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

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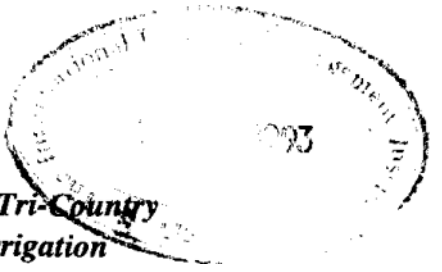

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**Senen M. Miranda and Amado R. Maglinao, editors**

**IIMI**

**INTERNATIONAL IRRIGATION MANAGEMENT INSTITUTE**

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

# Contents

FOREWORD ..... ix

OPENING ADDRESSES ..... 1
Welcome Address ..... 3
*R. Lenton*
Opening Remarks ..... 5
*F. A. Bernardo*

**SECTION I: TECHNICAL CONSIDERATIONS FOR RICE-BASED FARMING SYSTEMS: IRRIGATION SYSTEM MANAGEMENT** ..... 7

Water Management for Improving Irrigation System Performance in Bangladesh ..... 9
***M. A. Ghani. M. A. Hakim and M. K. Mondal***

Main Irrigation System Management for Rice-Based Farming Systems in Indonesia ..... 43
***Suprodjo Pusposutardjo, Hammond Murray-Rust and Sukarso Djunaedi***

Main Irrigation System Management for Rice-Based Farming Systems in the Philippines ..... 59
***Amado R. Maglinao, Danilo M. Cablayan, Rodolfo C. Undan. Tolentino B. Moya and Carlos M. Pascual***

Summary/Highlights of Discussions: Technical Issues on Main Irrigation System Management ..... 98

**SECTION II: TECHNICAL CONSIDERATIONS FOR RICE-BASED FARMING SYSTEMS: FARM-LEVEL WATER MANAGEMENT** ..... **101**

On-Farm Water Management for Rice-Based Farming Systems in Bangladesh ..... 103

*M. A. Ghani and M. K. Mondal*

On-Farm Water Management for Rice-Based Farming Systems in Indonesia ..... 129

*I.P. Wardana. Iis Syamsiah, A.M. Fagi. Iwan Juliardi, Sudamanto, Abdullah Abas Idjudin, H. Suwardjo, W. Sudrajat, Husein Suganda, M.A. Lantican, S.I. Bhuiyan and T. Woodhead*

Farm-Level Water Management for Rice-Based Farming Systems in the Philippines ..... 151

*D.F. Tabbal, R.C. Undan. M.M. Alagcan, R. Lampayan, S.I. Bhuiyan and T. Woodhead*

Summary/Highlights of Discussions: Technical Issues on On-Farm Level Irrigation Management ..... **175**

**SECTION III: ECONOMICS AND INSTITUTIONS IN IRRIGATION MANAGEMENT FOR RICE-BASED FARMING SYSTEMS** ..... **179**

Socioeconomic and Institutional Issues in Irrigation Management for Rice-Based Farming Systems in Bangladesh ..... 181

*M.A. Hakim. D.E. Parker and M.A. Ghani*

Improving Dry-Season Irrigation Management in Indonesia: Findings, Issues, and Manageable Alternatives ..... 213

*Douglas Vermillion and Hammond Murray-Rust*

Socioeconomic Issues in Irrigation Management for Rice-Based Farming Systems in the Philippines ..... 235

*Policarpio B. Masicat, Salvador Salandanan and Carlos M. Pascual*

Summary/Highlights of Discussions: Socioeconomic and Institutional Issues ..... 263

**SECTION IV: SYNTHESIS PAPERS ..... 267**

Main Irrigation System Management for Rice-Based Farming Systems ..... 269

*Senen M. Miranda, Hammond Murray-Rust, Amado R. Maglinao, Danilo M. Cablayan, A. Hakim and M. Abdul Ghani*

Technical Farm-Level Issues in Irrigation for Rice-Based Farming Systems: An Intercountry Synthesis ..... 211

*Sadiq I. Bhuiyan*

Opportunities for the Diversification of Asian Rice Farming Systems: A Deterministic Paradigm ..... 291

*Prabhu L. Pingali*

Summary/Highlights of Discussions: Synthesis Papers ..... 321

**SECTION V: SMALL GROUP OUTPUTS, DISCUSSIONS AND WRAP-UP ..... 331**

Summary/Highlights of Discussions: Group Reports and Wrap-up ..... 333

Concluding Remarks (i) ..... 341

*F.A. Bernardo*

Concluding Remarks (ii) ..... 343

*C. Abernethy*

Appendices ..... 345

Workshop Program ..... 347

Workshop Participants ..... 351

# 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***
International Irrigation Management Institute

# 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 irrigation 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

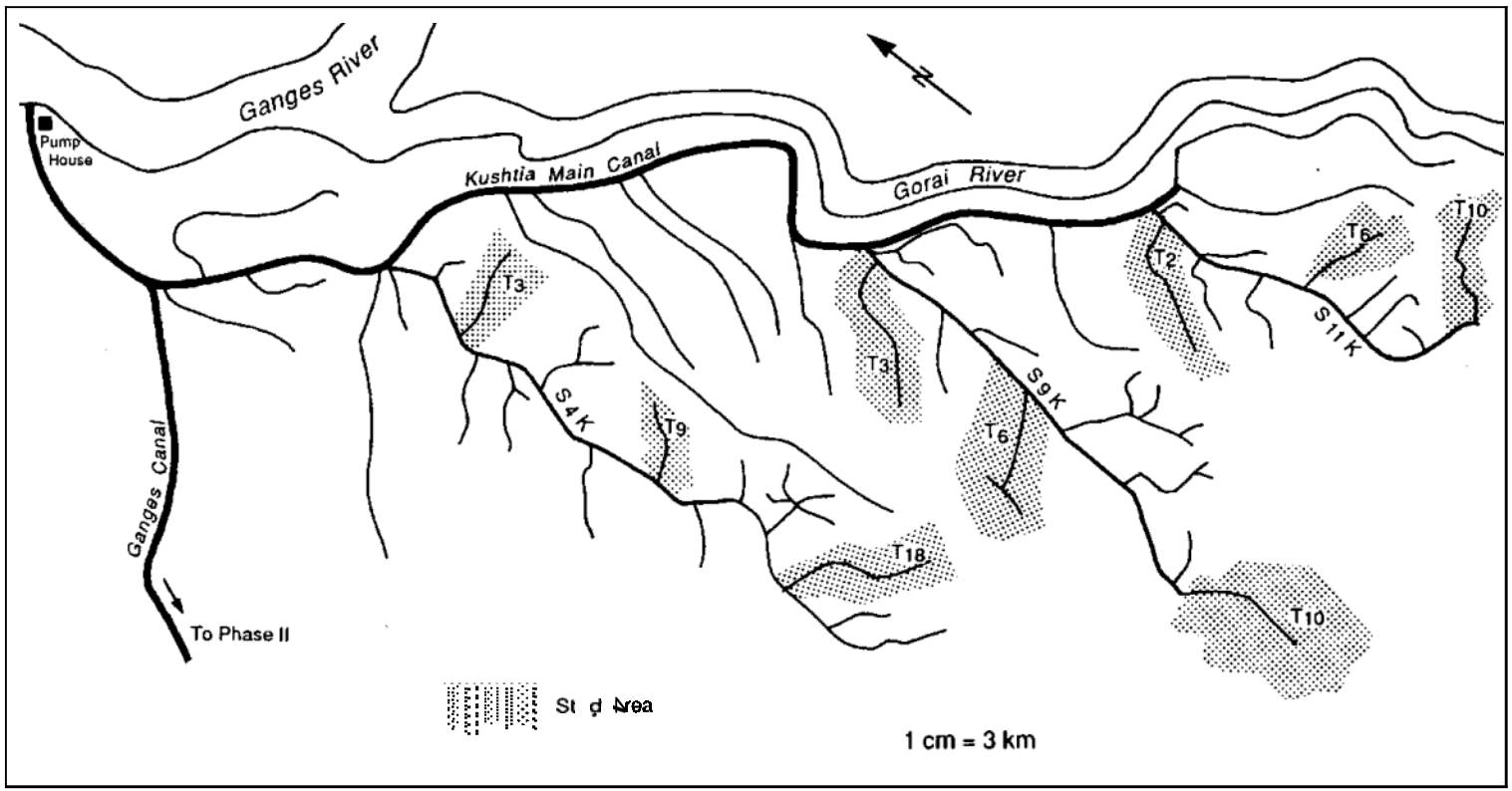
### Research Sites

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 areatorepresent 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** wasconsidered as theperiod 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-Augustto November-December), water **use** for land preparationwas **theamountcomputedfortheperiodfrom**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 15days 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** subsidiarypumps having a total capacity of 3.54CMS (125cusec) (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 U.S. 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.

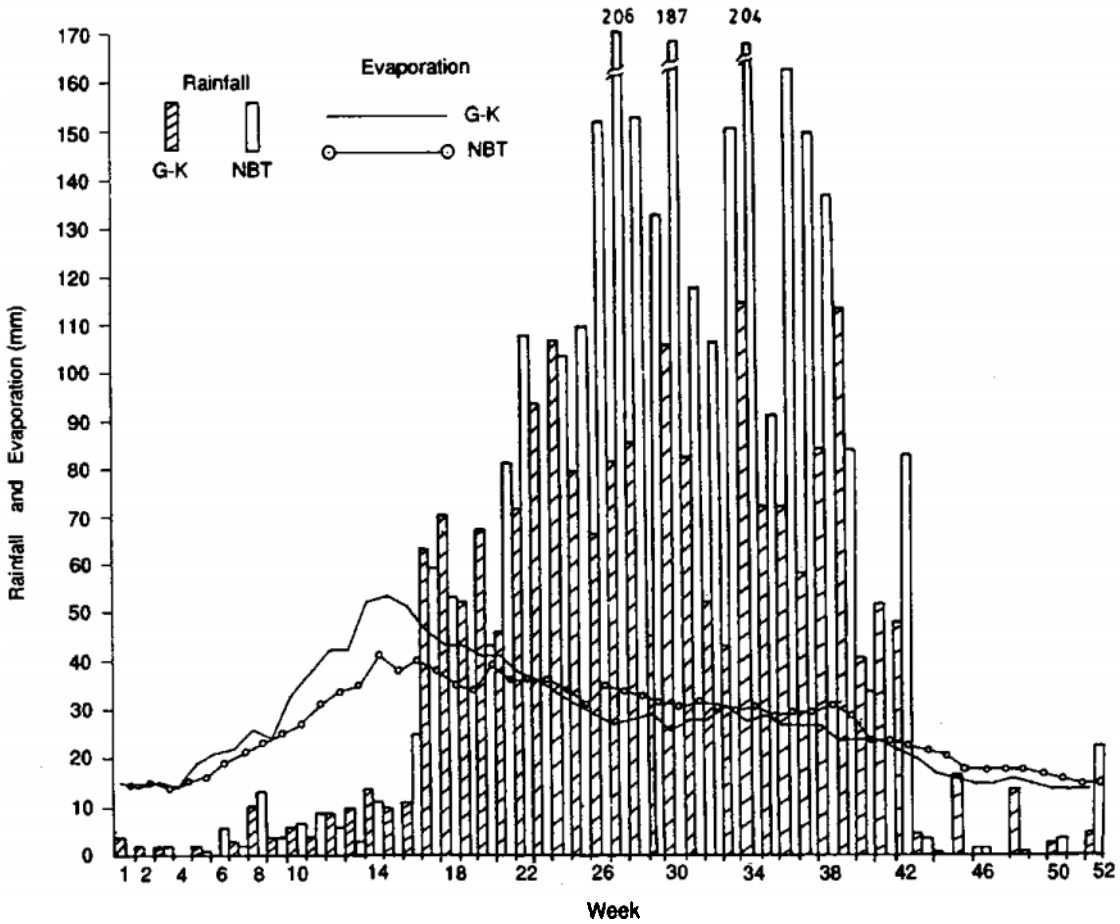
**Water distribution status.** Pumped irrigation water is distributed to the project area through a network of gravity canals consisting of the main, secondary and tertiary canals and field channels. The project was designed and constructed to operate initially as an automatic downstream control system.

*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 (all ocations) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | S4K | | | S9K | | | S11K | | |
| | | T3 | T9 | T18 | T3 | T6 | T10 | T2 | T6 | |
| 1983 | Period | 51 | 27 | | 43 | 42 | 26 | 39 | 32 | |
| | Volume | 0,579 | 8,086 | ND | 4.724 | 5,689 | 115 | !,329 | 58 | **31,580** |
| 1984 | Period | 10 | 13 | | 43 | I8 | 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 |
| A erage 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.*

| Year | Season | Pro/Act. | LOCATION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | T3/S4K | T9/S4K | T1864K | T3/S9K | T6/S9K | T10/S9K | T2/S11k | T7/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 (11-355cm) 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 availability (Phase Aus Season, 1990. status in the selected tertiaries of S8K, Ganges-Kobadak Project*

| 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 | | LOCATION | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | T3/S4K | T9/S4K | T3/S9K | T6/S9 | T10/S9 | 2/S11K | 6/S11K |
| 1983 | IR | 73 | 48 | 23 | 26 | 2 | 15 | 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.*

| Year | | LOCATION | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | T3/S4K | T9/S4K | T18/S4K | T3/S9K | T6/S9K | T10/S9K | T2/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 | | 149 | 155 | 172 | 155 |
| 1985 | IR | 389 | % | 898 | 117 | 83 | 77 | 41 |
| | RF | 55 | 47 | 68 | 67 | 47 | 43 | 33 |
| | Total | 444 | 143 | 966 | 184 | 130 | 120 | 74 |
| 1986 | IR | 78 | 76 | 75 | 640 | 60 | 56 | 94 |
| | RF | 70 | 71 | 72 | 58 | 60 | 61 | 60 |
| | Total | 148 | 147 | 147 | 122 | 120 | 117 | 154 |
| 1987 | IR | 74 | 71 | NID | 68 | 60 | 62 | 61 |
| | RF | 45 | 50 | | 60 | 58 | 63 | 61 |
| | Total | 119 | 121 | | 128 | 118 | 125 | 122 |
| 1988 | IR | 79 | 60 | | 39 | 37 | 37 | 54 |
| | RF | % | 111 | | 119 | 121 | 114 | 100 |
| | Total | 175 | 171 | | 158 | 158 | 151 | 154 |
| 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 | 8/S4K | 3/S9K | 6/S9K | 10/S9K | 2/S11K | 5/S11K | 10/S11K |
| 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 | I17 | 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 | I8 | 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 | I10 | 131 | I24 | I20 | I14 | 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 | I I2 | 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 | | After implementation | |
|---|---|---|---|---|---|
| | | Irrigation rea in Aman 86 (ha) | Irrigation area in Amar 87 (ha) | Expected ngable area I Aus seasor (ha) | Expected rrigable 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 dryseasonsmostlyusinganimprovedmethodinwhichthecanalbed

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) | |
| | I | 0 | 0 | 0 | 0 | |
| March | 2 | 0.24 | 39 | 0 | 0 | 3.12 |
| | 3 | 0.34 | 0 | 0 | 0 | |
| | I | 0.28 | 0 | 0 | 0 | |
| April | 2 | 0.27 | 4 | 0.65 | 0 | 4.26 |
| | 3 | 0.38 | 82 | 0.70 | 3.8 | |
| | I | 0.26 | 67 | 0.59 | 14.0 | |
| May | 2 | 0.40 | 123 | 0.79 | 168.7 | |
| | 3 | 0.66 | 81 | 0.73 | 0 | |
| | I | 0.51 | 5 | 0.59 | 73.7 | |
| June | 2 | 1.38 | 498 | 0.51 | 66. I | |
| | 3 | 1.61 | 102 | 0.90 | 56.0 | |
| | I | I .47 | 215 | I.42 | 97.0 | |
| July | 2 | I .37 | 25 | 1.42 | 76.0 | |
| | 3 | 1.01 | 102 | I .42 | 0 | |
| | I | I .02 | 39 | I .42 | 55.0 | |
| August | 2 | 1.42 | 74 | I .69 | 15.0 | 6.00 |
| | 3 | 1.37 | 40 | I .69 | 28.0 | |
| | I | 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 | |
| | I | 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 | |
| | I | 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 | Yield (kg/ha) 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 operating days | Totel operating operating hours | Per day operaing hours |
|---|---|---|---|---|---|
| A. | Those fulfilling MICA arget | 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.*

| Tubewell No. | Discharge capacity (lps) | Potential irrigable area (ha | irrigation coverage (ha) | | | | Increaced irrigated area | |
|---|---|---|---|---|---|---|---|---|
| | | | Before minimum irrigation program | | After minimum irrigation program | | | |
| | | | Actual irrigated area | % of potential irrigable area | Actual irrigated area | % of potential irrigable 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 | 73.1 | 1.8 | 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 | 5.1 | 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 | 24.1 | 124.2 |
| **All tubewells** | 899.3 | 205.9 | 85.9 | 491.6 | 155.9 | 897.1 | 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 Proprramme in North Bangladesh *Tubewell* Project, 1985-1990.

| 'uhewell no. | Discharge capacity (lps) | otential rigahle ea (ha) | Irrigation c :rage (ha) | | | | Increased irrigated area | |
|---|---|---|---|---|---|---|---|---|
| | | | Before minimum rrigatio rogram | | After minimum rrigatio rogram | | | |
| | | | Actual Tigated area | % of otential rrigable area | Actual rigated 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.**I | 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 | | | |
| I22 | 53.4 | 12.2 | 4.0 | 32.8 | 1.4 | 11.5 | -2.6 | -21.3 |
| I23 | 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.I |
| 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 | Discharge (lps) | Irrigable area (ha) | Irrigated area (ha) | Water used (mm) | | Total | Average yield kg/ha) | Productivity of wale, kg/ha/mm |
|---|---|---|---|---|---|---|---|---|
| | | | | Land preparation | Growing period | | | |
| 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 of water in the North Bangladesh Tuebwell Project, Ganges-Kobadak Project and Rajshahi tubewell sites of Bangladesh, 1983-1990.*

| Location | 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.

## Acknowledgements

The authors' sincere thanks are extended to the staff members of the Bangladesh Rice Research Institute, the Bangladesh Water Development Board, International Irrigation Management Institute and the International Rice Research Institute, and especially to the cooperating farmers of the study area. Sincere appreciation is extended to Mr. Md. Arifur Rahman and Mr. Md. Abdul Maleque for typing the manuscript.

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| Activity | 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 ᴍ 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. |

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

| Activity | Methodology/tools | | Actual/recommended methodologies for UTRIS | |
|---|---|---|---|---|
| | Existing | Recommended | Existing | Recommended |
| Planning | | | | |
| Estimation of Available Water Supply | | | | |
| - Dependabl rainfall | 5-year noving average | 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 | Weekly lependable ainfall values to e adjusted nnually as data s added to revious ecords. |
| Stream flow (River discharge) | 5-year noving average | Lon-Normal/Low Distribution Analysis augment existing data and re-analyze annually | Streamflow 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. | Weekly lependable river low values to e adjusted nnually 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 nequal distribution of water n day to day operation of system due to incorrect ssessment of water needs | Verified dam for use in planning and actual system operation. |

**Continued on *page* 93**

# 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 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.

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

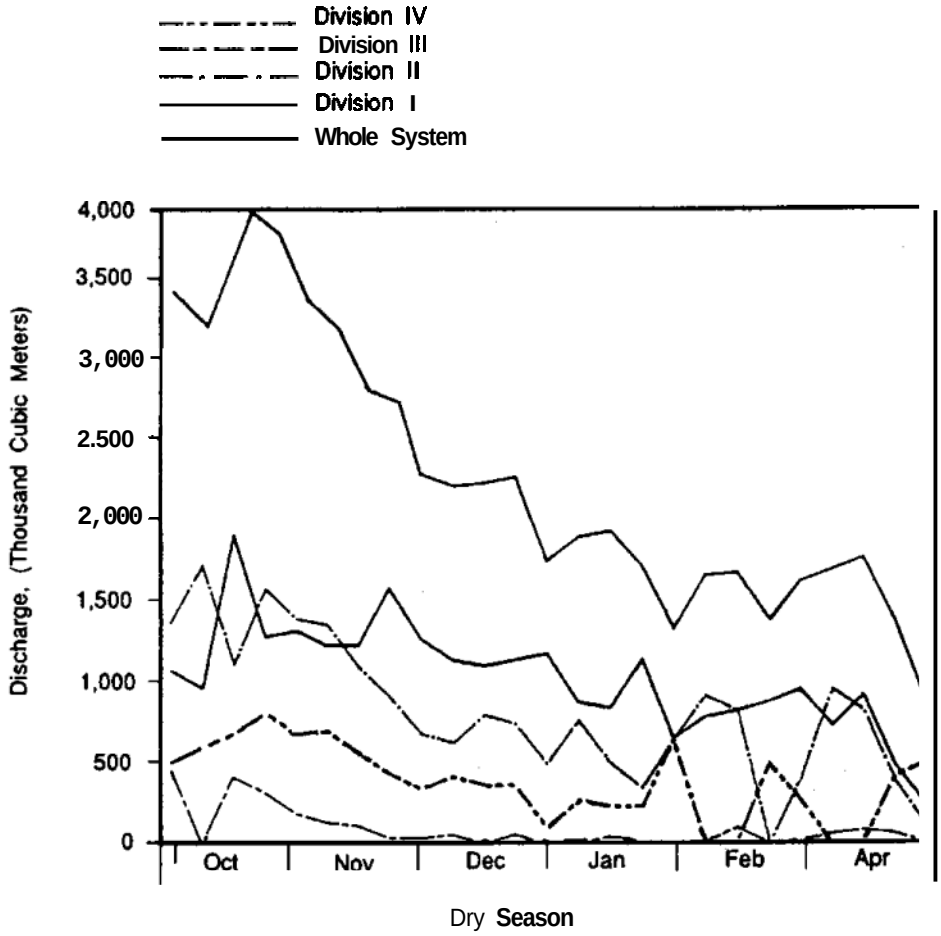


*Figure 18.* Weekly *diverted flows at main canal and division headgates, Laoag-Vintar Riwr Irrigation* System, *dry season, 1988-89.*

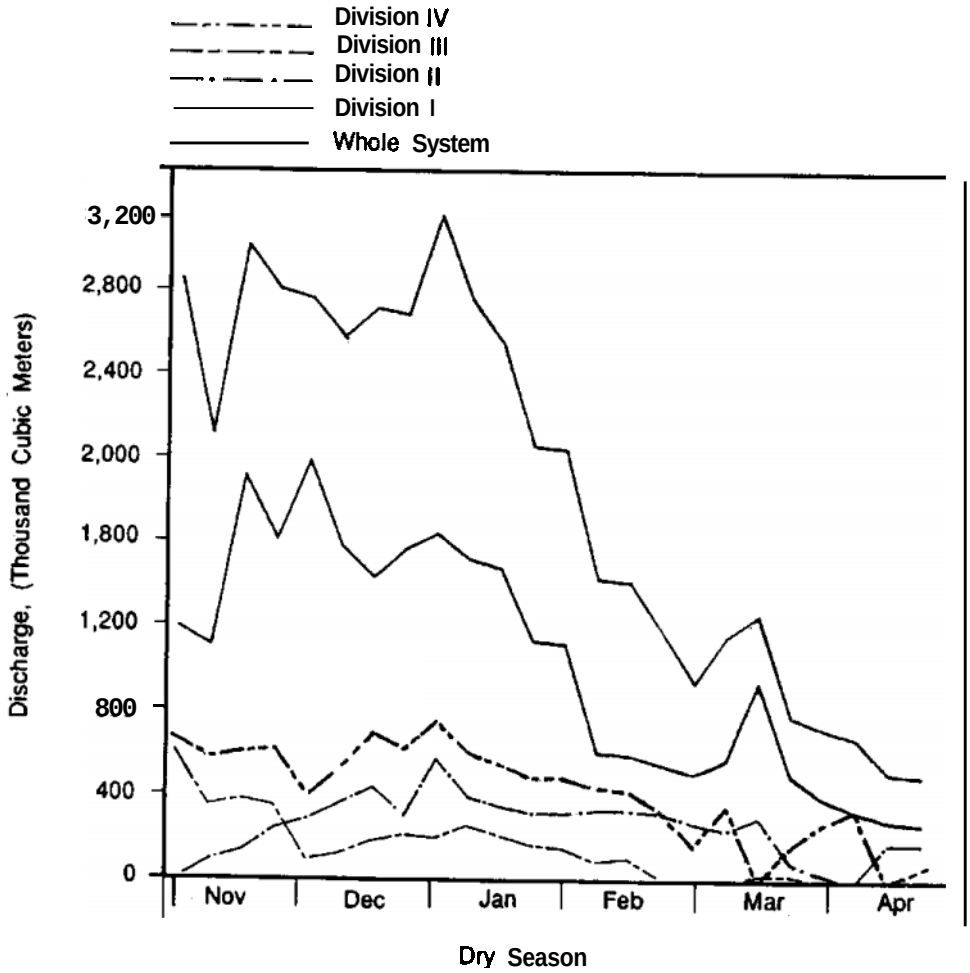


Figure 17. Weekly *diverted flows* at *main canal* and *divisional* kendgates, *Laoag-Vintar River* Irrigation System, *dry* season, *1987-88*.

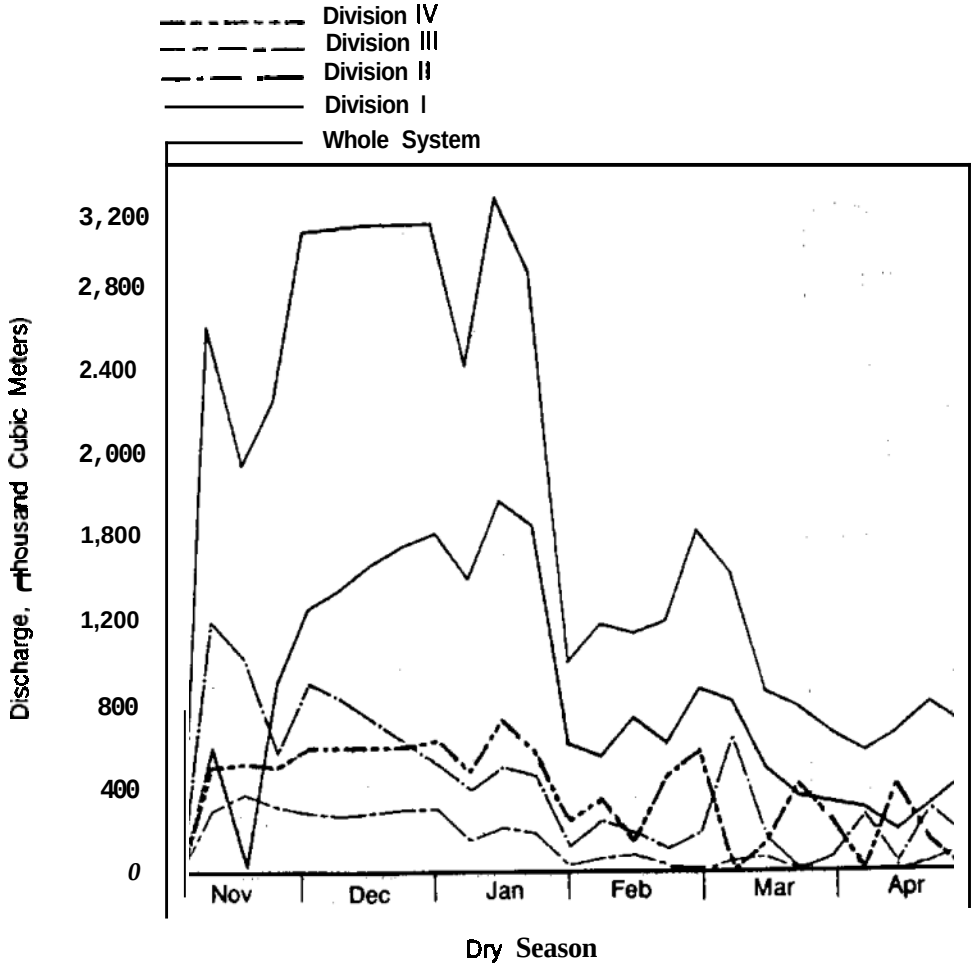


*Figure 16. Cumulative planted area, Laoag-Vintar River Irrigation System, dry seasons 1987-88, 1988-89 and 1989-90.*

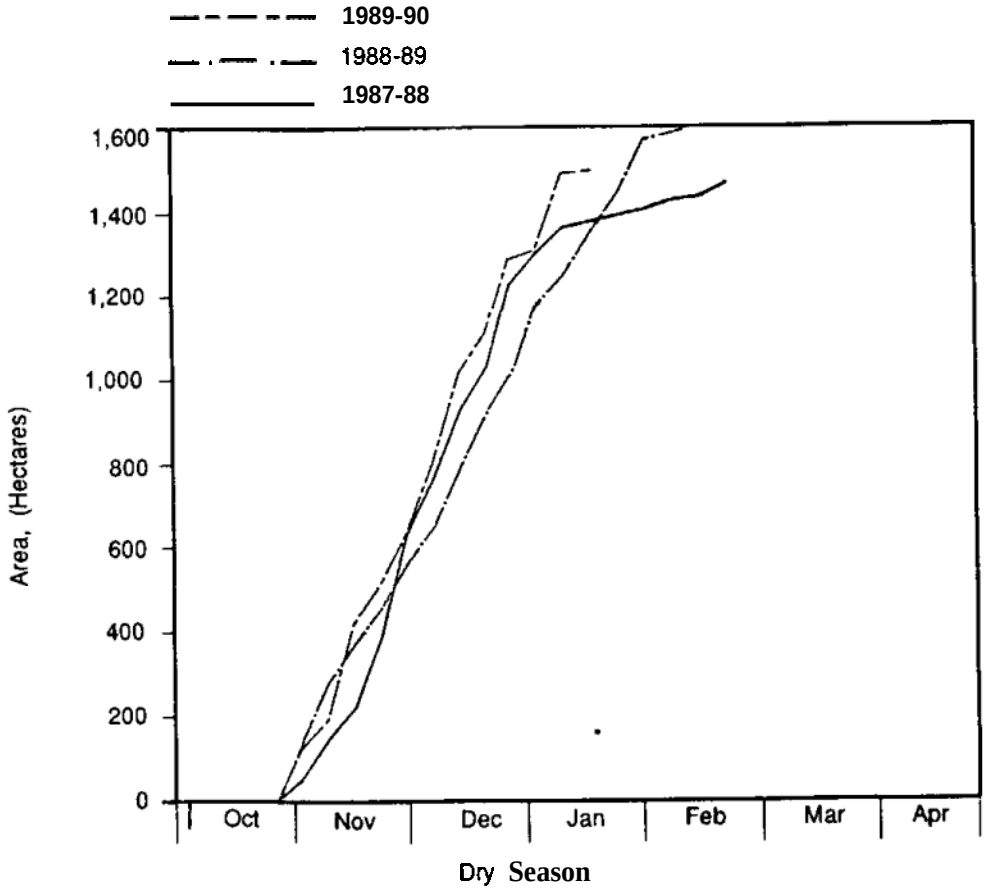
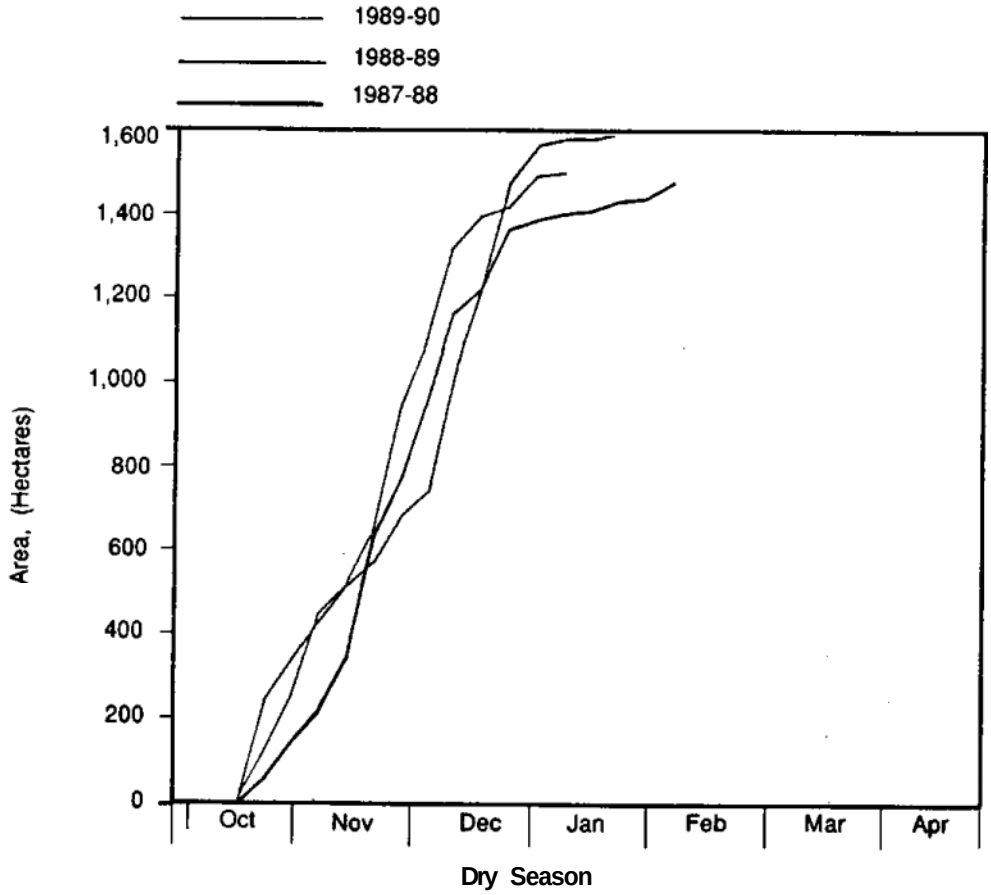


*Figure 15.* *Cumulative land-soaked area (started operation), Laoag-Vintar River Irrigation System, dry seasons, 1987-88, 1988-89 and 1989-90.*



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

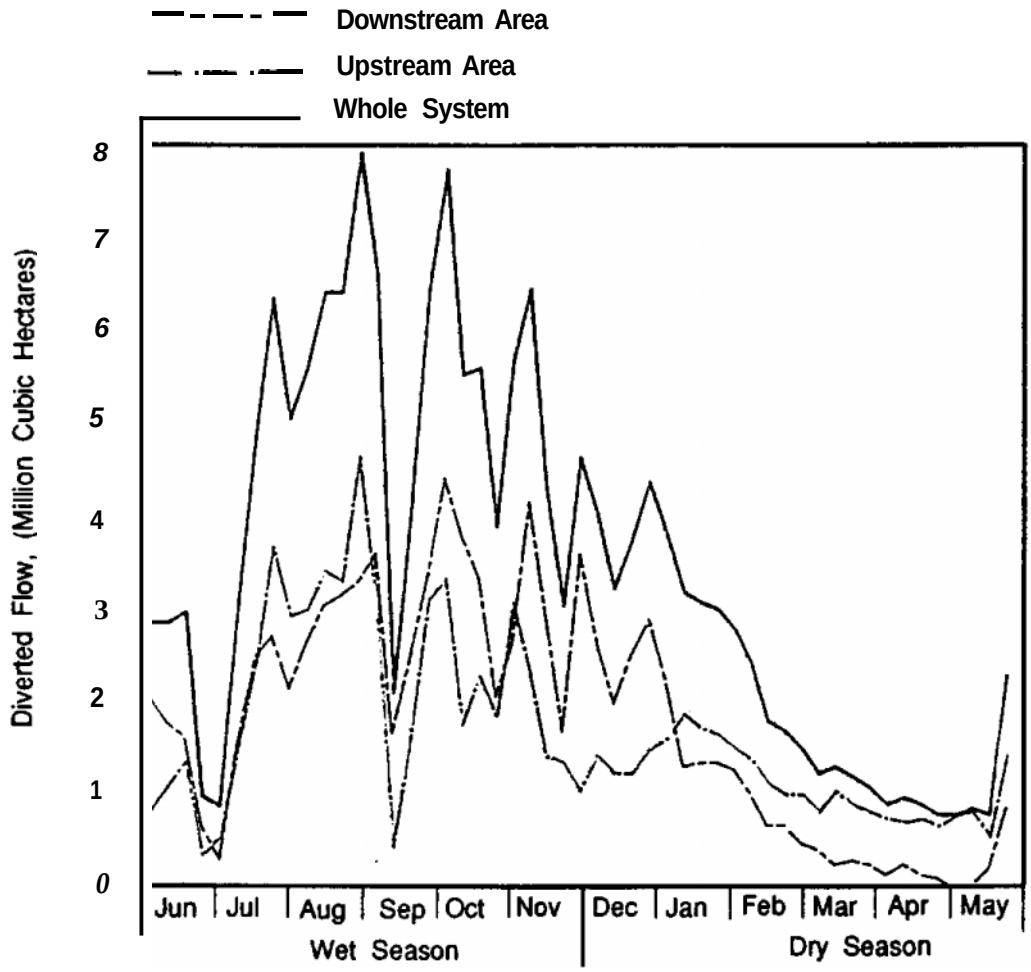


*Figure 13. Weekly diverted flow at canal headgate, upstream and downstream areas for the crop year 1988-89, Upper Talavera River Irrigation System.*

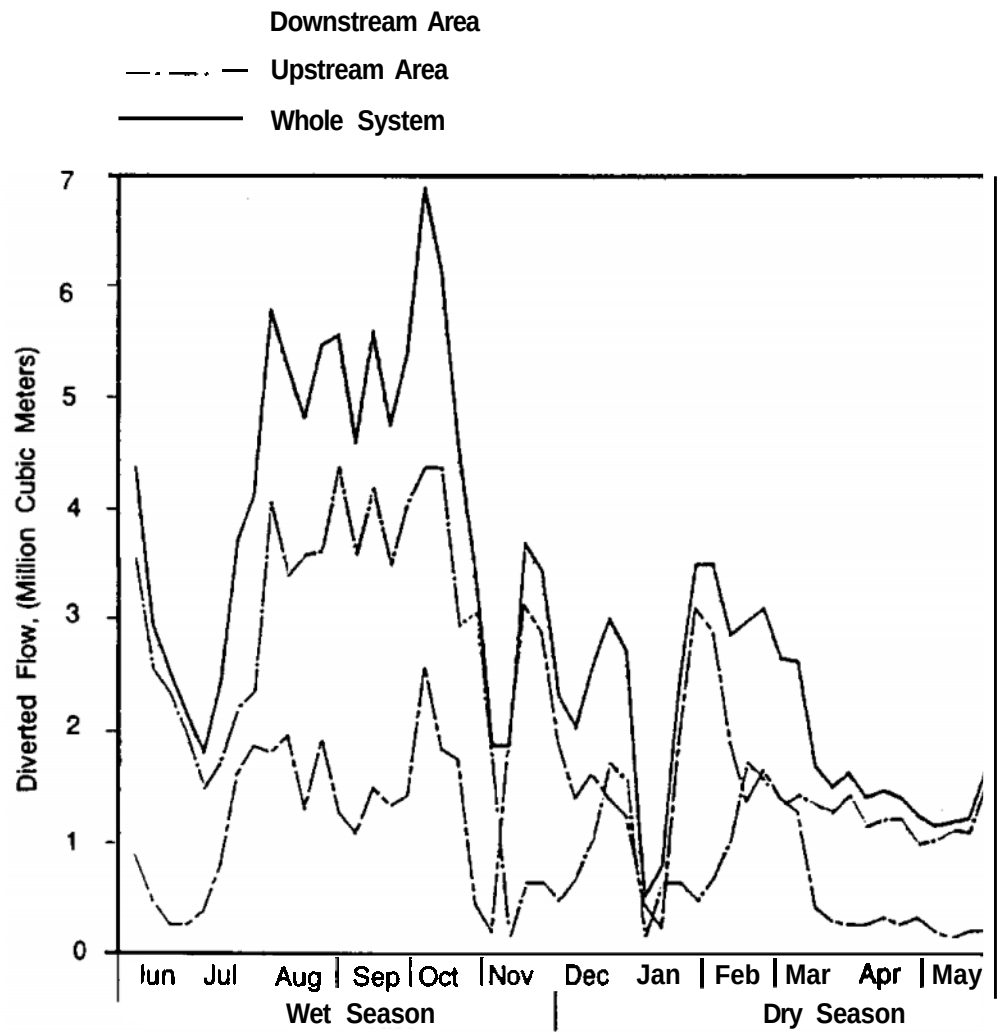


*Figure 12. Weekly diverted flow at canal headgate, upstream and downstream areas for the crop yenr 1987-88, Upper Talavera River Irrigation System.*

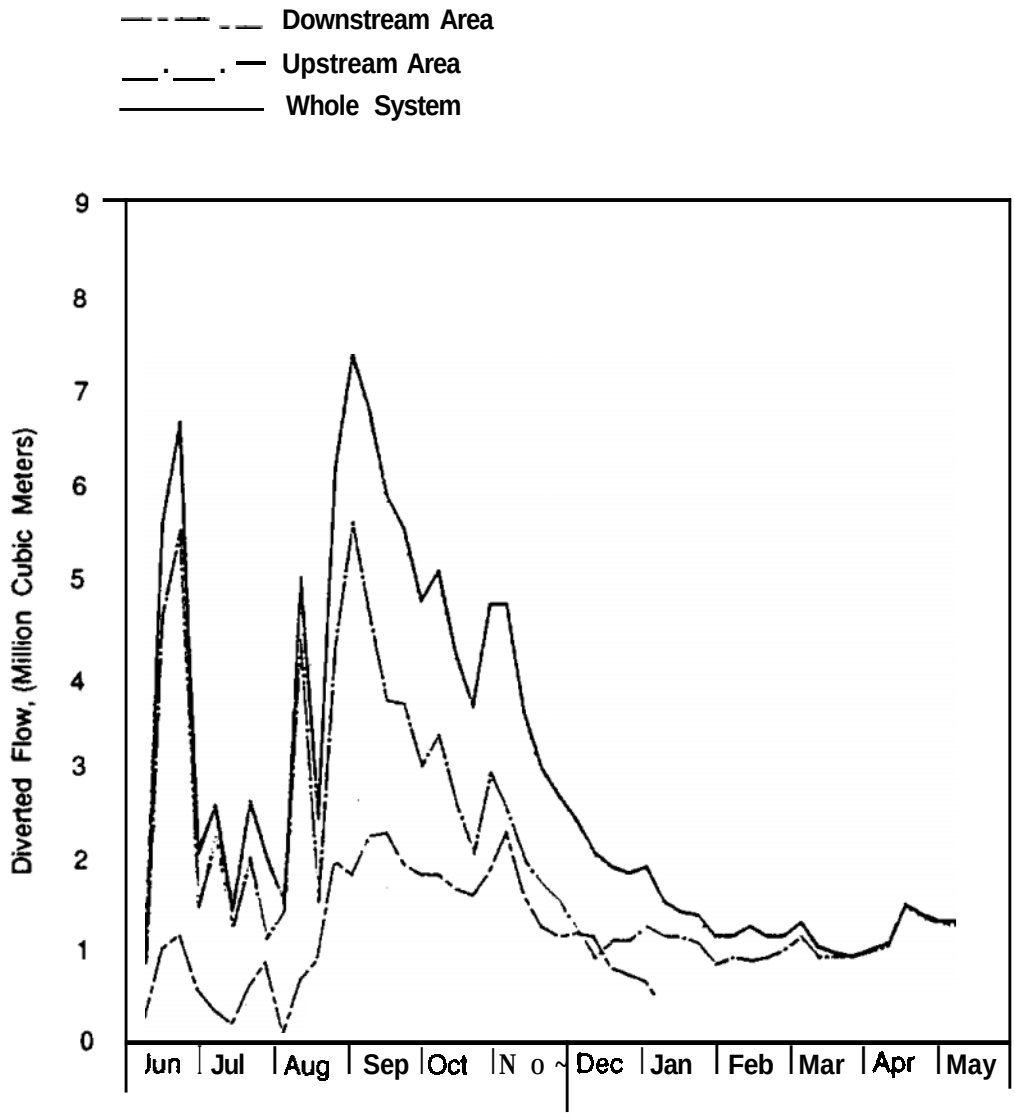
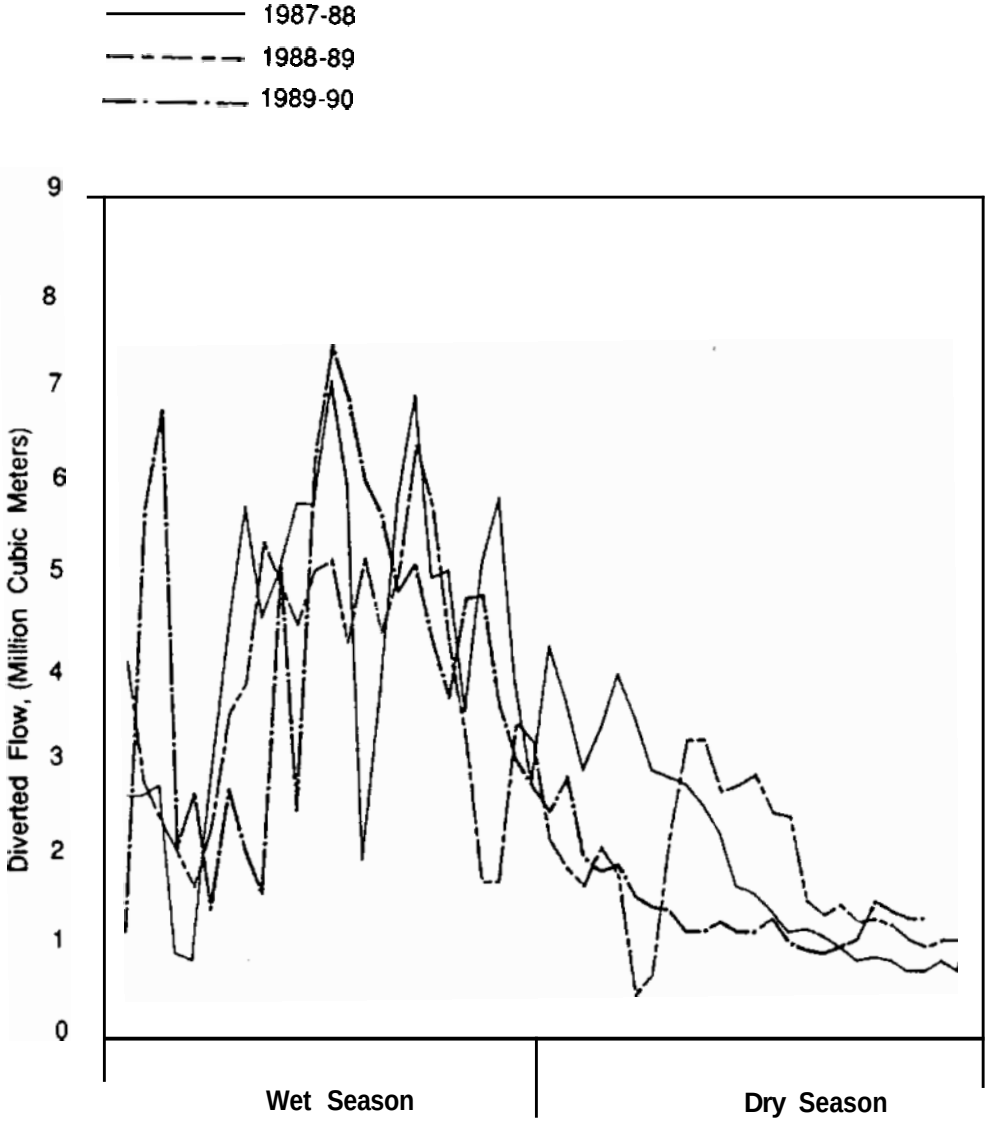


*Figure 11. Weekly diverted flow at main canal headgate for crop years 1987-88 and 1988-89, Upper Talauera River Irrigation System.*



| 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 | 1 | 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 10. Cumulative planted area, crop years whole system, Upper Talavera River Irrigation System*

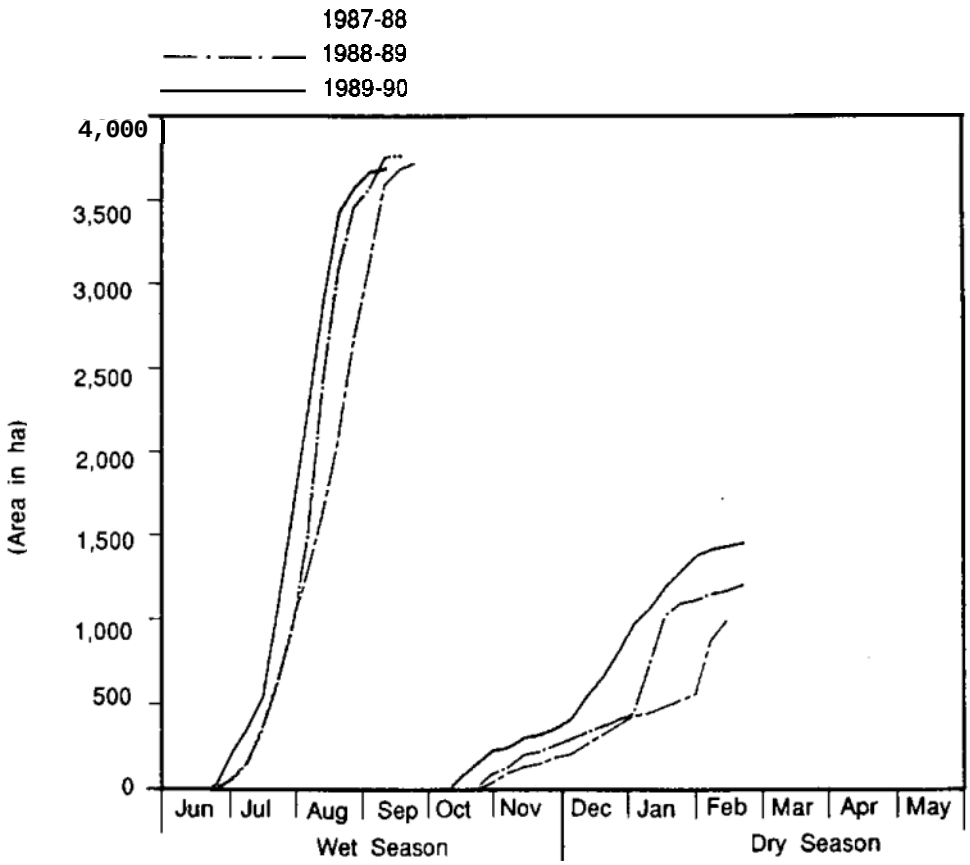
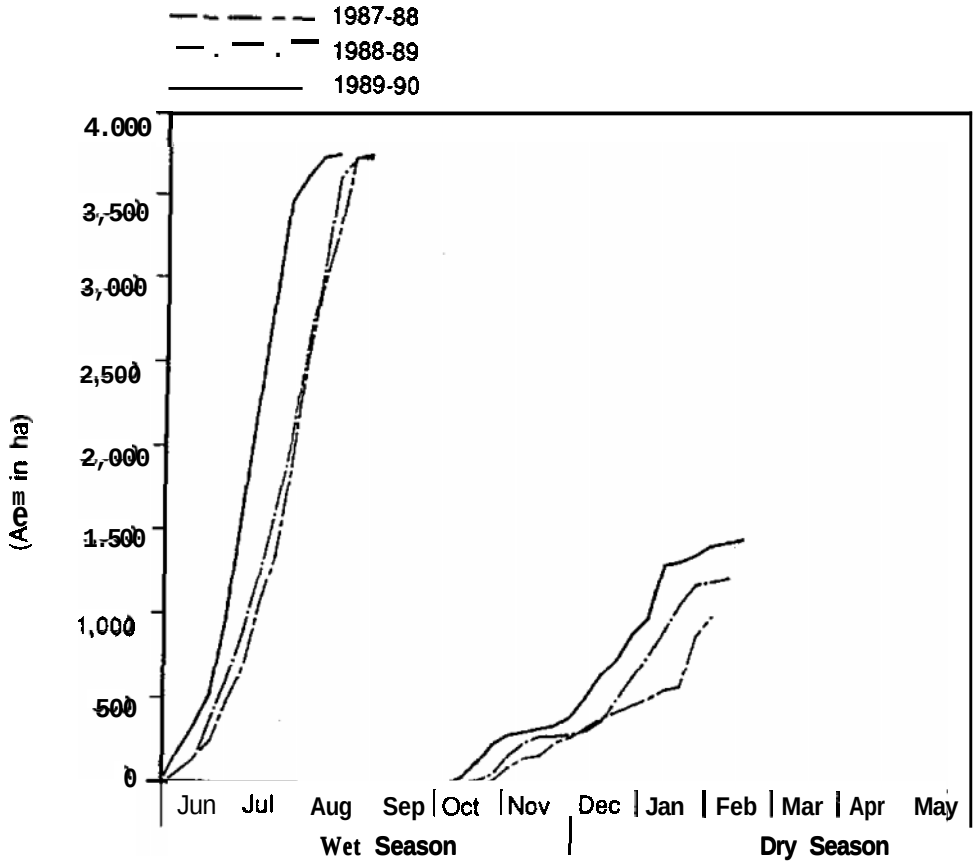


*Figure 9. Cumulative land-soaked area, (started operation), crop years 1987-88, 1988-89, and 1989-90, whole system, Upper Talavera River Irrigation System.*



(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).

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 side slopes 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

*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 | 93,189 | 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.

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 the 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).

# 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.

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

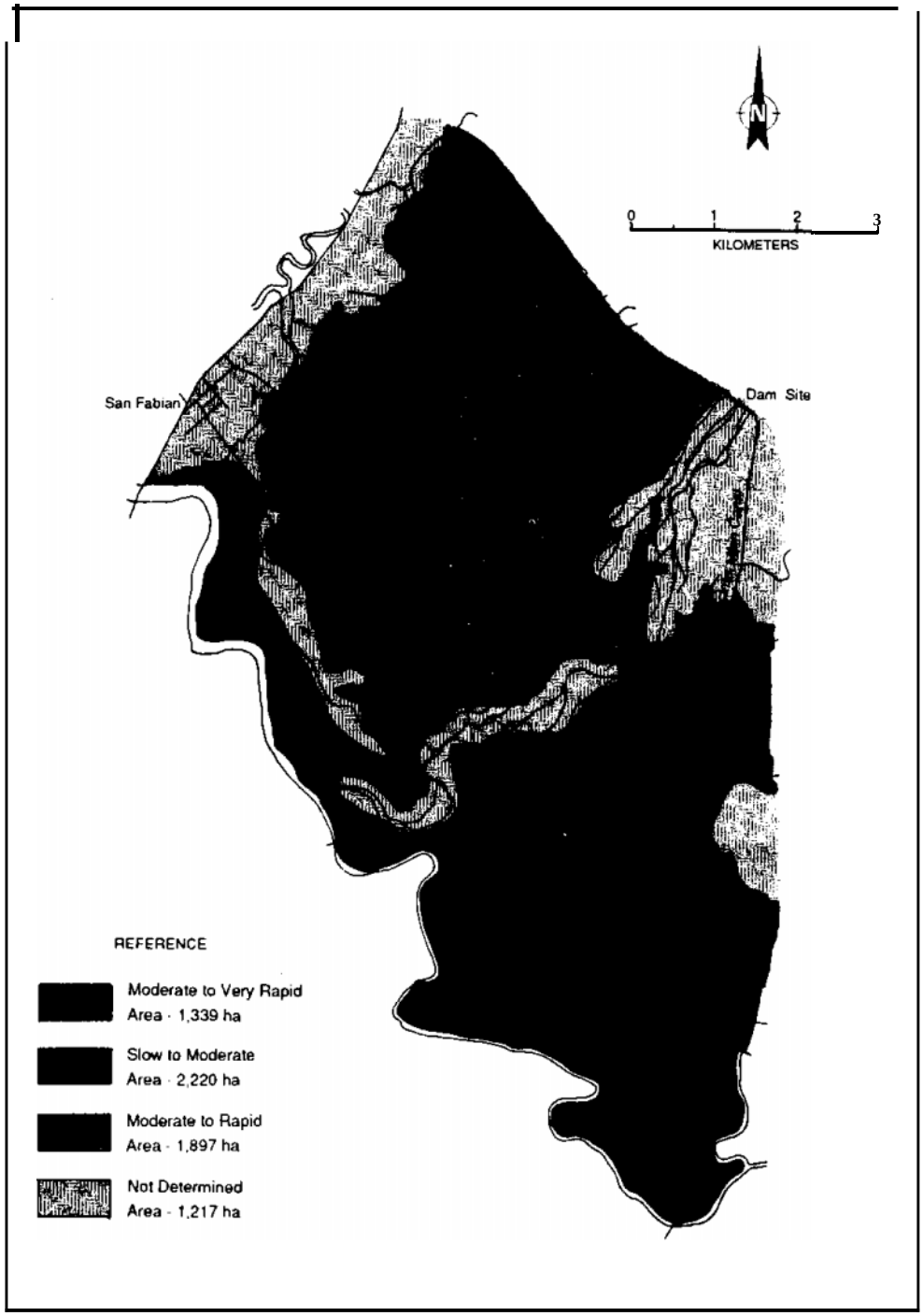


Figure 7. Agro-hydrological soil characterization map, San Fabian River.

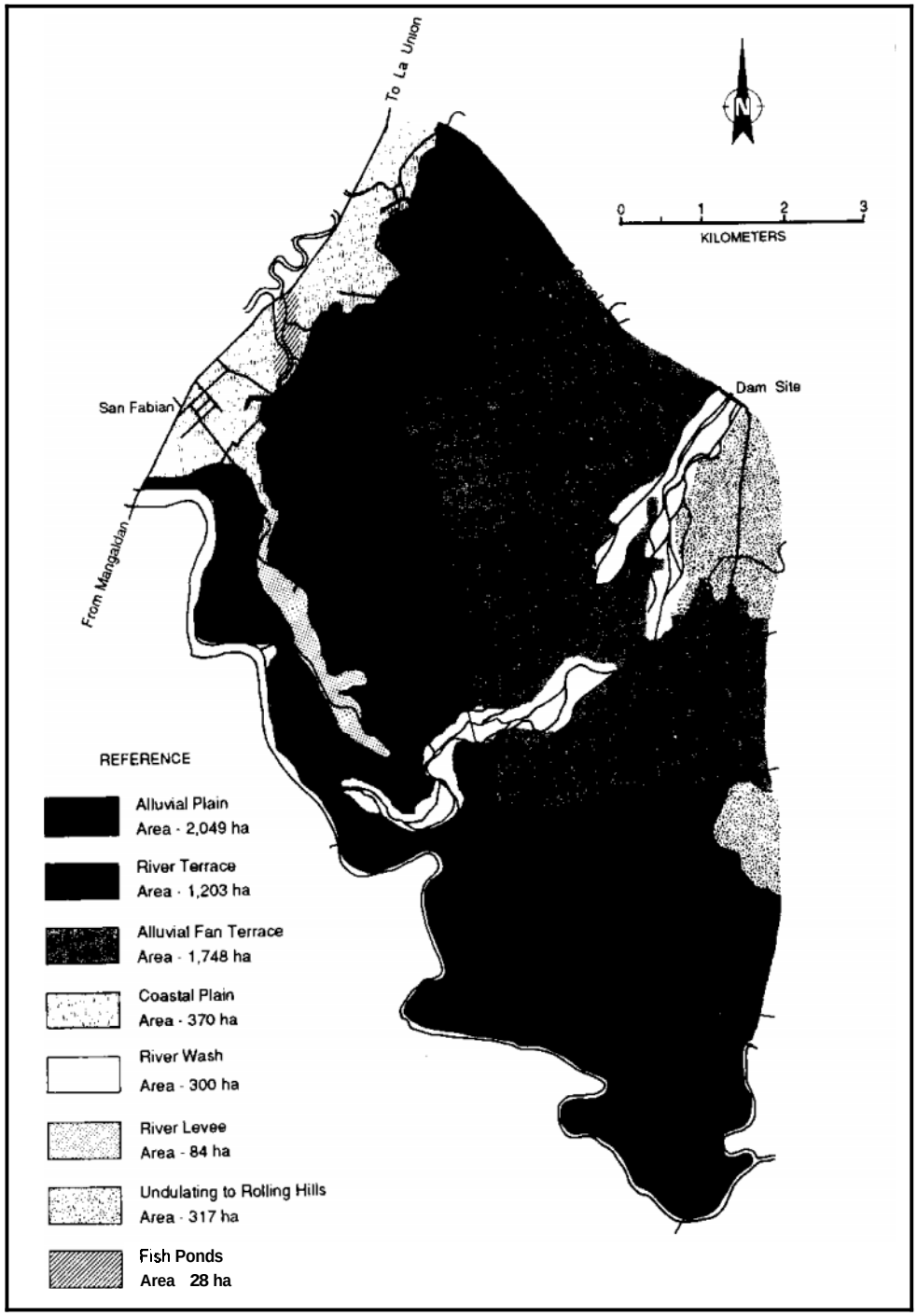


*Figure 6. Map of the San Fabian River Irrigation System.*

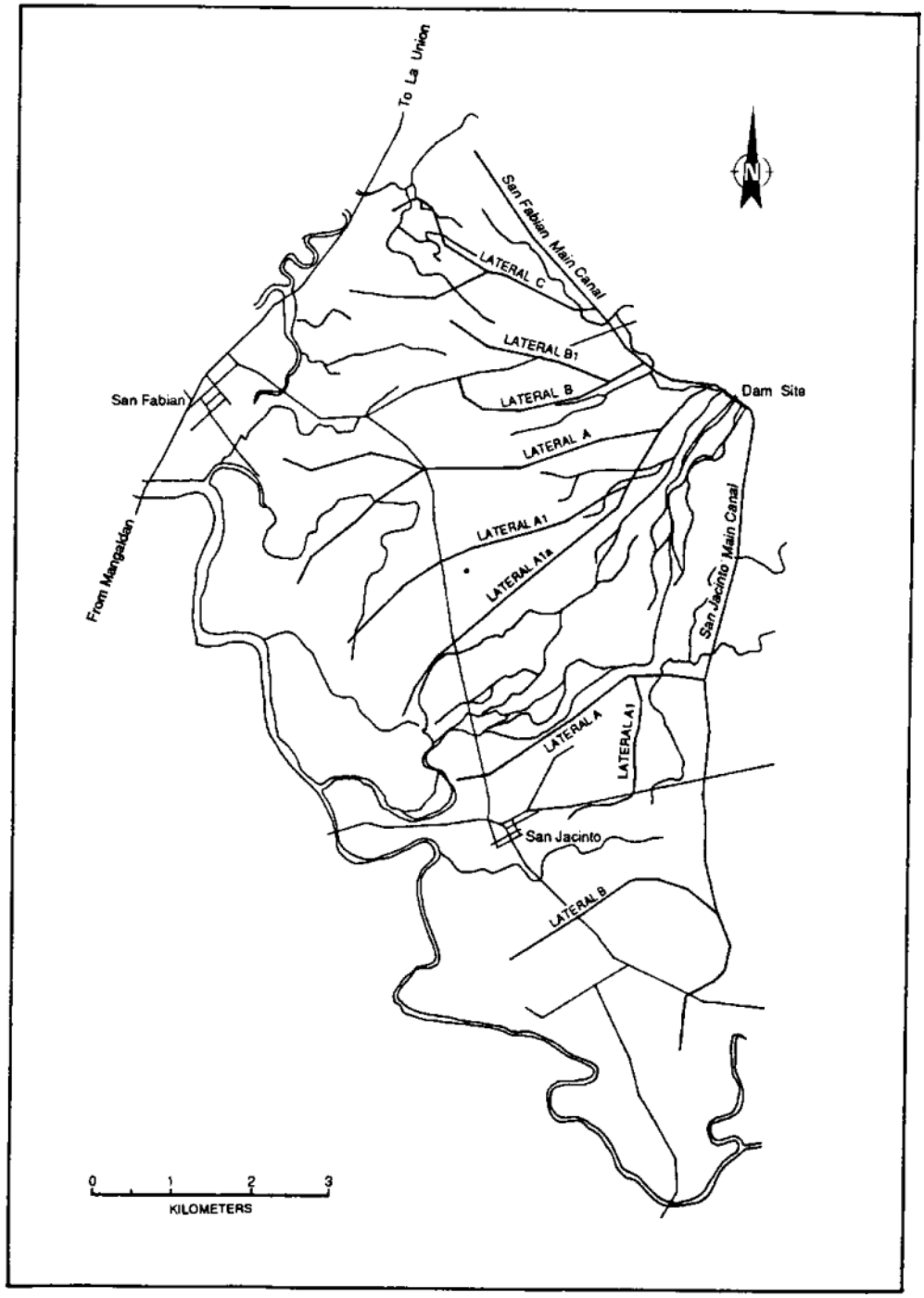


*Figure 5. Map of the Laoag-Vintar River Irrigation System.*

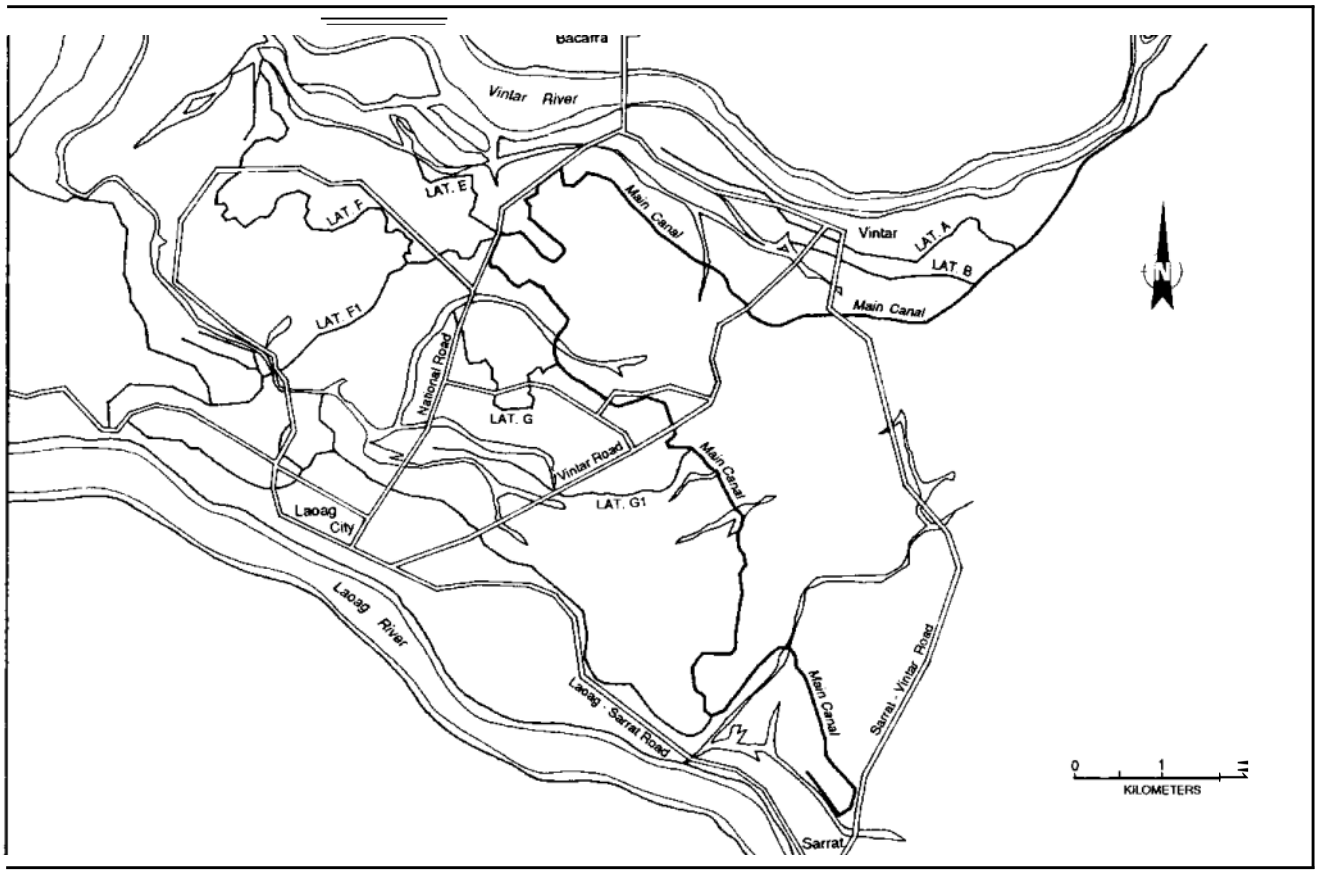
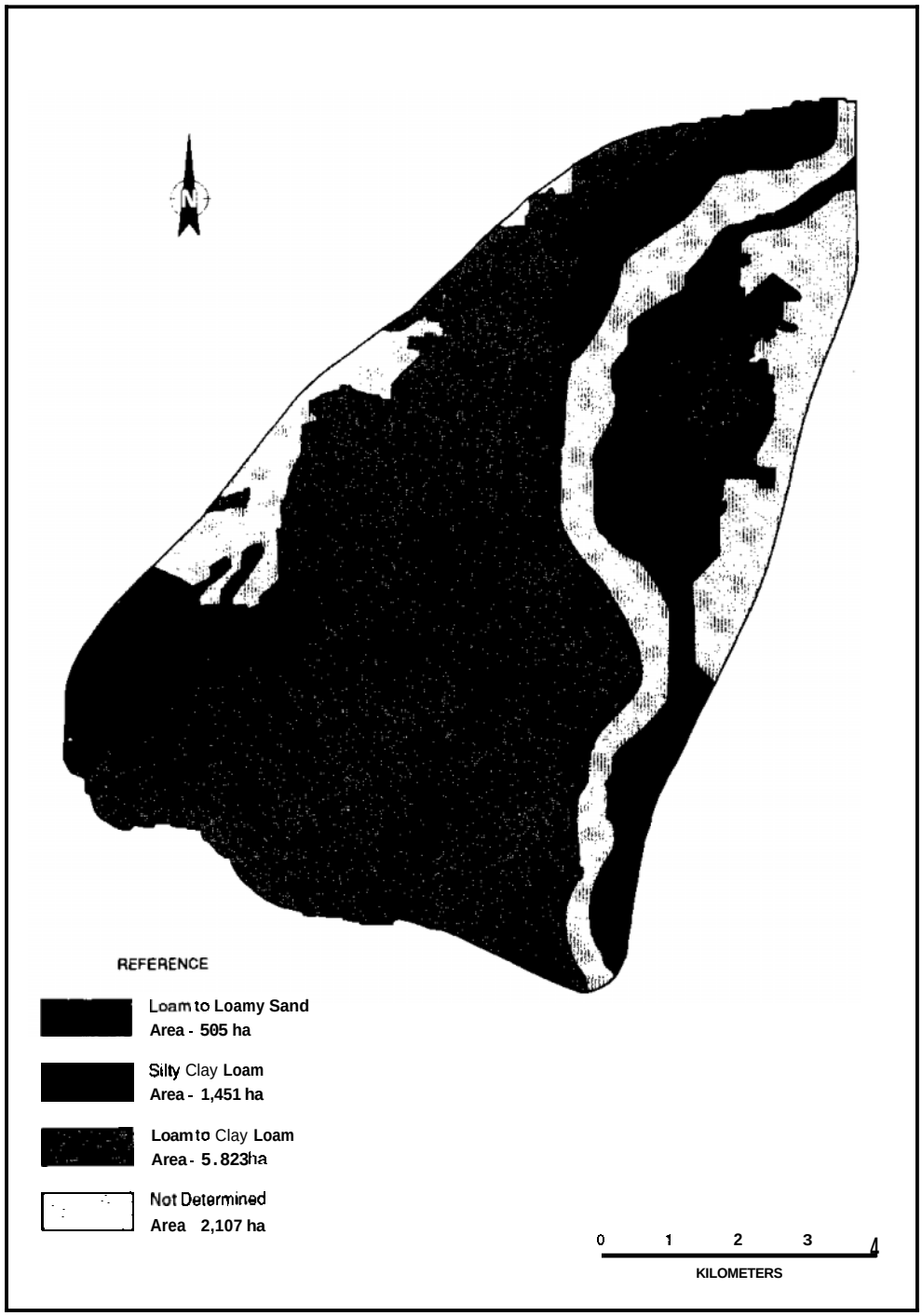


*Figure 4. Soil classification map of Upper Talavera River Irrigation System based on agro-hydrological soil characterization.*



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

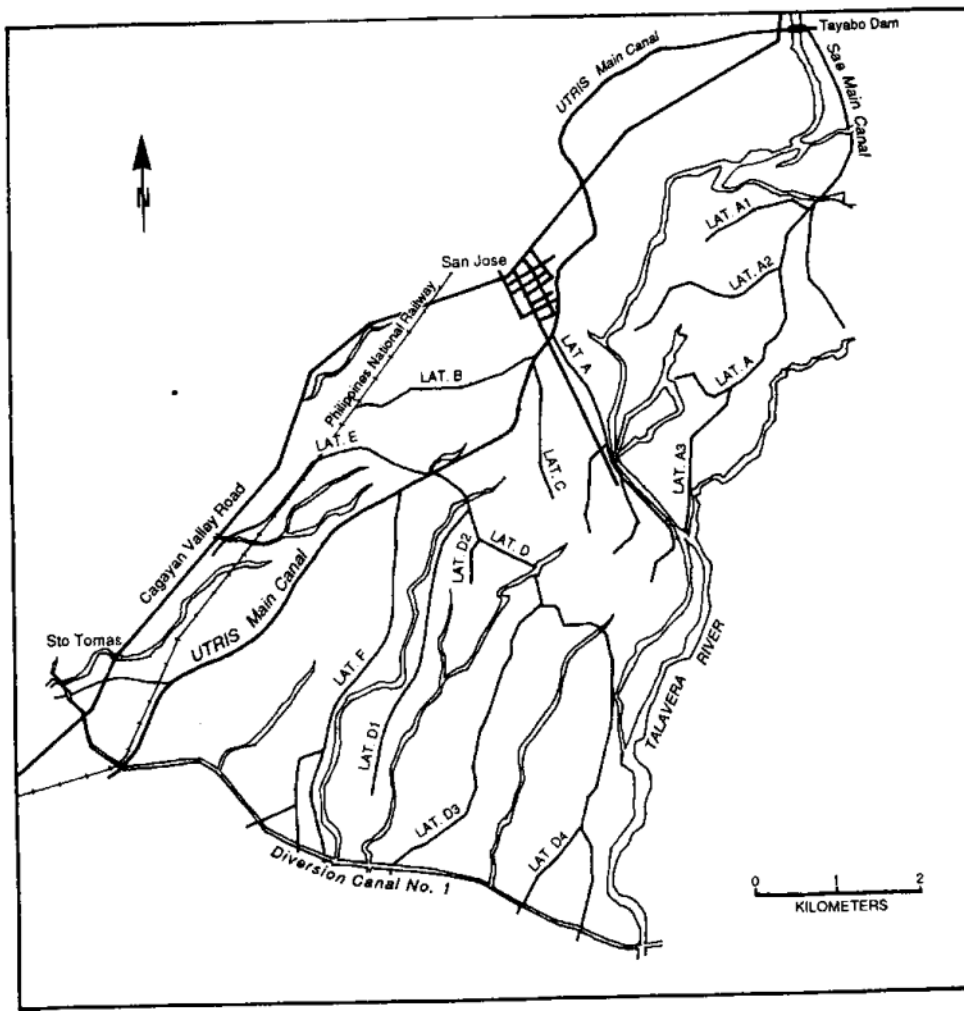
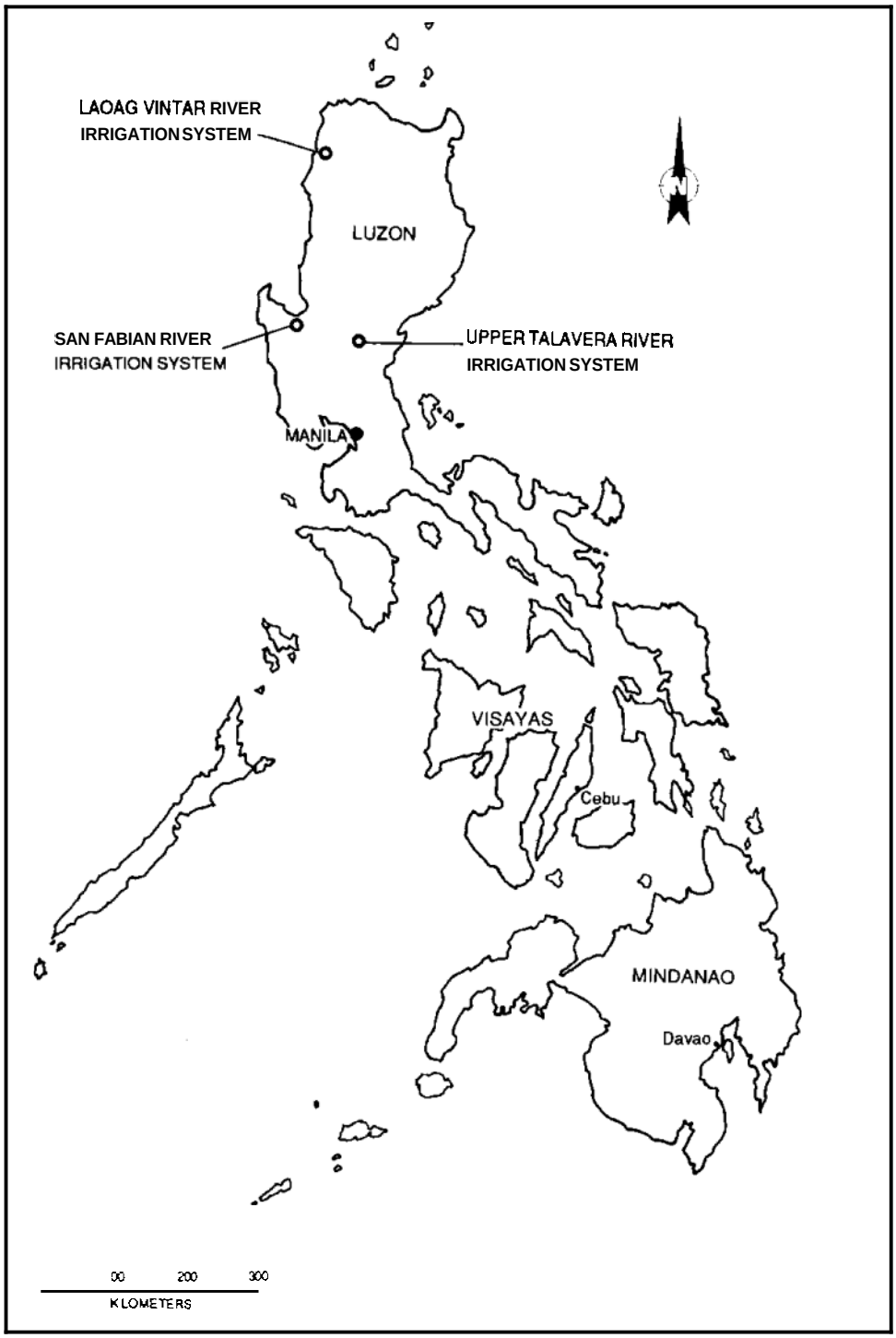


*Figure 2. Map of the Philippines showing location of study sites*



# IMPLEMENTATION ARRANGEMENTS

## Study Sites

T y vis ducted in three op erating irrigation systems in Luzon. es th pp e Talavera River Irrigation System (UTRIS) in Nueva Ecija, Laoag-Vintar River Irrigation System (LVRIS) in Ilocos Norte and the San Fabian River Irrigation Sl in Pangasinan (Figure The criteria used in the l c 1) irrigation system type and size; 2) presence € opp ; 3) current activities of IIMI and IRRI; 4) presence of a variety of soil classes; 5) rainfall p r ) existence of farmers' ani: i d 7) location and environment (whether peaceful or not).

All three are run-of-the ir ij;ai st November and dry the rest of the year, itl g , 5 , nd 4,000 ha for UTRIS (including the San Agustin Extension area), LVRIS, and SFRIS, respectively T k 1) Uplan r diversified crops such as onion, tobacco, cotton, rli ; etc., have been grown in portions of the service areas during

*Talavera River Irrigation System.* The UTRIS has two main c s ab o l 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 h 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 It has six main laterals and seven sub-laterals with l

*Table 1. General description of study sites.*

| System | Dam type | ig i (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 loom | 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.*

fi U IIS, p d i tl o i d g l l predominantly with some vegetables.

including San Agustin Extension area

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.

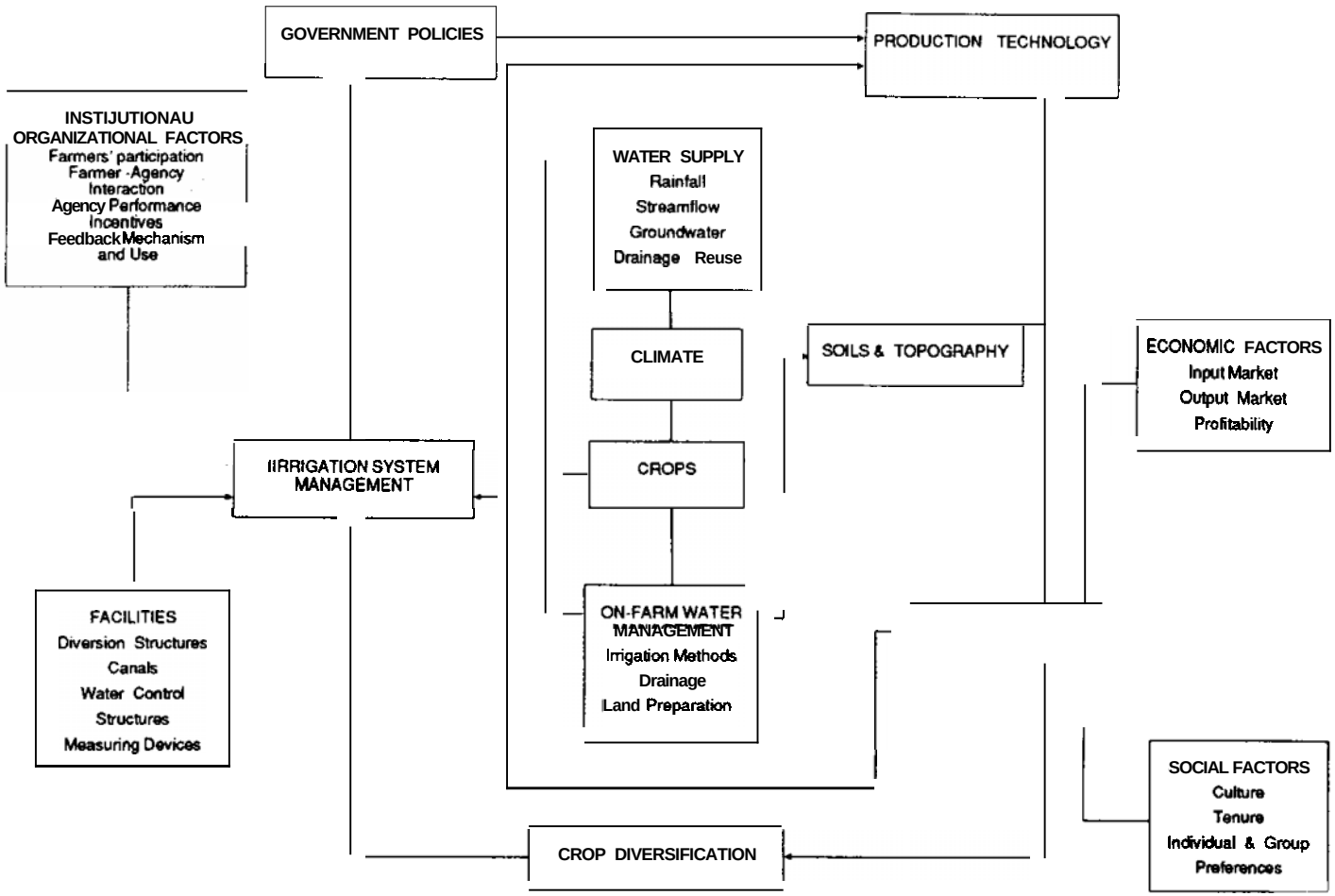
Management should monitor not only the inputs but also the outputs, the process, and the feedback, and make necessary changes in real-time operations in response to such feedback. Enhancing the management capacity of the decision-making and operating personnel of irrigation agencies, is the key to achieving 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.

*Figure 1. Interrelationship of factors affecting crop diversification*



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 benefited. 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.

# 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.

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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.

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:

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

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.

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

## TECHNICAL CONSTRAINTS IN MAIN IRRIGATION SYSTEM MANAGMENT

The last inventory conducted in 1988 by 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) | 19.582,112 |
| 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

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.

betweentheirrigationplanandtheexistingactivityinlandpreparation 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 |
| liddle (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 - dominantcrop.

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

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

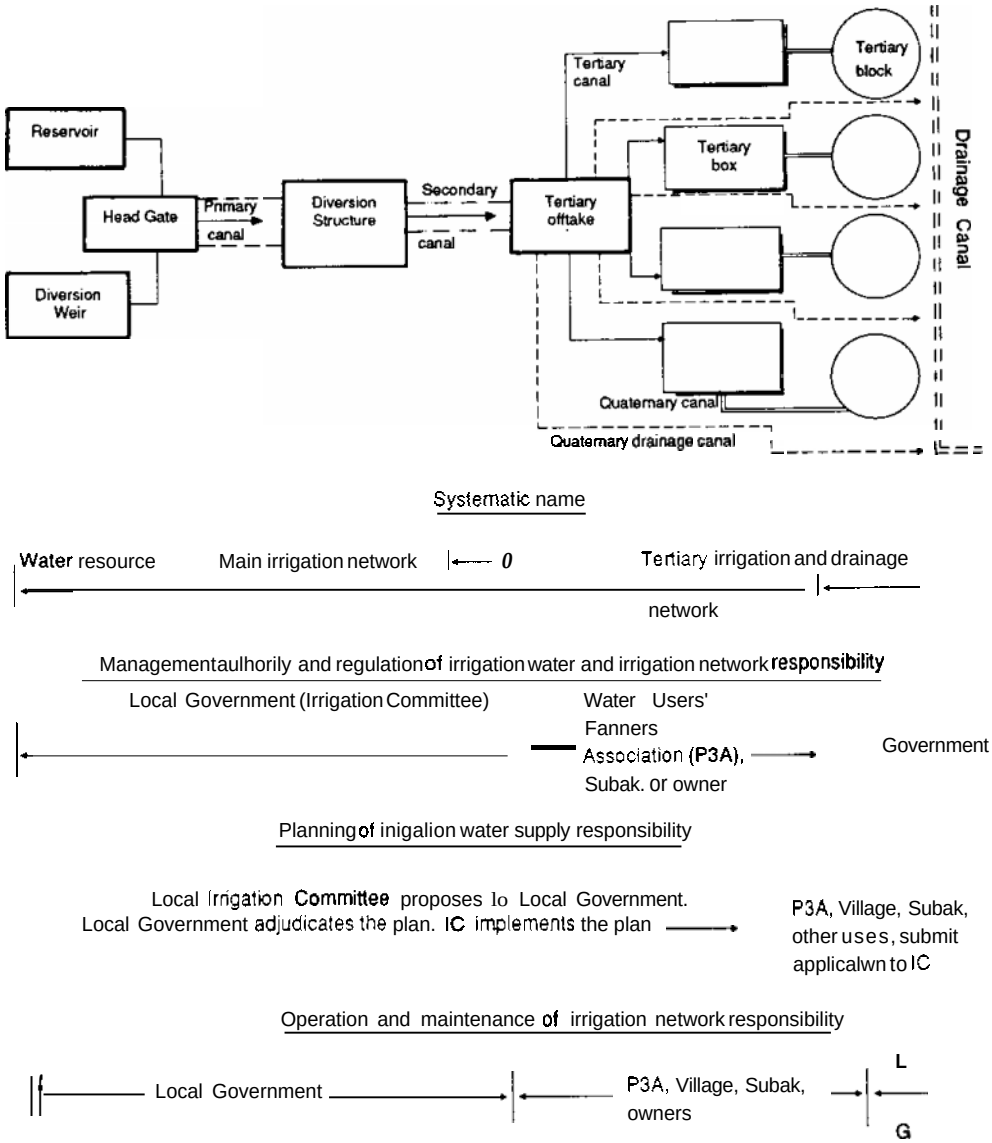
| Sufficiency Level | First rice crop | | | Second rice crop | | |
|---|---|---|---|---|---|---|
| | Head (N=270) | Middle N=266) | Tail (N=270) | Head (N=270) | Middle N=266) | Tail (N=270) |
| Water sufficient at all times | 62.5 | 97.6 | 78.9 | 52.1 | 53.5 | 36.3 |
| Water sufficient in 4 to 6 months | 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 |

(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.*



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

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 | | |

# 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.

## 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.l |
| 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

*Table 11. Costs and returns of chili, corn and mungbean by section, Cikeusik Irrigation System, Cirebon, West Java, Indonesia, 1988, DS II.*

| Item | Head | Middle | Tail | All farms |
|---|---|---|---|---|
| Chili | | | | |
| No. of samples | 13 | 2 | 1 | 16 |
| Mean yield (t/ha) | 8.87 | 6.52 | 4.00 | 8.27 |
| Total value of production (US$/ha) | 2,564 | 1,507 | 2,222 | 2,411 |
| Total paid-out costs (US$/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 | 130 | 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 | 159 |
| Total variable costs (US$/ha) | 136 | 276 | 207 | 206 |
| Returns above paid-out costs (US$/ha) | 95 | 116 | 149 | 116 |
| Gross margin (US$/ha) | 89 | 30 | 96 | 69 |

US$1.00 = Rp.1,800.

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

| Item | Head | Middle | Tail | All farm! |
|---|---|---|---|---|
| | 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 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 | 1 | 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 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 | 112 | 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 7. Comparative costs and returns of onion by land tenure, Cikeusik Irrigation System, Cirebon, West Java, Indonesia, 1988 DS I*

| 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 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 | I17 | 29 | 82 |
| Chili | | | | |
| No. of samples | 13 | 2 | 1 | 16 |
| N (kg/ha) | 183 | 201 | 360 | I96 |
| P (kg/ha) | 65 | 57 | 108 | 63 |
| K (kg/ha) | 44 | I29 | 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.

## 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 | 1 | 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 | 84 |
| 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 4 shows significantly higher mean yield per hectare of onion (10.74/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** |

UM1.00 = Rp.1,800.
***,**,*. significant at 1 percent, 5 percent and 10 percent, respectively.

*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 (%) | | | | |
| DSI | 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 II. 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.

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.

*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.*

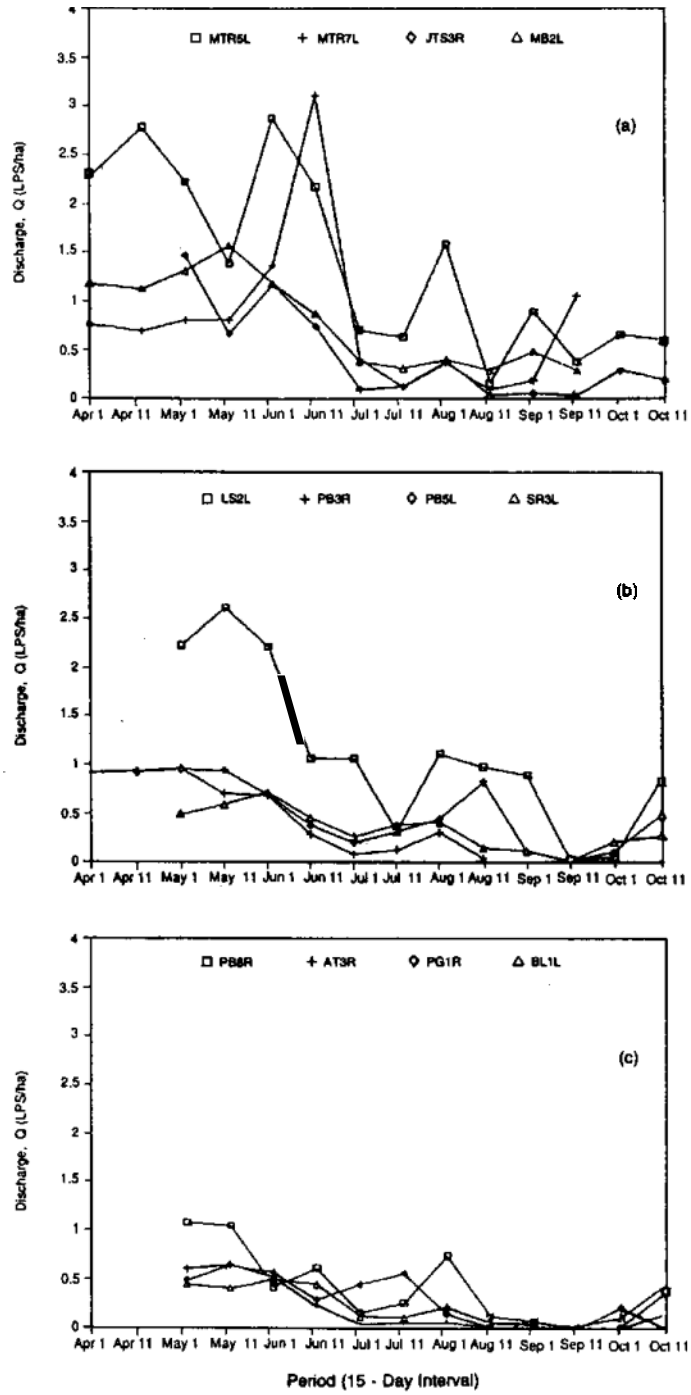


*Table 1. Factors contributing to water shortage and inequity problems, Cikeusik Irrigation System, Cirebon, West Java, Indonesia, 1988 DS I*[a]

| 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 Irrigation 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 |

Three tillage systems, zero tillage (To), strip tillage (Ts), and maximum tillage (Tm) were compared. For both maize and mungbean, seeds weresownby 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-bomeinsects. 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. Theleast-irrigatedplots (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

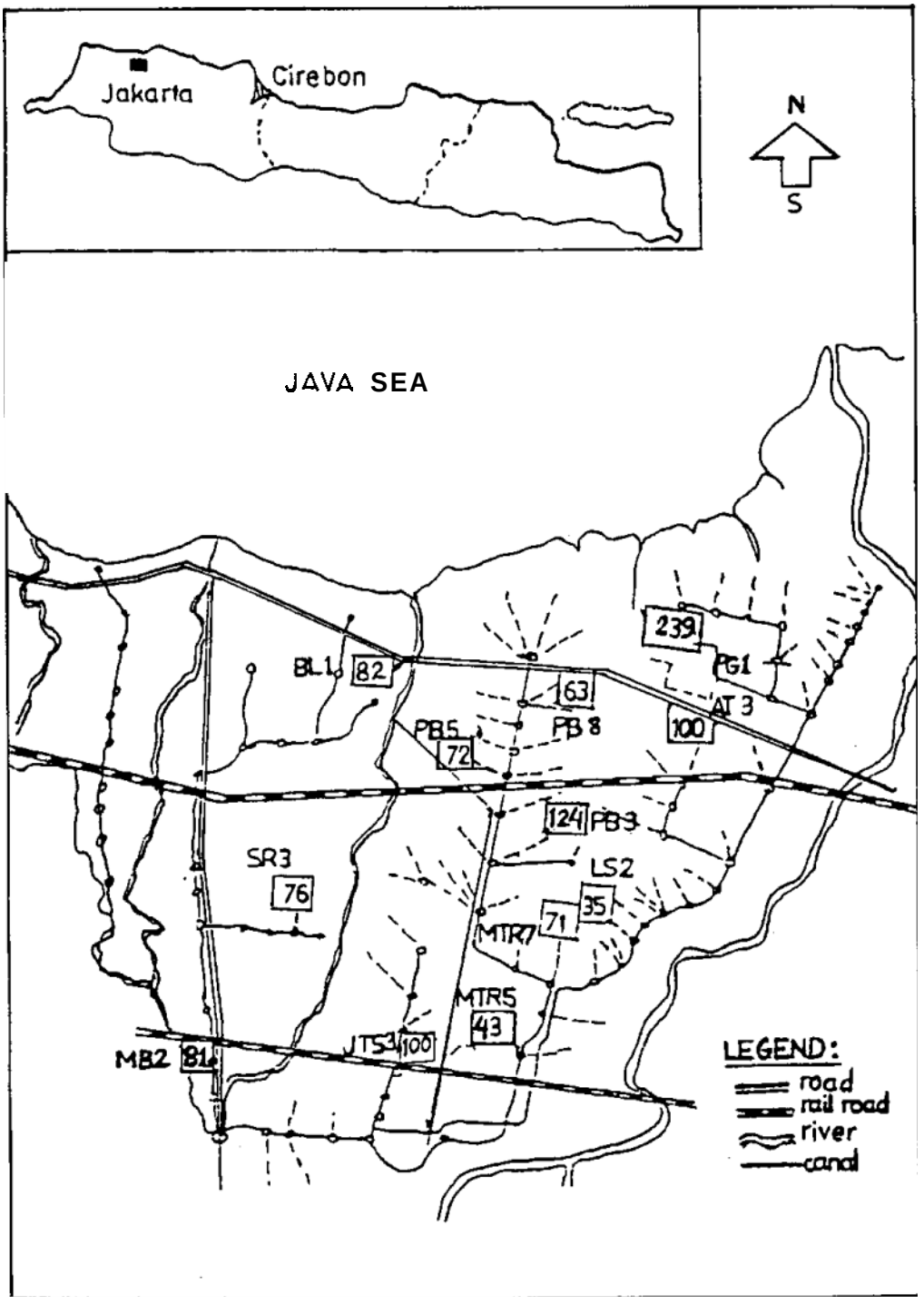
### Water Availability, Crop Choice and Cropped Area

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 seasonsprogressed. 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

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



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 (DSI) 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.

# 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 op intensification diversification and income by growing nonrice crops

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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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*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) | Phospho rus (kg/ha) | otash g/ha | R i a (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 irrigation coverage 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.* Farmersprefera waterdeliveryschedule which will allocate and distribute water to different areas or blocks of the service area

*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 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-BR11 | 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-BR11 | 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 | 11.44(11.44) | 10.89(10.89) |
| | | Kanchan-Millet-Pajam | 8.44(3.67) | 7.21(3.67) |
| | 142 | Fallow-Purbachi-BRII | 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-BRI1 | 6.61(6.04) | 5.66(5.09) |

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

*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". | Irriga-ble 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 V | 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 | 61.8 | 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 1 | 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 | 40.5 | 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 15. Adoption of different rabi crops in tke Ganges-Kobadak Project (Phase I), tke 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

*Tabl 14. eld (Kg/ ) of 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 10 t/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

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 alternative 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).

*Table 13. Average annual grain 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.

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 (T1) 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 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)**

## 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

## 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 | 37 | 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 | 48 | 20 | 28 |
| T6/S11K | 2.159 | 4.140 | 44 | 83 | 20 | | 11 | 29 |
| T10/S11K1,815 | 3.219 | 18 | 76 | 9 | 40 | 3 | 22 | |
| Mean | 3,240 | 4,250 | 67 | 94 | 31 | 41 | 18 | 25 |

*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.*

| 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) |
| '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 Ausand Amanseasons withlesswater supply thanrequiredformaintainingcontinuousstandmgwaterinthefield.While all known research indicates that continuousshallow 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 thesoilsurfaceduringabout 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).

*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 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 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 | 1,020 | 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* 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 | otal | IR | RF | Total | IR | RQ | Tota |
| T3/S4K | | | | | | | 185 | 05 | 19( | 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 | 12( | 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 | 24( | 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 |
| T9/S4K | 1,013 | 234 | 1,247 | 538 | 1,053 | 1,591 | - | - | - | 900 | 600 | 1,500 | 996 | 345 | 1,34 |
| T18/S4K | | | | | | | 709 | 307 | 1,016 | 902 | 561 | 1,463 | - | - | - |
| T3/S9K | | | | | | | 633 | 670 | 1,303 | 686 | 629 | 1,315 | 770 | 402 | 1,17 |
| T6/S9K | 873 | 499 | 1,372 | 633 | 1,052 | 1,685 | 503 | 789 | 1,292 | 610 | 671 | 1,281 | 768 | 353 | 1,12 |
| T10/S9K | | | | | | | 515 | 694 | 1,209 | 675 | 563 | 1,238 | 748 | 375 | 1,12 |
| T2/S11K | | | | | | | 336 | 710 | 1,046 | 737 | 411 | 1,148 | 662 | 493 | 1,15 |
| T6/S11K | 2,054 | 291 | 2,345 | 791 | 1,052 | 1,843 | 339 | 910 | 1,249 | 635 | 488 | 1,123 | 777 | 349 | 1,12 |
| T10/S11K | | | | | | | 265 | 586 | 851 | 755 | 350 | 1,105 | 707 | 408 | 1,11 |
| Mean | 1,313 | 341 | 1,654 | 654 | 1,052 | 1,706 | 514 | 606 | 1,102 | 751 | 507 | 1,258 | 834 | 378 | 1,21 |

***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 | 116 | 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 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 |

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 wholesystem. 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.

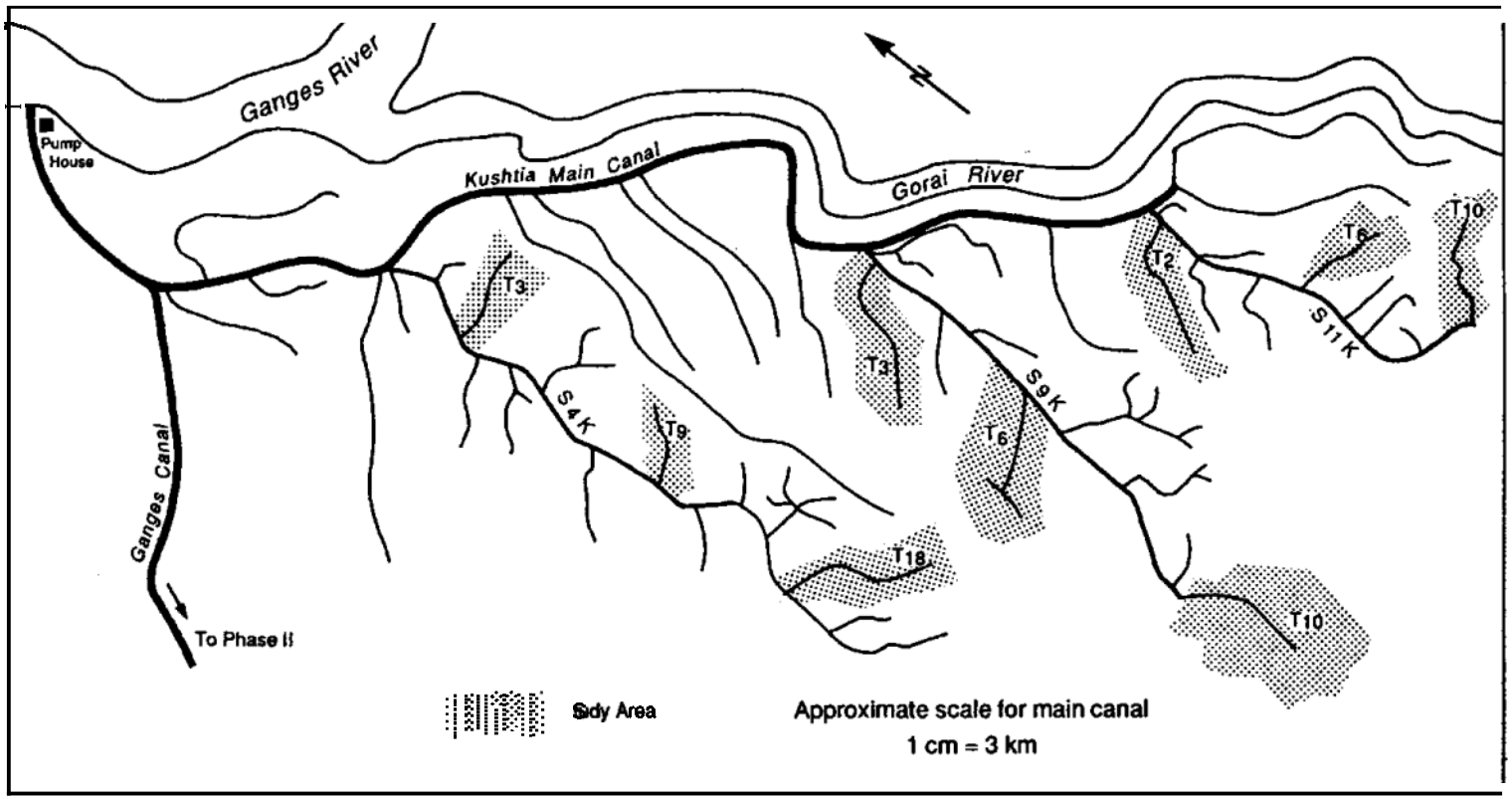
# RESULTS AND DISCUSSION

## 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

*Figure 1. chema Kobadak Bangladesh, showing selected secondary and*



## 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).

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

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# SECTION II

## Technical Considerations

## for

## Rice-Based Farming Systems:

## Farm-Level Water Management

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.

## 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

# 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.

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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.

## 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

## More Accurate Methods of Prediction

Indetermining water availability from river and rainfall, continuous datacollection is recommended to account for climatic and terrestrial changes. More reliable analyticalmethods should be used in analyzingsuch 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 islessreliableon the weeklypredictioncomparedwith 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, **inanalyzingafive-yearrainfalldataforacertain**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 watersupplysituations. Itwasobserved thatfarmersuse thesepumpsevenduring 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.

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.

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

*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.

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.**

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 recentpast. Due toelectricityfailures,the regularity and sufficiency of watersupply 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. Thesystem suffers from a number of weaknesses which may be enumerated as follows:

i. Length of assessment procedures. Underthepresentsystems, theagencies 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 identificationand 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)sendsthe 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 finalstage, 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. Thedistributionof demandnoticesamong theindividualfarmersalsotakes 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 disposedoforconsumed thecropleavinghim withinsufficient fundsto 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 Systemalonemorethanhalfamilliontakaisrequired topayforstationary). 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-

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.

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.

Table 9. Samplefanners' *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.

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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 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.

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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.

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 (Table7), **94** percent of Kushtia farmers and **40** percent of Thakurgaon farmers were ignorant of the criteria used for the determination of their present fees (Table8) and 93 percent of Kushtia farmers did not know who decided the fee rates (Table9). 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 (AgriculturalDevelopment) 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 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

*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 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 ig i i th receive. In the c ses o l DTWs systems irrigation fees include the rental / irrigation g p d by BADC on farmer groups. Average per year per hectare irrigation fees as shown in the table have been calculated by d id g s i r ati f i h r l h gross irrig t d area

[b] O&M costs include both direct and di t

[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 = Barind Integrated Area Development Project.
G-K = The Ganges-Kobadak. It is the largest gravity irrigation system in the country.
BWHD = Bangl de il W D l p B d.
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.

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.

**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.

*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 | 25 |
| Livestock | 2.9 | 2.9 | 2.9 | 29 |
| 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.

# 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.

# SECTION III

## Economics and Institutions in Irrigation Management for Rice-Based Farming Systems

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 tovarioussituations. What is necessary is todiscussthesein 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 pumpoperation to start in February and end in October 31. Theoptimum sowingtime forthenonricecropswillbeinthe middle of November. Thesecanthen 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 thiscroppingplan. 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 areplantingonion, 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.

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

# 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 farming 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 farmers 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.

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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.

| Crop planted | Average farm area ($m^2$) | Duration of irrigation (min) | Discharge (lps) | Depth ofwater 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.

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

| Items | UTRIS N=32 | SFRIS n=5 | T n=37 | I % |
|---|---|---|---|---|
| **Diameter of pump (cm)** | | | | |
| 7.5 x 7.5 | 3 | 0 | 3 | 8.3 |
| 10.0 x 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.

*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 | Total % |
|---|---|---|---|---|
| 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.

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** mand 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 (LateralB 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

| 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 |

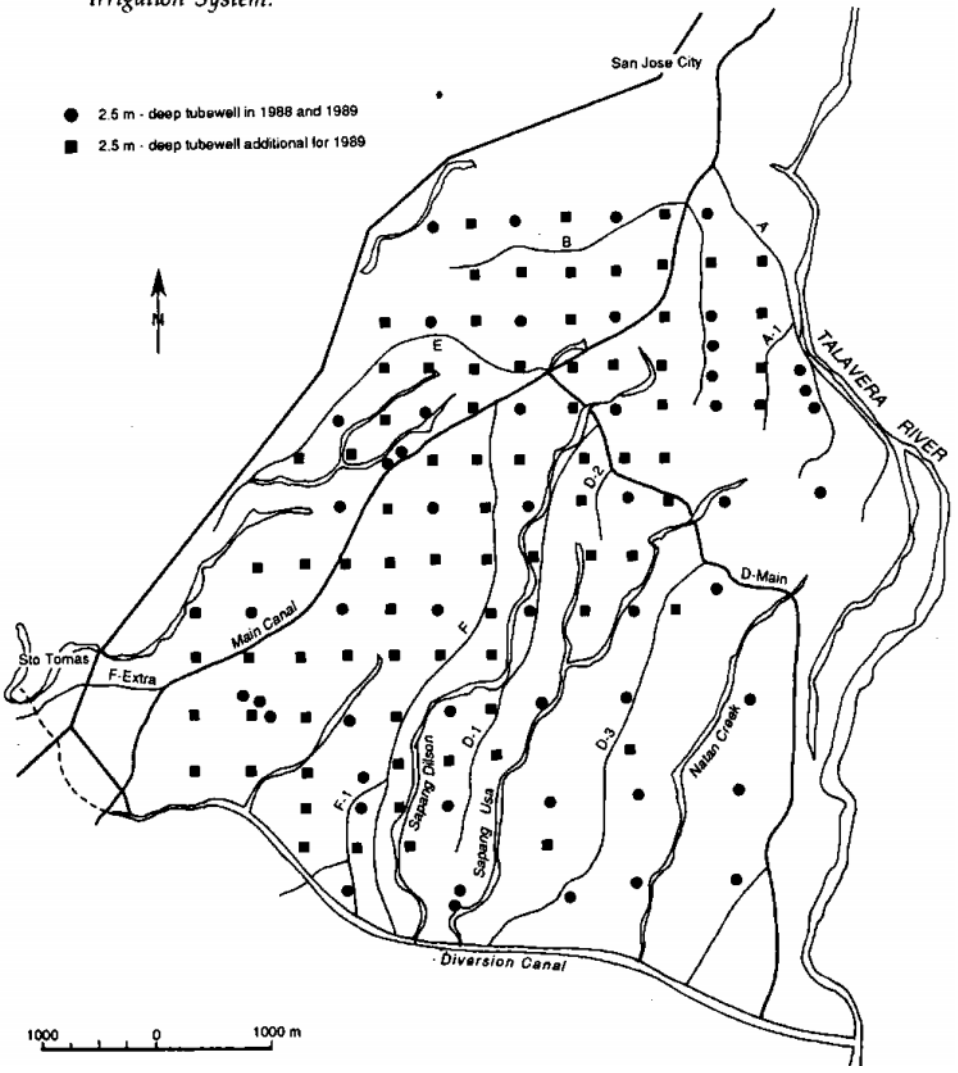
[1] Excluding irrigated or waterlogged areas
[a] 52 uniformly distributed sites.
[b] 123 sites with greater concentration.

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.

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



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

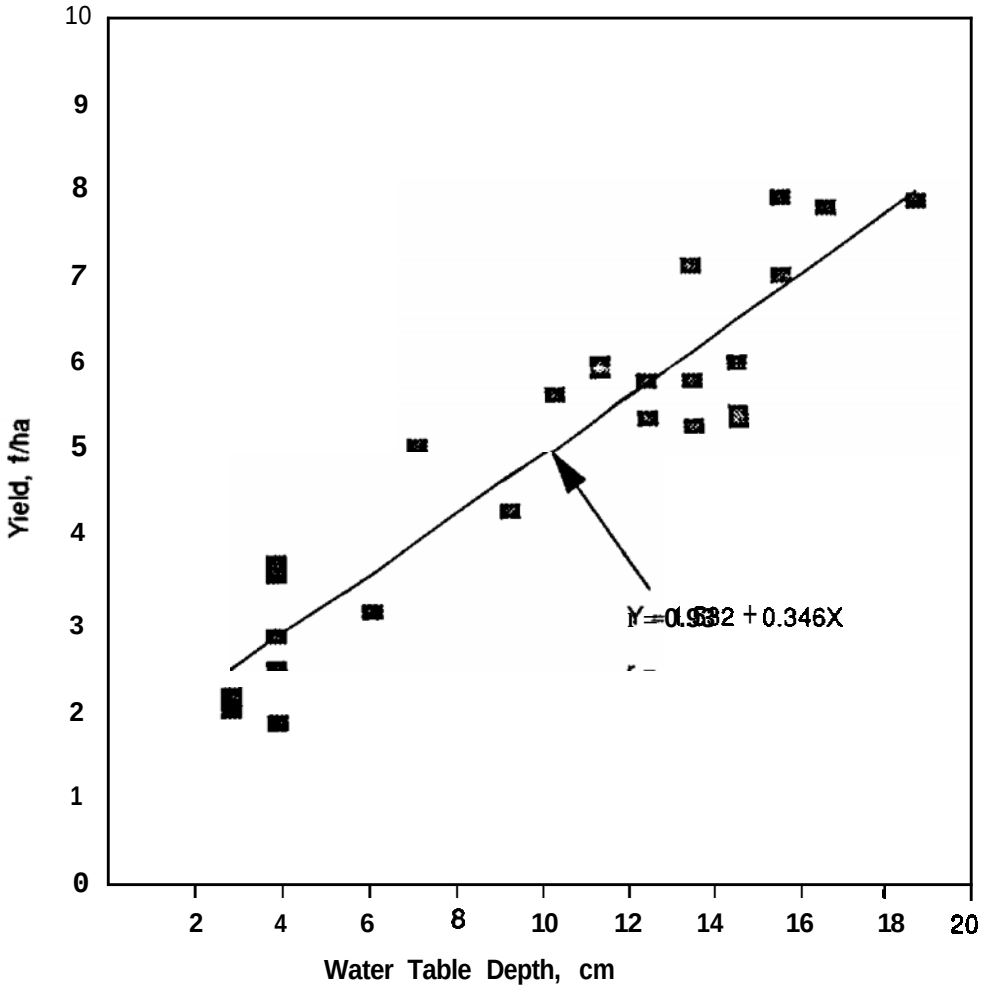


*Table 8. Average corn grain yield (t/ha), water table depth, plant height, and gross margin in each water* control *treatment, LTRIS, 1990 DS.*

| 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 f i i th dj l t i 6 2 t/h ritl 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-interceptorchannel 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-interceptorchannels. Results also indicate that corn production with such seasonal investment is more profitable than rice production.

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 corn 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 7. Current practice and corresponding alternative options of 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- ery at gh flow ites | otational rater deli- ery at igh flow ate for .5 days | )-hour ily water livery at gh flow te | 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 15ha, 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.

*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 | |

[1] Ap = f(Qu, Du, Ii, Dm); Dm = 1 for mulched; 0 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 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.