity failures are caused mainly by the theft of electric wires. Further, for the same reasons as in the G-K System, the maintenance of channels in many DTWs is inadequate.

Problems with the collection system. The collection efficiency of irrigation service fees in the BWBD projects is partly inherent in the system of collection itself. The system suffers from a number of weaknesses which may be enumerated as follows:

i. **Length of** assessment procedures. Under the present systems, the agencies have to go to through a lengthy five-stage process in order to give the final bill to the users. The first stage involves the identification and recording or booking of the irrigated plots for every farmer under the command area. The second stage involves hearing objections from farmers against the recording of their irrigated land. After booking is completed, the Patwari (the booking staff) sends the booking register to the Sub-Divisional Engineer (SDE), who sends it to the Executive Engineer (X-EN). The X-EN then circulates this booking information to water users and gives them one months' time to place their objections (if any). In the third stage the X-EN's office makes a preliminary assessment of irrigation fee for which two months' time is allowed. Water users are informed of this preliminary assessment and asked to file their objections, if any, against the assessed amount. The time allowed for informing the farmers and receiving objections from them is one month. The fourth stage involves the hearing of objections and finalizing assessments which require two months. In the final stage, which takes a further two months, demand notices are prepared for every farmer. After the demand notices are finalized they are sent to individual farmers through KSS managers. From irrigation booking to finalization of demand notices, therefore, it takes (officially) nine months. The distribution of demand notices among the individual farmers also takes additional time. A water user normally gets his demand notice three to four months after the harvest of his crops, a time by which he must have either disposed of or consumed the crop leaving him with insufficient funds to pay irrigation fees.

ii. Level of expense. The collection system is expensive in two ways — its implementation requires a great deal of manpower and a great quantity of stationary is needed for various forms, notices and registers (in the G-K System alone more than half a million taka is required to pay for stationary). BWDB has only a limited number of staff (Patwaris and Zilladars) to implement the system. The G-K System has only 23 Zilladars and 170 Patwaris to do assessment work for more than 120,000 farm families. In the NBTB System, there are only **59** Patwaris and no Zilladars to serve more than 14,000 water users. The assessment efficiency, like collection effi-

ciency, is very low in these BWDB systems. Official data from 1984-85 to 1988-89 showed that G-K was able to assess 52.8 percent of the total irrigated area. For the NBT System it is 49.8 percent (Table 11).

iii. Lack of financial autonomy. Under their present system, the BWDB agencies assess and collect fees but do not have any control over the use of these funds. The entire sum of fees is deposited in the government treasury. Financial autonomy, as noted, can be closely related to collection efficiency.

iv. Lack of effective incentives for fee collectors and agency officials. The system provides incentives to collectors of fees. It has been reported, however, that the collectors do not always get their incentive money in full or on time. As a result, collectors often do not take much interest in their work. Further, there is no incentive provision for agency officials who are involved in the assessment and collection of fees.

v. Lack of provision for farmer participation. This point has been discussed above.

Table 11. Irrigation fee assessment efficiency in BWDB systems.

System and location	Year	Area irrigated (ha)	Area assessed (ha)	Assessment efficiency (%)
G-K Kushtia	1984-85 to 1988-89	94	**713,872**	**52.8**
NBTP	1984-85 to 1988-89	74,945	**37,311**	**49.8**

Source. Compiled from official records.

G-K = The Ganges-Kobadak which is the largest gravity irrigation system in the country
NBTP = North Bangladesh Tubewell Project.

Nonenforcement of sanctions. Enforcement of sanctions against willful nonpayment of irrigation fees is very important for a system aiming at a high rate of collection efficiency. The rules provide that if a user does not pay his fee for a particular season, he may not be given water in the following season. This strong official sanction has not, however, been implemented in either the G-K or the NBT systems. This nonenforcement may be explained by such factors as (i) lack of financial autonomy, (ii) lack of sufficient manpower, (iii) less than satisfactory water supply, and (iv) fear of popular resentment and agitation, etc.

Communication and Interaction among Farmers and Project Officials

Irrigation system management involves the partnership of irrigation managers (often agency officials) and farmers. For efficient system performance regular and effective communication between these partners is necessary. To be effective, such communication must involve farmer leader representatives of the general irrigators and managers/officials who have the authority to attend to the problems faced by the farmers. In many parts of the study areas involved in the IIMI-IRRI research, these conditions were not met. As a result, effective and regular interaction and communication between officials and farmers did not occur.

Farmer Organization and Participation

Evidence from a variety of systems supports the proposition that irrigation management objectives can be furthered by the participation of farmers in system management (Uphoff 1986; FAO 1989; Pradhan 1989; Pant and Verma 1983). Especially where landholding is typified, by small and fragmented farms, it can be expected that farmer participation becomes more predictable, productive and sustainable if they participate in groups through some form of organization rather than on an individual basis.

The nature and dimensions of the irrigation activities which a farmer organization might perform depend on the type of irrigation system, the method of irrigation, the ownership of the system, and on many socioeconomic, institutional and cultural factors. To create a framework for the analysis of the role of farmer organizations in irrigation management one can identify some activities of a general nature. Uphoff (1986), for example, provides a list of such activities as follows:

Activities related to water use:

a) Acquisition of water from surface or subsurface sources;
b) Allocation of water by assigning rights to users;
c) Distribution of water among users; and
d) Drainage of excess water.

Activities related to the physical system:

a) Design of structures;
b) Construction of **structures;**
c) Operation of structures; and
d) Maintenance of structures.

Activities which include organization and management functions:

a) Decision making;
b) Resource mobilization;
c) Communication; and
d) Conflict management.

All these activities are highly interrelated. Ways in which farmers' groups might become involved in these functions are included among the recommendations of a workshop on "Irrigation Policy and the Management of Irrigation Systems in Southeast Asia" (Taylor and Wickham 1976). These recommendations included:

1. Taking more responsibility to pay for irrigation;
2. Assuming more responsibility to organize and perform O&M tasks;
3. Giving more feedback to irrigation officers on the field performance of systems; and
4. Exerting greater influence on decisions involving water allocation and scheduling.

The findings of the IIMI-IRRI project show that farmers' organizations of the G-K and NBT systems have not played much of a role in irrigation management. In the Rajshahi tubewell systems, the groups have performed a number of irrigation management functions, but again there is scope for broadening the involvement of farmers. The following are several constraints that these farmer groups' attempts at irrigation management participation are beset with

Inadequate irrigation management orientation. The formal fanners' organizations often have an inadequate orientation toward irrigation management. Frequently, they are societies more oriented toward credit — following the principles **of** the early credit cooperative societies which were later restructured along the lines of the two-tier cooperatives developed by the Comilla Academy. Their bylaws do not adequately deal with inigation management functions nor do they outline agency/farmer relations.

Water availability. One of the major conditions encouraging farmer participation in irrigation management is the availability of adequate water in a timely and certain manner. Often, too much or too little water is available which discourage farmers from participating in irrigation management. The relationship between water

availability and incentives for participation might be represented by an inverted U curve, farmers' willingness to participate being low at either extremes of water abundance or scarcity (Uphoff 1986). In the IIMI-IRRI study, poor fanner participation can largely be explained by water availability. In the G-K System, it was observed that the tail-end farmers do not get water in a sufficient and timely manner. They do not have enough water to manage — making participation irrelevant. Head-end fanners, on the other hand, often get (or manage to get) so much water that they have little need for organized efforts to conserve and manage the resource. In the NBT System the situation is similar to that in G-K while in the Rajshahi area the problem is not severe.

Ownership. A sense of ownership of the system is an important prerequisite for farmer participation in management. In almost all of the systems under the farmer organization study, the irrigation facilities are owned by the government. In Rajshahi, however, the de facto ownership of DTWs, to a great extent, lies with farmer groups. Farmers' sense of ownership of the system is relatively greater in the Rajshahi area resulting in more participation by the farmers. In the G-K and NBT systems, scope for farmer participation is limited by project design. In both systems BWDB is supposed to perform almost all irrigation management activities. There is no talk of turning over any significant degree of ownership of these systems to the farmers.

Factionalism. Farmers' organizations for irrigation management are not free from the problems of factional conflicts. Problems of family or lineage-based factions are reflected in their management. Factions that dominate the management often eliminate the participation of other factions to the detriment of widespread participation of a broad spectrum of farmers.

Training. The training of farmer group leaders in irrigation management has been found to be either absent or inadequate. Training of agency personnel to motivate them to accept farmer participation as an essential component of improved system performance is also generally absent.

Lack of participation of all irrigators. It has been noted that only irrigators in the Rajshahi DTWs and a portion in the NBT System and the BIADP of Rajshahi have no legal barrier to become members of the organizations because the organizations are irrigation community- or command area-based — precluding nonresident irrigators from becoming members.

Disadvantaged farmers' interests are not safeguarded. Since there is no legal provision to safeguard their interest and ensure their representation, the disadvantaged farmers (especially the tail-end and small farmers) do not have any incentive to join the organizations. Without their participation, the organizations cannot be expected to perform equitably. It has been noted in the literature on the subject (Parker 1979) that if farmers' organizations are allowed to become the tools of the most powerful people, the groups will not fulfill the purposes for which they were created.

Interagency Cooperation

To get increases in production, fanners must have access to increased amounts of their non-water inputs. For this to happen, there is a need for interagency cooperation — cooperation between the irrigation agencies, the extension department and the credit agencies. Such cooperation needs to be enhanced in all the systems studied. While some form of institutional infrastructure for such coordination does exist in all the study areas, there is still a need to energize and activate the system with appropriate management innovations evolved **through** applied research.

Training

The level of training of farmers, fanner leaders and agency managers on irrigation management was noted to be inadequate. Training courses on irrigation management generally cover (with varying levels of effectiveness) technical aspects of water management and crop production. Modules on communication, coordination, cooperation, leadership development, human relations and other related aspects of management are not given much emphasis. Further training on sustaining the institutional infrastructure for management is generally not included in the overall project O&M budget.

Ownership and Management Patterns

The study indicates that under similar agro-ecological conditions (i.e., excluding the BIADP tubewells which are located in the Barind area), there is somewhat better performance of DTWs under private (versus BADC rental group) ownership and management in terms of area irrigated, yield per hectare, irrigation fee collection efficiency, O&M costs per hectare, etc. (Table 12). This private management, however, has charged higher irrigation fees per hectare. Because the sample size was small, statistical tests of the differences in performance were not possible, so no strong judgements can be made on the relatively better performance of DTWs under private ownership and management.

Choice of Crop

Under the G-K Gravity Irrigation System, the option for growing rabi crops under irrigated conditions is unavailable at present because the system is kept inoperative during winter when such crops might be grown in order to overhaul machines and pumps. Under the DTWs irrigation systems, farmers can use irrigation water to grow rabi crops as a substitute for boro rice or in addition to growing a late (braus) rice crop. It has been observed that farmers do not generally grow rabi crops as

Table 12. Average irrigated area, yield, O&M cost, irrigation fee and irrigation fee collection efficiency of DTWs irrigation under alternate management under similar agro-ecological conditions in the Mohanpur area of Rajshahi District.

System and location	Average irrigated area per well (ha)	Average yield per hectare (in tons)		Average O&M cost per hectare (in taka)	verage rrigation ee per ectare (in taka)	rigation e collection fficiency percentage)
		Crop cut	Farmers reported			
BALX rental DTWs *with* RAKUB participation Rajshahi	22.76	3.94	3.85	2,460	2,287	79
BALX rental DTWs *without* RAKUB participation Rajshahi	21.59	3.41	3.82	2,005	3,273	96
Private DTWs Rajshahi	23.66	4.75	4.12	1.891	3,929	98

substitutes for rice. Islam, **(1990)** identifies the following factors that discourage NBT System farmers from growing wheat:

a) problems of seed storage due to insect attack;

b) uncertain irrigation water supply resulting from electricity failures;

c) problems of threshing because of wet weather at the time of harvesting and lack of threshing services;

d) problems of turn-around period; and

e) declining yield **and** low output prices.

The declining yield and low output price were the main reasons for fanners' unwillingness to grow wheat. In terms of cost-benefit ratios, rice (Purbachi variety) is superior to wheat and other upland crops such as millet and sesame. This is supported by a comprehensive agriculture sector review conducted recently (UNDP 1989). The review points out that, given the present configuration of input and output prices, Boro (rice) remains a relatively profitable winter crop. Pulses, oil seeds, mustard and other boro-competing crops are at a competitive disadvantage which is not likely to be removed by any foreseeable increase in prices or improvement of yields.

CANAL ROTATION AND MINIMUM IRRIGATED CROP ACREAGE EXPERIMENTS

Rotation

As the Ganges-Kobadak System does not have adequate water to meet the water in relation to the total needs of its command area, a nine-day rotation (with three days of flow followed by six days off) among secondaries has been followed for some years.

However, this rotation system had faced a number of problems which included: (i) nonobservance of rotation among tertiaries; (ii) deteriorated condition of canals and field channels; (iii) unauthorized cuts in canals; (iv) poor condition of hydraulic structures as well as of some bridges and culverts; (v) absence of farmers' organizations and participation; and (vi) a general lack of communication and interaction between farmers and project officials.

In 1990, the ten-day rotation (five days *with* water followed by five days *without* water) was introduced. The secondary canal chosen (denoted as S8K) was one of the more problem-ridden parts of the G-K System. Project officials arranged for repairs of this canal and its control structures and devised a system to ensure that the ten-day rotation could be strictly observed. Along with research team members, they made special efforts to keep the farmers along the secondary canal informed and to encourage their participation. In addition to numerous field visits, these efforts included a field workshop held in a centrally located village along S8K. At this workshop farmers were able to voice their concerns as well as participate in decisions regarding their (and the Project's) responsibilities in the rotation scheme. A good deal of cooperation between farmers and officials and among farmers of different tertiaries (notably absent in previous years, with head-end tertiaries taking all of the water) followed this workshop.

The impact of the rotation experiment on S8K has been highly positive in terms of area irrigated, yield and equity. Of course, the sustainability of this improvement in future seasons remains to be seen.

Area irrigated. Area imgated under S8K in the 1990 Kharif-I season increased to 528 hectares from 54 hectares in 1989 Kharif-I (Table 13) — an increase of 877 percent. This record of achievement at the macro level is supported by data collected from the sample fanners (Table 14). It is noted that the farmers included in the sample cultivated a total of only 1.6 ha in the Kharif-I season of 1989, as against 20.8 ha in 1990 — an increase of 1,170 percent. Seventy-five percent of the 1990 target of the Water Board on this secondary has been achieved as against an achievement of 61 percent in 1989.

Table 13. Area irrigated in S8K in 1990 (in hectares).

	1989 Kharif-I			1990 Kharif-I		
Tertiary (= T)	Target area	Area imgated		Target area	Area irrigated	
		Area	Percent of target area		Area	Percent of target area
TI	132.38	21.56	16.3	121.45	120.40	99.1
T2	236.84	27.97	11.8	238.46	179.49	75.3
T3	178.13	3.31	1.8	174.08	130.93	75.2
T4	90.28	1.33	I.5	103.64	97.14	93.7
Total	637.63	54.00	8.5	637.63	527.96	82.8

Table 14. Area irrigated by sample farmers fin hectares),

Tertiary	Head		Middle		Tail		All sample farmers	
(= T)	1989	1990	1989	1990	1989	1990	1989	1990
TI	0.47	1.68	0.50	1.94	-	0.85	0.97	4.47
T2	0.27	1.40		1.74		1.67	0.27	4.81
T3	0.40	2.30		2.03		1.20	0.40	5.53
T4		3.49		1.61		0.90		6.00
Total	1.14	8.87	*0.50*	7.32		4.62	1.64	20.81

Equity. The distribution of water among different tertiaries and among head, middle, and tail farmers along the various field channels has also become much moreequitable. Table 15 shows that in 1989, farmers of T4 irrigated only 2.5 percent of all land actually irrigated along S8K. In 1990, their share of total land irrigated increased to 18.4percent. The T4 target had been 16.3percent of the total S8K target. While this tail tertiary did not quite fulfill its own absolute target it did well in relation to its upstream tertiary neighbors. The position of T3 farmers also improved dramatically but not as much as that of the T4 farmers (an improvement from 3.1 percent of total S8K irrigated area in 1989 to 24.8 percent in 1990—the T3 1990 targeted share, however, was 27.3 percent). In addition, the share of tail-end farmers within each tertiary has improved substantially where it is shown; while they did not cultivate any land under irrigated crops in Kharif-I in 1989, they

irrigated 4.6 ha of land in 1990 (22.2 percent of land imgated by the **full** sample of head, middle and tail farmers). Furthermore, **all** of the sample tail-end farmers reported that they received sufficient water during the Kharif-I season.

Table 15. Distribution of irrigated land among different tertiaries (in hectares) in 1989 *and 1990.*

Tertiary (= T)	1989 Kharif-I		1990 Kharif-I	
	Area irrigated (ha)	(%)	Area irrigated (ha)	(%)
TI	21.56	39.93	120.45	22.81
T2	27.97	51.81	179.49	33.99
T3	3.13	5.80	130.93	24.80
T4	1.33	2.46	97.14	18.40
Total	54.00	100.00	527.96	100.00

Minimum Irrigated Cropped Acreage

The results of the other experiment to increase irrigation coverage, the minimum irrigated cropped acreage (MICA) and the trial conducted in the North Bangladesh Tubewell Project (NBTP), are not as positive as those of rotation in the G-K System. However, it also shows potential for improving system performance through management changes and farmer involvement.

A great number of deep tubewells (DTWs) in Bangladesh, including the wells of the NBTP tend to imgate much less than their technically practical command areas. Among the reasons for this tubewell underutilization are: (a) disruptions in DTW operation due to faulty power supplies, inadequate maintenance, etc., and (b) farmer organizational problems that create severe inequities in access to reliable supplies of water.

To encourage farmers at these tubewells to work together and promote more interaction between farmer groups and agency officials, the research project made a policy suggestion that BWDB adopt a minimum imgated cropped acreage system. Under this system the farmer groups would indent for irrigated water before a given season but the agency would only operate the well if some pre-determined minimum acreage was to be serviced. The rationale was that it would put pressure on each farmer group to solve at least some of its organizational problems that may have constrained the spread of irrigation in the past. Those few farmers who were normally using tubewell water, would have to accommodate other farmers' demands if anyone at all were to receive water. The agency, at the same time, would have to make strong efforts to improve the reliability of the operation of those tubewells where a minimum number of cropped acres are enlisted for an irrigation season.

Serious implementation of the MICA policy did not begin until the Aus season of **1990.** At that time the project officials and the research team made efforts to communicate the new system to the irrigators. Project officials and extension personnel spread word about MICA, primarily through the KSS leaders. Agency officers and members of the research team also held a series of field workshops aimed at explaining the program and getting a feedback from the farmers.

While participation did increase to some extent with the spread of MICA, the water demand indent system was easily abused as fanner groups only had to *claim* that they would be irrigating the minimum number of acres for the water to be turned on for the season. No system was devised for stopping the operation of the well during the season if the number of irrigation acres claimed did not materialize. In addition, the Project's ability **or will** to enforce sanctions against noncomplying tubewell groups was under some doubt though a formal test of that ability was avoided due to the manner in which the indent system operated.

Some of the impacts of the minimum irrigated cropped acreage experiment are as follows:

i. Area irrigated. Information on area irrigated is available from the **16** sample DTWs and from 80 others — all of the latter are located in Thakurgaon Upazila. **Four** of the sample **DTWs** are also from Thakurgaon. It has been found that of 80 DTWs of Thakurgaon, **3** were out of operation, **21** were able to achieve their minimum irrigated area targets, **15** were reported (as of May **15,1990)** to be expected to fulfill their MICA targets and **41 (53** percent) did not achieve MICA targets (Table 16). Of the **16** DTWs examined by the IIMI-IRRI research team, **5** could not achieve MICA targets while 11 fulfilled their minimum targets (Table **16).** Major reasons cited for nonfulfillment of MICA targets are:

a) Poor canal conditions;
b) Sandy soils;
c) Weak farmers' organization; and
d) Cultivation of wheat in some command areas.

Table 16. Utilization status of Thakurgaon Upazila DTWs and sample DTWs (of NBTP) in relation to MICA implementation in the Kharif-I season of 1990.

DTW category	Total number of DTWs	Number out of operation	Number in operation	Number under BADC farm	Number meeting MICA target	Number expected not meeting MICA target	Number not meeting MICA target
Thakurgaon [a] Upazila DTWs	80	5	75	2	19	14	40
Sample DTWs	16	-	16	-	11	-	4

[a] **In Thakurgaon, there were 84 DTWs of which 4 were included in the sample**

Table 17. Per DTW average MICA target, average actual area irrigated under MICA and average actual area irrigated before MICA (average for three years - 1987,1988 and 1989) of research DTWs and outside *research (Thakurgaon) DTWs.*

DTWs Category	Average MICA target (ha)	Average actual irri-gated area under MICA(ha)	Average irrigated area before MICA (ha)	Difference between MICA and Pre-MICA acreage (ha)
A. Research DTWs				
i. Those met MICA	15.61 (N=11)	19.83 (N=11)	16.90 (N=11)	2.93[a]
ii. Those did not meet MICA	15.61 (N=5)	7.20 (N=5)	3.67 (N=4)	3.53[a] (N=4)
Average	15.61 (N=16)	15.88 (N=16)	13.37 (N=15)	2.51'
B. Outside research (Thakurgaon) DTWs				
i. Those met MICA	17.00 (N=19)	22.00 (N=19)	14.25 (N=19)	7.73'
ii. Those did not meet MICA	15.10 (N=37)	7.30 (N=39)	6.66 (N=33)	0.67'
Average	15.74 (N=56)	12.12 (N=58)	934 (N=51)	2.78"
C. A + B				
i. Those met MICA	16.49 (N=30)	21.20 (N=30)	15.26 (N=29)	5.67***
ii. Those did not meet MICA	15.16 (N=42)	7.28 (N=44)	6.33 (N=37)	1.17*
Average	15.72	12.93	10.26 (N=72)	2.67' (N=74) (N=66)

Source: **From outside research (Thakurgaon) DTWs, compiled from official record. For research DTWs, field survey data.**

DTW = Deep tubewell.

MICA = Minimum irrigated crop acreage. 'No statistical test was done.

***Significant at 1 percent level.

*Significant at 10 percent level.

Table 17 shows average area irrigated by the DTWs. It shows that those research DTWs which achieved MICA targets irrigated more area than that in the Kharif-I seasons of the past three years. Although the unsuccessful research DTWs covered only about 50 percent of their MICA targets they also irrigated more land than they did in the previous years. Likewise, the successful non-research DTWs of Thakurgaon, performed better than in the previous three years. Even those non-research DTWs which failed to achieve MICA targets by even 50 percent have, in general, irrigated more land than in the past. Two general pictures emerge from Table 16 and Table 17.

a) The research DTWs have performed relatively better than those non-research wells indicating that the action-research component (involving the field workshops and the frequent presence of the research team at the sample tubewells) of the study achieved some success. If the component had been started on time (aspects of action research were started rather late) its success could have been more prominent.

b) As an approach to ensure optimal utilization of DTWs, MICA indicates the potential for increasing command area in the NBTP.

ii. **Yield.** Almost all farmers under the study grew the Purbachi variety of rice. Yield records obtained through crop-cuts showed that yield in the research DTWs varied from 4.3 to 7.9 t/ha (from the data that went into the averages shown in Table 18). In general, DTWs which were not able to achieve their MICA targets achieved lower yields than those DTWs which either reached or exceeded their minimum irrigated area targets. Comparable data are not available for non-research DTWs for the same season, i.e., Kharif-I of 1990. However, some area data collected for several past seasons by the BRRI-BWDB-IRRI research project showed a yield per hectare of **3.6** to 4.2 tons.

iii. Equity. In the sample DTWs, the equity situation has neither deteriorated nor improved over the years (Tables 19 and 20). The distribution patterns of irrigated land among head, middle and tail farmers and among small, medium and large farmers in 1989-90 are not, in general, different from what they were in the past years. In term of average yield per hectare, the head farmers of both groups of DTWs (those fulfilling MICA targets and those failing to fulfill their targets) have achieved the most, followed by the middle farmers. The tail farmers have achieved the lowest yield (Table 18).

Table 18. **Yield per hectare *of land* under research *DTWs* (in tons).**

Categories	Head farmers	Middle farmers	Tail fanners	Total average of head, middle and tail'	Difference between yields of head and middle farmers
Those met MICA target	6.54	5.78	4.86	5.54	1.68***
Those did not meet MICA target	5.43	5.09	4.24	4.86	1.19***

DTWs = Deep tubewells.
MICA = Minimum irrigated crop acreage.
*** Significant at 1 percent level.
Test conducted between the total averages shows that the difference is significant at 1 percent level.

Table 19. ***Distribution of irrigated* land of *sample farmers by* their *location* in *different* years (in *percentages).***

Year	Head	Middle	Tail	Total
1989-90	40.4	31.8	27.8	100.00
1988-89	40.2	32.2	27.6	100.00
1987-88	41.5	33.9	24.6	100.00
1986-87	44.1	31.8	24.8	100.00

Table 20. Distribution of irrigated land *of sample* farmers *by their farm sizes in* different years (in percentages).

Year	SF	MF	LF	Total
1989-90	12.1	59.6	28.3	100.00
1988-89	12.5	59.9	27.6	100.00
1987-88	11.0	57.6	31.3	100.00
1986-87	8.6	61.3	30.1	100.00

SF = Small farmers, having operated land from 0.02 to 1.01 hectares.
MF = Middle fanners, having operated land from 1.02 to 3.03 hectares
LF = Large farmers, having operated land of 3.04 hectares and above.
Operated land = Owned land + rented in land -rented out land.

CONCLUSIONS AND RECOMMENDATIONS

The research findings of the IIMI-IRRI project strongly suggest that there is great scope for substantial improvement of Bangladesh's rice-based imgation systems through improved management. The improved management should involve willing and active participation of irrigator farmers and irrigation managers — the two major partners in the systems.

The farmers can meaningfully participate in (a) taking more responsibility to pay more for imgation; (b) assuming more responsibility to organize and perform O&M tasks; (c) giving more feedback to irrigation officers on the field performance of systems; and (d) exerting greater influence on decisions involving water allocation and scheduling (Taylor and Wickham **1976).** Since farmers' participation can become more predictable, productive and sustainable if they participate in groups through some form of organizations than on an individual basis, (particularly in the Bangladesh context of small and fragmented landholdings), farmers' organizations should be developed, nurtured and sustained. While developing farmers' organizations care should be taken so that their irrigation emphasis is clear; principles of equity (Bromley, Taylor and Parker 1980) are followed so as to give representation to a cross section of farmers; they are organized on the basis of hydraulic characteristics of irrigation systems; some **sort** of quasi-ownership of the systems is given to the organizations (pending, in some cases, real and total ownership eventually); farmers, especially the farmer leaders, are provided with some training on socio-technical aspects of management, etc.

It would be useful if irrigation managers could participate in the improved management process not as administrators of the bureaucratic tradition but as managers with a participatory style. If farmer participation is to be effective, managers must first accept the idea that improved system management is dependent on that farmer participation. *As* demonstrated in the rotation and MICA experiments, managers can help initiate effective agency-farmer interaction, communication and cooperation. Farmer participation can be enhanced if imgation agencies or managers can ensure an adequate supply of water to the system delivered in a timely and certain manner. Irrigation managers need also to appreciate **the usefulness of cooperation with other line agencies and** take initiatives in that direction. To do all these, many irrigation managers could use training on various socio-institutional aspects of irrigation management.

Research, specifically action research with real participation by irrigation agencies and farmers, is needed to evolve and implement management innovations for the improvement of system performance of rice-based irrigation systems in Bangladesh. Some basis for such research has already been created in the IIMI-IRRI collaborative research. Action research on rotation in the G-K System and in minimum irrigated crop acreage (MICA) in the NBTP could usefully be continued and command area development (CAD) research could be started in the Rajshahi DTW irrigation systems. BWDB, BADC and Rajshahi Krishi Unnayan Bank (Rajshahi Agricultural Development Bank RAKUB) can meaningfully participate in this research. Eventually, other line agencies such as the Bangladesh Rural

Development Board (BRDB) and the Directorate of Agricultural Extension (DAE) might be included in the research network.

In regard to system finances, it is increasingly becoming clear that the Government of Bangladesh will be totally withdrawing its current subsidies on O&M costs. Both agency managers and imgators must adapt to these changing conditions. Needed changes include the development of a system of fee assessment and collection so that collection efficiencies can be raised. At the same time there is a need to increase the efficiency of the systems so as to reduce O&M costs. Farmer participation in system management can reduce O&M costs and financial autonomy of irrigation agencies can lead to better collection efficiency. Full or partial financial autonomy of the irrigation agencies could usefully be explored — along with ways to increase farmer involvement in irrigation management.

Growing rice under irrigated agriculture is still profitable but the declining trend in this profitability is likely to continue given the govemment policy of withdrawing subsidies on agricultural inputs and raising the price of fuel. The productivity of land and other inputs must be increased to face this situation and for irrigated agriculture to be sustained because output prices may not keep pace with the rise in input prices due to the influence of various macro-economic and political factors. Increasing the productivity of inputs is going to be an important task of imgation management.

Increasing the adoption of nonrice imgated crops in the dry season as a substitute for boro rice, however, faces some obstacles at present because of domestic demand patterns that are highly rice-oriented. In this situation, using price policy to encourage farmers to grow rabi crops might not be very effective. According to a UNDP document (1989) "..... using price policy to encourage diversification is likely to be a self-defeating enterprise, since at the price level required, demand is likely to vanish. For example, it would take a price increase of nearly 60 percent to make mustard competitive with HYV Boro; kheshari would require a 300 percent price increase for the same purpose." Crop diversification however, is likely, to become more important in the future as Bangladesh approaches self-sufficiency in rice production and as demand grows for vegetables, etc. This expected growth of nonrice crops is likely to raise various socio-institutional issues as regards the management of irrigation water as system managers struggle with providing for the diverse water needs of different crops.

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Improving Dry-Season Irrigation Management in Indonesia: Findings, Issues, and Manageable Alternatives

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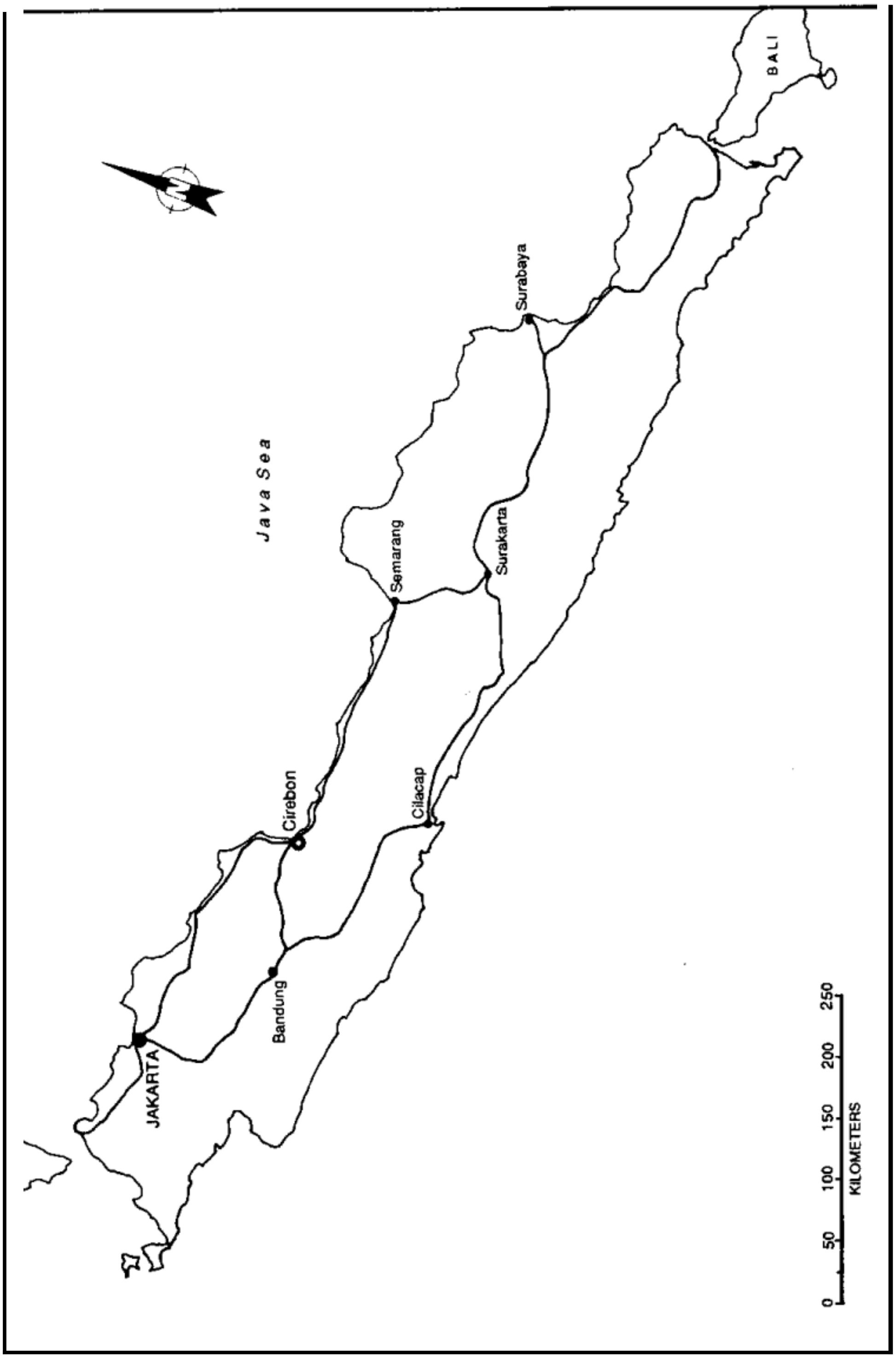
OVERVIEW OF THE STUDY

THIS STUDY WAS part of a two-year Phase II research and development program, funded mainly by the Asian Development Bank and the Ford Foundation. A grant from the Rockefeller Foundation enabled IIMI to conduct additional activities with particular emphasis on crop diversification and dry-season irrigation.

The observations made in this study were conducted in the 7,800 ha Cikeusik Irrigation System in the Cirebon Regency of West Java (Figure 1). It is a large-scale lowland irrigation system originally designed primarily for rice cultivation in rotation with sugarcane production. This traditional crop rotation has stimulated *palawija* (seasonal nonrice crop) production in the irrigable area of the system, including such crops as red onion, chili, green bean, mung bean, and groundnut — in rotation with rice and sugarcane.

This study has focused on two key aspects which have profound impacts on dry-season irrigation management performance: the annual crop plan process and rotational irrigation.

In Indonesia, *Rencan Tata Tanam Tahunan* (the annual crop plan) is an administrative arrangement for coordinating among local government, the agriculture and irrigation services, and offices responsible for local security. The purpose is to obtain a consensus about crop areas and planting schedules, as well as annual drying in the Provincial Irrigation Service (PRIS) systems. Such a consensus should satisfy national agricultural objectives as well as the aspirations of farmers who face local constraints, risks, and incentives. The annual plan requires coordination between government agencies at *kabupaten* (the regency) and *kecamatan* (district) levels, and village officials and water users' associations at the village level. The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primary interest of local government and the agriculture service in the plan is the achieved crop targets, which are handed down from the province level and reflect national priorities. The primary concern of the provincial irrigation service is to propose crop areas which it expects to be able to irrigate, within anticipated water supply and distribution constraints. This study compared the official plan process with actual implementation in the field to determine management constraints and potential for improvement through the identification of alternative approaches, which are suggested for further field-testing.

The second component analyzed conventional rotational irrigation in the Maneungteung System and included pilot testing of the formation and implementation of a modified approach to rotational irrigation. The objectives were: a) to analyze current rotation practices, b) to develop and field-test an improved rotation system, and c) to identify improved rotational methods which might have broader relevance in Indonesia, especially in rice-based systems undergoing crop diversification.

THE RELEVANCE OF MANAGEABILITY

Since both crop plan and rotational irrigation contain important government policy objectives (in short, productive and equitable irrigated agriculture), it follows that it is in the interest of the government to see that these processes are, in fact, manageable ones.

This paper assumes a standard definition of management, which is, "the process of setting and achieving objectives through the acquisition and utilization of resources." Good management performance is the "efficient and effective acquisition and utilization of resources to achieve organization objectives." Seven standard elements are generally referred to as required ingredients in making human enterprises manageable (Figure 2). These are:

1. Clear objectives. They should be specific and uniformly understood by staff, there should not be dual or conflicting official versus unofficial objectives, and objectives should be altered as the situation requires;

2. Implementation procedures. They should be practical and realistic to imple ment, given the resource and skill constraints;

3. Adequate resources. Staff, skills, technology, funds, materials, water, land and other inputs should be sufficient to accomplish the objectives at an acceptable level of efficiency;

4. Control. Managers should be able to ensure that the acquisition and use of resources leads to the achievement of objectives; it should be possible to attribute management activities and results to individual managers and staff and staff should not be held accountable for any outcome which goes beyond their control;

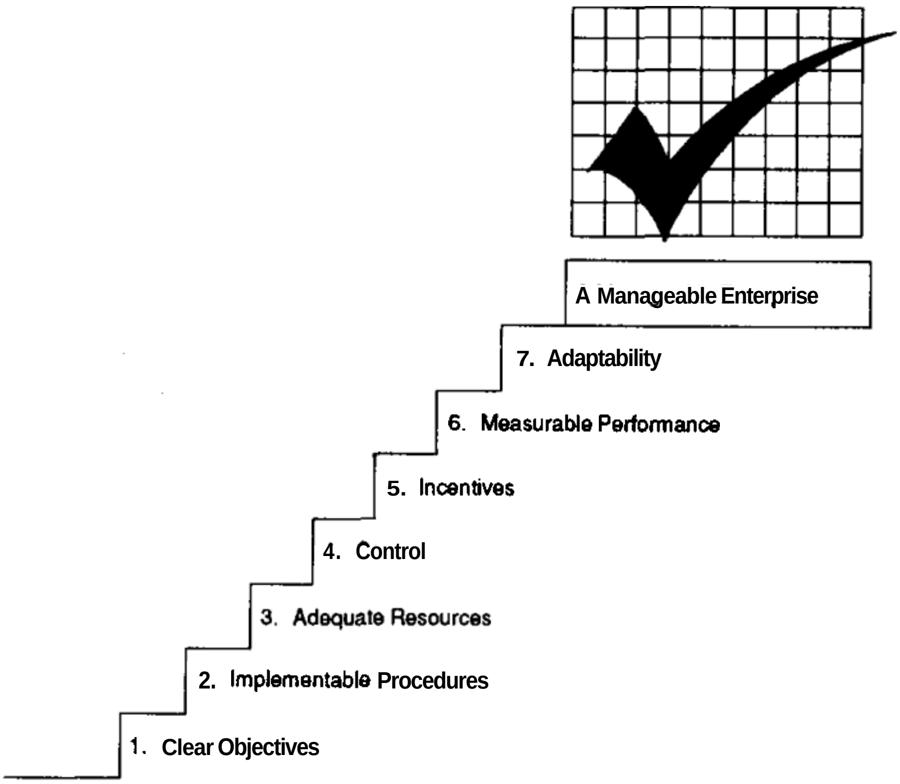
5. Incentives. There should be positive and negative inducements for managers and staff to be motivated to achieve the objectives of the organization;

6. Measurable performance. It should be possible to document and know what the outcomes of management are and whether or not the objectives were achieved; and

7. Adaptability. Organizations must be able to change any of the above six elements as changing conditions require it — either in order to continue to achieve objectives under new conditions, to achieve them more effectively or efficiently, or to achieve new objectives pertaining to new organizational purposes.

For prominent sources on these management ideas, see for example, Drucker (1979), Anthony (1988), and Israel (1989). For an example of application of management science to irrigation, see R. Chambers (1988).

Figure 2. *Sewn essential elements of a manageable enterprise.*



MAJOR FINDINGS

The Crop Plan

Objectives and procedures of the plan. The objective of the annual crop plan process is to plan and implement crop area configurations and planting times which are reasonably consistent with farmer preferences, with predicted irrigation supply constraints, and with government policy crop targets. In most areas of irrigated agriculture in Indonesia, rice is the standard crop for wet season. Hence, the more important and problematic part of the crop plan is that dealing with the dry season.

Each year the national and provincial level offices of *Departemen Pertanian* (the Agriculture Department) prepare annual targets for different crop types. While these targets are being disaggregated down to the level of regency imgation committees, the bottom-up process of assembling a Water Users' Association (P3A or WUA) planting proposals for the next year also should be underway. According to regulations, the WUAs should hold a meeting and decide on crop areas for the coming year, beginning from the dry season and running through the following rainy season. The fanner proposals are transmitted to the village agricultural officer. This officer assembles a report for each block or WUA in the village and reports the proposals to *juru pengairan* (the irrigation inspector) and the agricultural extension officer (PPI).

The inspector should collect the proposals for all WUAs in his area and report to the PRIS subsection head, at the district level. The subsection head revises the proposals based on considerations of demand/supply constraints, and passes on an aggregate proposal report to the PRIS subsection head, which specifies expected supply conditions per secondary canal per system.

A draft proposal is made at the district level and submitted to the regency irrigation committee, where the plan is discussed and approved by the *bupati* (regency head). At this level the plan is in the form of crop areas per district and village, not per tertiary block. The plan is sent to each district where village- and block-level targets are set. The village agricultural officers should be informed of the village- and block-level plan either in meetings at the district office or by communications from the irrigation inspector and agricultural extension agent.

Manageability of the crop plan process. From interviews and observations done by the Study Team at the section, subsection, and system levels of PRIS, and at the level of 12 sample tertiary blocks in the Cikeusik System, it is apparent that what is actually implemented is not always consistent with what is officially intended (for more detailed data of findings see Vermillion and Murray-Rust 1990). The objective of this study was not to find fault, but to determine to what extent the crop plan process is being implemented, what the management constraints are and what potential there might be for improving the process to achieve more productive dry-season imgated agriculture.

As observed, the annual crop plan does not appear to be able to adequately predict supply or demand, or to have a substantial impact on actual cropping

practices in the field, except where special intensive extension efforts are made in pilot areas, usually by the agriculture service. It does not seem to be a plan with a mechanism for implementation since the real crop planting decision makers, the fanners, are generally not included in either proposing the plan or being informed about it. There are no sanctions applied against unpermitted planting practices. The tendency to annually report the same proposals which are largely influenced by the current year's crop or local multiple-year crop patterns, gives the process a reactive rather than a directive nature, and may perpetuate inequities in cropping intensity between upper- and lower-end blocks. The process seems to be an overly intensive administrative exercise which is being implemented at a much lower level of intensity.

The annual crop plan can be assessed relative to the principles of manageability as follows:

How clear and specific are the objectives?

The crop plan represents a set of specific and clear objectives to be implemented at the systems and at tertiary levels. However, it is not clear what the primary criteria should be for developing the plan, whether it should be mainly farmer or block-level aspirations of the farmers, government crop quotas, etc. One key problem in the current method which based the plan on the block-level expected crop types for the coming year is that it perpetuates inequity in cropping intensity by accepting the status quo both in lower-end and upper-end areas.

How implementable are the procedures?

This is one of the weakest aspects of manageability of the crop plan process, in that, the original plan announced by the bupati sets crop targets according to regency and district-level administrative units, not according to tertiary blocks. This must be disaggregated and realigned according to hydraulic units (which is often difficult to do). At the farm level, farmers or village-level officials generally do not find it possible to designate which fields can plant padi or which cannot, during the dry season. Crop plan configurations within and between the blocks are not based on considerations about difficulty of estimating irrigation requirements and delivering appropriate amounts to areas with diversified cropping patterns within and between blocks.

How measurable are the results?

It is not difficult to measure the results (i.e., actual crop areas) and this is a routine practice. The only problem here is the question of whether or not area estimates and block maps exist or are accurate.

How adequate are the resources?

Staff, transportation and other resources for the tasks of collecting crop and water data and holding the prescribed extension meetings appear to be adequate, except for the low staff-pay levels.

How controllable is it?

Control is the other weakest aspect of the manageability of the crop plan. Clearly farmers generally decide on which crops to plant for any given season. This is usually done without a knowledge of, or reference to, the crop plan. Another aspect of poor control is the weak and only indirect link between prescribed PRIS management tasks relative to the plan and the outcome which is expected. Collecting crop and water data and announcing a crop plan to farmer representatives constitute a long step removed from actually seeing which crops get planted and when.

How accountable are the staff?

PRIS staff (especially inspectors) are reasonably accountable to their supervisors for the data and extension work due to the prevalence of weekly or biweekly meetings. However the subsection chief must also visit the field frequently in order to independently evaluate reports of the inspectors.

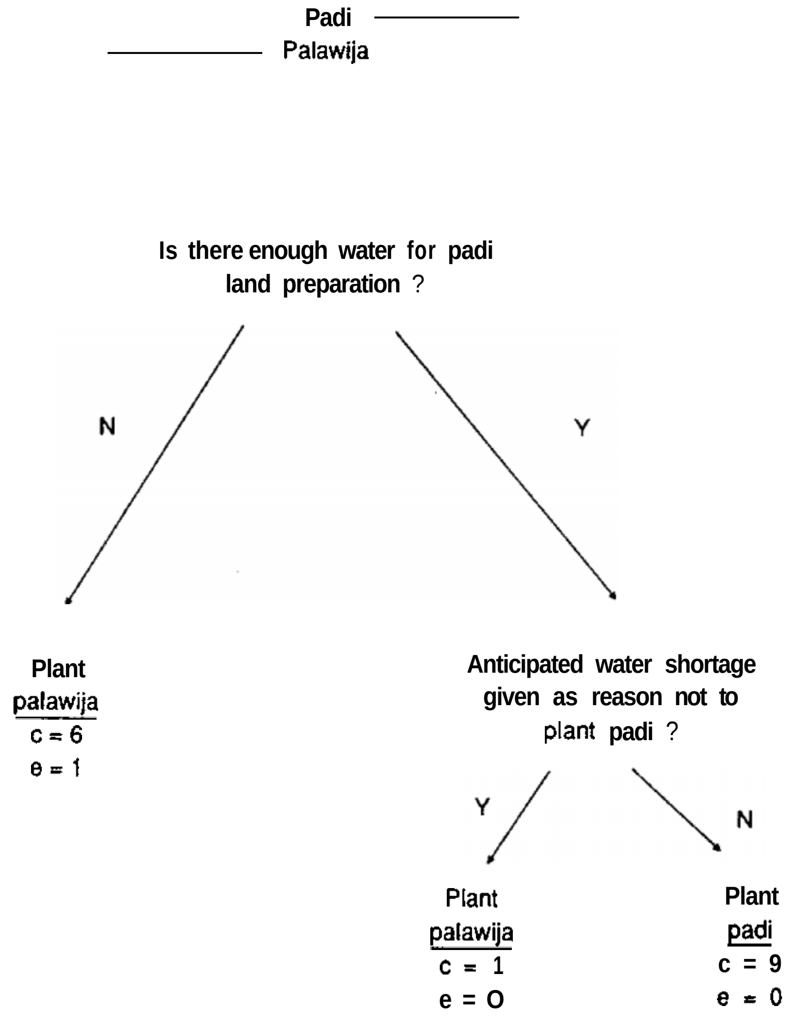
How supportive are staff incentives?

The low salary scales and outside income-earning of field operations staff weaken the incentive of inspectors to visit all the village agricultural officers for their input and to extend information to them about the plan. A low transport allowance to subsection chiefs may inhibit frequent field supervision. On the farmers' side, there is a wide number of local incentives which they consider in actually making a decision such as which crop to plant, perceived availability of water, drainability of soils, land tenure, threat of pest attack, perceived profitability, etc. However, farmer decision-making data suggest that the availability and drainability of irrigation water in the dry season are prominent factors in deciding whether to plant rice or nonrice crops (see Figures 3 and 4). This is usually considered and acted upon by farmers who are oblivious to the crop plan.

How manageable is the crop plan process?

The crop plan process is almost impossible to implement as planned, because of the difficulty of adapting administrative-based data to hydraulic units and the lack of agency control over crop decisions. Perhaps the crop "plan" should be reconsidered as a "guide," instead of a "plan," which implies a direct connection between staff action and desired result.

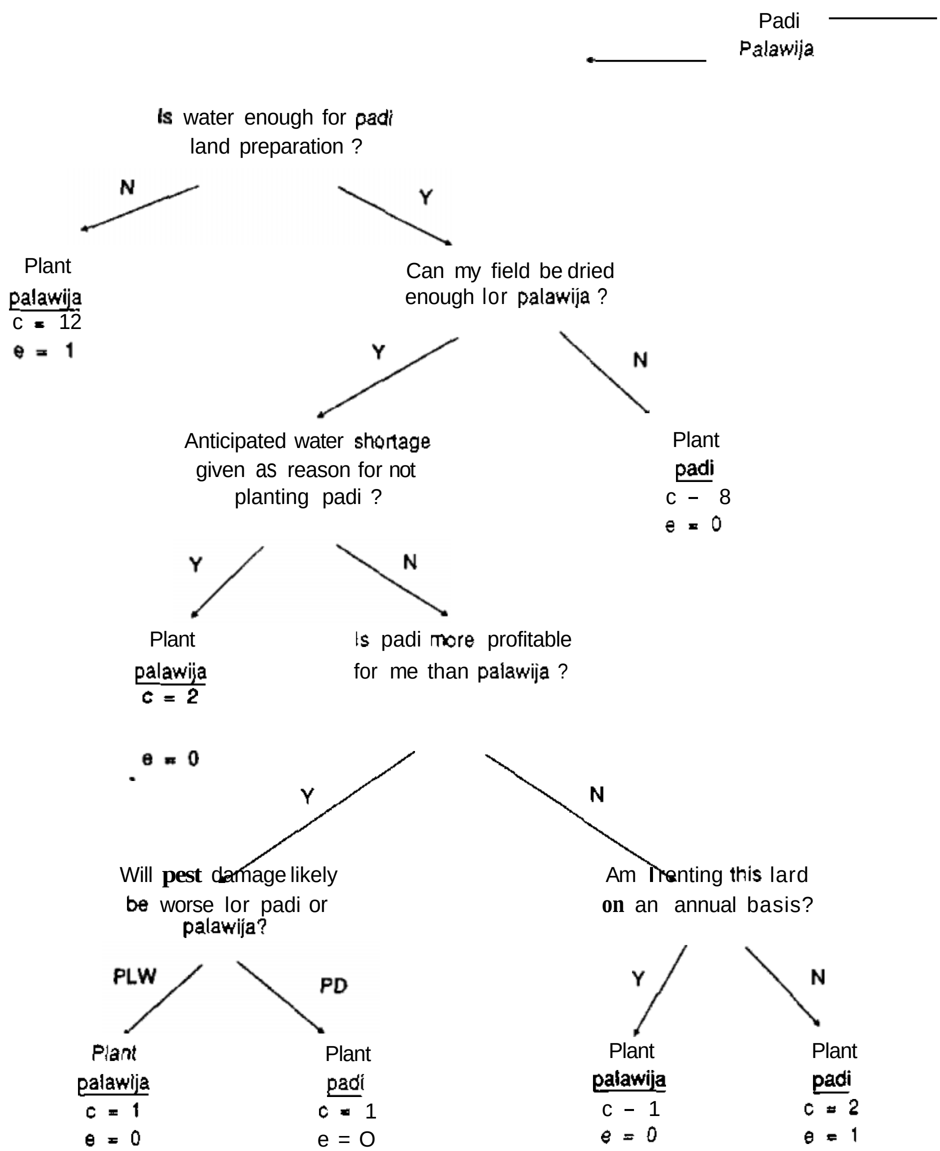
Figure 3. Farmer decision model to plant pndi or palawija, Jasem 7 Blo, West Java, for the first planting period of 1986 dry season (Gadu 1).



Correct responses: 15

Error responses: 1

Figure 4. Farmer decision model to plant padi or plawija, Jarot 2 Block, Central Java, for the first planting period of 1986 dry season (Gadu 1).



Correct responses: 27
Error responses: 2

Rotational Irrigation

Objectives ***and plan.*** There are three primary reasons why rotational irrigation is practiced 1) shortage of water to meet irrigation requirements, 2) conveyance difficulties when discharges are significantly below design capacity of canals, and **3)** the need to avoid overirrigating nonrice crops that are susceptible to yield reduction under conditions of excess water. This paper focuses on the first two reasons because they involve modifications to normal operating practices of rice-based irrigation systems. Rotations for agronomic reasons are usually conducted at farm or field levels and are therefore normally outside the operational jurisdiction of irrigation agencies.

The objectives of rotational irrigation are different from those of irrigation management when water is in sufficient supply to meet all or most of crop water requirements. During rotation, the basis for water allocation which pertains under continuous flow, is no longer valid and a new set of rules is applied. The altematives most often considered by system managers are:

1. Allocation based on proportionality of crop demand, i.e., where water is allocated in proportion to actual field-level demand, so that rotation unit sizes and locations are arranged to have similar water demands per standard unit of time, and will receive a fixed percentage of total available water; or

2. Allocation based on equity of proportional areas, where water is allocated in proportion to the total irrigable area (regardless of crop type), so that each farmer has equal access to scarce water supplies.

If the first alternative is adopted it is unlikely that the system will meet equity objectives because water is allocated in response to the proportion of area that has already been planted. Farmers who are able to plant crops before water shortages occur receive a larger share of water during rotation because they have a larger share of demand. This trend is particularly clear where head-end farmers are able to plant and establish rice crops. Despite the inequity caused by this management default, this situation maybe more efficient in terms of production per unit volume of water because the irrigated area is concentrated and conveyance losses will be lower than if the whole system is irrigated at a lower cropping intensity. However, this was not a policy or objective in West Java at the time of this activity.

Adopting equity as the primary objective may require greater management inputs from the irrigation agency: head-end offtakes have to be closely monitored to ensure they do not receive more than their fair share, and there will be more gates and structures to be included in the overall gate monitoring program. However, the net result ought to be that more farmers get water for at least some of their land and this has particular merit in places where farmers have limited off-farm income sources during the dry season and where water **users** are expected to pay some or all of the system O&M costs.

Over time, in a well-managed system that has equity as the major objective, these two alternatives will coincide: water will be allocated on the basis of the total irrigable area and farmers will adjust dry-season cropping plans to meet this overall condition.

Rotations can be implemented at a number of different levels in the system. The three most common levels are: rotation within tertiary blocks, rotation between tertiary blocks along secondary canals and rotation between secondary canals (or groups of tertiary blocks) along the main canal.

For rotation at the main system level, the entire system is divided into rotational units comprised of different secondary canals and groups of tertiary blocks. Tertiary blocks in each rotational unit may be scheduled to receive water simultaneously or subrotations between tertiary blocks within a rotational unit may occur between turns of the rotation units. If so, the two levels are usually planned and implemented wholly independently of each other. The arrangement of rotational units largely determines the extent to which crop demand or area equity takes priority. If meeting crop demand is the dominant priority, then each unit should have approximately the same total water requirement. If equity is the main concern, then each unit will have roughly the same irrigable area. Of course, either criterion may be modified to account for the differential effect of conveyance losses according to distances of blocks from the top of the system.

Manageability of the conventional rotation. For implementation of a rotation to be practical and still provide basic access to water, it must be based upon local system design and institutional constraints, rather than on simple administrative boundaries or agricultural quotas. From repeated day-and-night inspections and interviews with PRIS staff and farmers during the 1988 rotation in the Maneungteung System, the following observations were made:

1. The rotation did not have specific objectives or criteria to justify its conventional configuration of tertiary blocks (in fact, the PRIS subsection staff did not know the basis for its origin, which preceded their time in office);

2. Boundaries of rotation units were not always at locations where there was a proper control structure, making it difficult to prevent flows into areas not scheduled for irrigation;

3. The length of a canal section to be filled with water on a single day ranged from **12,458** meters on Wednesdays to **23,074** meters on Sundays, meaning that tertiary blocks at the tail end of long sections were highly unlikely to receive their planned share of water;

4. One case was observed where the upper end of a canal was scheduled for water on one day, drained completely the next day, and then water sent to the tail section on the third day, wasting scarce water in filling and draining canal sections unnecessarily;

5. There were a large number of gates, often in disparate locations, which needed to be monitored and operated;

6. Rotation unit sizes and relative water demand were very unequal and not in continguous units (making control difficult);

7. There was virtually no monitoring by the PRIS of where the water actually went;

8. Gates were often manipulated and canals blocked by self-interested farmers;

9. Staff received no bonuses and had little incentive for the intensive day-and-night tasks required to implement the rotation properly (monthly salaries of irrigation inspectors were the equivalent of about US$40 to US$50 per month plus rice. Salaries for gatekeepers were about US$15, some of whom received rice as well);

10. There was inadequate policing, farmers were not involved; and

11. There was no sanction against water theft, which was very frequent (head-end tertiaries had a higher proportion of observations of unplanned water deliveries). (Detailed data of findings of this study can be found in Murray-Rust, Vermillion and Sudarmanto 1990).

THE POTENTIAL FOR IMPROVING DRY-SEASON IRRIGATION MANAGEMENT

Alternative Approaches to the Crop Plan Process

The following points are suggested by the findings of the Study Team for discussion and for consideration as possible elements in future field experiments aimed at improving the crop plan process.

1. Perhaps there should be three seasons in the plan, rather than the current two seasons, because of the now widespread occurrence of three planting seasons in many parts of Java and elsewhere in Indonesia.

2. There need to be meetings of the irrigation committee at the district level in March and July to discuss the plan and possible revisions due to more recent information on weather and supply predictions at the outset and during the dry season. The committee should review last year's differences between the planned and actual targets in order to have a better learning mechanism at this level for making future adjustments.

3. At least one annual meeting of WUA heads and/or village agriculture officers is needed per irrigation system or river course management unit, at the subsection office immediately prior to dry seasons to discuss the crop plan, system and block-level water allocations and rules for adjustment if shortages occur. Irrigation rotation plans could also be discussed in the meeting. The meetings should be based on hydraulic or management units and would aim at coordination between WUAs and dissemination about the plan and agreed revisions thereof.

4. The official block and system imgation design areas should be either revised or not be used for planning and distributing irrigation water. The functional area should be used instead and be revised yearly. The functional area should be used both for the annual plan process and system operations and should not be related to PRIS budgets.

5. It would be helpful for PRIS to initiate a routine program at the section level to take temporary stream flow estimates in the dry and rainy seasons in suppletions or other significant unmeasured water sources which are tapped into irrigation systems, roughly calibrating water depth with approximate discharges.

6. DOI and PRIS need to obtain better or more complete information on palawija crop water requirements, especially for higher water consumptive crops such as red onion. Some of these should be given a special designation as unpermitted palawija crops. Standard information needs to be disseminated throughout PRIS about which palawija crops are high and which are low-water consumptive.

An alternative management approach. An alternative approach to the current crop plan process would be for the PRIS to restrict its role more to that of managing the supply of irrigation water to the tertiary outlets of its systems. It would be better able to set clear and implementable objectives, for which it retains control and accountability, if it were to focus on acquiring, estimating, communicating, monitoring and delivering agreed water allocations to certain locations and certain times. There would be advantages to having PRIS focus on the water supplying and delivery functions rather than being engaged in trying to get farmers to plant certain crops or delivering water primarily through reaction to the actual crops planted, regardless of the plan or supply. Such a simplified, and more focused role for PRIS in the crop plan process could involve the following features:

1. PRIS could develop a "Minimum Supply Prediction (MSP)" for each system as a standard guideline to follow perennially, based on historical supply averages and minimum frequency acceptable drought risk. PRIS is not particularly adept at closely predicting water supplies in a variable way from year to year (and neither is anyone else). The MSP would usually be the same from year to year, but could be revised occasionally due to long-

term weather changes or better information and ability to approximate seasonal supply averages.

2. The MSP would set the parameters for deriving a standard block-level "Minimum Allocation Prediction (MAP)," which would be a standard, estimated minimum likely allocation to be available for given seasons, from year to year. The MAP would be very important for the first and second planting periods of the dry season.

3. Within the supply constraints estimated by the MAP, any variety of crop combinations could be selected by farmers. PRIS could develop a menu-like set of frequent crop combinations per block (in the form of various combinations of areas per crop types). It might be termed something like the Seasonal Advised Crop Combinations (SACC). A separate SACC would be made for each block per season.

4. The WUA and/or village agricultural officer would be informed of the standard seasonal MAP and have copies of the Seasonal Advised Crop Combinations (SACC) and would use them as standing guidelines for coordinating crop combinations within the MAP.

5. The PRIS would not concern itself with whatever crops are actually planted in the blocks as long as their irrigation requirements do not exceed the MAP, as delineated by the SACC. The PRIS would hold meetings with WUA representatives prior to both planting periods of dry season and PRIS would remind WUAs that crop plantings must fit within the MAP as indicated by the SACC. PRIS would deliver water according to the MAP, with surpluses being distributed proportionately among blocks.

6. Under water scarce conditions where the MAP requirements cannot be met for all blocks, PRIS and the WUAs would have two basic choices. It could either initiate timed irrigation rotation or it could assign standard versus priority designations to blocks. The latter option somewhat resembles the Golongan System. All blocks would take turns between years receiving block water priority designations, between two levels (only two so as to remain simple), called priority or standard, for a given dry seascn.

7. Priority blocks would be given prior guarantee to ensure the MAP is delivered as long as the Factor K remained above a level where all priority blocks could be given their MAP delivery. If the supply dropped below this level, a rotation would begin, but still giving priority to the priority blocks. Standard blocks would be given residual deliveries after the MAP was ensured for priority blocks. The standard versus priority designations would be rotated automatically from year to year. Efforts would be made to ensure that WUAs, village officers, and all farmers would know what the block water designation is each year. However, the total area in priority

blocks should not be so large (it may only be a third of the system during a given dry season) as to cause standard blocks to go fallow.

8. This would eventually become common knowledge and could have the following beneficial effects:

   i. it should help farmers to better assess risks and enhance house hold-level planning for renting and labor arrangements,

   ii. by providing all blocks with priority status periodically, more blocks would have the opportunity, incentive, and security to at least periodically take the risk of investing in higher-value, higher water-consumptive crops during their priority seasons, thereby enhancing equity:

   iii. farmers would know well in advance when their priority years are and could save or prepare to invest in higher-value crops beforehand, and

   iv. it should increase the system level overall high-value crop production overtime.

9. Such an approach would leave the agriculture service with the task of trying to persuade farmers to plant certain crops, in accordance with national and provincial targets and within the parameters of the MSP and MAP. The agriculture service would have in their possession the system-level MSP and block-level MAP and SACC as standing guidelines within which they work out favorable crop combinations. This should not be PRIS's business. Agriculture would use the SACC as a menu and work out actual crop combinations with the farmers.

10. Under such a scenario the annual crop plan process would not require annual reports from the farmers through PRIS to the section level concerning crop planned forthecoming year. It would be sufficient for PRIS to keep the agriculture service and local government informed about the MSP, MAP, and SACCs, and of possible adjustments to them. PRIS would focus on estimating communicating, and delivering the MSP and MAP. Hence, the objectives would be clear, specific and implementable; the process would be controllable by the PRIS staff themselves (unlike the current situation where the PRIS staff are supposed to have a hand in what crops actually get planted in the field — which is really beyond their control); and each inspector would be clearly accountable to develop the MSP and MAP for the tertiary blocks in his or her area.

Alternative Approaches to Conventional Rotational Irrigation

With the PRIS deciding to develop a more equitable and manageable form of dry-season irrigation than had been used in the past, pilot testing of alternative rotational practices was camed out in the East Maneungteung System in the 1989 dry season. The steps involved in the evolution of the new rotation and its pilot implementationare listed below:

1. Monitor and evaluate the previous rotation system and facilitate conveyance of views among farmers, *KaUr EkBang* (villageagricultural officers) and PRIS staff about problems in the old rotation system;

2. Diagnose causes for the problems identified through data analysis, semi-structured interviews and direct field observation;

3. In discussions with the various actors involved in the rotation, specify the various criteria and objectives expressed for the rotation (such as equity per actual cropped area, equity per irrigable area, practicality of implementation, amenability of the plan to being controlled and enforced);

4. Identify a few feasible alternative rotation plans which optimize various specified criteria or effectively compromise among them;

5. Hold separate discussions on the pilot experiment between the Study Team and PRIS officials at different levels, agriculture and local government officials at the subsection level, and KaUr Ekbang;

6. Hold meeting of PRIS subsection chief and irrigation inspectors to discuss alternative rotation options and agree on one;

7. Hold a meeting of PRIS subsection staff, agriculture and local government officials, and KaUr EkBang to discuss alternatives and select one, sign an agreement to implement it, discuss and agree on joint policing plan involving fanners;

8. Conduct a planning and training meeting among PRIS subsection staff;

9. The PRIS subsection head, in consultation with KaUr EkBang decides on when to start the rotation;

10. Village-level arrangements are made to implement rotating village night guard groups to police the rotation schedule at night;

11. Implement the rotation until harvest of the second dry-season crop in late October; and

12. Monitoring and evaluation of the rotation by the Study Team and production and discussion of reports in subsequent meetings with PRIS and DOI.

Five alternative plans were developed in collaboration between IIMI and PRIS and the section and subsection level, in the effort to either equalize irrigable area of rotation units, equalize daily demand for water, have a more simple and implementable set of gate adjustments, or have a more controllable rotation.

Each alternative was discussed among the PRIS staff and again with PRIS staff officials from the agriculture service, the district government and village governments. A public consensus was reached to select alternative three, on the strength of its equity and practicality for implementation.

This alternative had the following characteristics:

1. All tertiary blocks should receive water for one day a week, with no exceptions permitted;

2. Greater equity in area scheduled for imgation each day: the daily variation in total imgable area varied from 564 ha on Tuesdays to 842 ha on Mondays a ratio of only 1.49 compared to 3.30 in the 1988 plan;

3. A reduction in the number of times when gates have to be either operated or monitored (i.e., "management inputs") from 279 in 1988 to 241 in 1989 (a 13.6 percent decrease), and a decrease in the number of total required gate operations (i.e., gates adjusted, closed and opened) from 219 in 1988 to 166 in 1989 (a 24 percent decrease); and

4. An increase in the estimated number of hours per week when gates have to be merely monitored to ensure they remain closed — from 16.0 in 1988 to 17.7 in 1989, a 10.6 percent increase.

Results of the field experiment with the new rotation procedures can also be assessed, relative to the principles of manageability described under *Manageability of the crop plan* **process.**

How clear are the objectives?

Prior to the pilot experiment, the new PRIS subsection chief was unaware of the criteria used to establish the earlier rotation. It was clear to him and other PRIS staff and farmer representatives that the old approach had many flaws, including its inequity, impracticality, and difficulty of control. In the discussions about results of monitoring the 1988 rotation and altemative plans, the criteria for selecting a new rotation were identified and clarified, namely that a new rotation should be based on equity of rotation unit areas (not cropped areas or real demand), it should be practical to implement, and it should be subject to management control. Clearly equity of the area sizes of rotational units (with unit size being somewhat inversely proportional to distance from the headworks) was a key objective.

How implementable are the procedures?

The new rotation, which was identified by the Study Team and selected PRIS was substantially easier to implement — in terms of a more efficient and small configuration of gates to be monitored and adjusted. Also boundaries behveen the rotation units were placed where there were adjustable gates. Also, because of the discussions and preparations which were made in advance, the 1989 rotation was able to be implemented much more quickly than in 1988, after discharge levels dropped off. The rotation was not started in 1988 until two weeks after system-level supply dropped below demand; in 1989, this was narrowed to less than one week.

How adequate are the resources?

Given the smaller amount of gate adjustments and monitoring needed under the new rotation, together with the mobilizing of farmers to help in policing the rotation at night, the labor resources were judged to be adequate to the tasks involved. Inspectors generally lived near their areas of work and at least had bicycles for transport, although nighttime use of bicycles to tour the system was considered somewhat dangerous, when done alone.

How controllable is the process?

Realigning rotation unit boundaries according to locations where there were adjustable gates, switching deliveries between rotational units at midday instead of midnight and involving farmers' rotation unit representatives in nighttime policing helped substantially to make the rotation more controllable by PRIS managers. Farmer night watch groups were observed to be functioning on many night inspections. However, partly due to the inadequate incentives of staff, nighttime field work by PRIS staff was probably not as intensive as was apparently needed (judging from the village irrigation issues which still continued in 1989, although at lower levels than before). Although unofficial issues were still frequently observed, they were not as frequent as in 1988, suggesting that some improvement in control was achieved.

How accountable are the staff?

The existence of a formal meeting and signed agreement about the rotation between PRIS and the village agriculture officials was an important factor in strengthening a general sense of accountability to the plan. The meeting enabled the PRIS subsection to discuss the rotation directly with village representatives, which help override more vested interests. The nighttime rotation guard groups (usually consisting of four or five fanners who went around together) usually sought out the irrigation inspector when an illegal issue or closure was observed. This helped make the PRIS staff somewhat more accountable to the water users, although there were reports that the groups often could not locate the inspectors or the disturbances often reoccurred later in the night, even after being corrected by

PRIS staff. Flags were placed at the head of secondaries to designate location of the rotation turn on a given day, thereby helping clarify implementation and making violations more discernible.

How supportive are the incentives for staff?

The average irrigation inspector receives approximately a US$30 to US$40 salary per month, plus a rice allocation. A small field travel allowance is also provided, although there is no difference in this amount between dry and rainy seasons. Unofficial incentives, or temptations to reallocate water according to special interests, can easily exceed the level of salaries. Furthermore, PRIS staff understandably often have sideline income-earning activities which often compete for time.

How measurable are the results?

Actual deliveries to rotation units on any given day could be monitored due to the realignment of unit boundaries according to locations of adjustable gates, nearly all of which had discharge measurement devices. Water adequacy is indicated in this study by the Delivery Performance Ratio (DPR), the ratio between actual and planned deliveries. In 1989, there was a much closer correlation between DPR at the system level and DPR at the level of the rotation unit level ($R^2 = 0.44$), than was the case in 1988 ($R^2 = 0.27$).

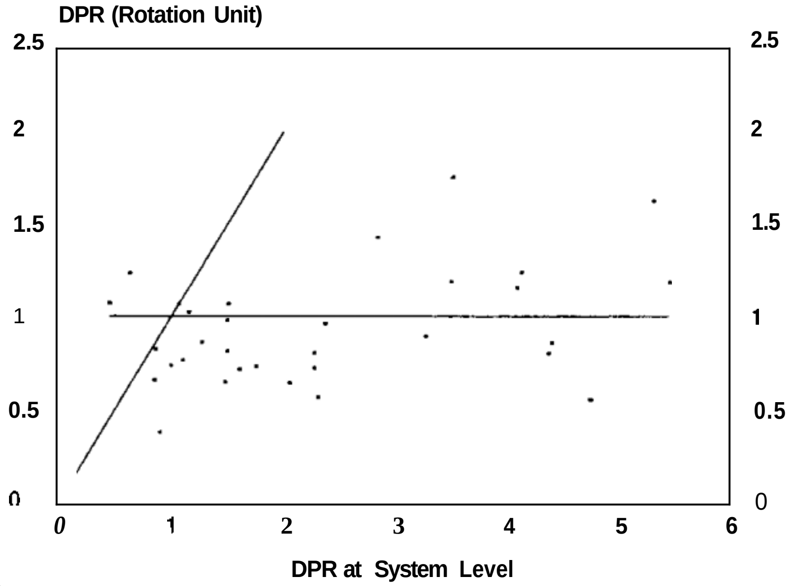
In 1989, whenever DPR was less than 1.0, the scheduled rotation unit received virtually all the water. When DPR was more than 1.0, the scheduled area tended to receive slightly more than its share, but not substantially so (see Figure 5). Surplus water tended to be directed to other blocks not scheduled for irrigation This contrasts sharply with the situation in 1988. There was a much closer link to water management at the main and subsystem levels in 1989. The DPR was introduced to PRIS staff at this level and was discussed during the rotation period as a performance monitoring tool.

The 1989 experimental rotation system is a more manageable one than the prior rotations used in the area in terms of specificity of objectives (especially equity of unit areas), implementability, reduced management requirements and measurability of results. It is somewhat improved in the adequacy of human resources (regarding farmer participation in approving and policing the plan) and control. However, it is not significantly different from the earlier rotation in manageability in terms of the more basic problems of staff accountability and incentives.

This study shows that significant improvements can be made in the manageability and performance of dry-season irrigation rotation at the local level using current resources. These include improvements in aspects such as the configuration of rotation units, scheduling, staff assignments and involvement of farmers in planning decisions and enforcement. However, such adjustments do not address, and by themselves cannot overcome, management control problems connected with weak staff incentives and accountability and the so-called "rent-seeking" patterns of water allocation which are driven by underlying economic and land tenure

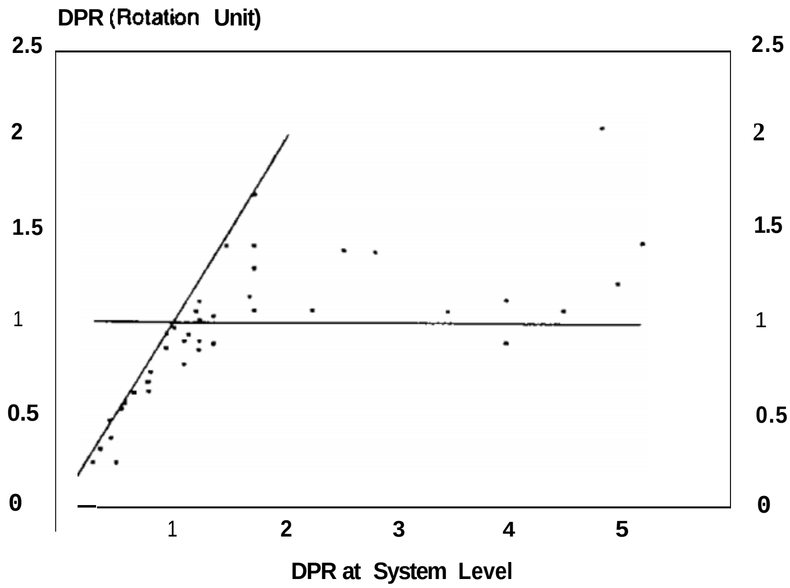
Figure 5. ***DPR at system and rotation unit, East Maneungteung System, West Java***

June – September. 1988



R^2 = 0.267

August – October, 1989



R^2 = 0.437

inequalities and which are especially manifested during periods of scarcity (Repetto 1986). Needed improvements in staff incentives and accountability, sanctions and the adaptability of the PRIS to changing agricultural preferences of farmers will require more basic institutional and policy changes. It is becoming widely recognized that irrigation line agencies around the world, which are funded by general national or provincial revenues, tend to have a weak institutional imperative to achieve and monitor performance objectives (Small et al. 1989).

CONCLUSION

This pilot experiment was an exercise where an international irrigation management organization collaborated with an administrative line agency to develop, implement, and evaluate an improved irrigation management procedure which is based on standard management principles of specifying clear objectives and implementable procedures to achieve measurable results. Line agencies often function less to achieve results than to implement administrative routines as prescribed from above. Frequently, agency staff pay little attention to whether or not the procedures are actually implemented or the results achieved.

In this experiment various new management activities were carried out on the momentum of a pilot research and development project. Study Team members and agency staff discussed equity and management objectives and identified ways to link new implementation procedures to the newly clarified objectives. Farmers were included in designating main system rotation units and in policing implementation. However, the experiment was not able to fully address the more fundamental problems of control and incentives. In order for this "management approach" to be sustained by the implementing agency its own institution must be reoriented toward a "need to manage," which is based on an institutional imperative to clarify objectives and achieve results. This more difficult challenge remains to be addressed.

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Socioeconomic Issues in Irrigation Management for Rice-Based Fanning Systems in the Philippines

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INTRODUCTION

DESPITE DECLINING PROFITABILITY of rice production, diversification into nonrice crops has not occurred rapidly in the Philippines. Systems where successful dry-season diversification has been observed are ones in which nonrice crops had been grown historically, and are not recent innovations. Where diversification is being promoted recently, the experience has not been satisfactory due to both soil-physical and socioeconomic constraints faced by the farmers.

This paper provides a synthesis of the Philippine studies examining these constraints to diversification out of irrigated rice production. It addresses three basic issues in imgated crop diversification: (1) physical and socioeconomic constraints to diversification out of rice; (2) the relative profitability of nonrice crop production; and (3) social issues in managing irrigation systems with crop diversification during the dry season.

CONSTRAINTS TO CROP DIVERSIFICATION

In the Philippines, it is argued that imgation systems were designed solely for rice production and are, hence, not suitable for nonrice crop production (Schuh et al. 1987; Levine et al. 1988; Rosegrant et al. 1987). For most of the Philippine systems studied, this argument does not seem to hold for the middle and lower sections of the irrigation systems. Although dry season diversification is becoming common, some systems such as UTRIS, LVRIS and TASMORIS have been practicing diversifying for a long time.

Tables 1 to 3 enumerate factors influencing farmers' crop choice. Family consumption or meeting the family's rice requirement is one factor which ranked first and second in two locations or irrigation systems studied. When wet-season rice crop is not enough to meet the family's rice requirement, then most likely fanners will plant a dry-season rice crop. Other factors include availability of irrigation water, availability of inputs, previous dry-season nonrice crop experience and market demand of the produce, among others. These factors are important in the decision making of farmers on what crops to be planted in the dry season.

Table 1. *Factors* **considered** *by farmers under BARIS in determining* **what crop** *to plant, 1986/87 and 1987/88 dry* **seasons.**

Factors	Rank					
	Irrigated rice		Irrigated corn		Rain-fed corn	
	1986/87	1987/88	1986/87	1987/88	1986/87	1987/88
For family home consumption	1	1		2		
Availability of water	2	2	1	1		3
Marketability of the produce	3		3		2	
Familiarity of the farmers in growing the crop			2		1	1
High returns perceived					3	
Suitability of crop		3				2
Ease of management				3		

Table 2. *Factors influencing fhe choice and area planted, UTRZS, 1968/87 and 1987/88 d y seasons*

	1986/87				1987/88			
	Onion (n=50) average rank (a)	% (b)	Rice (n=10) average rank (a)	%	Onion (n=80) average rank (a)	%	Rice (n=28) average	%
Choice of crop								
Perceived to provide highest returns	1.32	88	220	100	1.93	85	1.75	43
Previous experience	2.66	88						
Technology known to farmers	2.70	86					2.40	54
Ready market			2.71	70	2.93	88		
To meet rice requirement			2.89	90			1.84	89
Availability of water					2.88	64		
Area planted								
Availability of planting materials and other inputs	1.31	52	1.67	90				
Size of market	2.12	50	2.20	100	2.11	100	2.w	82
Previous experience	2.49	98			2.56	80	2.75	71
Availability of water			250	100	2.66	98	1.72	89

(a) Most important = 1, less important = higher value of rank
(b) Proportion of respondents reporting.

Source: Marzan (In Valera 1989).

Table 3. Factors considered by farmers under ARIP in determining what crop to plant, 1986/1987 and 1987/1988 dry season.

Factors	Rank				
	1986/198	1987/88			
	Irrigated rice	Irrigated rice	Irrigated corn	Rain-fed corn converte	Rain-fed corn
Availability of water	1	1	1	1	1
For family home consumption	2	2			
High returns perceived	3	3			
Less production expenses				2	
Shorter cropping seasons				3	
Availability of seeds and other inputs			3		3
Climatic condition			3		2

Soil-physical constraints. Cropping pattern is influenced by soil type, water availability or by the nature of the available water, i.e., whether the area is irrigated or rain-fed (Tables 4 and 5). There is a distinct soil type bias in cropping pattern, i.e., rice is grown in heavier clay soils, while nonrice crops are generally grown on sandy loam soils (Pingali et al. 1988).

Table 4. Characteristics of the samples being studied.

Characteristics	Lateral A	Lateral B	MCs
Number of farmers	7	11	12
Number of parcels	8	15	22
Distance from irrigation canal			
- near	4	6	8
- far	3	5	4
Cropping pattern			
- rice-rice	6		2
- rice-onion	1	8	5
- rice-onion+vegetable		3	2
- rice-rice+onion			3
Soil type			
- galas		11	6
- lagkit	6		4
- mestizo lagkit	1		2
Dry season water stress			
- yes	7	10	8
- no		1	4

Source: Pingali et al. (In Valera 1989).

Table **5.** *Clopping* ***patterns of farmas*** **under** ***ARIP*** *I,* **1995** ***to*** **1988.**

Type of farm	'85/86						1987188		
	Wet	Dry	%	Wet	Dry	%	Wet	Dry	%
Irrigated rice	ir	ir	58	ir	ir	93	ir	ir	99
	rr	rr	11	rr	rr	5	r/rc	ir	1
	rc	rr	6	rc/ir	rc/rc	2			
	rc	rc	12						
	rc	ir	4						
Rain-fed corn	others		3						
(converted)	rc	rc	62	ir	RC	28	ir	rc	15
	ic	rc	10	ir	ir		ir	rc	75
	ir	ir	15	rc	rc	8	irc	rc	5
	rc	f	5	irc	f	5	ir	irc	5
	irc	irc	2	others		19			
	ir	rrc	2						
	others		4						
Seepage corn	sc	sc	8	sc	sc	13	ir	sc	100
	ir	ir	38	ir	ir	44			
	rc	rc	46	ir	rc	12			
	fallow		8	rc	rc	31			
Rain-fed corn	rc	rc	81	ir/rc	ir/rc	13	r/rc	ir/rc	19
	ir	ir	6	rc	rc	65	rc	rc	55
	rc/rc	r/rc	6	ir	ir	6	thers		26
	others		6	others					

Legend: ir - irrigated rice. ire - **irrigated rice+corn. rr - rain-fedrice.**
rrc - rain-fed rice+corn. rc - rain-fed corn. sc - seepage corn.

Source: **Bacayag (In Valera 1989).**

The distance of the rice field to the water source and the relative position of the rice field to other rice fields also somehow influence the choice of crop to be planted. At the main canal turnouts of UTRIS where farmers have to grow onion and rice side by side, onion is planted at the higher fields. In Lateral A which is lower than any other section of the system, rice is grown throughout the year. In Lateral B, the middle section, onion is the main crop grown during the dry season. In general, land **utilization in the dry season is less than in the wet season, and the TASMORIS 1987/ 88** dry-season land utilization is higher due to the government's massive corn production campaign (Table 6). On the other hand, LVRIS showed a decreasing land utilization by crop and by position/distance of the rice field to the **source** of water (Table 7).

Cropping Pattern	1986/87		1987/88	
	Wet season	Dry season	Wet season	Dry season
Rice - Rice	98	72	98	99
Rice - Nonrice	100	58	100	90
Rice - Rice + Nonrice	91	58	92	76

Table 7. Average cropland **utilization by** *crop and cropping* **pattern,** *LVRIS, dry season 1988-1989.*

Items	Head	Middle	Tail
	(in hectares per farm)		
Available cropland	.94	1.45	1.26
Effective cropd area			
rice crop1	.54a (57.55)	.90b (62.00)	.49ac (38.80)
garlic-mungol	.30a (32.00)	.26ab (17.59)	.47c (37.63)
garlic-crop1	.16a (17.22)	.12a (8.28)	.18a (14.60)
mungo-crop1	.14a (14.78)	.14ab (9.31)	.29c (23.02)

[d] **Proportion of the available cropland utilized for individual crop namely: rice, garlic and mungo and the rice-fallow and garlic-mungo patterns.**
Numbers in parentheses are percentages of effective crop area.

[1] **ANOV procedure to test the joint hypothesis of differences in means among the three types of farms was significant.**

Means by type of farms followed by the same letters are not significantly different

Source: Esteban, Z.H. 1990.

Credit. Generally, farmers do not have the needed capital for crop production especially for nonrice crops l i e hybrid corn, garlic and onion. **These** crops need almost **three** times more capital than rice. Whenever farmers do not have savings from wet-season rice crops and need a sizeable amount for producing nonrice crops, then a credit scheme is necessary. Most farmers have outstanding balances from previous government loan programs like `Masagana 99,' 'KKK,' and `Maisagana 100,' etc. Of course, banks charge lower interest rates from borrowers **on** these programs, but because of unpaid loans and collateral requirements fanners prefer

nonformal sources of credit like traders, millers, relatives and friends. But high interest charge is often the common problem with these nonfonnal credit sources (Bacayag 1989). In the case of onion fanners at UTRIS, lenders who are usually traders do not charge interest but they have the exclusive right to purchase all output at market price during harvest. Trader-lenders benefit substantially from the significant price increase between harvest and postharvest months. The price increase more than offsets the foregone interest charges and storage cost (Pingali et al. 1988). Also in UTRIS, fanners' loan for onion production was four times as much for rice production in the 1988 dry season (Table 8). In the 1989 and 1990 dry seasons, fanners' loan for onion production was twice as much as the loan for rice production (Tables 9 and 10). Usually fanners take a loan in kind such as seeds, fertilizers and pesticides from the dealer who is also often a trader or a miller. The situation is also true in MCIS, BARIS, and ARIP (Bacayag 1989) and in other areas where crop diversification is practiced, and even in rice-rice cropping pattern areas.

Table 8. Amount of loan by crop and by source, UTRIS dry season, 1988.

Source of loan	Pesos/ha	Interest (%)
Traders/private lenders		
Palay	2,125 (3)	108
Onion	9,663 (8)	84
Banks		
Palay/onion	1,146 (1)	12
Traders/relatives	3,791 (6)	0

Table 9. **Amount** *of loan* **by** *crop and* **by** *source, UTRIS, dry season, 1989*

Sources	Crops					
	Pa /		Onion		Palay/Onion	
	Amount	Interest	Amount	Interest	Amount	Interest
	Pesos/ha		(Pesos/ha		Pesos/ha)	
Traders/private lender	1,922 (2)	97.5	2,869 (2)	45	3,333 (1)	120
Friends/relatives	3,333 (1)			90	2,222 (1)	120
			4,142 (2)	0	20,000(1)	0
Cooperatives			1,550 (2)	20	2,308 (1)	20

() no. responding

Table 10. Amount of lam by crop and bu source, 1990 UTRIS dry season

Source of loan		
Millers/traders		
Cooperatives		
Millers/traders	7,006 (2)	105
Cooperatives	3.085 (5)	20
Friends/	4,416 (5)	63
Relatives	8,000 (1)	0
	Palay/onion/vegetables	
Cooperatives		
Friends/relatives		

in LVRIS, labor use by location/distance to water source has been found to be significantly different. Farmers at the head of the system or lateral use more labor than those at the tail-end section (Table 11). Material input use in the head is also higher than the material input use in the lower section of the system (Table 12).

Onion production in UTRIS is, therefore, highly labor-intensive and, compared to rice it uses four times as much labor (Table 13 and 14). Increasing efficiency of labor use is one important development in the area. For one, the yield-labor ratio for onion has increased from 28 in the 1988 dry season to 33 in the 1990 dry season, and from 49 in the 1988 dry season to 105 in the 1990 dry season for palay. Farmers at the UTRIS area have, hence, been increasing their efficiency of labor use for both crops.

Table 11. Labor use by cropping pattern and by location, LVRIS, dry season, 1988-1989.

Crop/cropping pattern		Head	Middle	Tail
		(inman-day	ian-animal day per hectare)	
Rice				
Total labor		181a	120b	126ab
	Land preparation	28a	19ab	16b
	Planting/transplanting	74a	46ab	36b
	Irrigation	3a	2ab	8c
	Care of the crop	20a	14a	21a
		55a	39a	45a
By source				
	Family labor	10%	68b	77ab
	Hired labor	77a	52a	49a
By type				
	Man-days	155a	102b	lllab
Garlic-mungo				
Total labor		486a	499a	343b
By activity				
	Land preparation	100a	84a	5%
	Planting	102a	102a	78b
	Irrigation	15ab	16a	10b
	Care of the crop	94a	114a	66b
	Harvesting/postharvestin	175a	182a	132b
By source				
	Family labor	388a	409a	25%
	Hired labor	98a	90a	86a
By type				
	Mandays	%la	480a	319b
	Man-animal days	25a	19a	24a
Garlic				
Total labor		371a	418a	275b

Continued on page 245

Crop/cropping pattern		Head	Middle	Tail
		ın man-day,	an-animal d	per hectare:
By activity				
	Land preparation	79a	71a	42b
	Planting	101a	97a	74b
	Irrigation	12a	13a	9a
	Care of the crop	79a	103a	56b
	Harvesting/post harvesting	100a	134b	94ac
By source				
	Family labor	287a	338a	199b
	Hired labor	84a	80a	76a
By type				
	Man-days	365a	413a	265b
	Man-animal days	6ab	5b	10a
Mungo				
Total labor		115a	81b	68bc
By activity				
	Land preparation	21a	13b	14bc
	Planting	1a	5b	4b
	Irrigation	3ab	4a	2b
	Care of the crop	14a	10a	10a
	Harvesting/postharvestir	76a	49b	38bc
By source				
	Family labor	101a	71b	58bc
	Hired labor	14a	10a	10a
By type				
	Man-days	96a	68b	54bc
	Man-animal days	19a	13b	14ab

• **ANOV procedure to test the joint** hypothesis **of differences** in **means among the three types of farms was significant.**

Means by type of farms followed by the same letters are not significantly different.

Source: Esteban, Z.H. 1990.

Table 12. Material *use by crop/cropping pattern and* by *location, LVRIS, dry* season 1988-1989 [a].

Crops/cropping pattern	Head	Middle	Tail
		pesos/h	
Rice			
Total material use	2,346a	1,632b	1,869ab
Seed	303a	280a	311a
Fertilizer	1,801a	1,219b	1,455ab
Chemical	242a	133b	103bc
Garlic-mungo			
Total material use	26,496a	26,909ab	37,960c
Seed	24,119a	24,240ab	34,159c
Fertilizer	1,447a	1,516ab	2,521c
Chemical	929a	1,153a	1,280a
Garlic			
Total material use	25,296a	25,493ab	36,398c
Seed	23,307a	23,325ab	33,077c
Fertilizer	1,447a	1,516ab	2,521c
Chemical	542a	652a	800a
Mungo			
Total material use	1,200a	1,416a	1,562a
Seed	813a	915a	1,082a
Chemical	387a	501a	480a

[a] ANOV procedure to test the joint hypothesis of differences in means among the three types of farms was significant.

Means by type of farms followed by the same letters are not significantly different

Source: Esteban, Z.H 1990.

Table 13. Labor inputs/ha, onion, *UTRIS, dry season.*

Activities	m-days (total cost)		
	1988	1989	1990
Land preparation			
Plowing and harrowing			
Machine	0.92	0.64	053
	(550.00)	(300.00)	(426.192)
Animal	6.04	6.63	3.945
	(302.00)	(236.37)	(68.023)
Harrowing			
Machine	1.12	0.68	0377
	(515.00)	(236.37)	(68.023)
Animal	6.56	7.58	4.78
	(338.00)	(379.00)	270.353)
Seedbed preparation/seeding	1029	22.30	161316
	(205.80)	(55750)	(354.875)
Pulling seedlings	30.00	1823	14.767
	(600.00)	(410.15)	(354.875)
Tran	80.00	78M	63.43
	(1600.00)	(1768.50)	(1753372)
Mulching	16.00	12.73	5.93
	(320.00)	(31825)	(215.606)
Application of fertilizer	4.33	2.51	2.078
	(86.00)	(50.20)	(66.252)
Application of insecticide	5.10	3.49	3.437
	(102.00)	(87.25)	(130.625)
Weed control			
Hand weeding	61.58	51.18	25.698
	(1231.60)	(115155)	(699.696)
Chemical weeding	126	0.99	1.686
	(25.20)	(19.80)	(50.581)
Irrigation Management	1128	12.90	52
	(225.00)	(322.50)	(156.00)
Harvesting, bunding, drying	88.50	83.60	58.842
	(1170.00)	1881.00)	1740.998)
Total	323.18	302.06	206.724
	(7270.60)	(839192)	(6609.949)

Table 14. Labor inputs/ha, palay, UTRIS, dry season

Activities	ME lays (total st)		
	1988	1989	1990
Land preparation			
Plowing and harrowing			
Machine	5.14	5.57	5.325
	(1028.00)	(1110.00)	(663.844)
Animal	8.25	15.5	1.942
	(41250))	(797.75)	(126.25)
Seedbed preparation	1.59	1.10	1.073
	(39.75)	(65.55)	(32.19)
Pulling seedlings	0.44	1.04	3.215
	(105.00)	(159.78)	(116.18)
Transplanting/direct seeding	17.64	7.83	6.647
	(352.80)	(195.75)	192.22
Application of fertilizer	1.63	1.44	1.849
	(32.60)	(36.00)	(59.19)
Application of insecticide	2.24	0.60	1.03
	(44.80)	(15.00)	(41.192)
Weed control			
manual	398		
chemical	0.74	(0.54)	0335'
	(13.50)	(10.05)	
Irrigation Management	12.22	6.334	nil**
	(78.86)		
Harvesting	21.01	28.74	18.662
	(420.00)	(1275.41)	(1111.505)
Threshing			
manual			
thresher	21.00	3.66	3.701
	(819.00)	(1483.85)	(779.59)
Hauling	3.47	2.08	0.502
	(150.00)	(157.36)	(133.875)
Total	80.35	74.44	44.281
	(3743.25)	(4388.71)	3266.086)

• Contract: paid 7 cents/bundle in 1988; paid 8 cents/bundle in 1989/90

** Direct seeding increase, yes but pays application of fertilizer and chemicals by contract labor, so job is done faster, usually less than 8 hours of the whole day for Pesos 30.00/day.

Table 15. Summary of *mean* returns *above variable cost (pesos/ha)* of irrigated and rain-fed crops

	Rice		Mungbean		Hybrid		Native		Garlic		Onion	
	1987	1988	1987	1988	1987	1988	1987	1988	1987	1988	1987	1988
Irrigated crops												
LVRIS	6890	5807	5493	3865			-	-	8123	400[illegible]	-	-
BP#2	5630	5656	3404	6185			-	-	9060	724[illegible]	-	-
TASMORIS	4374	4930	4 2	-404	4371	7572	-	-	-	-	-	-
UTRIS	8185	6463					-	-	-	-	1676[illegible]	1108[illegible]
ARIP	6021	7120				3288	-	2488	-	-	-	-
BARIS	5657	6240			3282	5309	3152	-	-	-	-	-
Rain-fed crops (within or near the systems												
						-	-					
						-	-					
TASMORIS					1407	-	-					
UTRIS						-	-					
ARIP						1993 1993	- -	2187				
BARIS					1815	3332 3332	2041 2041	3142	-			

Source: Adriano (In Valera 1989)

PROFITABILITY

Another issue which farmers have to face in order to diversify is the profitability of the crop to grow. It has been known that if water is sufficient to support a rice crop, then low resource farmers will certainly plant rice. But in areas where water is limited during the dry season, it is a choice between planting nonrice crops or fallowing. Again, if credit is available, farmers will plant nonrice crops. But due to high input and labor costs, especially for garlic and onion, farmers may plant only a small portion of the field and rent out the other portion. In extreme cases where seasonal farmers are not available, that portion remains unplanted.

Garlic and onion are the most profitable crops planted by farmers. In LVRIS and BP#2 the net returns to garlic is twice as much as the net returns to rice in the dry season (Table 15). Onion farmers in UTRIS had a net income per average harvested area that was three times as high as that of rice farmers in the 1988 dry season, although most farmers planted both crops. In the 1989 and 1990 dry season, rice had a higher net income per average area harvested (Table 16 and 17). As perceived by farmers, this is due to a decline in the yield and price of onion brought about by a hailstorm in the middle of March 1989 and by a virus infestation in 1990. These affected the quality of onion produced and hence lowered its price.

Irrigated corn in TASMORIS had a higher gross return than rice in the 1988 dry season (Table 18). In all the other systems being studied in the 1987 and 1988 dry seasons, other crops except garlic and onion had lower net returns compared to rice (Table 15). In LVRIS, the upstream farmers had relatively higher yield than the downstream farmers (Table 19). With regard to farm income per hectare, rice farmers in the head got significantly higher income per hectare than rice farmers in the tail section of the system. Garlic and mungo farmers have the same farm income per hectare irrespective of location/distance of the rice field to the water source (Table 20).

Table 16. ***Relative costs and*** return to *onion* production: ***UTRIS, dry seasons, 1988, 1989,1990.***

Inputs	Year		
	1988	1989	1990
	Pesos/ha		
seeds*	6087.04	524839	2561.89
Fertilizer	2470.71	2901.36	2984.77
Insecticide	715.33	532.45	563.48
Herbicide	262.08	392.61	348.84
Rice straw	141.67	800.00	680.23
Labor cost	7629.80	791257	6609.23
Irrigation fees	367.20	39720	464.68
Land rent	4960.10	5055.22	1728.48
Total	22633.93	23239.80	1594232
Average yield (kg/ha)	9063.00	6796.05	6918.67
Gross income (Pesos/ha)	71751.00	43226.39	26041.89
Net income (Pesos/ha)	49117.07	1998659	10099.57
Average area harvested	0.49	0.65	0.66
Net income per average harvested area [Pesos)	24067.36	12991.28	6665.72

* By 1990, *very* few got loans in terms of seeds; they get loans m cash and pay for the seeds. What they get in kind are fertilizer and chemicals, especially those who are members of cooperatives.

Table 17. Relative costs and returns to palay production: dry season 1988, 1989 and 1990

Inputs	1988	1989	1990
	Pesos/ha		
Seeds	644.20	936.87	718.79
Fertilizer	1149.53	1130.79	1090.10
Insecticide	351.96	135.62	262.26
Herbicide	80.57	45.76	61.96
Rice straw			
Labor cost	3743.00	5388.81	3266.086
Irrigation fees	612.00	584.67	590.25
Land rent	1707.83	3347.02	1248.01
Total	8289.09	11569.54	7237.456
Average yield (kg/ha)	3967.00	5052.50	4627.73
Gross income (Pesos/ha)	13863.00	21870.41	23754.13
Net income (Pesos/ha)	5573.91	10300.87	16516.674
Average area harvested	1.43	1A6	1.36
Net income per average harvested area (Pesos)	7970.69	15039.27	22462.68

Table 18. Total yield, average price and gross returns of fums *in TASMORIS, 1986/87 and 1987/88 dry* seasons.

	1986/87			1987/88		
	Total yield (kg/ha)	Price Pesos/kg)	Gross returns (Pesos/ha)	Total yield (kg/ha)	Price (Pesos/kg)	Gross returns (Pesos/ha)
Irrigated rice	3165	2.84	9131	2814	3.15	8856
Irrigated corn	2361	3.63	8557	3475	3.43	11876
Semi-irrigated mungbean	126	9.13	1241	100	10.00	998
Rain-fed mungbean	207	9.50	1972	124	9.83	1241
Rain-fed corn	1096	4.15	4308	-	-	-

Source: Bacayag (In Valera 1989).

Table 19. Average yield by crop and by location, LVRIS. dry season, 1988-89.

Crop	Head (kg/ha)	Middle (kg/ha	Tail (kg/ha)
Rice			
Total production	4,013.33	2,848.50	2388.35
Garlic			
Total production	1,687.82	2,063.27	1,981.04
Mungo			
Total production	518.25	419.23	396.66

1 ANOV procedure m test the joint hypothesis of differences in means among the three types of farms was significant.
Source: Esteban, Z.H. 1990.

Table 20. Farm income by crop/cropping pattern and by location, LVRIS, dry season, 1988-1989.

Crop/	Head		Middle		Tail	
	Perfarm	Perha	Per farm	Per ha	Per farm	Perha
	(in pesos)					
Rice						
Net cash farm income	1,555.83a	2,851.95a	686.12ab	321.47ab	-351.54b	-900.1%
Net noncash farm income	1,699.47a	1,209.44a	3,311.30b	4,505.52a	1,237.31ac	1,936.77a
Return above variable cost	3,255.30ab	4,061.39a	3,997.42a	4,726.99a	855.7%	1,036.59b
Garlic-mungo						
Net cash farm income	9,519.88ab	52,852.25a	7,149.36b	52,930.24a	12,619.50a	63,200.47a
Net noncash farm income	3,589.19a	24,415.91a	4,995.17a	44,700.68b	4,191.43a	23,476.87ac
Return above variable cost	13,108.27a	77,268.16a	12,144.52a	97,631.02a	16,810.94a	86,677.34a
Garlic						
Net cash farm income	9,244.73ab	51,542.46a	7,011.00b	52,483.80a	12,233.33a	62,480.48a
Net noncash farm income	3,674.23a	25,266.96a	4,884.26a	44,395.27b	4,373.54a	24,451.97bc
Return above variable cost	12,918.96a	76,809.41a	11,895.26a	96,879.07a	16,606.87a	86,932.45a
Mungo						
Net cash farm income	274.35ab	1,309.79a	138.77b	446.54a	386.18a	719.99a
Net noncash farm income	-85.04a	-851.05a	110.90b	305.41b	-182.11ac	-975.11ac
Return above variable cost	189.31a	458.75a	249.26a	751.96a	204.07a	-255.11a

[1] ANOV procedure to test the joint hypothesis of differencesin means among the three types of farms was significant.
Means by type of farms followed by the Same letters are not significantly different.
Source; Esteban. Z.H. 1990.

Water **use *efficiency.*** It has been found that upstream farmers use more irrigations than downstream farmers without a significant yield advantage. Tables **21 to** 23 show farmer yields by distance from irrigation canals and frequency of irrigation. There is no significant yield difference between farmers with **5-7** irrigations and those with more than 7 irrigations. In this case the potential for water use efficiency is high. One measure to **increase** water **use** efficiency for the head or upstream farmers is to alter irrigation fee payment based on actual **use** instead of **using fixed** rates. Further down the lateral, farmers use supplementary irrigation from shallow well pumps. Pump **users** ought to be efficient in their water **use,** applying only a maximum of four irrigations (Tables **24** to 26), and still get a comparative yield with those having more irrigation coming from the canal.

Table 21. Dry-season onion: Frequency of irrigation and distance from irrigation canals, UTRIS, 1988.

Lateral	Distance from irrigation canal	1	2		6	7	8	9	10	11	12
B	Near	1	1								
	Far	3									
MCs	Near			1(10838)			1	1(8936)	1	1	
	Far		1	2			1(9853)	B			

( ) mean yield

Table 22. Dry-season onion: Frequency of irrigation and distance from irrigation canals, UTRIS, 1989,

Lateral	Distance from irrigation canal	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
A	Near	1(5800)														
B	Near			1	2	1(8174)										
	Far	1	1	2	2	1(9903)										
MCs	Near		1		1	1(8649)		1		1	1	,	1	3	1	(7267
	Far		1		(7328)1	1					1	1	(5408)			

( ) mean yield.

Table 23. *Dry-season onion:* Frequency of irrigation and *distance from irrigation canals: UTRIS,*

Lateral	Distance from Canal	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
A	Near			1(10095												
B	Near	1		1(10095												
	Far	1		2	1	!(13528)a										
MCs	Near					1(7905)b			1(7382)							
MCs	Far	1				1	1	1(4887)		2	1	2	2	1(7236		
	Far	1					1	1	8179)2	!(6270)			1(10095)			

( ) mean yield.
[a] one farmer with pump.
[b] with pumps.

Table 24. Frequency of supplemenfay irrigation using pumps, *UTRIS* 1988, *dry season*.

Proximity to irrigation canal	Lateral B					
	0	1	2	3	4	5
Near	4		2			
Far	1		1	1	2	

Table 25. Frequency of supplementary *irrigation* using pumps, *UTRIS* 1989 dry season.

Proximity to irrigation canal	Lateral B					
	0	1	2	3	4	5
Near	4	1	-	-	-	-
Far	1	1	3	1	-	-

Table 26. Frequency of supplementary irrigation using pumps, UTRIS 1990 dry season.

Proximity to irrigation canal	Lateral B					
	0	1	2	3	4	5
Near	3				1	
Far	3	1	1		1	

* Two farmers do not farm in B anymore (seasonal). Their farms in Lateral B are actually owned by P. Manzano, another cooperator.

SOCIAL ISSUES

Farmers' participation in planning and scheduling of water distribution is a key factor in a successful irrigation system management. The National Irrigation Administration (NIA) recognizes this, so that whenever possible they organize "Irrigators' Associations" in almost all national and communal systems in the country. Tables 27 and 28 provide a listing of Irrigators' Associations organized in UTRIS and LVRIS. They also show the year each was organized, number of members and area served. Cablayan et al. (1989) found that Irrigators' Associations have been helpful not only in smooth and satisfactory water distribution but also in collecting irrigation fees. The 1990-2000 NIA corporate plan showed a current account collection of 39.72 percent and a 50.87 percent total collection (Table 29). In UTRIS, payment of irrigation fee is from 40 percent to 50 percent with more farmers further from the canal paying the fees (Table 30). Wickham (1973) showed the same trend and the logical reason is to ensure timely and adequate water supply. Farmers near the canal or water source can get water even if they do not pay their irrigation fees, so fanners further from the canal in effect bear the burden of irrigation cost while at the same time receiving less benefit from the system (Pingali et al. 1988). Although it is difficult to achieve equity in water use, it seems that there is a chance to improve irrigation fee collection efficiency. If farmers near the canal can be made to pay irrigation fees, by altering or changing the irrigation fee payment structure, then the efficiency of water use at the upstream section could be increased. An Irrigators' Association may help in this activity, but in some cases, although a collective action is desirable sometimes it is not usually feasible. Organizing farmers further from the water source where there is not enough water during the dry season will prove futile. The best these farmers can do is to invest in shallow well pumps.

Table 27. Organized farmers irrigators' associations. Upper Talavera River Irrigation System, Upper Pampanga Integrated Irrigation Systems, Central Luzon, Philippines.

FIA Name	Canal/lateral	Members	Area (ha)	Year Organized
San Agustin IA**	SAE	546	776	1979
Cristamakita IA*	Main canal	604	691	1982
Catanaca IA*	Lateral B	218	212	1986
Tusita IA***	Main canal	241	339	1984
Camacalo IA***	Main canal and Lateral C	335	437	1984
Dalangirin IA***	Drainage reuse anc Lateral E	140	194	1984
Sto. Pag-Asa	Main canal and Lateral F-Extra	183	356	1990
Sitosan IA	Laterals F and F1	139	288	1990
CSSR IA	Laterals D, D1 and D2	228	336	1990
Dica IA***	Laterals D and D3	321	446	1984
Talipa IA	Laterlas D and D4	213	331	1990
Total		2,054	2,812	

* R gi d with Securities and Exchange Commission and have ISF collection contract.
** Registered with Securities and Exchange Commission and have both ISF and canal maintenance contract.
'R[illegible] i[illegible] and reactivated in 1990

Source: Cablayan, et al. 1990.

Name of IA	Location	Area covered (ha)	No. of farmer-members	Year organizesed/ registered
Degulla-Bubuisan Sonson-Narpayat IA	Lateral A	82	160	1982
San Roque-Lubnac IA	Lateral B	64	112	1982
Labasa IA	MC downstream Laterals E, G, F and H	1967a	14472	1979
Total area under IAs		2113	14744	

* Distributed by division as follows: Division 1 - 248 ha; Division 2 - 685 ha; Division 3 - 381 ha: and Division 4 - 653 ha

Source: Cablayan, et al. 1990.

Table 29. Irrigation fee collection and collection efficiency, 1979-1989.

Year	Total Collection (M)	Back Account collection as% of back account collections	Current account collection as % of current account collectibles	Total collection as % of current account collectibles
1979	43.35	4.94	31.53	41.50
1980	59.24	4.99	38.29	53.25
1981	52.74	3.86	35.60	44.89
1982	58.43	3.97	44.26	55.94
1983	72.72	3.65	41.57	53.13
1984	98.95	4.75	42.95	55.76
1985	143.28	5.36	39.85	49.19
1986	179.90	4.44	40.28	50.79
1987	173.97	3.34	40.89	51.75
1988	181.79	2.48	39.14	48.65
1989	213.83	2.92	42.60	54.75
Average		4.05	39.72	50.87

Source: NIA, Corporate Plan, 1990-2000.

Table 30. **Payment** *of irrigation fees.*

Distance			D				Wet Wet			
	Paid			Not paid			Paid		Not paid	
	88	89	90	88	89	90	18	89	88	89
Lateral A Near	1	0	0	2	2	3	0	1	2	1
	2	2	0	2	2	4	1	0	3	4
Lateral B Near	2	1	I	4	4	3	I	I	2	2
	3	1	2	2	5	1	3	1	5	3
Lateral B Near	3	0	I	5	1	9	2	2	8	8
	3	2	3	1	4	4	2	4	4	3
Total	14	6	7	16	21	24	0	9	24	21

SUMMARY AND CONCLUSIONS

A change in the cropping pattern of farmers under an irrigated environment is hindered by factors as soil physical constraints, credit support facilities, and labor availability should farmers expand areas for nonrice crops. These constraints vary to some degree from irrigation system to system in the country. Government intervention in policies and support services governing credit constraints in the countryside will definitely help farmers meet their financial requirements in planting nonrice crops. Farming equipment and tools designed for nonrice crops are a welcome development when labor becomes a critical constraint in expanded areas of crop diversification.

Profitability issues between rice and nonrice crops somehow hide the real issue of water scarcity during the dry season. Although it is important to know which crops are more profitable than rice in specific areas or systems, all other crops planted by farmers during the dry season are still profitable relative to a rice-fallow pattern. Therefore, it is imperative for fanners to plant during the dry season because sources of nonfarm income in these areas like cottage industries and other livelihood programs may not be able to accommodate all farmers.

Irrigators' Associations, as envisioned by NIA in solving water scheduling and distribution issues at the farm level, have for some years now contributed to a smooth and better management of irrigation water, as well as in irrigation fee collection. Sustaining an Irrigators' Association, hence, needs constant advice and follow-up in order not to fizzle out, so that reorganization will not be necessary. In

some cases, organization of Irrigators' Associations is somehow not possible (like when there is practically no water to manage), which usually happens in the tail section of the system during the dry season. As such, while collective action is desirable, it is just not feasible.

Some 40 to 50 percent of the farmers pay irrigation fees, most of whom have farms further from the canal. They have to pay to ensure timely and adequate water supply for crop sustenance. In contrast, farmers near the canal can easily get water resulting in inefficiency of water use. Altering the irrigation fee payment structure to reflect the number of irrigations as the basis rather than the fixed rate, may increase the efficiency of water use in the upstream area of the system. In effect, more water will be available downstream, increasing the area irrigable during the dry season.

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Summary/Highlights of Discussions: Socioeconomic and Institutional Issues

MR HAKIM DISCUSSED the socioeconomic and institutional issues in irrigation management for rice-based farming systems in Bangladesh. He emphasized the substantial improvement of the irrigation system through improved management. The improved management should involve willing and active participation of irrigator farmers and irrigation managers.

The results of the pilot experiment on the management approach for irrigation management in Indonesia were presented by Dr. Vermillion. For the approach to be sustained by the implementing agency, it must be reoriented toward a "need to manage" mode which is based on an institutional imperative to clarify objectives and achieve results.

Mr. Masicat provided a synthesis of the Philippine studies, examining the constraints to diversification from irrigated rice production. He addressed the basic issues related to the physical and socioeconomic constraints to diversification from rice, the relative profitability of nonrice crop production, and the social issues in managing irrigation systems with crop diversification during the dry season.

The discussions that followed highlighted the following points:

1. Irrigation Service Fees. The distribution cost in tubewell systems in Bangladesh is paid by the farmers. The irrigation fee paid by the farmers covers the whole capital cost although at a subsidized rate. This is particularly true in systems managed by the private owners. The farmers themselves do the distribution but sometimes hire other people to do the job.

   However, in the study area in Bangladesh, most of the irrigation systems, even the sample tubewells, are still mostly managed by the government. As a supply-oriented system, the idea is for the system to supply irrigation for rice. About 75 percent of the systems is for rice irrigation, but steps are also being taken to utilize them for other crops.

   The suggestion of altering the irrigation fee with respect to the number of irrigations may be ideal but the problem is how to monitor the number of irrigations provided to the individual farms on a system-basis. The farmers can irrigate at night which makes it difficult for the irrigation staff to monitor them. In this regard, other ways and means should be sought to better manage the system so that irrigation efficiency can be improved.

2. Accountability of the Agency to the Fanners. Farmers' lack of participation may be related to the accountability of the management to the farmers. Financial autonomy with direct involvement by the farmers can bring in accountability by the agency. When irrigation fees are collected, the irrigation managers become accountable when these fees are used for operation and maintenance of the system and for sustaining its functionality.

   When farmers pay their irrigation fees to the public enterprise, it becomes binding to the agency to supply water for their crops in the field. For example, if the farmers pay their fees to the Bangladesh Agricultural Development Corporation, it must make sure that the water gets in, at the time of farmers' need.

3. Farmers' Participation. There was a great concern on whether farmers' participation in irrigation management was for the benefit of the agency or for the farmers themselves. With participation, the farmers are asked to pay more for the irrigation service, assume greater responsibility to organize and perform O&M tasks, and provide morefeedback to the irrigation officers. Although farmers are asked to do all these they may not always bring in benefits to them. For instance, in the Rajshahi area, the farmers were participating and doing what they understood was the basis of the administrative process but the O&M cost was just as high as in the other systems with a lower level of participation. The benefits that could be derived by the farmers seem to be mere statements of hope without concrete evidence.

   In the Rajshahi area, there is some evidence showing that interaction results in better management. The water productivity was much higher than in the G-K and the North Bangladesh Tubewell projects. It should be noted, however, that in the Rajshahi area, only one of the four categories of sample wells was directly managed by the agency, i.e., the Bangladesh Agricultural Development Corporation. All the others were managed by the farmers who pay for the tubewell. In the other systems, the agency bore all the O&M cost and the farmers paid only a very minimal irrigation fee. When farmer users pay more for water, they usually have more interaction among themselves which can increase productivity.

   Farmers' participation provides better communication with the agency managers. They should be able to tell the agency their problems by communicating in a regular manner. It can serve as a means by which the farmers can be assured of water supply. It should, however, be participation by the majority of the fanners and not just by a few.

   In the G-K Project, the action research on rotation which involved farmers' participation and communication enabled more water to reach the tail-end farms, more farmers to get water, and more equitable water sharing.

4. Support Services and Agency Linkages. Linkages or networks with other agencies are also necessary to improve irrigation management as these relate to other support services such as credit, markets, etc. In the Rajshahi area, the Agricultural Development Bank is already participating in financing the irrigation O&M costs and in some cases, the production cost of the farmers. In the G-K Project, credit, extension and irrigation management are already built-in into the system. Outside the study area, there is the Bangladesh Rural Development Board which also provides support. In the famous "Comilla" model, the support services are built-in into the system.

   The IIMI-IRRI Project has provided the interagency linkages which may have contributed to the effective implementation of the research and pilot testing of improved innovations on irrigation management. The issue now is the institutionalization of the introduced innovations, i.e., whether the agency and the farmers can sustain the innovation after the completion of the project.

5. Factor K. Factor K is a modification of the earlier traditional system known as the *pasten* system. The pasten system was developed during the colonial period for assessing the irrigation requirement and water supply for rotation between commercial crops like sugarcane, rice and other nonrice crops. Factor K is a coefficient at the level of the system of diversion which compares the irrigation demand for the entire system with the supply entering the system at the point of diversion. A factor of 0.6 means that 60 percent of the water requirement is available. In general, rotation is initiated when at one level, the factor drops below point 6. Another level of rotation is done when it drops below point 4.

6. Agency Plan versus Farmers' Choice. It seems that the IIMI-IRRI Project in Indonesia is coming out with an endorsement of a crop plan and crop targeting as a means of diversifying from rice. This would appear to go against individual crop choice and individual decision. However, this is a wrong conclusion as the approach simply requires the agency to determine the minimum allocation and supply of water for a given year or season. The agriculture service comes up with a season crop combination advice as to what crop combination can be planted in the field, assuming the predicted water supply is available. The actual crop choice is made by the farmers.

7. Organization of Irrigators' Associations. It was stated that organizing Irrigators' Associations in the tail-end area is not feasible because there is no water anyway. This is the precise reason why farmers in the area should be organized. They have to coordinate with the farmers upstream who get more water.

   Organized farmers have a voting right to form the executive committee which will look after the day-today operations, maintenance and water distribution in the system. The group can also change the committee.

8. Labor. Looking at the farm-level analysis, it is difficult to conclude that labor is a constraint when moving from rice to nonrice crops. It is true that there are labor peaks and the demand can be high when it comes to nonrice crops but, without taking the system as a whole and analyzing the supply pattern, it is not safe to conclude that labor is a constraint. This can be true for a small area and where the opportunity cost of labor in the rural area is approaching zero, which means that there is a lot of scope for labor demanding activities.

   As observed in the field, there are more transient workers during the peak of field operations. If the area for crop diversification is expanded, labor will become scarce. For example, for onion about 300 man-days per hectare are needed.

   The thinking that the opportunity cost of labor in the rural areas is near zero is not true. There are few slack months, but during the cropping season when the main activities are going on like transplanting, weeding, and harvesting, labor becomes very scarce. In the Philippines for example, there is a lot of unemployment but this is usually in the city, but not in Central Luzon. Based on a general equilibrium and more sector-level analysis of labor supply and employment patterns, it is shown quite clearly that there is a labor constraint when shifting the demand for labor from a rice-only system to a rice-nonrice system.

   Labor availability as a factor in crop diversification can be studied at the level of the farmers themselves. Farmers tend to adjust. For example, if the labor and cost of producing onion is four times the cost of producing rice, the farmer usually tills only a portion of the farm for onion and still uses the same resource.

SECTION IV

Synthesis Papers

Main Irrigation System Management for Rice-Based Farming Systems

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INTRODUCTION

THE DECLINE IN the profitability of rice production and the resulting decline in the income of rice farmers have been attributed largely to the success of the rice seed fertilizer technology and the rapid expansion of irrigated areas since the mid-1960s. Due to conscious government initiatives to expand rice production, irrigation systems have been built in the humid tropics of Asia to provide a more reliable supply of water during the wet season for the cultivation of rice under wetland conditions. Except for systems provided with storage facilities or those pumping from groundwater sources, irrigation during the dry season is a secondary consideration. In most cases, the reduced water supply is used to grow an additional crop of rice on a more limited area.

By the middle of the 1980s, governments and international agencies tied to encourage farmers to turn to nonrice crops to increase their incomes as well as to stabilize the price of rice. However, due to lack of experience in managing irrigation for nonrice crops, irrigation agency staff tend to continue to plan and implement rice-based operation schemes. This is true in the Philippines and Bangladesh and to a much lesser degree in Indonesia (Java) where the cropping intensity observed is highest and where the third cropping (second dry season) has been decreed by the government to be devoted only to the cultivation of nonrice crops. Rice, however, is still being grown in the poorly drained low-lying areas where the groundwater table is high.

The need is obviously not to displace rice — for which the demand continues to grow with increasing population — but to find better ways to grow other crops in association with rice, particularly in areas of imgation commands suited to diversified crops during the dry season when water becomes the scarcest resource. The need is to provide options for farmers to grow more profitable crops as determined by market forces in which they could have a comparative advantage.

Among the key issues to be addressed in this regard is the development of imgation management procedures in terms of management skills, as well as the appropriate use or modification of the existing facilities for controlling the water resource to enable the flexibility of incorporating changes in the farming systems in the service area.

This paper provides a synthesis of the main irrigation system management issues for rice-based farming systems while recognizing their strong relationship with on-farm level, socioeconomic and institutional concerns. The presentation is divided into significant findings discovered or verified under the Project and recommendations that are either already utilizable or still subject to further study. These are gleaned from three stages of research effort: a) gaining an understanding of current and informal practices; b) problem identification, which included suggestions to overcome the diagnosed management constraints; and c) pilot testing of suggested or revised procedures or innovations intended to lead to improvements in irrigation performance with respect to reliability, equity, productivity and sustainability objectives.

CHARACTERISTICS OF IRRIGATION OPERATIONAL OBJECTIVES

To put the significant findings and recommendations in their proper perspective, the primary characteristics of the irrigation operational objectives in the three countries are compared below:

- The intensity of operational planning, implementation, monitoring and evaluation of plan varies across the three countries and sites within each country.

- The pasten method of irrigation planning in Indonesia that aims at calculating overall water supply and actual field-level demand every 10 or 15 days, leading to revision of target discharges at every structure and every tertiary block during each time period is the most complex method currently used.

  While there is an implicit aim to match water supply with water demand considering soils and crop requirements, the methods applied in the Philippines and in Bangladesh are much simpler and less rigorous than those applied in Indonesia.

- The standards for irrigation structures, in comparison, are most sophisticated in Indonesia where the aim is to provide control of water and associated facilities for measurement of discharge at every division structure and offtake of the system.

- In Indonesia, the annual and seasonal planning procedures that survey probable farmer crop choices and compare the choices with the provincial and national objectives to come up with a detailed irrigation plan for each tertiary block, are not practiced in the Philippines and in Bangladesh.

- The systems in Indonesia and in the Philippines are of the run-of-the-river type while those in Bangladesh are of the lift-from-the-river and deep tube well pumping types. The type of system influences the availability of water and consequently, the water delivery and distribution schedule.

SIGNIFICANT FINDINGS

1. The active involvement of farmers in irrigation operational planning, implementation, monitoring and evaluation has the potential for enhancing system performance as verified by pilot testing of improved management procedures in all three countries. It could result in better sharing of water and increased irrigated area.

2. Rotational irrigation is emerging as a key irrigation practice resorted to when total water supplies are inadequate to operate the system and still maintain proper hydraulic conditions at each control structure. This is done for both rice and nonrice crops. The level of rotation which can be below or at the tertiary, secondary, or along sections of the primary canal, depending upon the nature and the severity of the water shortage, needs some further rationalizing to improve equity and reliability of water delivery. The notquite-satisfactory weekly rotation being implemented in Indonesia and the Philippines and the 9- to 10-day rotation in the G-K Project in Bangladesh are indications in this regard. Developing new rotational plans is a gradual process involving negotiation and testing.

3. Regular meetings between the irrigation staff and farmer leaders during the implementation of the plan such as after each water rotational delivery proved to be effective in improving communication between them and in identifying specific water problems and their solutions at the secondary and tertiary levels. This was observed during the pilot testing of certain agreed irrigation managment innovations in the three countries.

4. Reliability of water delivery according to a predetermined rotational schedule is considered of paramount importance to a farmer who grows rice but more so with nonrice crops since he has to be present to receive and apply the water to his fields. Unreliable water supply served as a disincentive for the farmer by increasing labor costs because of the additional time he spends in waiting for the water which reduces opportunities for off-farm employment. His anxiety is also increased because of the risk of losing his heavy investment on cash inputs and labor, resulting from reduced crop yield if he does not get his water supply on time.

5. Irrigation systems properly designed and constructed for implementing irrigation for wet-season rice which can meet the land-soaking and land preparation requirements have enough canal capacity for the intermittent flow of water needed for irrigating nonrice crops, although the need for greater canal-water regulation is apparent. Moreover, the "free board difference of 10 percent normally added to the design depth for typical canal cross sections enables the accommodation of an increase in the hydraulic head and in flow area. Among crops requiring the greatest increase in hydraulic head at the turnout level is tobacco when irrigated by plot-to-plot flush-basin flooding as reported in SFRIS in the Philippines.

6. Inequity of water delivery between head and tail sections of the system is observed with the head having better access to the supply. The causes are managerial, physical and social. There is, relatively, a lack of accountability and motivation among irrigation staff due to weaknesses in the management system, especially in performing monitoring and feedback for the decision-making process, interferences of influential people, etc. Func-

tional flow-regulating and measuring facilities are often lacking if not missing, and the physical system is also often poorly maintained and in deteriorated condition in many parts. Many farmers tend to be uncooperative, probably because of their noninvolvement and lack of appreciation for and trust in system management.

RECOMMENDATIONS FOR CHANGES IN MAIN IRRIGATION SYSTEM MANAGEMENT

1. Involvement of farmers and farmers' organizations as early as the planning stage should be institutionalized to minimize problems during implementation. Active participation of farmers in decision making and managing of the system increases their awareness of the system's capabilities by helping them undestand the plan and the reasons for actions taken. This could give them a sense of commitr ent to abide by the plan.

2. Regular meetings between the irrigation agency staff and farmers or their representatives should be instituted to serve as a means for monitoring the operations of the system. The meeting could provide the needed feedback mechanism to make the schedule more realistic and to settle conflicts in water distribution, if any.

3. Rotational imgation should be introduced when required for hydraulic reasons. The area planned for imgation for each day has to take into account the ability of the irrigation staff to maintain control of the structure to delimit the rotational boundaries. The system of rotational units should aim at maximizing equity by taking into account travel time, conveyance losses and other hydraulic conditions. Once agreed upon and published, rotation schedules must be strictly followed so that farmers can have confidence in obtaining water according to the priorities already established. A priority system that guarantees water to a certain area but specifies which areas would get water in excess of what is expected could be used within season scheduling of rotational imgation.

4. In managing water during the wet season, irrigation releases should match the annual cropping plan and avoid excessive releases so as not to adversely affect the dry-season cropping either by delaying the plan for nonrice crops or by encouraging a second rice crop which may suffer from moisture stress with declining water supply during the later part of the dry season. During the wet season, management should be largely geared to responding to excess water conditions, while in the peak of the dry season rotation should be implemented to require the imgation agency to take control at progressively higher levels in the system.

5. The annual planning process should move toward allocating water based on the area capable of being irrigated to minimize discrepancies in cropping intensities between head- and tail-end areas. This would result in the allocation of water on a proportional basis, using areas as the primary determinant rather than the existing cropping patterns. In cases where there are significant deficiencies in soil and drainage conditions, these should be taken into account in modifying the allocation.

RECOMMENDATIONS FOR FURTHER RESEARCH

1. The assessment of both available water supply and water demand needs to be improved to better match the two under-diversified cropping conditions. For nonrice crops during the dry season, the water supply should consider not only canal and drainage flow and rainfall but also subsurface supply from the moisture stored in the soil profile and from the contribution of the groundwater table. There is also the augmenting supply from shallow tube wells put up by farmers to increase the reliability of their water supply as observed in the tail-end sections of the MIS in Java and UTRIS and SFRIS in the Philippines. On the water demand, outside of improved mapping of areas and soils and determination of actual canal conveyance losses, more information needs to be collected periodically in the field on the type, extent and growth stage of nonrice crops. The latter could be facilitated with better organized farmers' participation in the joint management of the irrigation system. It could also be simplified by trying the Seasonal Advised Crop Combination (SACC) as a standing guideline for coordinating crop combinations as proposed in Indonesia.

2. The pilot testing of irrigation management innovation methodology, with a view of institutionalizing the management changes in both the irrigation agency and the farmers, needs to be evaluated and fine-tuned in terms of its suitability for it to become a foolproof and effective process.

SUMMARY

The results of the three-year project have shown a number of management options and strategies which could enhance the performance of irrigation systems for rice-based farming systems. These are either new findings or verified strategies, all amplifying the different considerations that have emerged from earlier studies on irrigation management for rice-based cropping. As indicated in the final report on a study on irrigation management for diversified crops in the Philippines, the following points should be considered:

1. Activeparticipationoffarmersindevelopingannualandseasonaloperaing plans and in implementing agreed delivery schedules.

2. Reliable and equitable allocation and delivery schedules based on good match between estimated water supply and crop water demand.

3. Improved monitoring and communication of the implementation of actual water deliveries.

4. A dear policy for dealing with deviations from the agreed delivery schedules.

5. Enhanced intensity to achieve these requirements by the management and field operations staff.

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Technical Farm-Level Issues in Irrigation for Rice-Based Farming Systems: An Intercountry Synthesis

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INTRODUCTION

AS FARMING PRACTICES within an imgation system become more diversified, the demand on the management of water supplies assumes a greater degree of complexity. This process is being currently experienced in many irrigation systems in Asia, which were developed primarily for producing two rice crops within the year. But the profitability from rice production has remained low for various reasons in recent years; consequently, the demand to replace rice with cash crops has increased. So has the value of irrigation water. Since the investments in new imgation development are likely to remain low through the 1990s, it is expected that the demand on irrigation water for both rice and nonrice crops within existing irrigation systems will continue to increase during the present decade.

From technical viewpoints, crop diversification or the substitution of rice with other crops is most attractive in areas where the soil is light-textured and controlled imgation water is available. The climatic suitability, of course, plays a crucial role in the selection of crops to be grown. Favored by the physical and climatic factors, about 9 million ha in China have adopted the rice-wheat cropping system (Zandstra 1990).

Quick draining of excess water from the land and good internal soil drainage are desirable requisites to achieve high yields of nonrice crops. Heavy soils can often be used for profitable production of irrigated nonrice crops by appropriately modifying the land for better water control and excess water removal. But economic production of nonrice crops in the dry season is not practicable in many areas with suitable soils if irrigation water is not available. In many such cases, a supplemental source of water, which is often the groundwater, makes the difference between success and failure to grow the nonrice crops in the dry season.

This paper presents a synthesis of chosen technical farm-level issues and relevant findings conducted in three countries — Bangladesh, Indonesia, and the Philippines — through the Irrigation Management for Rice-Based Farming Systems projects. The project was coordinated jointly by IIMI and IRRI, and implemented in collaboration with selected institutions in each country (e.g., Bangladesh Rice Research Institute [BRRI] and Bangladesh Water Development Board [BWDB] in Bangladesh; Agency for Agricultural Research and Development [AARD] and Directorate General for Water Resources Development [DGWRD] in Indonesia; and Philippines Council for Agriculture, Forestry and Natural Resources Research and Development [PCARRD], National Irrigation Administration [NIA], and Central Luzon State University [CLSU] in the Philippines). It was financially supported by the Rockfeller Foundation. The project activities in each country started with the identification of priority local research issues and problems that should be addressed through the project. The identification was achieved in each country separately through small group workshops or discussion meetings at which selected individuals from key national institutions as well as from IRRI and IIMI participated. Some of these resource persons later became active partners in the implementation of the recommended research.

RESEARCH ISSUES AND FINDINGS: SOME COMMON GROUNDS

A common background of the research studies is that they were conducted in areas where rice is the only crop grown in the wet season and the areas were served by gravity-fed surface irrigation systems developed mostly for rice culture. In Bangladesh, the research on the farm-level issues was concentrated in the G-K Irrigation System (GKIS) and the North Bangladesh Tubewell System (NBTS); in Indonesia it was the Cikeusik Irrigation System (CIS); and in the Philippines it was the Upper Talavera River Irrigation System (UTRIS) and the San Fabian River Irrigation System (SFRIS).

The GKIS and NBTS in Bangladesh are somewhat different from the others in that GKIS uses lift-pumping from the river at the headwork, but essentially works like other run-of-the-river or reservoir-supported systems studied in Indonesia and the Philippines; and NBTS is a conglomerate of over 350 deep tubewells each of which acts independently for a command area of 50 ha or less, and in the dry season it is used mostly for wheat irrigation.

A direct comparison of the research findings from the three countries is not appropriate because, as indicated above, the problems addressed in each country are not the same. Despite this limitation, a number of useful common grounds to discuss, based on the research findings and generalizations, may be made from them. It must be emphasized that one must not make too broad generalizations disregarding important biophysical and socioeconomic differences that may exist between the sites where the research was conducted and other regions of the country.

A universal element in the research findings of the three countries is that dry-season water supply for irrigation is much less than the demand, and farmers' cropping decisions as well as the choice of crops are critically influenced by the expected availability of irrigation water. The augmentation of water supplies is, therefore, vitally needed for increasing land productivity in the dry season, especially the lands in the tail reaches of irrigation canals. Figure 1 exemplifies this feature for the Cikeusik Irrigation System (CIS) in West Java, Indonesia.

Research conducted toward this goal presents the following comparative findings:

Conjunctive use of groundwater. Use of groundwater to supplement canal supplies in the dry season was significant in both the Indonesian (CIS) and the Philippines (UTRIS and SFRIS) sites. Through an extensive survey of shallow groundwater use in the Philippine sites, Undan et al. (1990) found that open wells with concrete casings, 0.75 to 1.0 m in diameter and 3.5 to 7.5 m in depth, were used in the tail ends of the irrigation systems to pump water using centrifugal pumps with discharge ratings that ranged from about 19 to 38 lps. The static water table in the wells increased up to about 3.0 m from the surface in April; it was about 4.0 m in the wells of SFRIS area in April.

Figure 1. Discharge per unit area for 4 tertiaries of the middle section, Cikensik Irrigation System, Cirebon, West Java, Indonesia, for 1988 dry seasons I and II.

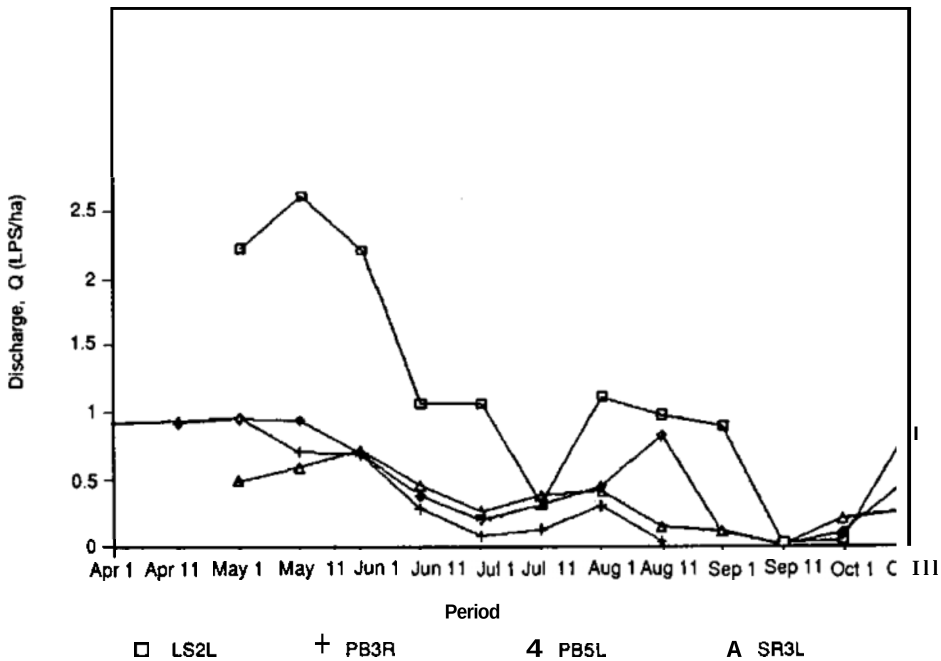

Table 1 gives details of groundwater use to supplement canal supplies in CIS, Indonesia, in the *dry* season. An interesting feature with CIS, which contrasts with the UTRIS or SFRIS situation in the Philippines, is that there is more use of groundwater in the upper reaches of lateral canals than in the tail reaches. This is because the tail areas have more salinity in the groundwater because of their proximity to the coast and some of their lower areas suffer from waterlogging. It is also probable that the high cost of groundwater development and use discourage the tail-reach farmers from investing on wells, as they have to depend almost entirely on pumped water for dry-season cropping. Canal water deliveries to these areas during the dry seasons is very limited (Figure 1).

Table 1. **Groundwater** ***use*** by section **and** by ***season, Cikeusik*** **Irrigation System,** ***Cirebon,*** West **Jaw,** Indonesia, ***1988*** **DS *I* and *II*.**

Item	Head n=26	Middle 2=29	Tail n=24	All farm n=79
Percent of fanners using groundwater				
DSI	23	3	17	14
DS 11	58	52	4	38
Purpose of groundwater use:				
a. To supplement canal supply (%)				
DS I	100	100	75	92
DS II	20	27	0	16
b. For full crop water requirement (%)				
DS I	0	73	25	8
DS 11	80		100	84
Percent of farmers owning the well				
DS I	100	100	25	75
DS II	93	60	0	51
Cost of groundwater use (US$/ha/season)[a]				
DS I	69	45	53	56
DS II	51	58	100	69

US51.00 = Rp. 1800. Only variable costs are included.
Source: Wardana et al. 1990.

In the Bangladesh case (G-K Irrigation System), groundwater use for supplementing canal supplies in the Aus season, or for the winter (Rabi) season cropping is almost nonexistent despite the need and the availability of groundwater in most of its area. The reason behind this situation is the Bangladesh Water Development Board (BWDB) policy which does not allow the construction of tubewells within the service area of their surface water irrigation systems. However, during the past 2-3 years, the Board has relaxed the implementation of the policy and has not been against the use of groundwater by the small number of farmers who have tried it. Clearly, significant benefits can be achieved if this policy is reversed and fanners encouraged to use groundwater. The Rabi season is potentially a very productive part of the year because of abundant sunshine and dry weather, and its fullest possible use should be made for increasing food supplies in the country.

The use of groundwater in the dry season is economically attractive in both the Indonesian and Philippine cases (see Table 2 for the Indonesian example in which the users achieved a much higher gross margin than the nonusers). It is expected that similar groundwater use, especially for the Rabi season cropping, would also be economically attractive to farmers of the GKIS area in Bangladesh.

No study has been conducted in any of the three irrigation systems to determine what amount of groundwater extraction in these areas could be considered sustainable, i.e., the extraction rate which will not initiate a mining effect on the water table due to groundwater withdrawals in excess of the aquifer recharge. However, considering the high rainfall amounts and the vast amounts of surface water that recharge the groundwater aquifers through the unlined earth canal network annually, there should be no major concern about groundwater mining in these systems underlain mostly with unconfined aquifers. In fact, it is expected that greater use of groundwater may help in the control of waterlogging problems in the low areas. Appropriate policies and programs are needed to encourage the use of groundwater in the command areas, especially the tail reaches of these canal irrigation systems.

Use *of residual* soil water. Residual soil water is used in a significant proportion of the GKIS area in Bangladesh for growing Rabi-season crops following Aman-season rice. Wheat, onion, garlic and legumes are the popularly grown Rabi crops with residual soil water. Crop yields vary significantly from year to year due to differences in rainfall amounts (in some years, high rainfall at flowering stage causes yield reduction), planting time (delayed establishment of wheat, for example, is adversely affected by increasing temperatures after February) and inputs used (researcher-managed legume crops have on the average yielded 15-35 percent higher than farmer-managed crops). Table 3 shows the extent of nonrice crop culture in the system during 1983-1990. The number of farmers using residual soil water from a crop did not vary much between 1984 and 1990, but the number of farmers growing the different crops varied widely between years. Kheshari (lathyrus), the most commonly grown crop in the Rabi season, is usually relay-seeded to the rice field a few days before harvesting Aman rice in November, which allows the available soil water to be used for crop establishment. The average kheshari yield achieved by farmers is about 1 t/ha (Mondal et al. 1990). If relay-seeding is not practiced, pregerminated seeds are used.

Table 2. Comparative costs and returns of onion, groundwater users versus nonusers, Cikeusik Irrigation System, Cirebon, West Java, Indonesia, 1988 DS II.

Item	Groundwater		
	Users n=15	Nonusers n=24	Difference
Mean yield (t/ha)	10.74	6.02	4.72***
Total value of production (US$/ha)	2129	I020	1109***
Costs of production (US$/ha)			
Seeds	499	404	95
Fertilizer	144	90	54**
Insecticide	220	113	107**
Labor			
Hired	375	283	92'
Family	207	141	66*
Other costs	107	91	16
Total paid-out costs of production (US$/ha)	1345	981	364**
Total variable costs of production (US$/ha)	1552	1122	430***
Returns above paid-out costs (US$/ha)	784	39	745***
Gross margin (US$/ha)	577	(102)	679**

US$1.00 = Rp. 1800
***, **, * Significant at 1 percent, 5 percent, and 10 percent probability levels, respectively
Source: Wardana et al. 1990.

Table 3. Adoption of different Rabi crops by farmers in the Ganges-Kobadak Project (Phase I), Rabi seasons, 1983-84 to 1989-90.

Year	Percent adoption							
	Kheshari (Lathyrus)	Wheat	Gram	Onion	Pea	Lentil	Oil seed	Total
1983-84	7.3	3.8	0.7	8.4	-	-	1.6	21.8
1984-85	27.8	11.1	5.3	8.2	0.9	-	0.7	54.0
1985-86	22.9	11.1	11.1	8.7	3.3	-	-	57.1
1986-87	9.1	13.6	19.8	8.4	4.2	1.1	-	56.2
1987-88	18.7	5.3	7.3	15.3	2.2	1.8	-	50.6
1988-89	21.0	3.3	16.0	6.9	4.7	-	2.4	54.3
1989-90	13.0	12.3	3.8	15.8	2.3	0.8	2.0	50.0
Mean	17.1	8.6	9.1	10.2	2.9	1.2	1.7	41.9

Source: Mondal et al. 1990.

In contrast to Bangladesh, no significant area is grown to dry-season crops depending entirely on the residual soil water in the case of Indonesian and Philippine irrigation systems. A 1988-89 study looked into the potential availability of residual soil water in the service area of UTRIS, Philippines, for crop use. It was found that in about 40 percent of the nonirrigated, non-waterlogged locations sampled, usable resources of shallow residual soil water existed following the harvest of wet-season rice. In about 25 percent of the nonimgated locations, the perched water table persisted within 10-100 cm depth for more than 20 days indicating the potential of establishing well a leguminous crop such as mungbean (Tenedora et al. 1990). Juliardi et al. (1990) concluded, for the West Java condition, that the yield of shallow-rooted mungbean can be increased by over 30 percent if shallow tillage is practiced.

Irrigation Water Supply Effects on Land Productivity

Land productivity is affected by the availability of irrigation water for all crops grown, rice or nonrice. In an inadequate water supply situation, the crop yield suffers directly from drought stress and indirectly from reduced inputs used by farmers. There may be also a loss of yield due to the interaction effects between stress and other inputs used.

Canal water supply rates to farms are generally inversely related to their distance from the source of water (see Figure 1 for example). This phenomenon was evident in almost all cases that were studied. The Indonesian CIS example has been discussed. A component study in the GKIS in Bangladesh compared the fertilizers used and rice yields obtained by farmers at the head, middle and tail reaches of a main canal during the Aus and Aman seasons of 1986-89 (Bhuiyan et al. 1990). The average rice yield from the 4 Aus seasons was 26-30 percent less in the tail farms compared to the head or the middle farms. The gradient of fertilizer use was likewise steep from head to tail area farms. In the Aman season there was not much difference in yields or fertilizer use because in contrast to the Aus season, when irrigation supply is crucial for good timely crop establishment and growth, the Aman season normally receives high amounts of rainfall. For the same reason farmers used more fertilizers in the Aman than in the Aus season, and the difference was higher for the tail farmers (Table 4). Similar findings have been established in earlier studies in rice in the Philippines.

One approach to solve the problem of low supply of irrigation water at the lower reaches of irrigation canals is to establish better control over the use of water in the upper reaches where much irrigation water is often misused. With implementation of appropriate water rotation methods, improved efficiency of water use and better equity of water distribution among users can be achieved. A study of water rotation for the GKIS, Bangladesh, is currently in progress. However, the cost of sustaining water distribution improvements can be high, which underscores the importance of assessing economic viability of alternative ways of alleviating water distribution problems within various types of irrigation systems.

Table 4. Average fertilizers (NPK) used and rice yields in the head, middle, and fail reaches of the main canal of the G-K Irrigation System (Phase I), Bangladesh, 1986-89.

Location	Aus season Fertilizer (kg/ha) N	P	K	Aus season Yield (t/ha)	Aman season Fertilizer (kg/ha) N	P	K	Aman season Yield (t/ha)
Head, S4K	73.9	41.1	28.1	3.36	106.9	36.4	24.1	4.53
Middle, S9K	70.4	27.2	17.2	3.20	96.0	39.5	25.0	4.16
Tail, S11K	31.9	14.2	6.9	2.36	82.1	44.1	27.8	4.29

Source; Bhuiyan et al. 1990

Crop Water Requirement versus Actual Use

The higher amounts of water required for rice compared to most other field crops is often a dominant reason for promoting production of nonrice crops in the dry season. In the NBTS, Bangladesh, for example, rice culture in the dry season is prohibited and wheat cultivation encouraged because ideally wheat takes about 20 percent or less of the water required to grow rice in the light-textured soils of the systems area. For the same reason, fanners in UTRIS, Philippines, and CIS, Indonesia, are encouraged to grow nonrice crops in the dry season.

But findings of research conducted in 1988-90 through this project indicate that actual use of water by fanners for nonrice crops is far in excess of the actual requirements and in some cases not much different from the amounts used for rice cultivation. In UTRIS, for example, the average water use for crop growth in onion production was almost the same as that used for rice (834 mm versus 877 mm). Likewise, water used for tobacco in the SFRIS was about 80 percent of the water consumed by rice (Tabbal et al. 1990).

The primary reason for the high water use for upland crops is the high water loss suffered in the methods used in irrigating nonrice crops. In certain cases, adoption of effective water conservation measures, e.g., the use of straw mulching in onion fields, will reduce the field water application requirements drastically (by 45 percent for onion in UTRIS) and also give some other benefits such as reduced weed growth. In UTRIS, straw mulching is practiced in areas which suffer chronic water shortage.

The relative high water requirements for rice have put the crop at a comparative disadvantage and in certain areas served with tubewell water, which is much more expensive than canal water, dry-season rice is being replaced with nonrice crops. Since rice price is expected to continue to be controlled by the governments of the major rice-consuming nations in Asia, continued shifts from irrigated dry-season (when rice productivity is higher than in the wet season) rice to nonrice crops may create a significant decline in rice production.

A desirable solution to this problem is to develop techniques of water management that will reduce water consumption in rice and make rice production more competitive with other crops. Some progress has been made in that direction. Recent research in farmer fields in the Philippines indicates that in clay loam soils with the water table **1** m or deeper, improved techniques of water management aimed at percolation loss reduction will save 25 to 55 percent of water from the amount needed in the standard practice, without sacrificing yields or needing additional weed control measures (Soriano and Bhuiyan **1989).** Similar studies conducted in the GK Irrigation System area in Bangladesh produced comparable results. In the North Bangladesh Tubewell System area, where many farmers have recently abandoned wheat cultivation (apparently because of economic disincentive) and have been keeping some of the previous wheat-growing land fallow, there is a great pressure on the system to deliver water for rice cultivation in the dry season. Water-saving rice irrigation techniques and suboptimal irrigation for rice may become attractive options for that situation.

Water Control, Land Use Efficiency, and Drainage

In areas with adequate supply of irrigation water, farmer's choice of dry-season crop is influenced by the degree of control over excess water that can be economically established on the farm. In certain situations, farmers seem to have no choice but to grow rice because neighboring farms are grown to rice, or because the area has a very shallow water table contributed by seepage and percolation water from the irrigation canals and from neighboring imgated rice fields. Appropriate land surface modifications can alleviate the excess water problem, but usually with a significant proportion of the land used for the purpose and at high costs because they are seasonal and have to be undone for the wet season rice cultivation. In a general sense, a relevant question is: how compatible is nonrice crop cultivation in an imgation system developed primarily for rice and what may be the desired modifications for improving compatibility? Some authors have recently recommended that rehabilitation or upgrading of rice irrigation systems would be necessary to make them suitable for large-scale crop diversification.

Irrigation infrastructure compatibilrty between rice and nonrice crops. Research conducted in two diversion type rice irrigation systems in the Philippines (UTRIS and SFRIS), in which both rice and nonrice crops are grown in the dry season, concluded that the canal network facilities of well-functioning rice irrigation systems can adequately support the water delivery needs of both rice and nonrice crops in the dry Season without any redesign or upgrading specifically for that purpose (Bhuiyan **1989).** At the farm level, water control, distribution, application and drainage functions for nonrice crops may require some facilities, mostly in the form of channels, additional to those in existence for rice culture for specific nonrice crops (such as tobacco) which are normally handled by the farmers adequately. These additional facilities are seasonal and erased out in the beginning of the wet season to release the occupied land for rice cultivation (Tabbal et al. 1990).

Land ***use efficiency.*** In UTRIS, Philippines, onion is grown after rice keeping the rice landscape and size essentially unaltered, but adding some special water control facilities such as interceptor channels to protect the field from seepage water from an adjacent canal or farm ditch and mid-rice field drainage channels for quick removal of extra surface water after application. Irrigation water is applied using the basin-flushing method at 1-to 2-week intervals (less frequent irrigation if straw mulching is used). The extra water control facilities normally use about 15 percent of the rice land (Tabbal et al. 1990). In contrast, the Maneungteung Irrigation System (MIS) farmers in Indonesia lose 25-30 percent of their land from production in order to construct the high beds and deep trenches on the rice field to grow onion or chili following wet-season rice. The beds are usually 1.2-1.4 m wide and the trenches are about 50-cm deep and 40-cm wide, which are kept filled with imgation water up to about 25-30 cm from the bed surface. All crop establishment and crop husbandry operations as well as irrigation applications, done at least once daily, are done manually from the trenches. These trenches are again filled up when rice is grown on the fields.

The Philippine (UTRIS) method of onion cultivation was tested through a farmer's field experiment in two seasons of 1988-89 in the clay loam soil of the MIS area. The findings show that significantly higher land productivity can be achieved without constructing the trenches than with the trenches, when irrigation is applied at 4- or 6-day intervals (Setio Budi et al. 1990). The yield per unit cropped area (With only the bed area counted) was higher in the traditional Indonesian model which received daily irrigations, because the amount of land savings achieved in the UTRIS model was significant. There is potential for greater gains if the yield per unit cropped area in this model of onion culture could be increased, which should be expected with experience. Another major advantage to be reaped from using the UTRIS model is the reduced cost of production due to savings in labor input, especially the labor for irrigation.

Drainage and water table management. The prospect of drainage water reuse has been studied in the G-K Irrigation System in Bangladesh to extend the benefit of irrigation to adjacent rain-fed or poorly irrigated areas within the system's command. Drainage discharge measurements were made in a selected major drain during 1988-89 and it was estimated that an additional area of 1,225 ha could be irrigated during both the Aus and Aman seasons if the drainage outflows were checked by an appropriate structure and the water lifted by pumping (Islam et al. 1990). The authors reported that several check structures that were initially provided for drainage reuse at other points within the system have fallen to disrepair and disuse.

In UTRIS, the Philippines, it seems that there is a similar scope for drainage water reuse, 'especially the excess outflow at night, but no study has been undertaken to establish the extent of the scope or its viability.

The challenge of managing a high water table contributed by seepage from the adjacent unlined canal and surrounding rice fields was addressed in a research conducted on a farmer's field in the service area of the Lower Talavera River Irrigation System (LTRIS), the Philippines, in the 1990 dry season. It established that

a properly designed interceptor-cum-drainage channel constructed around and across the average size field could convert a high water-table area unsuitable for crops such as maize to a maize production area. The best treatment area, in which no irrigation input was needed throughout the crop growing season because of the presence of a shallow water table, produced 7.3 t/ha of maize compared to 3.3 t/ha in the control area. The cost of managing the water table for the best treatment area was only $40/ha which yielded a gross margin difference of $660/ha from the control. There was a gross margin advantage of $193/ha in favor of the maize grown in the best treatment area when compared to rice production (6.2 t/ha yield) on part of the same farm (Alagcan and Bhuiyan 1990). This method of water table control provided the much desired option to the farmer for his choice of crops in the dry season.

Other Technical Concerns

In addition to the above-stated topics of general interest, a number of other technical issues have been addressed through the project in the specific country situations, which also have a bearing on irrigated land productivity on other regions. These would include issues such as water-fertilizer interactions and annual productivity maximization for areas with unreliable water supplies in the Aus season in Bangladesh; and tillage and irrigation interactions on leguminous crops in the Philippines and in Indonesia.

CONCLUDING COMMENTS

Many technical water and land productivity issues and problems within "rice irrigation systems" of the different countries are similar, although the settings in which these problems exist and interact with the farming systems may be quite different in the various countries. Most of the specific findings generated through research under this project seem to have wider applicability. Needless to say, caution should be exercised in applying recommendations of research from one location to another, and the need for appropriate adjustments should be kept in mind.

Technical farm-level production problems are many and they must be alleviated if diversified farming systems are to be adopted by farmers. However, it must also be recognized that socioeconomic constraints to achieving higher productivity and farmer income are often dominant. Much more efforts should be given to identify these constraints and to assess means to alleviate them.

The project has greatly benefited the involved institutions and professionals. It has provided the opportunity for collaborative undertakings in the three countries for research focused mainly on water-related problems of rice land productivity, which were identified jointly by concerned local institutions with inputs from IIMI and IRRI. The experience gained and knowledge generated are of significant importance toward the goal of attaining higher food production and farmer income.

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Opportunities for the Diversification of Asian Rice Farming Systems: A Deterministic Paradigm

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INTRODUCTION

DECLINING PROFITABILITY OF rice production and the consequent decline in rice farmer income and welfare have increased interest in crop and income diversification. Policy discussions on diversification have often been preceded by farmer initiatives to sustain their incomes by moving at least partially out of monoculture rice production into other crops and/or into other enterprises. Indeed, Thailand, a predominant rice exporter, has exhibited the highest levels of diversification from rice production in the region. A smaller, though significant, shift from rice monoculture has been observed in the Philippines and Indonesia.

This paper views diversification from rice monoculture into a multi-crop/ enterprise system as an essential consequence of agricultural development. This process is induced by the changing relative profitability of rice and nonrice enterprises. Diversification from rice to nonrice crops will not always be profitable and will face both physical and economic constraints. This paper attempts to identify and evaluate these constraints for each of the major rice growing environments. Research priorities were assessed for rice and rice-based farming systems keeping in view the relative profitability of rice production by environment.

This paper draws on a variety of data sources both primary and secondary. Panel data sets for the Philippines, Thailand and Indonesia collected by the Social Sciences Division of the International Rice Research Institute for the years 1980 and 1988 are used to examine changes in farmer crop and non-crop enterprise choices over time and to examine the changing profitability of rice versus nonrice enterprises. These data sets were complemented with data from other published sources and from the literature to provide a continent-wide (Asia-wide) perspective for the conclusions reached.

CHANGING PROFITABILITY OF ASIAN RICE PRODUCTION

The long-term profitability of rice production depends on three factors: (a) long-term price of rice; (b) current and potential yields; and (c) input costs. The prospects for sustaining income primarily through rice monocropping are bleak, given low rice prices, stagnant yields and high input costs.

The long-term decline in the real price of rice. Despite the recent increase in world rice prices, several analysts predict a downward trend in real price over the longer run. Figure 1 shows the trends in real world rice prices from 1900 to 1987. This graph was adapted from Mitchell (1987) and used 1964-66 as the base period. It shows that despite frequent and prolonged price fluctuations, the world rice market has been characterized by almost a 50-year declining trend in real rice prices. The major causes of the long-term decline in rice prices are discussed by Mitchell (1987a, 1987b), Mitchell and Duncan (1987), Schuh (1987) and David (1987).

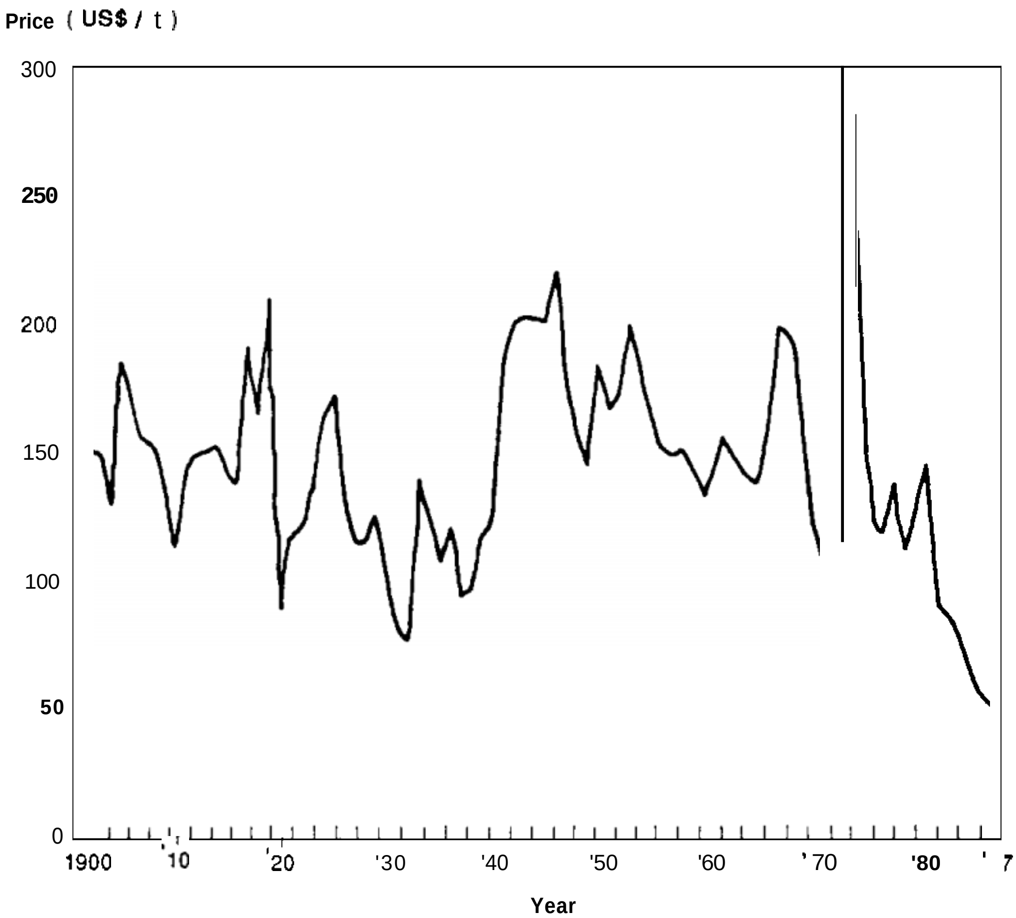
Although, many Asian governments have some form of protection of the domestic producers from the international rice market fluctuations, the long-term trends are passed on to them at least in direction if not in magnitude. If this is the case, other things being equal, the relative profitability of rice production has been declining. Where alternatives to rice production are not easily available, the long-term decline in rice prices leads to a sharp decline in the welfare of rice producers. This downward trend in producer welfare can be arrested if one or both of the following can be achieved: a) a significant reduction in the unit cost of rice production; and b) a reallocation of resources from rice to nonrice enterprises (both crop and non-crop).

Significant reduction in the unit costs of rice production can be achieved either by an increase in farm yields or by an increase in the efficiency of input use.

The diminishing yield gap. During the last two decades, yield increases on farmer fields were obtained by exploiting the gap between the technological yield frontier and actual yields obtained on farmer fields. Recent evidence indicates that the technological yield frontier has stagnated and shows signs of long-term decline (Pingali et al. 1990; Flinn and de Datta 1984). Farm-level evidence indicates that farmer yields are catching up to the yield frontier and that further exploitation of the yield gap is not economical (Pigali et al. 1990). Incremental costs of achieving further yield gains exceed the incremental returns.

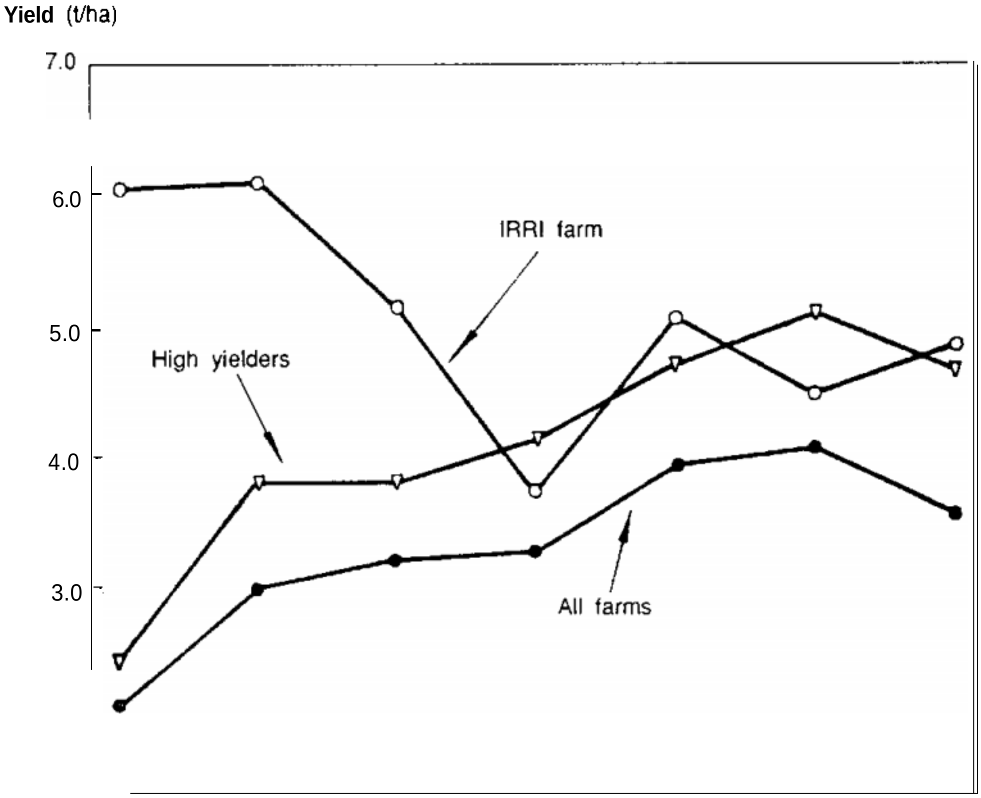
Figures 2 and 3 graphs the highest yielding entries in the maximum yield trials for the wet season at the IRRI farm and at the Maligaya Rice Research and Training Center (MRRTC). These figures show that wet-season rice yields per hectare on the experiment stations have declined from a high of 6.2 tons in 1965-70 to a level of 5.3 tons in 1986-87 in MRRTC and 4.9 tons at IRRI. Similar declining rice yield trends have been observed in other experiment stations in India, Thailand and Indonesia (Nambiar and Ghosh 1984; Gypmantasiri et al. 1989; INSURF 1987).

Figure 1. Trends in *world* rice prices *(1900-1987)*



Source: **Adapt from Mitchell, 1987.**

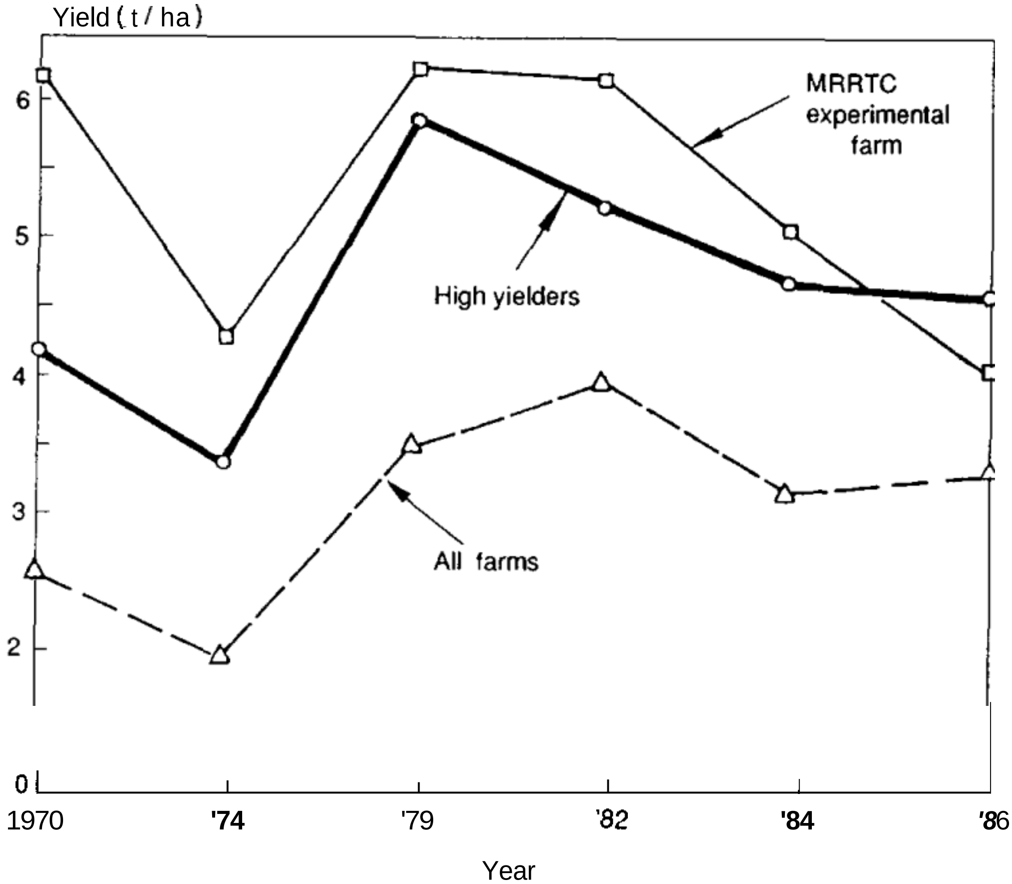
Figure **2.** *IRRI farm data come from the maximum yield trial with N=60 kg/ha. High yielders are the highest yielding 10 farmers out of* **a** *sample of* **35.** *All farms in the sample average.*



Source: **IRRI Agronomy Department and Economics Department.**

IRRI farm data w m e from the maximum yield trial with N=60 kg/ha.
High yielders are the highest yielding 10 farmers out of a sample of 35.
All farms in **the sample average.**

Figure 3. MRRTC maximum yield trial data with N=60 kg/ha. High yielders are the highest yielding 5 farmers out of 20. All farms in the sample average.



Source: IRRI Agronomy Department and Economics Department

MRRTC maximum yield trial data with N=60 kg/ha. High yielders are the highest yielding 5 farmers out of 20. All farms in the sample average.

The long-term decline in the irrigated-yield frontier under intensive rice monoculture can be attributed to one or more of the following: a) increased pest pressure; b) rapid depletion of soil micronutrients; and c) changes in soil chemistry brought about by intensive cropping and the increased reliance on low quality irrigation water. While the rice research system has been generating varieties with increasingly higher yield potential, the rate of degradation of the rice environment is greater than the rate of increase in the genetic yield potential; hence, a long-term decline in the yield frontier is being observed (Pingali et al. 1990).

Data indicate that the farmers have caught up and that the yield gap with the experiment stations is negligible. The Economics Department of IRRI has been following two groups of randomly selected farmers, the sample in Laguna has been monitored from 1966 to 1988 and the sample in Central Luzon from 1970 to 1988. These samples provide the most accurate information over time of rice-related technical change. For a complete description of the Laguna and Central Luzon samples ***see*** Herdt (1987).

The following information on yields was obtained from each of the samples: a) mean yield per hectare for the sample (adjusted to **14** percent moisture content); b) the average yield of the top third highest yielders for each year. The Central Luzon sample was compared with the experiment station yields from the MRRTC, while the Laguna sample was compared with the maximum yield trial on the **IRRI** farm (Figures 2 and **3).**

Results from Central Luzon showed that in 1970, the gap between the average sample farmer and the experiment station yield was almost 4 t/ha in the wet season. Figure **3** shows a steady reduction in this gap, reaching less than a ton per hectare in 1986. Comparison between the top third of the sample and the experiment station showed a gap of approximately two tons in 1970 which diminished to less than half a ton within a decade. In 1986, the top third outyielded the experiment station by almost half a ton.

Comparison between the highest yielding entries on the IRRI farm and the **Laguna sample farmers shows a** similar pattern. The yield gap between the average sample farmer and the IRRI farm in 1984 was less than half a ton per hectare. The top third in Laguna started off with a 2.5-ton difference in 1965 and outyielded the IRRI farm by 1975. Since then the top third of the Laguna sample have consistently outyielded the IRRI farm.

While the average farm yields have been rising, the top third yields in both Laguna and Central Luzon have peaked and are decliniig. The trend in the top third yields is very similar to the trend in the experiment station yields. One could extrapolate this information onto the average farm yields to predict that a similar peak and decline can be expected on those farms (See Pingali et al. 1990 and Pingali and Moya 1989 for further details).

At least for the irrigated lands in the Philippines, given current technology, the exploitable yield gap between the experiment station and the farmer yields is very small and the long-term prospects are for a stagnation and/or a decline in average irrigated farm yields. Three other implications come out of this analysis:

a. If this trend in stagnant and/or declining yields is widespread, one needs to question the long-run sustainability of intensive irrigated monoculture rice production, as currently practiced in the tropics of Asia. In this context, crop diversification would have to be examined in much greater depth as a mechanism to reverse rice-yield declines in intensive systems.

b. If yield per crop is expected to stagnate, this avenue to greater productivity and profitability is limited. Major attention must be focused on increasing crop production and income per year through intensification or diversification. This may involve fitting in additional rice crops per year, or partially replacing rice with other crops and/or other enterprises, or both.

c. If declining rice productivity becomes a long-term trend in Asia's rice bowls, then rice production and supplies would be affected and projections of a long-term decline in rice prices will no longer be valid.

Degradation of irrigation infrastructure. The degradation of existing irrigation infrastructure in Asia is contributing to an extent to the expansion in areas under nonrice crops. Since the mid-1960s the growth rate of irrigated area in the world has declined by about 60 percent; in Asia, it has declined by 72 percent (Rosegrant and Pingali 1990). This has been due to a sharp reduction in irrigation investments which was caused in part by the relatively favorable food security in Asia and the collapse of the world rice price. The problem is exacerbated by the poor maintenance of existing irrigation infrastructure, despite a relative shift in overall irrigation investment in the 1980s from new construction to rehabilitation and maintenance of existing irrigation infrastructure. An analysis of 92 irrigation systems in the Philippines shows that almost a third of them have declining trends in wet- and dry-season irrigated areas and wet- and dry-season yields (Masicat et al. 1990). Between 1979 and 1989, the absolute wet- and dry-season irrigated areas in Luzon declined by 20,466 ha and 36,175 ha, respectively. Even in areas that continue to be irrigated, the quality of irrigation, in terms of the amounts of water supplied and the reliability of water supplied, has deteriorated over time. Where irrigation water reliability is low, there is a strong case to be made for dry-season crop diversification, both for increasing the efficiency of water use and for sustaining farm incomes.

Increasing input costs. Costs of inputs per hectare could rise due to two reasons: a) holding input levels constant, the unit costs rise; and b) holding unit costs constant, the quantity of inputs used per hectare rises. All inputs like land, labor, all purchased inputs and supervision time are included in the discussion.

Agricultural intensification, measured in the Asian rice context in terms of cropping intensity, leads to an increase in input use per hectare, per crop (Pingali and Binswanger 1987; Herdt 1987). Pingali and Binswanger (1987) discuss the reasons for increasing input use with intercropping intensities. Sustaining yields and soil fertility over time in rice monoculture systems with double and triple cropping requires increasing levels of labor, fertilizers, other chemicals and mechanical power than single crop systems. Farm-level evidence from the Philippines, Thailand and Indonesia provides support for the above proposition.

For the Philippines, a panel of 132 irrigated rice farmers in Nueva Ecija monitored in 1980 and 1988 showed that a 13 percent increase in yield per hectare was achieved with a 21 percent increase in nitrogen fertilizer, a 34-percent increase in seeds and a 24 percent increase in hired labor. For Suphan Buri, Thailand, average irrigated rice yields, for a panel of 146 farmers, increased by 65 percent between 1982 and 1988, while nitrogen fertilizer levels increased by 24 percent, pesticides by 53 percent and seeds by 35 percent. Similarly, for a panel of 71 irrigated rice farms in West Java, Indonesia, average yields increased by 23 percent between 1980 and 1988, while average phosphorus fertilizer use increased by 65 percent and pesticide use increased by 69 percent. Real returns to rice production were stagnant during the periods concerned for each of the three countries (Pingali et al. 1990).

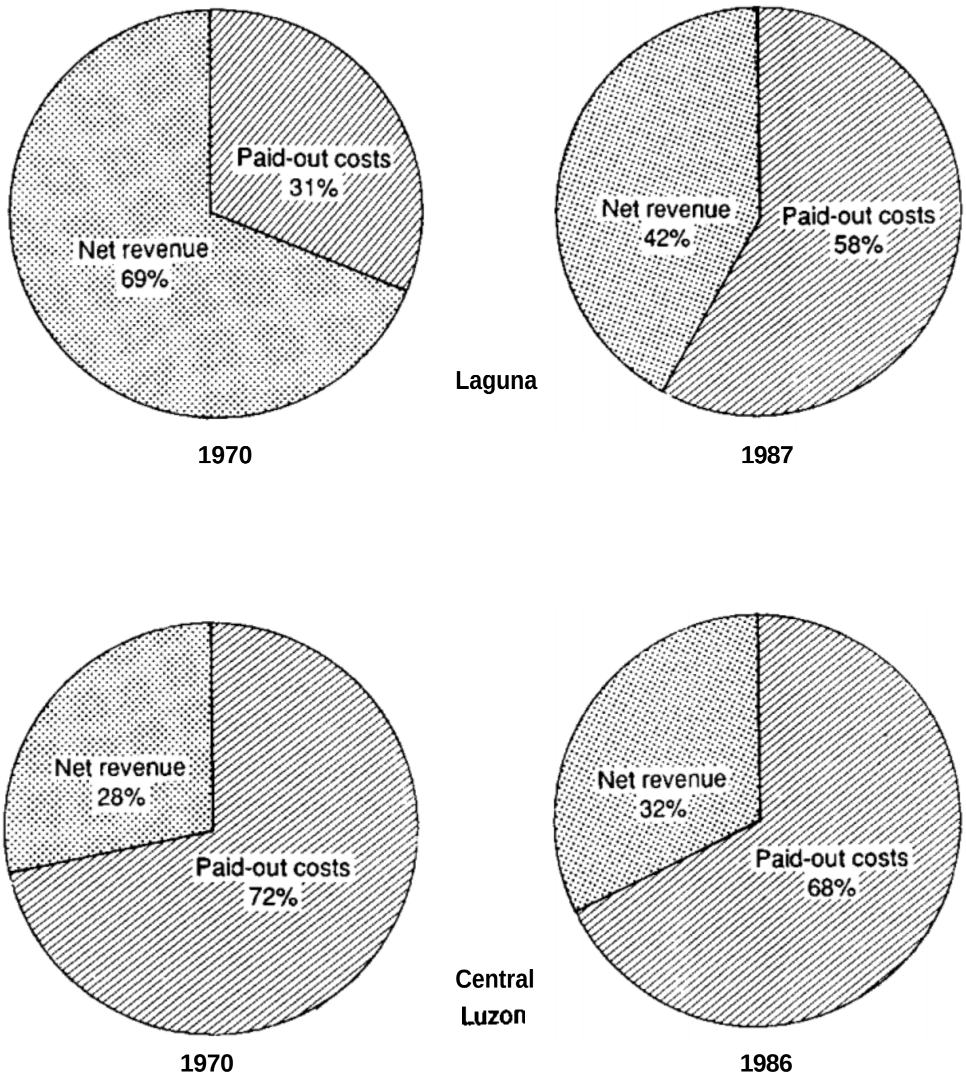
There are several implications of the above on the demand for inputs and the future trends in unit input costs. Land values are positively associated with agricultural intensification (Binswanger and Rosenweig 1986). Given current population growth rates in these countries, the prospects are for relatively higher opportunity costs of land and higher land rental values. Labor costs are also expected to be higher, both for hired and family labor. Hired labor demand during the peak seasons increases as cropping intensities increase. This, coupled with an increase in the opportunity cost of labor due to increased non-farm employment opportunities, necessitates the provision of greater levels of management and supervision.

If rapid efficiency gains in the use of chemical inputs are not achieved, one could also observe a significant increase in the per hectare use of chemical fertilizers and pesticides. Even with these efficiency gains, the long-term prospects are for significant increases in the total demand for chemical inputs.

Declining **long-term** profitability *of rice* ***production.*** Given low rice prices, declining or stagnant yields and increasing input costs, the profitability of rice production has been steadily declining. Figure **4,** shows the Philippine situation. Along with profits, the net income and the welfare of the rice farmer have been declining. The prospects for improvement in this situation are not bright. Improvements in the profitability of rice production depend on either or both of the following factors: a) a substantial increase in experiment station yields that will reverse a twenty-year trend; and b) substantial increase in input use efficiencies.

Sustaining and increasing the incomes of rice farmers will, therefore, depend to a large extent on crop and income diversification. This progression to crop and income diversification has taken place smoothly in countries where product markets operate relatively freely. In Suphan Buri, Thailand, for instance, the

Figure **4.** *Changes in net* **revenues,** *Central Luzon and Laguna* farms.



adoption of nonrice enterprises was closely associated with recent rice price trends. Between 1985 and 1988, 79 percent of **143** households first adopted nonrice enterprises (Table 1). Rice prices in Thailand were on a declining trend between 1980 and 1986, reaching their lowest level during the 1985/1986 period. The nonrice enterprises adopted included: nonrice crops such as vegetables and fruit orchards; non-crop farm enterprises, such as shrimp farming and livestock production; or non-farm activities, **such** as rural industries or urban employment. By 1987, 91 of the 143 households had adopted diversified farming systems. It is interesting to note that a third of these switched back to exclusive rice production in 1988 when rice prices went up again following the drought of 1987. The process of diversification has been slower in the Philippines, Indonesia and Bangladesh where rice profits were buffered to a greater extent by government intervention.

Table 1. Number of household adopted nonrice enterprise classified by type of enterprise and the first year of adoption.

	Year of first adoption										Total house-hold
Type of enterprise	**before 1980**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	
Cattle	2	0	1	0	2	3	2	6	5	13	34
Poultry	4	0	0	3	2	1	2	4	1	2	19
Prawn and fish	0	0	0	0	0	0	0	2	3	0	5
Vegetables	0	0	0	2	1	0	5	10	13	5	36
Fruit trees	0	0	0	2	1	0	1	1	0	1	6
Seasonal crops (short periods)	0	0	0	0	1	1	3	6	8	2	21
Sugarcane E	0	0	0	0	0	0	1	2	7	3	13
Sugarcane C	0	0	0	0	0	0	0	0	5	2	7
Off-farm work (Ag)	0	0	0	1	0	1	0	0	0	0	2
Total	6	0	1	8	7	6	14	31	42	28	143
Price of unhusked rice (baht/ton)	-	-	na	2470	2415	2273	2230	2398	3122	3726	

Source: Srianrunrungreauang, S., **1989**.

OPPORTUNITIES FOR DIVERSIFICATION OUT OF RICE

The opportunities for diversification from rice production depend on both physical and economic factors. A synthesis of the above factors into a predictive framework for the process and magnitude of diversification out of rice is presented.

Flexibility of Crop Choice by Ecosystems, Seasons and Soils

Flexibility is defined in terms of the level of interventions (both physical and human capital) required in switching from rice to nonrice crops and back. For instance, nonrice crops are grown year-round in Indonesia in a Sorjan (ditch and dike) system which involves high levels of investments in drainage control. Flexibility of crop choice is considered to be low in such a system because moving out of monoculture rice to upland crop production on elevated dikes or moving back into monoculture rice production involves high physical investments. On the other hand, upland areas can switch between rice and nonrice crops with minimum additional investments. This system has a high flexibility of crop choice.

Considering different ecosystems and environments, flexibility of crop choice in the wet Season is extremely low in all but the upland environments, because the investment requirements for drainage are high in the lowlands (e.g., sorjan system) (Table 2). Wet-season drainage investments, once made, are not easily reversible. Due to the ease of switching between crops, the uplands have always been extremely diversified in the wet season. Switching between rice, maize and other crops is possible in the uplands because the fields are not bunded and do not require to be puddled before crop establishment.

During the dry-season, crop choice is constrained by two major physical factors: water availability and drainage. The irrigated lowlands have the most reliable water supply. These areas depending on the severity of the drainage constraint have the highest flexibility in dry-season crop choice. Switching from dry-season rice to nonrice crop production will involve a certain amount of investment in temporary drainage structures and in learning nonrice technology, cultivation practices, and irrigation water management. Onion farmers in UTRIS, the Philippines, construct multipurpose ditches and levees in the rice fields for facilitating the drainage of excess water (Tabbal et al. 1990). Other examples of temporary drainage structures can be found for the Philippines (Moya 1990; Alagcan and Bhuiyan 1990; Maglinao and Valdeavilla 1990). The amount of land modification required is related to soil texture: heavy soils require elaborate drainage structures while light sandy soils may not require any drainage structures at all. The returns to these investments are highest for the irrigated lowlands with moderate to well-drained soils and, hence, these areas will tend to diversify more than the other ecosystems as the relative profitability of nonrice crops improves.

Ecosystem	Wet season	Dry season
Imgated lowland	LOW	Moderate to high (a)
Rainfed lowlands	Low	Low to moderate (b)
Deepwater and tidal wetlands	LOW	Low to moderate
Uplands	High	Moderate (b)

(a) This period includes the post-rice period (late wet season) or the pre-rice period (dry-wet transition).
(b) Conditional on rainfall level and distribution.

Irrigated lowland soils can be classified into: well-drained soils, moderately drained soils, and poorly drained soils. Flexibility of crop choice for each of these soils by season is presented in Table 3. For the wet season only the well-drained soils have possibilities for nonrice crop production; investments in a bed and furrow system or a sorjan system are required for successfully growing nonrice crops. On the other hand, for the dry season the flexibility of crop choice in irrigated ricelands is high for all but the poorly drained soils. Only heavy textured waterlogging-prone irrigated rice soils have little option but to specialize in rice production. For this last category the amount of drainage investment that has to be made prior to growing nonrice crops is often prohibitive. Imgated areas in South and Southeast Asia that have a long history of dry season diversification have all limited their nonrice crop production to well-drained soils while intensive rice production has continued concurrently on poorly drained soils.

The length of the period of irrigation water availability is also an important determinant of dry-season diversification. The large partially irrigated areas which cannot support a dry-season rice crop have a natural advantage in diversifying into upland crops during the dry season. But crop choice may again be limited on heavy textured, poorly drained soils, in which water control to avoid waterlogging or drought is difficult.

The relative speed of diversification of rice lands in Suphan Buri, Thailand, for nonrice crop production and for nonrice enterprises has been mentioned in the last section. Diversification of Suphan Buri rice lands took two forms, dry-season diversification and year-round diversification. Dry-season diversification was into vegetables and other seasonal crops, such as, maize and sweet potato; 39 percent of the households adopted a dry season nonrice crop. Land investment requirements for establishing these crops is minimal and when the rice price improved in 1988 these lands quickly returned to rice production (Table 1). Year-round diversification was into sugarcane, shrimp and fish farming, and fruit orchards; 14 percent, 3 percent and 4 percent of the households, respectively, adopted these enterprises.

Season	Well-drained soils	Medium drainage	Poorly drained soils
Wet season	Moderate (a)	Low	Low
Dry season	High	High	Low to moderate (b)

Investment requirements for year-round diversification from rice are very high and would only be made if expectations of relative long-term profitability are in favor of the particular nonrice enterprise. For fish and shrimp production, for instance, the initial investment costs are about 110,000 baht per hectare (approximately US$4,400).

Input and labor requirements are also higher for nonrice enterprises, both in the dry season and the year-round enterprises. Table 4 provides data on the relative input requirements and the profitability of rice and nonrice enterprises. Sriarunrungreauang (1989) using the above panel data for Thailand finds that if the rice price drops by 20 percent, dry-season nonrice crops would be relatively more profitable than rice, but year-round diversification would not be a profitable alternative to rice in the irrigated lowlands.

The opportunities for dry-season diversification in the rain-fed lowlands and the deep water areas are limited by water availability for post-rice crop production. In the humid and subhumid zones, rainfall level and distribution are such that a post-rice or pre-rice crop in the rain-fed lowlands is possible. Post-rice cropping of legumes (e.g., mungbean), cereals (wheat, maize) or vegetable crops may be possible on late season rains and residual moisture. This practice has become much more feasible on that portion of rain-fed ricelands which now produces earlier-maturing rice cultivars, which are harvested before the onset of the dry season. In the Cagayan Valley of the Northern Philippines, the replacement of traditional rain-fed rice varieties of six-month duration with early-maturing modem varieties has led to double cropping of rice in the lower elevations and the introduction of a pre-rice crop of mungbean on the upper elevations (Garrity et al. 1988). Pre-rice crops in the lower elevations are only possible on ridges to prevent waterlogging (Pernito and Garrity 1988). The strategy of increasing cropping intensities in the rain-fed lowland will only be successful if modem rice varieties adapted to these problem hydrologies (i.e., drought-prone, flood-prone and drought- and flood-prone conditions) are available.

In rain-fed environments where there is a sharp and prolonged dry season (especially the semiarid zones) post-rice crops are not possible without supplementary irrigation. In the rain-fed lowlands of South Asia, Northeast Thailand, Cambodia and Laos, dry-season crops on residual moisture would not be possible even if traditional rice varieties were replaced by appropriate short-duration

Table **4.** *Relative input requirements and profitability of rice and nonrice enterprises, Thailand,* 1988 *(baht/year).*

Inputs	Enterprises			
	Rice-rice	Rice-vegetable	Sugarcane	Prawn
Fertilizer (B/ha)	2915	27174	995	627
Pesticide (B/ha)	964	19224	280	
Other costs (B/ha)	294	17037	8389	18589
Feeds (B/ha)		42049		
Suh-total	4173	63436	9664	61265
Labor (mds/ha)				
Family	42	595	17	YO
Hired	41	445	60	2
Total	83	1040	77	92
Labor costs (B/ha)	5730	71916	5325	6362
Total costs (B/ha)	9912	135352	14989	67627
Gross returns (B/ha)	28427	160517	32399	104485
Net returns (B/ha)	18515	25165	17410	36858

Source: Srianrunrungreauang, S. *1989.*

modem varieties. There **is** potential, markets permitting, for a short pre-rice crop followed by a short-duration rice crop, suitable candidates being mungbean and green manure crops such as sesbania.

Where supplementary irrigation is available, as with pumps, opportunities exist for a dry-season rice or nonrice crop. In Nueva Ecija, Philippines, where there **is** a six-month dry season, the introduction of deep tubewells has led to the adoption of maize followed by mungbean in the dry season after a rain-fed wet-season rice crop (Gines et al. **1988).** It ought to be emphasized that diversification occurred only on the upper paddies with light textured and easily drained soils ***(turod).*** The lower paddies, on the other hand, with heavy textured soils that are prone to water-logging (*lungog*), were used for cultivating a dry-season rice crop. While two rice crops are also possible on the turod soils with the dry-season crop being irrigated by pumps, the private and social returns to a diversified cropping system dominate the rice-rice cropping system. This is ***so,*** primarily because the costs of irrigation for rice are high and a significantly smaller area can be irrigated efficiently (Gines et al. **1988).** Engelhardt **(1984)** reports, for the semiarid tropics of India, the emergence of a diversified cropping system with the introduction of deep well pumps. Rain-fed rice in the wet season is followed by either groundnuts, sorghum

or vegetables. In Bangladesh, approximately 60 percent of the dry-season cultivated area is imgated by tubewells and pumps (Hakim et al. 1990). Much of this area is planted to a rain-fed wet-season rice crop followed by an imgated dry-season nonrice crop like wheat, potato, gram and onion (Mondal et al. 1990).

Dry-season diversification in the upland areas similarly depends on the level and distribution of rainfall. In areas with a sufficient growing period, a post-rice crop can be grown. Maize, sweet potato, and vegetables are common sequential crops. In Northern Mindanao, the Philippines, for instance, where the average annual rainfall of 2,350 mm is evenly distributed over an eight-month period, double cropping of maize is practiced on a quarter of the upland area (Mandac et al. 1987). On the other hand, in Northern Laos, where the average annual rainfall is 1,400 mm, diversification from one upland rice crop to two nonrice crops is not feasible due to risk of drought stress for the second crop (Fujisaka 1990). For the lower rainfall upland areas in much of the subhumid and semiarid zones, rice production is generally not profitable due to the risk of drought stress. Where irrigation is not available wet-season sorghum, millet and pulses such as pigeon pea and chick pea are commonly grown (Walker and Ryan 1990).

Diversification out of rice production in response to changes in the relative profitability between rice and nonrice crops would be most feasible in the dry season. The rice ecosystems in which it will be most profitable and feasible will be the irrigated lowlands, because of greater reliability of water supply and higher return to diversification investments.

Market Infrastructure Versus Physical Constraints as Determinants of the Profitability of Diversification

Market infrastructure may be divided into two categories, good market access and poor market access. If market access is good, output demand is relatively elastic and hence the returns to investments in land, learning and technology are relatively higher. Physical constraints are represented by drainage problems in the irrigated lowlands and the susceptibility to soil erosion in the uplands.

Table 5 presents, for irrigated lowlands, the physical and market constraints to diversification. The irrigated lowland soils are divided into two categories, well-drained soils and poorly drained soils. In the dry season, in areas with good market access, the profitability of diversification will be high on well-drained soils and moderate to low on poorly drained soils, the latter being dependent on the level of investments required for drainage. In areas with poor market access the profitability of diversification on well-drained soils will be moderate to low, depending on the nature of output demand. If demand is highly inelastic (due perhaps to the high cost of transporting the output to markets) then the profitability of diversification will be low. For poorly drained soils with poor market access the profitability of diversification will be very low.

Table 5. **Market** ***infrastructure uersus physical constraints as determinants of the profitability*** **d** ***diversification.***

Category	Welldrained soils	Poorly drained **soils**
Good market access	High	Moderate to low (a)
Poor market access	Moderate to low (b)	Very low

Table 6 presents, for the uplands, the physical and market constraints to diversification. The upland soils are divided into two categories: soils that are highly susceptible to erosion (i.e., generally lands on moderate to steep slopes) and soils not highly susceptible to erosion. If market access is good, the profitability of diversified field crop production on soils not highly susceptible to erosion is high. For soils susceptible to erosion, profitability of field crop production is determined by the level of erosion control investments required. Where high levels of erosion control investments are required, tree crops may be a more viable option than field crops, particularly after land degradation has been allowed to occur through field crop production.

In upland areas with poor market access, the returns to diversification out of subsistence rice production are limited in areas with soils that are both susceptible and nonsusceptible to erosion. It is important to note that this argument is only valid if the subsistence crop in the area is rice. There are of course, areas with other subsistence crops (e.g., maize).

Category	Serious soil chemical' constraint and/or erosion hazard	Without major soil constraint
Good market access	High input diversified cropping systems or agroforestry systems	Diversified fanning or cash cropping
Poor market access	Shiftiig cultivation systems	Subsistence cropping

[a] **Includes highly acid soils with potential aluminum toxicity/P deficiency.**

On soils that are susceptible to erosion, the slash-and-bum agricultural system persist as long as population densities are low. **As** population densities, rise, permanent cultivation systems evolve for low-input, low-yield rice production. These systems are often characterized by rudimentary farmer investments for erosion control (Pingali 1987; Pingali and Binswanger 1987). On soils not highly susceptible to erosion, the incentives for diversification out of subsistence rice production are low due to inelastic output demand for rice and nonrice crops.

The relationship between the flexibility of crop choice and erosion control investments becomes very pronounced on the sloping uplands. Sloping lands are extremely susceptible to soil erosion. There are various options for erosion control to maintain permanent cropping on these lands, ranging from grassy strips to stone wall terraces. Farmers' choice of erosion control strategy depends on population pressure on the land, on market access, and on the appropriate erosion control techniques available. Pingali (1990), Fujisaka and Garrity (1988) argue that farmer interest in erosion control measures is directly related to land values and market access and is conditional on suitable technologies being available to them.

Dominant Crop and Non-Crop Options for Sustaining Incomes

Income generating activities are classified as follows: rice production, nonrice crop production, noncrop activities and diversified production systems. Noncrop activities consist of off-farm employment, livestock husbandry, cottage industries, and others. The dominant activity for sustaining income is defined as that activity which provides the major share of income in a particular environment and season. Table **7** provide the dominant income-generating activities for each season and environment. Empirical evidence on the sources of income by rice environments is provided in Tables 8, 9, 10 and 11 for the Philippines, Thailand, Indonesia and Cambodia, respectively.

Table 7. Dominant crop and non-crop option for sustaining incomes by environment

Environment	Wet season	Dry season
Irrigated lowlands	Rice	Rice/nonrice crops
Rain-fed lowlands	Rice	Off-farm employment
Deepwater and tidal wetlands	Rice	Off-farm employment
Uplands	Diversified production systems	

Table 8. Sources of household income, ricefarms classified by environment, Philippines, 1988.

Type of income	Rain-fed farms		Upland farms		Irrigated farms	
	Percent of total income	Number of households	Percent of total income	Number of household!	Percent of otal income	Number of households
Rice incnme	48.1	48	3.0	39	56.7	129
Nonrice income	6.3	41	31.0	39	0.4	1
Noncrop income	9.0	39	16.0	50	6.5	60
Off-farm income	1.0	20	10.0	28	10.2	35
Non-farm income	35.6	53	40.0	15	26.2	95
Total value of (in Pesos) income (in US$)	22748 1078	'49	15777 748	'54	33975 1610	'132

' Total number of samples for each category; some households have two or more sources of income.

Source: Social Sciences Division, IRRI. 1988.

Table 9. Number of villages, number of rural households, sources and levels of net household income by province, Thailand, 1980-81.

Region and province	umber of villages	Number of households	Sources of net household income (baht/percent)				
				Nonfarm			
			Farm	Other sources	Wage	Other	Total
Northeast							
Khon Kaen	8	141	13275 (47.4)	3385 (12.1)	6627 (23.7)	4713 (16.8)	28000 (100)
Roi Et (rain-fed)	5	75	4889 (22.4)	6047 (27.7)	5514 (25.2)	5404 (24.7)	21854 (100)
North							
Chiang Mai (Upland)	9	163	6046 (18.8)	10629 (33.0)	11417 (35.5)	4095 (12.7)	32187 (100)
Center							
Suphand Buri (irrigated)	3	42	29232 (70.8)	-409 (-1.0)	9027 (21.8)	3461 (8.4)	41311 (100)
All provinces	25	42 I	10643 (35.5)	6284 (21.0)	8544 (28.5)	4481 (15.0)	29952 (100)

Source: Onchan and Chalamwong (Forthcoming). Rural off-farm income and employment in Thailand: Current evidence. future trends and implications.

Table 10. Proportion of total income by source, West Java.

Village	District	Agriculture sector	Nonagriculture sector	Total
Sentul	Serang	33	61	100
Mariuk	Subang	82	18	100
Jati	Cianjvr	52	48	100
Suka Ambit	Sumedang	41	59	100
Balida	Majalengka	63	37	100
Wargabinangun	Cirebon	61	39	100

Source: Wiradi, Gunawan (Landlessness, tenancy and off-farm employment in rural Java: A study of twelve villages).

Table 11. Distribution of farm household by source of income, Cambodia, 1989

Type of income	Rain-fed	Irrigated	Recedinn floodplain
Rice income	99	1	54
Nonrice income	18	0	0
Non-crop income	71	9	2
Off-farm income	11	3	1
Non-farm income	73	11	2
Total number of household	99	15	4

During the wet season, rice will continue to be the dominant source of income in all but upland environments. This is not to imply that rice is not an important source of income for the uplands, but rather to stress the fact that the uplands have always been very diversified. Several different crop and noncrop activities are possible on the uplands during both seasons. Generalizing across upland environments would therefore be difficult.

In the dry season, one observes a mixture of activities for sustaining incomes. In the irrigated lowlands, dry-season rice will continue to be the major source of income. Areas with good market access and those near urban centers will

increasingly diversify to nonrice crops and vegetable production. The dominant dry-season activity for the rain-fed lowlands and the deep water areas will essentially be noncrop activities, off-farm employment, livestock production and cottage industries. There is scope for post-rice crops on residual moisture, or pre-rice crops during the early wet season. However, the share of total income from this activity would be lower than that from the other activities. Dry-season cropping activities in the rain-fed areas are limited because of technical problems in timely and effective crop establishment, limited moisture (or excess moisture in some cases), and generally modest yields and high-yield instability. Off-farm activities will often be more dependable income sources, suggesting that dry-season cropping intensities will remain low even if technical problems in crop production are solved.

The above discussions lead to the conclusion that irrigated environments, while having an absolute advantage (relative to the other environments) in a rice-rice cropping pattern, may, at the same time, have a comparative advantage in a rice-nonrice cropping pattern. The extent of comparative advantage for the irrigated lowlands in dry-season diversification depends on the physical constraints and the market opportunities for nonrice crop production. On the other hand, during the wet season, the upland environments have both an absolute and a comparative advantage in nonrice crop production.

DYNAMICS OF CROP DIVERSIFICATION

The Dynamics of Farmer Land Preferences

Within an irrigated micro-environment, lands with the greatest preference for rice production are heavy clay soils and lands that have the best access to irrigation water (lands in the head section and fields close to irrigation canals). Yields almost always decline from the head to the tail of the irrigation system (Chambers 1988; l'ingali et al. 1990). Table 12 summarizes data from Sri Lanka on differences in rice yields and incomes by location along the head and tail reaches of an irrigation system. Incomes and net returns to labor decline more sharply than yields (Chambers 1988). The unit cost of rice production would be the lowest on the head lands as compared to that in the tail section, fields far from the irrigation canals and those with more sandy soils (Pingali and Masicat 1990; Wardana et al. 1990). As long as the returns to rice production dominate all alternative crops within the system, the demand for and the price of the head lands will be higher than the others in the system.

Table 12. Average yields, cost and net returns by canal location, Gal Oya Project, Sri Lanka:

	Uhana-Mandur subsystem		Left bank main canal		Gonagolla canal	
	Top	Tail	Top	Tail	Top	Tail
Average yield bushels per acre (four seasons)	53	33	48	33	45	37
Cost per bushel of unhusked rice in rupees	35	53	30	53	29	55
Net returns per family labor day	+27	-48	+28	-11	+44	-8

Source: Chambers 1988. p. 23.

As the relative returns to dry-season nonrice crops rise, one observes an increase in preference for lands normally considered marginal to rice production. Within the irrigated lowlands, the following could be considered marginal to dry-season rice production: upper rice fields that are difficult to irrigate; well-drained soils, sloping lands and stony gravelly land. All these lands would be more suitable for dry-season nonrice crop production due to good drainage characteristics. Investment requirements for drainage are lower on these lands as compared to: low-lying rice fields, heavy clay soils and land with better water access. Wardana et al. (1990) document for the Cikeusik Imgation System in West Java, Indonesia, differences in yields and net returns for rice and nonrice crops (Table 13). They find the relative profitability of nonrice crops to increase on lands further away from the head of the system, to a point where water scarcity could be a problem. Pingali and Masicat (1990) document similar cropping pattern choices for UTRIS in the Philippines. Two crops of rice are grown on the upper portions of the system, while onion, chili and vegetables are common in the midsection. Dry-season crop choices at the tail of the system are conditioned by the reliability of water supply. Where farmers have access to pumps, nonrice crops are grown (Bacayag 1990).

Table 13. *Cost and returns per hectare onion by section, Cikeusik Irrigation* System, *Cirebon, West Java, Indonesia, 1988 DS* I.

Item	Head n=26	Middle n=29	Tail n=24	All farms n=79
Mean yield per hectare (t/ha)	9.7	10.5	8.4	9.5
Mean price of onion (US$/kg)	0.16	0.17	0.16	0.16
Total value of production (US$/ha)	1676	1822	1332	1590
Costs of production (US$/ha)				
Seeds	494	421	301	396
Fertilizer	137	134	86	116
Insecticide	177	231	143	181
Labor				
Hired labor	556	468	423	477
Family labor	414	215	239	284
Other costs	150	76	168	134
Total paid out costs of production (US$/ha)	1514	1330	1121	1304
Total variable cost of production (US$/ha)	1928	1545	1360	1588
Returns above paid-out costs (US$/ha)	162	492	211	286
Gross margin	(252)	211	(28)	2

US$1.00 = Rp.1,800
Source: *Wardana* et al. *1990,* Table *13.*

In the irrigated lowlands, when the dry-season returns to nonrice crop production dominate the returns to rice production, the demand for and the price of land with the least constraints to diversification out of rice will be the highest.

Pingali et al. (1989) examine the changing land preferences in UTRIS in the Philippines. Over the last five years, UTRIS has observed dramatic changes in the preferences for dry-season cultivation of land and consequently changes in land values. The system consisting of areas of heavy clay soils (Lateral A), and areas of sandy loam soils (Lateral B) showed that in the last five years, land preferences have switched from the heavy clay soils to the sandy loam soils. Land values in Lateral A which were once the highest for the entire system are now dominated by Lateral B.

Dealing with Credit, Labor and Risk Constraints to Diversification

The switch from rice monoculture to diversified farming requires substantial start -up investments plus operating expenses. This switch is generally not possible without long-term and seasonal credit arrangements. Where diversification has occurred successfully, farmers have managed to acquire credit through private or public sources. In UTRIS, the main alternative to dry-season rice production is onion. The credit constraint to onion production has been alleviated by arrangements with onion traders. Onion traders from San Jose City provide credit for the purchase of all the required inputs in exchange for a commitment from the farmers that they have the exclusive right to purchase all output at the market price at harvest. No interest is charged for this credit, but the traders benefit substantially from the substantial price increase between the harvest and post-harvest months. This price increase more than offsets the foregone interest charges and the storage costs, Similar credit arrangements from merchants has been observed for vegetable and sugarcane production in Suphan Buri, Thailand where longer-term credit is provided by the government and the agricultural cooperatives.

Relative to rice, the per hectare labor requirements for onion, vegetables and other high-value crops are substantially higher. Providing temporary drainage structures which requires labor is an essential activity immediately following a rice harvest. Planting, weeding, harvesting and post-harvest operations are also extremely labor-intensive for these crops (Table 14). Recent research by IIMI in the Philippines estimated the mean labor demand for rice, mungbean, onion and garlic as 85.7, 68.7, 468.5 and 241.0 man-days per hectare, respectively. Labor requirements for nonrice crops are higher at the head of the system than at the lower portions, presumably because of the greater need for drainage investments in the former (Wardana et al. 1990).

Diversified cropping aggravates labor peaks between the harvest of the rice crop and the planting of the nonrice crop. The land preparation activity for nonrice crops following rice crops would require breaking the rice hard pan (the compact soil surface caused by puddling rice soils). If this hard pan is not broken, there would be problems with root penetration and hence the establishment of a nonrice crop (Zandstra 1990). The power requirement for this soil modification is higher on heavy clay soils than on the lighter soils. Mechanization can, to an extent, alleviate this labor peak. However, the machine power required for upland crops is substantially greater than that required for puddling rice fields. This incompatibility in machines can be overcome by contract hire operations, but these would be profitable only when large areas are grown to nonrice crops. Expansion of nonrice crop area is constrained by, among other things, the nature of the output market, the supply of labor, the prevalence of credit contracts, and farmers' aversion to production and price risks.

Table 14. Relative costs and return (/ha) to palay and onion production, dry season 1988, UTRIS, San Jose, Nueva Ecijn, Philippines.

Inputs	Palav	Onion
Seeds	644	6086
Fertilizer	1150	2471
Pesticide	433	917
Other costs	2320	5469
Labor costs	3743	7630
Total costs	8290	22634
Gross Income	13863	71751
Net Retum	5573	49117

In addition to crop labor requirements, the supervision time required of the farmer is significantly higher. Supervision time rather than the higher labor requirements is suspected to be the dominant labor constraint to high-value nonrice crop production. This would be so, given the highly inelastic nature of management labor available in the farm household, while hired labor supply being augmented by seasonal migrants tends to be relatively more elastic. In UTRIS, the supervision constraint for larger onion producers (greater than 2 hectares) was overcome by dividing their farms into two, cultivating one part and providing the other part to seasonal tenant farmers. Seasonal tenant farmers either come from Lateral A or from neighboring areas to cultivate onion during the dry season. These farmers get land and half of the purchased inputs from the landowner in exchange for 50 percent of the total production.

Unlike in the case of rice, price risks dominate production risks in nonrice crop production. In UTRIS, seasonal tenancy arrangements, could also be a method of diffusing price risks associated with nonrice crop production. The means by which the smaller onion growers do this, is to divide their farms into two, cultivate one part and give the other to a seasonal tenant who pays a fixed rent of pesos 3,000 per hectare plus water charges. This way the landowner gets a certain income from a part of his land and gambles on the remainder. The supply of seasonal tenants has been increasing over the last few years, especially from Lateral A and similar lands with agronomic constraints to diversification.

Collective Action for Water and Land Management

In irrigated environments that have a diversified cropping pattern, collective action is needed, a) to ensure adequate water supply, b) to regulate timing of water supply, and c) to prevent excess water into the nonrice crops. In the Philippines, collective action is achieved through the formation of Irrigators' Associations (Pingali et al. 1988), in Indonesia through Water Users' Associations, in Bangladesh through the Farmer Cooperative Society (Hakim 1990) and in India through the formation of Water Cooperatives (Chambers 1988). These associations have similar operational constraints. The main problem with organizing a viable association is that farmers at the head of the system do not have as much of an incentive to join as farmers at the lower parts of the system since they have a relatively better access to water. Farmers at the lower end of the system find that their access to water improves only marginally by joining the association since the inefficiency of water use or water stealing by the head farmers continues. It is only the mid-section farmers that benefit from the formation of a Water Users' Association. In UTRIS, as reported by Pingali et al. (1989), farmers in Lateral B are well-organized in an Irrigators' Association, while farmers in Lateral A despite several attempts have failed to organize themselves. Lateral A is located in the upper portions of the system and thus has adequate water supply during the dry season. Moreover, the entire lateral grows rice, hence the need for in-season regulation of timing which is minimal but there is no problem of having too much water in the field. Farmers in Lateral B, on the other hand, grow exclusively nonrice crops (onion) during the dry season. The timing of water supply is important. Water flow has to be regulated to prevent excess water flowing into the onion fields. Hence, the need for collective action in B and the success in organizing into an Irrigators' Association.

Collective action although desirable may not always be feasible. Farmers at the tail end of Lateral B organized themselves into an Irrigators' Association but they found that this did not result in any increase in water allocation to their farms. There was not enough dry-season water to service them. After two years, these farmers stopped paying membership fees to the Association and began depending exclusively on pumps for meeting their water needs.

The experience of Bangladesh in the organization of Irrigators' Associations has been similar to the Philippines experience. In the country's largest gravity irrigation system, farmers at the tail end abandoned efforts to secure reliable water supplies through the collective pressure of an Irrigators' Association. But at the head of the system repeated efforts to organize an association failed since these farmers having adequate water had no incentive to join an association (Hakim 1990). Hakim reports that collective management was more successful in the relatively smaller pump irrigated systems than in the large gravity irrigation systems. Chambers (1988) reports on the Indian experience with Water Cooperatives where failures were common despite substantial government encouragement and support. Associations designed to improve efficiency of water use and equity in allocation have generally not worked because their design does not adequately consider: the head farmer-tail farmer conflict; the differential incentives for joining the association; and the high overhead and management costs involved in running the association.

An issue related to collective action is one of efficiency of irrigation fee payment. Experiences reported from Bangladesh and from the Philippines indicate substantial inefficiencies in imgation fee collection. Hakim (1990) reports that there is a wide variation in collection efficiency among the different imgation systems. Collection efficiency was relatively higher in private schemes and in the small tubewell schemes. In large gravity imgation schemes that are publicly managed, the efficiency of fee collection is very low. Fanners at the head of the system can afford to shirk on fee payment since they can resort to 'water stealing,' while farmers at the tail of the system are not assured of adequate water even if they are regular in their irrigation fee payment. Philippines has had similar problems with irrigation fee collection. In UTRIS, farmers close to the irrigation canal are the most delinquent in fee payment while farmers far from the canal had to make regular payments in order to ensure that they get at least some water (Table 15). Farmers far from the irrigation canal, while bearing a higher burden of the irrigation system cost receive a smaller share of the benefits.

In order to increase the farm-level efficiency of water use at the head of the systems and in fields close to the canal, two conditions are required (i) irrigation fees have to be based on the number of applications rather on a fixed rate; and (ii) more involvement is required of Irrigators' Associations in monitoring water use and fee collection.

Table 15. Payment of irrigation fees

Lateral	Distance	Paid	Not Daid
A	Near	1	2
	Far	2	2
B	Near	2	4
	Far	3	2
MC	Near	3	5
	Far	13	I
		24	16

Source: Pingali et al. 1989

Collective action for land management for uplands and the lowlands is equally important. In the uplands, group action for making watershed-level investments for erosion control are essential for developing long-term sustainable cropping systems. Sloping land management systems in the Philippines and terraces in West Java are examples of such collective effort (Fujisaka 1990; Soemarwoto and Soemarwoto 1984). In the irrigated lowlands, crop choice decision making requires collective consensus, on whether the crops are to be grown at the system or the lateral level; without such a consensus the ability of farmers to influence the system management to change water allocation rules for nonrice crops will be limited.

Finally, security of land tenure is crucial for making long-term land investments required for diversification from rice to nonrice crops and nonrice enterprises. Formal landownership as characterized by the possession of titles also helps farmers in acquiring credit for making the necessary investments in the land. Evidence on landownership and investment is provided for Thailand by Feder and Onchan (1987) and Chalamwong and Feder (1986).

IMPLICATIONS FOR RESEARCH PRIORITIES FOR RICE AND RICE-BASED FARMING SYSTEMS

Given current technology, farmer crop-management practices and the long-term decline in real rice prices, the decline in the profitability of rice production is expected to continue. Rice farmers will continue to face pressures to seek alternative income-earning opportunities. Sustaining the profitability of rice production in the face of competing opportunities for resources will require farmer access to technologies that either a) increase yields, b) increase input efficiency, or c) increase cost of rice production per hectare.

Irrigated Lowland

In the short to medium term, understanding the causes of the decline in experiment station rice yields must be a priority. A better understanding of the causes of this decline is essential in arresting and reversing the trend. If the trend toward declining yields is not reversed, the implications for future national production trends and to the economic viability of rice cultivation are serious indeed. Perhaps, this issue, which has not received significant research attention to date, must rank as important as that of increasing the yield ceiling in the future.

Long-term research will, of course, concentrate on breaking the current yield ceiling. But the relevance of a higher yield is conditional on crop husbandry techniques that can sustain the yield gains. Sustaining current yield gains would require the identification of the optimal crop management techniques and understanding the net effects of the interactions of the various component technologies. It is unlikely that there will be one general prescription to achieving incremental yield gains. Rather, one suspects the answer will differ from location to location. This reality highlights the importance of close collaborative research between the national programs and IRRI in sustaining the yield gains already achieved.

Research into appropriate crop management techniques should investigate the comparative long-term productivity of the continuous cropping of rice versus alternative rice-based cropping patterns. Providing break crops in a rice cropping system helps to maintain or regenerate soil fertility, reduces weeds and pest build-up, and provides more diversified options to sustain farm incomes (Westcott and Nikkelson 1988). Grain legume crops such as mungbean or cowpea, leguminous

green manures, or vegetable crops may be particularly suitable rotation crops with rice. Wheat and maize are not only popular rotation crops, but nutrient-demanding cereals. There is a concern that yields in rice-wheat rotations are also declining in some areas.

Input-saving technical change like integrated pest management, integrated nutrient management, direct seeding techniques in place of transplanting, and more efficient water use shows the savings in purchased input use with the adoption of these techniques (Table 16 and 17 are examples for direct seeding). Pesticide use in Laguna declined significantly without a consequent reduction in yields per hectare during the period 1984–1987. The average number of applications per season dropped from 3 to 2 and the average dosage per application also declined. These data indicate a more judicious use of chemical pesticides.

Table 16. Distribution-ricefnrms switching from transplanting to direct seeding, dry season 1980-1988, Philippines and Thailand.

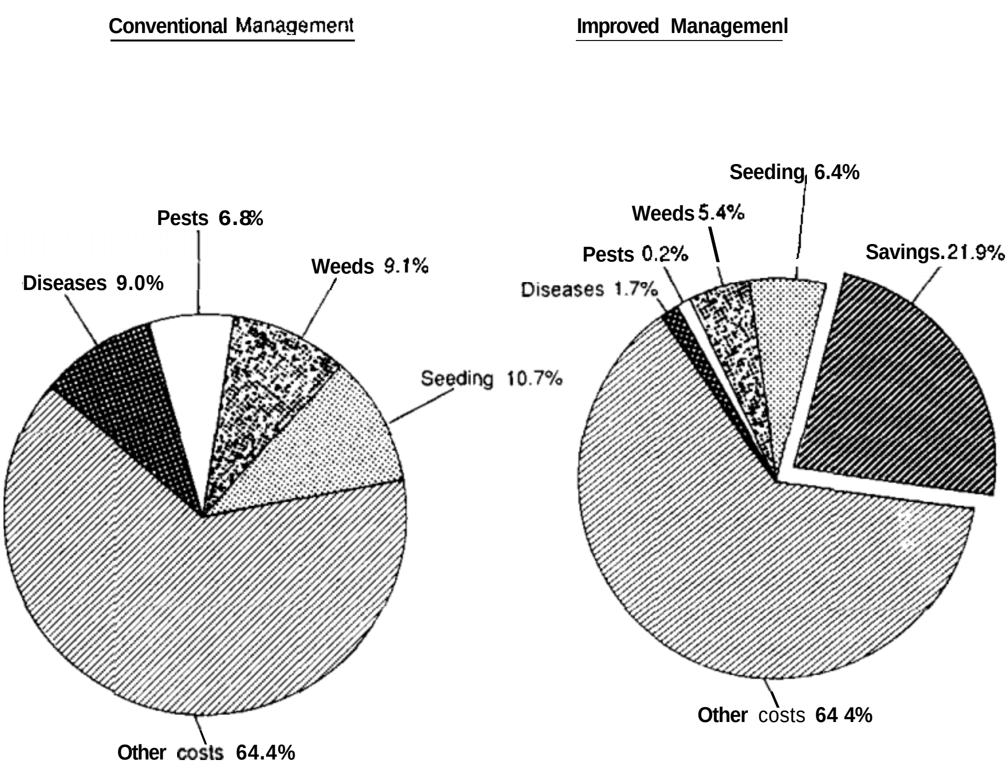
Philippines	1980	1988	Percent change
Transplanting	153	71	-115.49
Direct seeding	14	112	87.50
Thailand	**1982**	**1988**	**Percent change**
Transplanting	75	19	-294.74
Direct seeding	71	127	44.09

Table 17. Comparative input use for transplnnted and direct seeded rice, Nueva Ecijn, Philippines.

	Dry season, 1988		Percent change
	Transplanted	Direct seeded	
No. of sample (parcel)	71	112	36.61
N (kg/ha)	95.21	103.2	7.74
P (kg/ha)	27.01	20.06	-34.65
K (kg/ha)	22.03	13.22	-66.64
Seed (kg/ha)	196.04	161.62	-21.30
Pesticide (P/ha)	551.00	708.00	22.18
Yield/ha (kg/ha)	4966.57	4963.83	-0.06
Labor use			
Family	24.74	14.09	-75.59
Hired	70.83	36.02	-96.64
Total	95.57	50.11	-90.72

Integrated management research that critically addresses the contribution of every production factor to the overall cost and productivity can substantially reduce input costs but maintain yields in many cases. Figure 5 shows how production costs were reduced in Columbia by the equivalent of 1.2t/ha without affecting yields. This had dramatic effects on the profitability of rice production. Such work may be essential in counties where there is a real concern that current rice production levels cannot be maintained if the current low profitability of the rice enterprise continues.

Figure 5. Savings in production costs in irrigated rice by changing from conventional to improved crop management, 1986.



Total costs: ₱ 5162/ha; Average yield: 5234 kg/ha; Total costs: ₱ 3994/ha; Average yield: 5234kg/ha

Source: CIAT. 1987

Given the decline in real rice prices and the stagnant rice yields, there is an incentive for farmers to adopt efficient input use technologies. The increasing importance of off-farm income and other nonrice activities as a result of increasing income diversification make labor-saving technologies very attractive. However, technologies that provide efficiency gains are extremely knowledge-intensive since they require substantially greater levels of farmer judgement and supervision. The generation and adoption of these technologies would require high levels of national program involvement.

Diversified cropping patterns in the irrigated environments can be a definite strategy for increasing the efficiency of input use, the objective being to maximize the residual or carry-over effects of inputs from one crop to the next. The common example is rice legume systems which allow for lower levels of nutrient application for the subsequent rice crop. In wheat-rice systems, the P applied to wheat is efficiently available to rice (since P availability increases in the flooded soil). Also rice-break crop systems are available for reducing pesticide demand for the subsequent rice crop. An issue that has not received sufficient research interest is optimization of input use over the entire cropping pattern rather than on a crop basis (Kundu and de Datta 1988). This ought to be the strategy of a rational farmer in diversified agricultural systems.

Rain-fed Lowlands

The rain-fed lowlands are extremely diverse, but in general, rice yields and further intensification in these environments are constrained by production instability resulting from a highly variable field water regime. Drought, submergence, or prolonged waterlogging seriously affect rain-fed lowland rice in different environments. To raise yields, it is essential to introduce technical innovations which overcome or alleviate these constraints. The development of more stress-resistant cultivars can significantly improve yield stability. For example, the increased submergence tolerance of late generation cultivars is encouraging (Mackill personal communication).

A more holistic diagnostic approach will be required in future research on rain-fed rice to accelerate yield improvement and reduce yield variability. Improved crop and water management practices are essential for achieving and sustaining higher yields. However, input use efficiency in the rain-fed lowlands is very closely related to the reliability of the water regime. Where the reliability of water supply is low, the efficiencies of input use will necessarily be low.

Perhaps, less than 20 percent of the rain-fed rice area is cropped to anything but a single rice crop per year. Increasing the intensity of cultivation on these lands is promising. The demand side constraints to increasing cropping intensity are discussed in detail in Pingali et al. (1987) and Binswanger and Pingali (1988). Intensification of land use is induced by population densities and market demand for the output.

Technically, double cropping of rice on the favorable rain-fed lowland areas is possible with the early maturing varieties and the more determined research on the management constraints. However, the real potential for increasing cropping intensities lies with expanding nonrice crop production. Among the supply side constraints to crop intensification in the rain-fed lowlands the following deserve special attention: a) better crop establishment practices for the pre-rice and post-rice crops, and b) a better qualitative understanding of the competition for labor between crop and non-crop activities during the nonrice growing season. Pingali (1987) provides an example of the latter for Northeast Thailand, where attempts to encourage a pre-rice green manure crop are hampered by the high cost of foregone wages from off-season work in Bangkok.

Uplands

In the Asian uplands, rice is grown primarily as a subsistence crop. Very little upland rice is marketed, which is understandable due to two reasons: a) the upland farmer has a wide range of crops to produce for cash income other than rice; b) the relative profitability of rice production is quite low. These factors provide a backdrop to the unique research imperatives for the upland fanning systems in which rice is grown.

Upland rice yields are highly unstable due to drought, blast disease, weeds, and other stresses. Rice yields are often unsustainable due to production on highly acid, erosive soils which drastically lose their production potential after a few years of cropping. Technology development for upland rice must be directed primarily to stabilizing and sustaining yields, as it attempts to modestly improve them.

The development of ecologically sound and economically attractive crop rotations, within which upland rice is produced, will be a major vehicle for meeting these objectives. Upland rice research in most environments ought to be conducted within a framework of an overall land management strategy, in which appropriate investments in erosion control at the farm level are part of the research strategy. Diversified cropping in the uplands will be an essential part of a viable and sustainable upland farming system.

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Summary/Highlights of Discussions

Synthesis Papers

THREE PAPERS WERE prepared to present the synthesis of results from the three countries concerning the technical considerations and socioeconomic issues on irrigation system management and on-farm level management for crop diversification in rice-based irrigation systems. These were presented and discussed by Drs. Miranda, Bhuiyan and Pingali for the main system management, on-farm management, and socioeconomic issues, respectively.

1. *Target of recommendations.* It is very important to consider that in making recommendations, the targets should be clearly specified. In dealing with the main irrigation system, the problems in managing the main irrigation system should be addressed properly. Even the social aspects like the regular meetings between agency staff and farmers cannot be disregarded.

   It would seem though that irrigation management has been discussed in general terms. The recommendations were encompassing and can probably apply to any type of system. This should be expected instead of coming out as a surprise. Considering the various country-specific objectives, it may be noted that in the case of Bangladesh, the growing of rice is still very much the focus, and in terms of improving the management of the irrigation systems, rice is still emphasized. Even the rotation that is recommended is not oriented to nonrice but more to stabilize the water supply and make it reliable for rice production. While the emphasis in the Philippines and Indonesia may be on how to manage the irrigation systems constructed and designed for rice to be able to produce and accommodate nonrice crops, the process of setting the objectives will be essentially the same. There may be differences but there should be certain commonalities because what is looked at is the same re- source used to produce rice during the wet season and to produce nonrice crops in association with rice during the dry season.

2. *Productive technology and pilot testing.* There is a fairly strong recommendation for field-testing. In the pilot-testing process, it is not the researcher nor the irrigation staff who will determine the technology to be piloted. It should be a tripartite arrangement with the farmers. It is a successive type of approximation where the researcher will supply the information on the innovative technology to be tied and present this to both the irrigation staff and the farmers. Once there is agreement among the three, it can then be field-tested, considering the defined responsibilities of each. The question of how long the testing should be done so that the irrigation staff and the farmers alone will continue on their own has yet to be addressed.

3. ***Yield decline and sustainability.*** Over a period of 5,000 years, the rice systems of Asia have been the most sustainable in agriculture that the world has ever known. However, there is still the question of the sustainability of the more diversified and intensified production of having two or three crops a year.

4. ***Rice prices.*** Looking at the period from 1900 to 1970, the data on the prices do not allow any other interpretation as a group except that the world rice price has been constant. There is a series of declines which had been interrupted by major world events. During the European war of 1914 to 1918, there was an increase in rice price but this did not have a long-term effect. There was another decline until the Japanese invasion of China in 1936 when the price stayed high. It again declined and increased with the Korean war. Another increase was observed in the early '70s because of the oil price crisis. Therefore, one should be careful in using the data to predict policies on the basis of likely trends in world prices which are brought about by major nonagricultural events.

5. ***Diversification, issue or nonissue.*** On the issue of whether crop diversification will happen or not, it seems that there is a need to consider the questions of demand and dietary changes. The increasing affluence in Eastern and Southeast Asian countries has resulted in diversifying diets as reflected by a declining per capita consumption of rice. This tendency is expected to carry on for decades as the countries move up the wealth scale and the reliance on a single major staple decreases. Thus, there is little doubt that diversification is going to happen.

   Actually, diversification is an essential part in the economic area. It is happening wherever incomes are growing and it dces not have to be pushed. One participant claims that when the conditions are right, diversification will take place, and will take place completely on its own without government involvement. For example, in Thailand, which has the highest diversification in the region for the last ten years, 80 percent of the 200 farmers monitored have moved from a rice monoculture to diversified production without the government being involved at all.

6. ***Government intervention in crop diversification.*** Another participant pointed out that nowhere in the world, including the US or EEC, have farmers been allowed a free hand in farm decision making. The governments in one way or another have been involved in monitoring signals. There is a strong need for government support in the poor countries to push crop diversification. For example, the government must be conscious enough to limit the importation of soybean and provide other incentives for the local farmers to grow soybean.

   The point is, if the market signals reach the farm, the farmer is in the best position to decide. When the demand for vegetables and fruits in Japan

increased substantially, the Government of Thailand just opened up the export market. It made sure that there were no export taxes and no regulation on exports, just physical regulation. There was no organized diversification program, but the central plains of Thailand, which constitute the major rice bowl in Asia, moved from a rice-rice system to a rice-nonrice system. Much of the exportable surplus of rice comes from the rain-fed lowlands and not from the irrigated areas.

What the Government of Thailand did was to remove any restrictions that may have been existing. It adopted a completely free market which is the opposite of what is being recommended by other government policies.

Indonesia has a different experience in increasing agricultural productivity, having gone through several decades of fairly high support for agricultural development. There were subsidies on inputs, crop targeting systems, and a great deal of government involvement to ensure agricultural productivity. This brought Indonesia from a net importer of food crops to a position of self-sufficiency. However, it also increased the budgetary burden on the government's part. During the last **two** years, many of these subsidies have been removed. The question is whether the country will remain self-sufficient in rice if the subsidies will be withdrawn. The projection of the Harvard Institute of International Development team based in Jakarta is that this year, Indonesia will be importing approximately a quarter million tons of rice, which can increase further.

7. Farmer *association/organization/participation.* Participation would perhaps improve timing of water delivery. Because of more timing problems in raising nonrice crops, setting up a Water Users' Association may improve it.

   In the Philippines, there is growing evidence to show the benefits from the involvement of Irrigators' Associations in even nonwater aspects like credit and input supplies. In a coming workshop to translate the research findings into action plans, one major consideration is the establishment of cooperatives under the Irrigators' Associations without disturbing their identity.

8. ***Credit.*** Public credit institutions have influenced in many ways the growth in agriculture in Bangladesh. There is no doubt that the credit systems have contributed to agricultural growth, and this does not need verification. However, no study has yet proven that credit institutions have led to agricultural development. A World Bank review of credit experiences across Asian countries last year showed that government-managed credit contributed little to agriculture development. The more successful credit came from the private sector. Government credit institutions have had a very poor record in performance.

Section V

Small Group Outputs

Discussions and Wrap-Up

Summary/Highlights of Discussions

Group Reports and Wrap-Up

THE SESSION ESSENTIALLY consisted of the presentation and discussion of the outputs of the three working groups which were given the task of looking at, in greater detail, the different issues related to irrigation management both at the farm and system levels. These issues included the technical, social, economic and institutional considerations that should be given attention to, in diversifying rice inigation systems. Conclusions and recommendations, primarily based on the results of the three-year study on imgation management for rice-based farming systems, were identified and agreed upon.

Group Reports

GROUP A MAIN IRRIGATION SYSTEM MANAGEMENT IN RICE-BASED FARMING SYSTEMS

Background Issues

There were differences in the objectives, cropping calendar, and climatic conditions between Indonesia and the Philippines, on the one hand, and in the Bangladesh situation, on the other. In the humid tropics, there are no serious constraints to growing rice except the problem of water supply. In Bangladesh, the problem is sequential, between the dry winter season and wet summer season. It is then a question of timing the activity so that the seasons do not fall into each other and constrain cropping choices.

There is also a very big difference between the large gravity systems in Indonesia and the Philippines, and the tubewell systems in Bangladesh. The tubewell systems have the advantage of a fairly steady discharge, making time allocation as the major concern of management. In gravity systems, there are variations in the discharge, in the head, and in the timing, making the management task more complex.

Lessons that *can* be learned from other irrigation environments may be helpful. In the dry environment of Pakistan, Morocco and Sudan, for instance, diversification has been practiced for quite sometime. It may be that management issues in those countries are simpler or better understood. It may be good to make some comparison between these dry areas where diversification has been well-establiihed and those in the humid tropics which are purely rice-based.

Responding to Diversification

If the external environment is encouraging the farmers to diversify, how should main system management respond? The group agreed that changes should be introduced in the planning, implementation, monitoring and evaluation procedures being followed by the irrigation agency. The objectives of the plan should be made clear and the plan should be translated into clear operational rules. It was strongly recommended that fanners' organizations be a part of the planning process. Also, part of the process should be a good prediction of reliability of water availability.

Water distribution should pay more attention to reliability of **timing** than trying to meet adequacy. The fanners can do the fine-tuning at the lower level. Plans should be known by all (agency and fanners), and should have the flexibility to respond to different levels of water deficit.

Rotational imgation in some form is almost inevitable. First, there should not be overirrigation. Nonrice crops can easily be damaged by overirrigation. Second, even though the demands in terms of discharge per unit area may be reduced, there is still a need to maintain a higher head to push the water around faster. It was also the consensus of the group that rationing by time is easier than rationing by discharge.

There is a perceived need for different levels of rotation to cope with different levels of water deficit or supply. One rotational plan may not be sufficient. The selection of alternative rotational plans should be agreed upon by the imgation agency and the farmers. This should consider: a) suitability for farmers in terms of different types of delivery patterns; b) manageability by the agency; and c) technical feasibility in terms of conveyance, limitations, cross-regulations, etc.

As much as possible, the plan should be followed strictly and early warning should be made whenever there is any change. This needs reliable and effective communication — an effective information management. Monitoring and feedback evaluation will be useful in making the implementation more effective. Information management becomes an almost impossible task if the strategy is to meet actual crop water requirements where demand vanes both in time and space.

Unresolved Issues

There were issues that were unresolved due to inadequate information. These are:

a. **Design** of *main system.* The irrigation systems in Bangladesh, Indonesia and the Philippines are different in design, so it is difficult to make any comparison. Are the physical facilities enough to have some kind of rotation or is it necessary to put in temporary structures to do it?

b. **Crop** ***choice.*** Should the government get involved directly through such a mechanism as crop plans? Are we trying to plan the crops to be planted or giving a water right and letting the farmers make the individual decision?

c. *Physical environment.* This refers to what should be done in systems that are not homogeneous, i.e., when some portions of the system are very good for growing rice while the others are not because of different soils, drainage conditions, etc. Will everybody still get equal water supply or is there a need to make some proportional allocation according to the physical environment?

d. *Main system management versus strategic management.* There is a need to clearly distinguish between specific recommendations for operation and maintenance monitoring and specific recommendations for planning, evaluation and modification.

GROUP B: FARM-LEVEL WATER MANAGEMENT FOR RICE-BASED FARMING SYSTEMS

Factors which Influence Options for Change

Income stability was identified as the major consideration influencing the farmers' decision to diversify or not. In terms of crop choice, the farmers will eventually think of how much gain or profit will accrue from adopting a certain cropping pattern. Considered here are the benefit-cost ratio, market information system, local and international markets and area programming. The government may get involved in terms of idenhfying what and how much area should be devoted to a certain crop.

Other factors that influence the options for change are:

a. *Availability of adequate water.* With adequate water supply, the farmers can have a variety of options. They can grow rice or nonrice in combination. If the water supply is inadequate, then the option is to grow nonrice crops or reduce the area for rice.

b. *Land suitability.* The suitability of the land in terms of soil texture, capacity to store moisture, drainability, etc., significantly affects the choice of the crop.

c. *Climatic conditions.* Onion, for example, should not receive so much rainfall, particularly during the bulb formation, to avoid damage.

d. *Availability of management technology.* Farmers may not grow a certain crop if there is no available technology to grow it.

e. ***Time constraint.*** This is particularly important in increasing the intensity of cropping. When the harvest of the first crop of rice is delayed, the next crop will eventually be affected.

f. ***Farmers' preference and resources base.*** The fanners have their own preference for planting certain crops in certain seasons. Shifting from puddled to nonpuddled soil conditions requires some type of implements to facilitate the conversion from one condition to another.

g. ***Tenurial status.*** Landowners may want to plant crops of their choice and even lend some parcels of land to different fanners to plant different crops.

Responding *to* Changes

Both the farmers and the irrigation agency should respond to changes that occur. At the farm level, the farmers should assume more responsibility in water sharing and the provision of additional facilities that are needed to support nonrice crops. Observations have shown that the farmers can adequately handle the construction of these additional facilities.

The on-farm changes should complement the greater responsibility for monitoring field activities and irrigation deliveries at all levels by the irrigation personnel. The agency should explore groundwater use and night storage to supplement water supply. It should review the policy on irrigation service fees vis-a-vis water conserving practices such as mulching and water augmentation. The irrigation personnel should also improve their linkages with the farmers. This is for better technology transfer and better understanding among all involved in irrigation management. Training and organizing farmers can address this requirement.

Utilizable Technologies

The group also identified technologies that are already utilizable. These are:

a. ***Water table control.*** This can be done in specific areas but further tests are needed in areas with heavy clay soil.

b. ***Zero tillage and* mulching.** This can be done for optimal use of residual soil water for mungbean and onion and for water conservation.

c. ***Water augmentation using groundwater.*** In some areas within the irrigation system, water pumped from shallow wells has been used to irrigate during the later part of the dry season.

d. *Method of irrigation.* The basin method of irrigation has been adopted by some fanners; this can also be applied in other areas.

e. *Timing of irrigation.* Optimal yields have been obtained when the soil moisture depletion was not allowed to go beyond 40 percent of the available soil moisture.

f. *Cropping pattern.* Rice-mungbean-maize pattern has a higher productivity than the rice-rice-nonrice pattern for systems without adequate water.

Further Research

Further studies are needed on the following:

a. Evaluation of plow-broadcast-harrow method of tillage as compared with other methods of crop establishment.

b. Techniques for improving water use efficiency and productivity for rice.

c. Tolerance of direct seeded rice to water stress

GROUP C ECONOMIC AND INSTITUTIONAL ISSUES IN IRRIGATED RICE-BASED FARMING SYSTEMS

Dry-Season Cropping Options

The different cropping systems that the farmers may consider during the dry season were identified. These include leaving the land fallow, planting nonrice crops alone, growing combinations of nonrice crops or rice and nonrice crops, and planting dry-season rice crop.

Major Factors Influencing Options

The factors that influence the different options are: a) crop scheduling/timing, b) tenurial status, c) input and product prices, d) land suitability, e) drainage constraints, f) availability of residual soil moisture, g) experience/skill/attitudes of farmers and irrigation agency, h) labor and farm power, i) farmer controllability of water, j) availability of and access to technology, and k) government policies.

Responding to Changes

With diversification, there will surely be variability in water demand both in time and space, increase in cropping intensity and increase in farm ditch and drainage canal densities. The imgated area can be expanded. Management over time may be needed and irrigation service fees may have to be adjusted.

Again, in responding to these changes, the demand for management by both the farmers and the agency may increase. Reliable irrigation delivery will be needed, conjunctive use of surface water and groundwater should be enhanced, drainage information should be considered, and most of all, coordination among farmers, between farmers and irrigation agency, and among agencies, should be strengthened and maintained. Considerable information and a number of technologies have come out of the project which can be further tested with the end in view of fine-tuning for ultimate adoption and institutionalization.

DISCUSSION

The discussion following the presentation of the three reports led to a deliberation of several issues, the most critical of which are:

Irrigation Services Fees

Policies on irrigation service fees should be reviewed considering the differences in managing the system for rice versus nonrice. Consideration should be given to farmers who are using water more efficiently, or who practice water conservation measures like mulching and water augmentation. It was also suggested that the review look at strategies to encourage farmers to pay irrigation fees.

Tenurial Status

The status of land tenure has implications on farmers' attitude towards improving land productivity. Not owning the land deters the farmers from using the recommended technologies in their farms. The landlord-tenant arrangement also does not provide a clear indication as regards membership in Irrigators' Associations and the payment of irrigation service fees. The present situation does not provide any mechanism to address the problem, or to improve land productivity through crop diversification.

Farmers' Decision to Diversify

A number of factors influence the decision of farmers to plant rice or nonrice, for which they should be allowed adequate flexibility. However, such flexibility should consider not solely the farmer's own benefit but also its influence on other

farmers and the flexibility of the imgation system itself. What may be done is for the imgation agency and other support services to be ready with options to match the requirements of not one but a larger group of farmers. Likewise, the agency should also have some kind of mechanism to influence the farmers.

Farmers' Organizations

Organizing farmers may not be an absolute necessity for effective irrigation management. In Pakistan, where water is delivered by fixed turns, the irrigation system is operating alright. The farmers **use** the water as they see fit. This cannot be done in the Philippines, Indonesia and Bangladesh where there is no fixed water right for the farmers. Somehow, there is a need for the sharing of responsibility between the farmers and the agency. The nature of the sharing arrangement will depend on the sociopolitical situation in the area where the system is located.

RECOMMENDATIONS FOR FUTURE ACTION/RESEARCH

The various papers presented, the reports of the three workshop groups and the discussion throughout this workshop point to one direction: the project may be completed, but much remains to be done. Useful information and technologies have emerged which are expected to enhance irrigation management. However, the participants strongly feel that these should be further evaluated through some kind of piloting. It is anticipated that a gradual internalization process is needed to really feel the impact of the recommended innovations.

An action plan is called for to implement the findings so far obtained. A more active participation of the irrigation agency and the farmers is envisioned. Other agencies involved in agriculture from production to marketing should likewise be included. The involvement of the research group will diminish as the recommendations are adopted and institutionalized.

As research is a dynamic process, the project has likewise provided ideas or areas for further research. It was pointed out during the discussion that drainage problems have not been given due attention. Basic drainage facilities should be provided, particularly for upland crops. Farmers' motivation to participate in irrigation management should be studied in greater depth than its relationship to the formation of the Irrigators' Associations. Sound agency-farmer relationship is a necessary part of diversification but has still a long way to go. This has to be related to reliability of water delivery and variability which cannot be controlled. **A** practical measure of reliability is yet to be developed. Market forces and postharvest facilities should also be given due consideration.

In implementing these recommendations, the role that IIMI and IRRI can play is apparent. Collaboration among agencies has shown positive effects and should be sustained. In fact, other agencies not earlier involved have been suggested to participate, particularly in the piloting activity. Interested fund donors should also be identified. IIMI and IRRI could possibly assist in this aspect.

Concluding Remarks (i)

Fernando A. Bernardo
Deputy Director General
International Rice Research Institute
Los Baños, Laguna
Philippines

Thank you, Senen

I AM GLAD I am still here. Yesterday, I was told that my plane would be leaving at 1:30 p.m. and that by 1030 a.m. today, I should be at the airport. I am glad there was a change in schedule.

I would like to thank and congratulate all of you for your valuable contributions to this workshop. I enjoyed interacting with and listening to the participants from the three countries and our colleagues from IIMI. I think I should not say more about the workshop itself, its outputs and possibility for future activities. In the opening ceremony, I mentioned that it is IRRI's pleasure to be collaborating with IIMI, the new member of the CGIAR with whom we have been working even before its acceptance to the CG system. We really feel that water as a commodity is very important and that the increases in rice yields that we had achieved in the Green Revolution could be attributed partly to the proper utilization of our water resources.

In the World Food Council, questions such as,. could we extend the Green Revolution?, or could there be a second Green Revolution? have been raised. In the paper which I have been requested to write, I said that the Green Revolution of the late 1960s and 1970s is still going on in some countries, like Kampuchea, Laos, and others which are a little bit behind in the adoption of modem technologies. In other countries, the Green Revolution has leveled off and has reached a plateau. As population continues to increase, there is a challenge of changing this plateau and achieving a quantum leap to have another Green Revolution. In terms of research, IRRI is hying to achieve this or contribute to another quantum leap in rice productivity by developing types of rice other than the semi-dwarf varieties that are popular in rice growing countries. In addition, we have to reckon with the resource management, particularly soil fertility and water management.

In the 1960s and the 1970s, the national governments realized the importance of irrigation and invested in many irrigation systems. In spite of the increasing demand for rice and other food crops no new investments are made. Having a second Green Revolution would be difficult without water, thus this current scenario of low investments in developing more irrigation systems and maintaining the present systems should be addressed.

Aside from challenging the national governments to put more investments on new irrigation systems, improving the potential capacity of the present systems is another strategy. I am not an engineer but I also think of how we can increase the yield potential of existing irrigation systems. I think of system efficiency, of how to extend the area coverage of the existing irrigation systems. I think it is a wonderful thing and a big challenge. It is difficult and it cannot be done without research. It cannot be done without working with scientists, farmers and agencies responsible for national imgation systems. It is an important area for further study because aside from maintaining the irrigation systems, there is some scope for increasing their capacity.

We get a lot of water during the peak of the rainy season and a lot of this water is wasted. The management of the irrigation system, in my view as a layman, is very important indeed. I am glad that this workshop has also discussed the interagency approach. We have emphasized the importance of the farming systems research approach, where we involve the fanners and the agency in charge of the crop commodity. I think this should be pursued, particularly if there is government interest in a particular Commodity. Investment in processing is probably something which should be considered. The problem in many of the national development plans is that they do not look at the whole thing or adopt an integrated approach. Quite often, we have excess production and if we have no way of handling the excess, the price plunges and the fanners suffer. Yet we know that during the off season, there is a big demand for many of the farm products.

Agriculture is not complete unless we think in terms of inputs, production, processing, and marketing. We should keep this in mind, particularly if we go into what many of you would like to pursue — piloting. Piloting only in production, I think, is going to be disastrous. We have to think in terms of the whole sweep of modem agriculture.

Again, I would like to express my gratitude to IIMI for inviting me. I really take pleasure in being with you, in participating in this session, although I am not an imgation expert. I look forward to more participation because you deal with a very valuable commodity without which a second Green Revolution will not be possible.

Thank you.

Concluding Remarks (ii)

Charles Abernethy
Director of Programs
International Irrigation Management Institute
Colombo, Sri Lanka

Dr. Bernardo emphasized the importance of the Green Revolution a couple of times. We at IIMI feel very humble about this. Five years after IRRI's establishment, there was the Green Revolution all over the place. We have been in existence for five years and we have not got a Green Revolution to claim yet. We are very conscious though that IIMI is extremely young in comparison with IRRI and one or two of the other senior international agricultural research centers. Nevertheless, we feel some pride in what we are doing. We recognize that we have a long way to go to reach maturity.

I would like to say a couple of words about our institutional nature and how our meeting of this sort matters to us. Our task at the International Irrigation Management Institute is to try to internationalize this subject, to try to discover what things in management of imgation can be shared among countries. We do not exist as a consulting firm does, to go to a specific country and help improve its irrigation mechanism. Our function is to try to promote an international culture in irrigation which I think has a long way to go. Events like this are helpful in beginning to break down some of the national barriers that exist.

One follow-up action to this event will be to find some ways of facilitating some kind of observation by some of the people who participated in this project in countries where there is no rice at all. Diversified systems in Egypt, Morocco, Chile or Brazil could provide lots of lessons to be learned. I know that there is a great need for comparative studies of the management modes in those countries and in traditionally rice-based countries. We need people who are experienced active managers in such countries to write reports reviewing what the differences and what the similarities are. This is the sort of thing I hope IIMI will be able to promote to internationalize the profession.

One of the things that I find most striking is the way in which almost every country that we deal with has evolved a specific national style of doing irrigation. Every place organizes its irrigation in different ways from most other countries. It is something I find most astonishing. We do not have any Indian participants here but if we do, we will be hearing completely different management styles from what we find in the Philippines, for example. And it cannot be that both are right and I do not believe that both are just country-specific. I think there are probably good and bad features in every one of them. A large part of IIMI's mission is to promote interaction and sharing.

As a corollary to that, I hope, through time, that most of the people in this forum are going to become quite familiar with the city of Colombo and I hope that we are going to see a long-term interaction. The Headquarters of IIMI is becoming a great familiar place that matters in the lives of the irrigation management community. There is no way of saying goodbye to everybody. This visit will be the first of a chain of events, interactions and relationships. I thank everybody for their participation in the three years of the project and in the three days of the meeting. I look forward to much more interaction in the future.

Appendices

PROGRAM

12 November (Monday)

08:30	**Registration**
09:00	**Opening Ceremony**
	Welcome Address : R. Lenton, IIMI
	Opening Remarks : F.A. Bernardo, IRRI
	Overview of Project Objectives and Expectations
	Introduction of Participants
10:00	**TEA/COFFEE BREAK**

SESSION I: TECHNICAL CONSIDERATIONS FOR RICE-BASED FARMING SYSTEMS: MAIN IRRIGATION SYSTEM MANAGEMENT

	Chairman:	**A. Valera**
	Rapporteur:	**D. Cablayan**
1030	**Bangladesh**	**M. A. Ghani, M.A. Hakim**
	Indonesia:	**P. Suprodjo, M.E. Busro**
	Philippines:	**A.R. Maglinao, D. Cablayan, C. Pascual**
	Discussion	
12:30	**LUNCH**	

SESSION II: TECHNICAL CONSIDERATIONS FOR RICE-BASED FARMING SYSTEMS: FARM-LEVEL WATER MANAGEMENT

	Chairman:	**T. Woodhead**
	Rapporteur:	**C. Pascual**
14:00	**Bangladesh**	M. A. Ghani, M.K. Mondal
	Indonesia:	T. Woodhead, I. Juliardi, A. Abas, S. Iis
	Philippines:	D. Tabbal, R. Undan
15:30	TEA/COFFEE BREAK	
16:00	**Discussion**	

13 November (Tuesday)

SESSION III: ECONOMICS AND INSTITUTIONS IN IRRIGATION MANAGEMENT FOR RICE-BASED FARMING SYSTEMS

	Chairman:	**D. Parker**
	Rapporteur:	**M. Kikuchi**
08:00	**Bangladesh**	M. A. Hakim, D. Parker, M. A. Ghani
	Indonesia:	D. Vermillion and Sardjono
	Philippines:	P. Masicat, S. Salandanan, C. Pascual
	Discussion	
1000	TEA/COFFEE BREAK	

SESSION IV PRESENTATION/DISCUSSION OF SYNTHESIS PAPERS

Chairman: F.A. Bernardo
Rapporteur: R. Undan

10:30 Synthesis Paper# 1: Main Irrigation System Management for Rice-Based Farming Systems
S.M. Miranda, H. Murray-Rust, A.R. Maglinao, D. Cablayan, A. Ghani.

Synthesis Paper # 2: Farm Level Water Management for Rice-Based Farming Systems
S.I. Bhuiyan, T. Woodhead, D. Tabbal, A.M. Fagi, A. Ghani

Synthesis Paper # 3 Economics and Institutional Issues on Irrigated Rice-Based Farming Systems
P. Pingali, D. Vermillion, D. Parker, C.M. Wijayaratna

Discussion

12:30 **LUNCH**

1400 Briefing on Small Group Workshop Discussion

1430 Small Group Workshop Discussion

Group A: Main Imgation System Management for Rice-Based Farming Systems

Group Leader: H. Murray-Rust

Group B: Farm Level Water Management for Rice-Based Farming Systems

Group Leader: D. Tabbal

Group C Economics and Institutional Issues on Irrigated Rice-Based Farming Systems

Group Leader: C.M. Wijayaratna

14 November (Wednesday)

SESSION V: WRAP-UP SESSION

Chairman: **C. Abemety**
Rapporteur: **A.R. Maglinao**

08:00 Presentation/Discussion of Small Workshop Group Outputs

1000 **TEA/COFFEE BREAK**

10:30 Conclusions and recommendations of the workshop

11:00 Chairman's synthesis/comments

CLOSING SESSION

11:30 Concluding Remarks - IRRI, Dr. F. A. Bernardo
IIMI, Mr. Charles Abemethy

Vote of Thanks - Dr. Senen M. Miranda

1200 **LUNCH**

15:00 Briefing and Visit at IIMI Colombo Headquarters

1700 Brief Colombo City Tour

15 November (Thursday)

Departure for home country

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