Irrigation Management for Crop Diversification in Indonesia, The Philippines and Sri Lanka:

A Synthesis of IIMI's Research

Senen M. Miranda

INTERNATIONAL IRRIGATION MANAGEMENT INSTITUTE
IIMI Technical Paper 1

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Miranda, Senen M. 1989. Irrigation management for crop diversification in Indonesia, the Philippines, and Sri Lanka: A synthesis of IIMI's research. Colombo, Sri Lanka. xx 120p

/ irrigation management / irrigation practices / irrigation systems / intensive cropping / diversification / constraints / incentives / research / rice / irrigated farming / rain / water use / water supply / water users / farmer-agency interactions / communication / equity / soil moisture / drainage / crop yield / production costs / rotational issue / Indonesia / Philippines / Sri Lanka /

DDC: 631.7

ISBN: 92-9090-106-3

Summary: This paper is a synthesis of IIMI's research on irrigation management for crop diversification in Indonesia, the Philippines, and Sri Lanka. It provides some conclusions and recommendations on the potentials and constraints to more intensive non-rice production during the drier part of the year in irrigation systems that have been developed primarily for rice production. The research results obtained from selected irrigation system sites in the three countries from 1985 to date were analyzed and compared by establishing common reference points where they existed, such as common constraints, potentials, and institutional arrangements, and by explaining differences based on observed data for each system. Relevant secondary data other than from the research sites were located to shed further insight in the synthesis.

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Responsibility for the contents of this publication rests with the author. Funds for printing and dissemination of this publication have been provided by the Asian Development Bank.

Cover photograph by Senen M. Miranda

IV -

Table of Contents

Figures

Tables

Preface

When the International Irrigation Management Institute (IIMI) was established in mid-1984, a number of what had been rice-importing countries in the region were on the threshold of becoming self-sufficient or had already attained self-sufficiency. This situation has been ascribed to the new rice seed fertilizer technology and the rapid expansion of irrigated areas where rice was grown. The success in increased rice production has, however, spawned a second-generation problem of declining incomes of farmers from rice production.

It is in this context that IIMI, shortly after its establishment, responded to a request from the Asian Development Bank (ADB) to explore the potential for, as well as constraints to, accommodating non-rice crops in irrigation systems which have been designed, constructed, and operated to grow rice in the Philippines and in Indonesia. By early 1985, IIMI had begun the study in the Philippines. Thereafter, similar research was started in Sri Lanka on the request of the Institute's Sri Lanka Consultative Committee. The work in Indonesia got underway before the end of 1985.

In January 1988, as part of an ADB Regional Technical Assistance grant to IIMI, financial support for a synthesis including dissemination of the research in the three countries from 1985 to 1988 was made available. The synthesis was done through a comparison of the results obtained and the use of secondary materials whenever it was found essential to reinforce some of the findings. Some conclusions and recommendations on the potential for, and constraints to, more intensive non-rice production during the drier part of the year in rice-based irrigation systems are presented, as well as an indicative research agenda to tackle the outstanding issues.

The highlights of the synthesis were presented in an organizational and planning workshop for a research network on irrigation management for diversified cropping in rice-based systems held in Bangkok from 30 November to 3 December 1988. The participants - 34 senior irrigation, agricultural, and planning officials from 8 humid tropical countries in Asia – elected the members of a steering committee to oversee the research network to promote intercountry comparisons and information dissemination. The implications of the findings of this synthesis on the rehabilitation and modernization of rice irrigation schemes were discussed in a lecture given at the recently concluded Asian Regional Symposium on the Modernization and Rehabilitation of Irrigation on Drainage Schemes, held at the Development Academy of the Philippines, which was attended by 115 participants from 19 countries.

As mentioned above, there are still a number of technical, socioeconomic, and institutional issues identified as important, if not more so than irrigation management, in enhancing cultivation of non-rice crops. Some of these issues are better addressed by national agricultural research systems. In tackling the outstanding issues on the subject, however, IIMI will be able to collaborate with the relevant irrigation and research organizations in developing and disseminating irrigation management innovations through the newly organized research network.

The manuscript was prepared by the author with materials contributed and suggested by A. Valera, H. Murray-Rust, D. Vermillion, C.R. Panabokke, D. Groenfeldt, N. Raby, E. Martin, and D. Merrey - all at IIMI - as well as by IIMI's field research staff and the staff of national collaborating irrigation management agencies and research organizations in the three countries where the research is being conducted.

Special thanks is due to M. Agalawatte and D. Bandara for their assistance in preparing some of the tables and figures, T.M.K. Wijesinghe for drawing some of the figures, Ms. Champa Fernando for editing the text, and Ms. Dewaki Nugawela for typing the manuscript.

Finally, the financial support provided by the ADB as part of and ADB Regional Technical Assistance grant is gratefully acknowledged. This assistance made possible the preparation, publishing, and dissemination of this report.

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Executive Summary

In mid-1984 when IIMI was established in Sri Lanka, a number of what had been rice-importing countries in humid tropical Asia were either becoming self-sufficient or had already attained self-sufficiency in rice production. These included countries like Indonesia, the Philippines, and Sri Lanka. Improved rice seed and fertilizer technologies, along with heavy investment on irrigation facilities, have been ascribed to be responsible for this success.

It has become apparent, however, that a glut in the rice supply has resulted in declining incomes of farmers from rice production. It is in this context that IIMI, soon after its establishment, responded to a request by the ADB to study the potential for, as well as constraints to, accommodating non-rice crops in irrigation systems which have been designed, constructed, and operated to grow rice. The study is an offshoot of an earlier study undertaken jointly by the International Food Policy Research Institute (IFPRI) and the International Rice Research Institute (IRRI). This study, completed in May 1984, concluded that the Philippines, the country that was used as a model, had a comparative advantage, relative to imports, in the production of both irrigated rice and some non-rice crops. The study further identified the critical issue of the need to examine the technical and socioeconomic constraints to profitable production of irrigated diversified crops.

IIMI started addressing the issue in early 1985 in the Philippines, later in Sri Lanka, and before the year was over, in Indonesia. Several irrigation system research sites were selected in the Philippines and Indonesia where IIMI received the ADB's technical assistance, and only two sites in Sri Lanka where the Institute had to rely on its unrestricted funds. The Bank, through its Regional Technical Assistance, provided funding to IIMI to make this comparative synthesis of the results of its research on irrigation management for crop diversification in the three countries.

It became apparent early in the conduct of the research that rainfall distribution – and not so much the annual total - significantly influences the cropping pattern. The rainfall pattern itself is determined by the prevailing monsoon and the presence of mountain barriers. During the first wet-season cropping, the primary crop grown is rice, as to be expected, in all three countries. During the second or third cropping season, the irrigation and cultivation practices observed vary across countries and situations. In the Philippines and in Sri Lanka which basically have two cropping seasons, the service area is reduced to a fraction of the area served during the wet season. The reduced irrigated area is rotated every year in the Philippines while institutional sharing of reduced area is practiced in Sri Lanka. In Indonesia where the cropping intensity is highest, the third cropping has been decreed by the government to be devoted only for cultivation of non-rice crops.

Rice, however, is still being grown in the poorly drained low-lying areas. Except for the residual soils in the Sri Lanka sites, the soils in Indonesia, and in the Philippines are all alluvial. The soils range from sand to clay texture, from poorly drained to well-drained, and from good rice land to diversified land class. The Philippines is currently pushing the cultivation of non-rice crops in the diversified and dual land class soils while Sri Lanka is now promoting the same in the well-drained soils.

In the management of the irrigation systems, the intensity of operational planning and implementation, monitoring, and evaluation of the plan vary across countries and sites within each country. The basic principle in planning in any case is simply to match as closely as possible the water supply with the water demand or soils and crop requirements. The planning process observed can be very simple or complex, depending on the scope for manipulating supplies according to the demand. Irrigation and other associated government officials meet with farmers to decide formally on the plan before it is finalized and operationalized. The implementation of the agreed plan is dictated by the availability of water at the start of the main season. The type of system, whether run-of-the-river or storage type, influences the availability of water and, consequently, the water-delivery and distribution schedule. The monitoring of the implementation leaves much to be desired. It tends to break down as it goes lower in the system. Except where there is active farmers' participation, it is more geared towards office reporting rather than towards day-to-day operations. Consequently, it is generally found that the tail-end portions of the systems suffer from deficiencies of water whereas the head or upper portion has excess water. On-farm operations observed are relatively flexible in terms of the farmers' capability to cope with different conditions of water availability. With reliable water supply at the turnout level, sharing of the water among farmers is better organized with greater equity and fewer conflicts. The reverse situation, however, triggers off a chain of undesirable reactions.

It is now possible to make some conclusions and recommendations on the potentials for, and constraints to, more intensive non-rice production during the drier part of the year in irrigation systems that have been developed primarily for rice production. Some of the potentials are:

* There are non-rice crops grown in each country showing higher and consistent profitability than rice.

* There are well-drained and coarse-textured soils in parts of the commands of the irrigation systems which are well-suited to diversified crops.

* A limited water supply not adequate to meet the requirements of rice during the dry season is observed in many schemes with favorable soils. Related to this is the distinct unimodal rainfall pattern which makes it possible to have the desired well-aerated soil condition during the dry season.

* No major land movement or landshaping is needed to irrigate non-rice crops, although farmers have to introduce a rudimentary system of on-farm supply and drainage ditches in these plots to facilitate the timely application of water to their fields, and removal of water. Rice basin

bunds are retained where the appropriate seedbeds are prepared according to the water-application requirements of specific non-rice crops.

* Irrigation systems properly designed and constructed for supplementary irrigation for wet-season rice, which can meet the land soaking and land-preparation requirements, have enough canal capacity for the intermittent flow of water for irrigating non-rice crops, although the need for greater canal water regulation is apparent.

* Greater interest among all concerned from farmers to policy makers and the donor community is now being generated, and attention paid, to the various issues of evolving a viable strategy for rural diversification of which irrigated crop diversification is a key ingredient.

There are, however, the following constraints:

* Water control is more demanding in terms of supply and removal for non-rice crops due to their far stricter requirements of soil moisture. The intermittent delivery of limited and uncertain water supply during the dry season requires greater joint management effort and, in turn, needs effective communication between irrigation staff and farmers.

* To provide the necessary functional water control, regulation, and measuring facilities have to be present to enable effective monitoring and feedback of the water supply.

* Farmers who have grown only irrigated rice before are unfamiliar with the agronomic and irrigation practices for non-rice crops.

* There are greater economic risks associated with non-rice crops than with rice. Cash and labor inputs can be three or four times higher for non-rice crops than for rice crops. Institutional credit is scarce while noninstitutional credit carries usurious interest rates.

* Unlike in the case of rice, unstable prices and lack of organized marketing for non-rice crops increase the risks for farmers involved in their production.

Some of the general conclusions and recommendations that can be considered by policy makers are:

* For diversified cropping those irrigation systems with a limited water supply whose conditions are not adequate to meet the requirements of rice for the whole command during the dry season, and which have substantial areas of well-drained, coarser-textured or diversified land class of soils, should be selected first.

* The irrigation system should be at least in a physical condition that would enable a satisfactory level of water delivery and control at various levels of the system.

* There is an urgent need to improve the interaction between irrigation staff and farmers in irrigation system management, from planning and implementation to monitoring of irrigation

deliveries. Some form of joint management by encouraging increased organized farmers' participation in the irrigation management process is needed to meet the more demanding requirements of non-rice crops in a situation of limited and uncertain water supply.

* A more vigorous extension program to disseminate the irrigation as well as agronomic practices for non-rice crops showing potential profitability is suggested to help farmers consider options on what non-rice crops to grow.

An assured and stable market, competitive price, and ready availability of credit are a must in promoting and sustaining irrigated crop diversification.

The synthesis of the research results strongly suggests the following indicative research agenda to tackle the outstanding issues on the subject:

* Research should focus more on irrigation systems in which management manipulations, practices, and technologies can be applied with the least cost and highest possible efficiency to alternate between rice and non-rice cropping patterns.

* Research needs to focus on the assessment of suitable methodologies for the introduction of an effective process for bringing about the desired improvement in communication between agency staff and farmers in the management of the more demanding intermittent water delivery.

* There is a need to come up with improved methodology for assessing and matching water supply and demand, including water supply augmentation possibilities under diversified cropping conditions.

* To reduce, if not eliminate, the undesirable excess soil moisture condition, there is a need to work out appropriate alternative designs of irrigation and drainage systems which enable the timely application and removal of water by evaluating a spectrum of available technology from the ingenious rudimentary ways of the farmers to the capital intensive practices already being applied in Japan and Taiwan.

Some of the research issues are better addressed by national agricultural research systems or by international crops research institutes because they are better endowed to do so. On the other hand, through the newly organized research network on the subject, IIMI will be able to collaborate with irrigation management agencies and research organizations in developing and disseminating irrigation management innovations to help solve the outstanding problems.

CHAPTER 1

Introduction

In mid-1984 when the International Irrigation Management Institute (IIMI) was established, a number of countries that had been rice importing countries in humid tropical Asia were either becoming self-sufficient or had already attained self-sufficiency in rice production. The traditional exporting countries like Thailand were beginning to feel the pinch of a shrinking international market and declining price of rice (Table 1). This glut in the rice supply has been ascribed to the new rice seed fertilizer technology introduced by the International Rice Research Institute (IRRI) and the rapid expansion of irrigated areas where rice is grown. The heavy investment in irrigation provided the controlled flooded water environment found necessary to take advantage of the full potential of the new high-yielding rice varieties. The apparent success of this strategy, however, has resulted in declining farmers' incomes from rice production. With assistance from their governments and international donor agencies, farmers began to seek to diversify their production and income sources.

Table 1. World prices of major primary commodities (in 1985 constant US$/ton).

	Year					
Crop	1970	1980	1985	1990	1995	2000
Sugar	222	604	90	322	265	253
Wheat	172	182	173	147	136	133
Maize	160	120	112	100	85	94
Palm oil	712	557	501	374	450	420
Coconut oil	1088	643	590	428	500	482
Cotton	173	196	132	137	165	165
Rubber	126	155	92	96	108	110
Rice	395	414	216	233	214	206

Source: Schuh and Barghouti (1987)

It is in this context that IIMI, shortly after its establishment, responded to a request from the Asian Development Bank (ADB) to explore the potential for, as well as constraints to, accommodating non-rice crops in irrigation systems which have been designed, constructed, and operated to grow rice in the Philippines and in Indonesia. By early 1985, IIMI had begun the study in the Philippines. Thereafter, IIMI started a similar research effort in Sri Lanka as requested by its Sri Lanka-IIMI Consultative Committee[1]. The work in Indonesia got underway before the end of 1985.

The general objective of the research is to identify the physical, managerial, and institutional changes in irrigation management that must be made before non-rice crops can be more intensively cultivated in irrigation systems developed primarily for rice production. The study also examines the technical and socioeconomic factors that constrain as well as encourage more intensive non-rice production during the drier part of the year when water is insufficient to grow rice over entire systems. Because of its mandate, however, IIMI has consciously tried to focus its attention primarily on the critical role of irrigation management in the crop-diversification process. Lately, in its collaborative project with IRRI on the problems of irrigation management in rice-based farming systems, IIMI has further concentrated its focus on the main-system management concerns, in which it has a comparative advantage, and is leaving the on-farm irrigation management questions for IRRI to tackle.

This paper is intended to provide a synthesis of IIMI's research on irrigation management for crop diversification in Indonesia, the Philippines, and Sri Lanka through a comparison of the results obtained from 1985 to the present. Secondary materials are used whenever it is essential to reinforce some of the findings.

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[1]Irrigation management specialists and officials from irrigation agencies as well as IIMI staff are included in this committee. Ensuring that IIMI's program is responsive to Sri Lanka's needs and communicating IIMI's research findings to key officials of irrigation management agencies are its aims.

CHAPTER 2

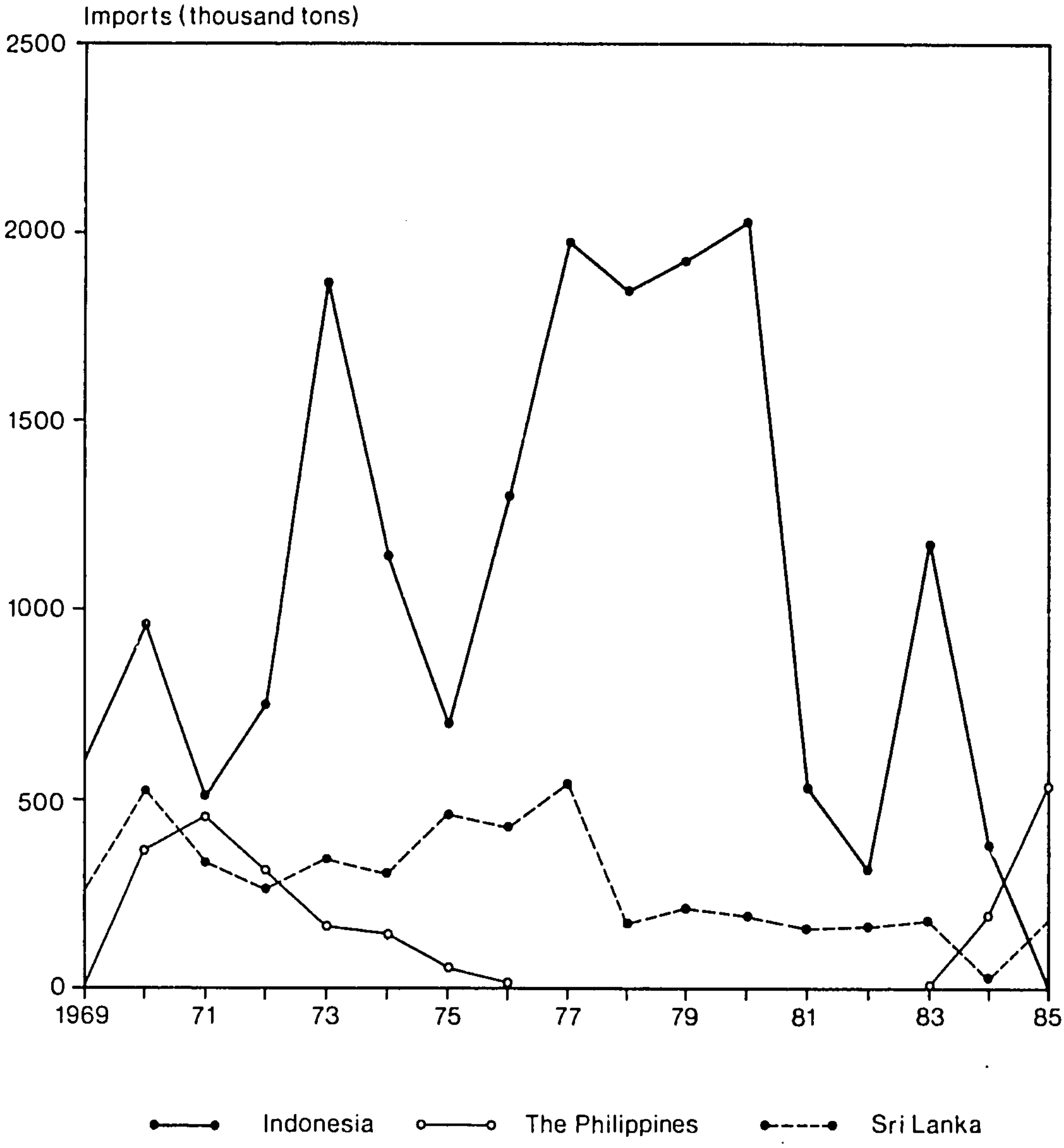
Research Objectives And Rationale

UNTIL RECENTLY, INDONESIA, the Philippines, and Sri Lanka were large importers of rice, with Indonesia being the world's largest in the 1970s as shown in Figure 1. Over the years they have adopted rice production policies aimed towards self-sufficiency. Self-sufficiency, however, was not attained until 1977 in the Philippines and 1984 in Indonesia. The Philippines became a marginal exporter up to 1983 but, due to unfavorable weather, was an importer again beginning in 1984. Sri Lanka is nearing self-sufficiency and may even generate surpluses in the next few years.

The main government policy initiatives to expand rice production in the three countries have included investment in irrigation expansion and improvement, investment in research capacity for development of rice varieties adapted to specific country conditions, rice intensification programs to encourage the dissemination of new technologies and inputs, rice price support and stabilization policies, and investment in rural infrastructure. Rice is the most important crop in respect of area, number of producers, and contribution to agricultural production. From 1966 to 1975 and from 1976 to 1980, while the average annual rate of growth in rice production in Asia as a whole was 2.6 percent, it was 4.3 percent in Indonesia, 4.9 percent in the Philippines, and 3.6 percent in Sri Lanka as shown in Table 2. The average annual rate of growth in rice yield obtained by the three countries was about twice the 1.6 percent for Asia. This yield increase is graphically shown in Figure 2. Most gains in rice production have stemmed from increased yields rather than expansion of the area cultivated to rice. The productivity of arable land has been increased by irrigation. Between 1966 and 1980, irrigated land increased at an annual rate of 1.88 percent in Indonesia, 3.93 percent in the Philippines, and 2.00 percent in Sri Lanka (Table 3). The share of rice area irrigated from 1975-1979 is shown in Table 4 for each country, ranging from 42 percent in the Philippines to 84 percent in Indonesia. The percentage of area planted to modern varieties ranged from 50 percent in Indonesia to 68 percent in the Philippines.

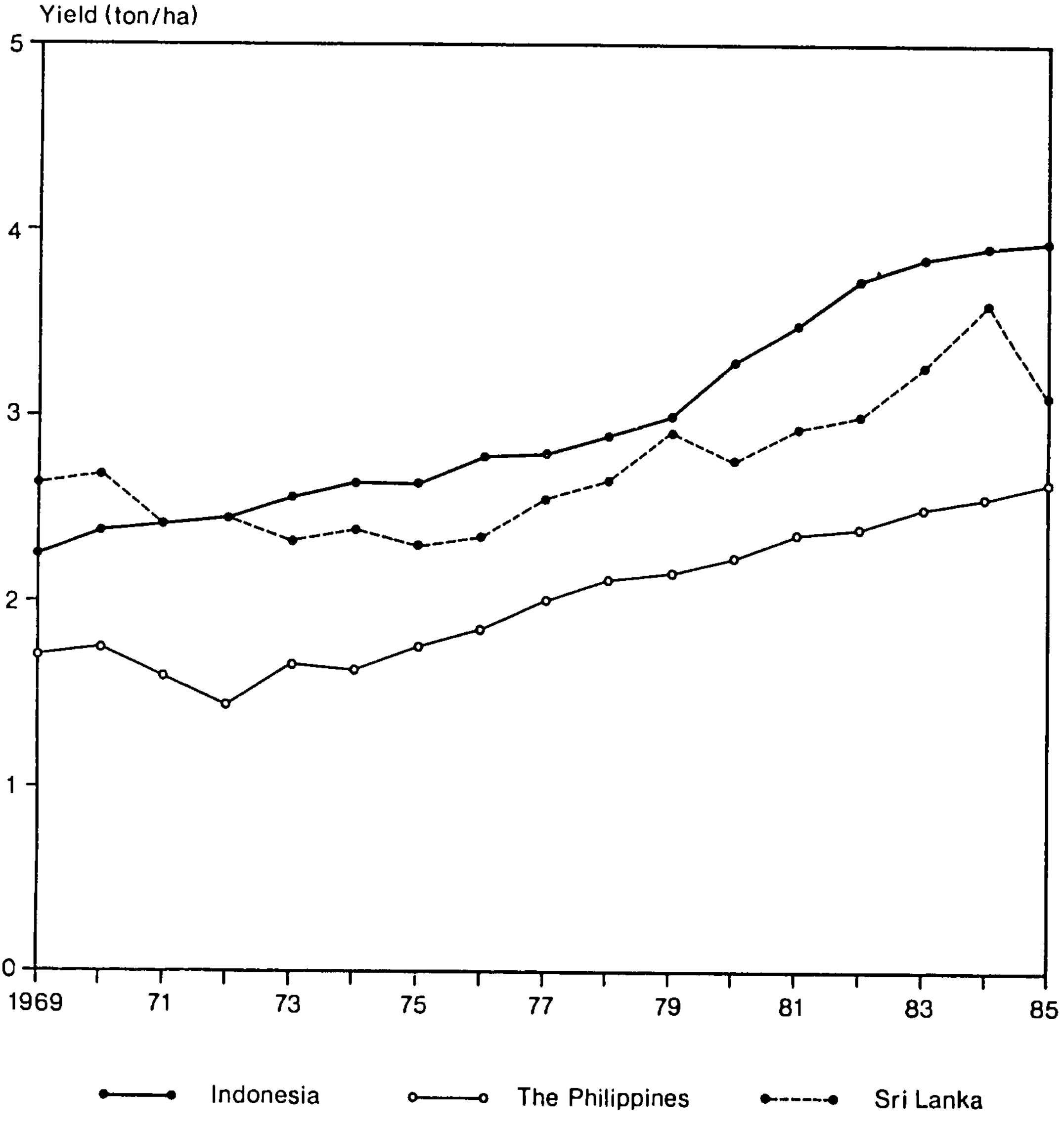
The success in increased rice production has spawned a second-generation problem by creating surpluses beyond domestic requirements and depressing rice prices and lowering farm incomes in all three countries including most Asian economies. The relative decline of rice in these economies in the changing of agricultural production is shown in Table 5.

Figure 1. Rice imports during 1969 to 1985 in Indonesia, the Philippines, and Sri Lanka.



Sources: Rosegrant et al. (1987) and Customs Returns, Sri Lanka (1969-1985).

Figure 2. Rice yield during 1969 to 1985 in Indonesia, the Philippines, and Sri Lanka.



Source: Rosegrant et al. (1987) and Ministry of Agriculture Resources and Development, Sri Lanka (1969-1987).

Table 2. Average rice production, area, and yields, 1966-1975 to 1976-1980.

Country	Production of rice '000 metric tons		Annual rate of growth 1961-75 to 1976-80	Area '000 ha		Annual rate of growth 1966-75 to 1976-80	Rice yield (mt/ha)		Annual rate of growth 1966-75 to 1976-80
	1966-75	1976-80	(%)	1966-75	1976-80	(%)	1966-75	1976-80	(%)
Indonesia	18.738	25.695	4.3	7979	8906	1.5	2.34	2.89	2.9
Philippines	5.060	7.221	4.9	3287	3524	0.9	1.54	2.05	3.9
Sri Lanka	1.321	1.721	3.6	658	702	0.9	2.00	2.45	2.7
Asia	279.665	338.015	2.6	118278	127375	1.0	2.37	2.66	1.6

Source: Adapted from Barker, Herdt, and Rose (1985).

Table 3. Arable land and irrigation development, 1966-1980.

Country	Total arable land ('000 ha)			Irrigated land ('000 ha)			Ratio of irrigated/ arable land (%)	
	1966	1980	Annual rate of growth (%)	1966	1980	Annual rate of growth (%)	1966	1980
Indonesia	12600	14200	0.86	4175	5418	1. 88	33.13	38.15
Philippines	7120	7050	-0.07	740	1269	3.93	10.39	18.00
Sri Lanka	792	1025	1.86	398	525	2.00	50.25	51.22

Source: World Bank (1988b).

Table 4. Share of rice area irrigated and planted to modern varieties, 1975-1979.

Country	Share of area planted to modern rice (%)	Share of rice area irrigated (%)
Indonesia	50	84
Philippines	68	42
Sri Lanka	61	64

Source: Barker, Herdt, and Rose (1985).

Table 5. Selected statistics for Indonesia, the Philippines, and Sri Lanka showing the declining status of the rice economy.

	Year	Indonesia	Philippines	Sri Lanka
Population (million)	1965	109.50	32.60	11.20
	1985	168.40	56.80	15.90
Per capita income (US$)	1985	560.00	760.00	360.00
Paddy yield (tons/ha)	1960	1.81	1.16	1.02
	1985	3.87	2.49	2.80
Share of GDP (%) Agriculture	1965	51.00	26.00	58.00
	1985	24.00	27.00	24.00
Rice	1965	18.80	5.20	7.20
	1985	7.80	3.40	6.30
Labor force	1965	66.00	54.00	55.00
	1985	55.00	49.00	46.00

Source: World Bank (1988a).

As domestic requirements for rice have been met locally and prices of rice in world market declined in the mid-1980s, diversification policies involving complementary programs for non-rice crops have received priority attention in these economies. The issue is somehow intertwined with broader agricultural development strategies, especially the interplay between short-term policies designed to meet immediate government objectives for the sector and the long-term relationship of agriculture to the rest of the economy during the process of structural changes.

Rice is uniquely important to the three countries. Its labor intensity, high productivity at low input costs, widespread cultivation in millions of small farms generating positive growth linkages, and its adaptability to the cultural practices under flooded conditions have made it difficult to design diversification programs.

The primary aim of the irrigation projects implemented since the mid-1960s in the three countries has been to provide a more reliable supplementary supply of water during the wet season for the cultivation of rice under wetland conditions. Irrigation during the dry season is a secondary consideration. In most cases the reduced water supply is used to grow an additional crop of rice on a more limited area. There are exceptions to this, as will be discussed, in some of the systems included in IIMI's research where the growing of non-rice crops was considered from the design stage. Otherwise, sites for irrigation projects have usually been selected because of their suitability for rice, and the systems planned for rice production. Most of the areas have very heavy clay soils. There are some limited areas with relatively light and well-drained soils. The heavy clay soils are suitable for rice and the well-drained soils are suitable for non-rice crops.

The ADB and the World Bank have played major roles in financing the extensive investments in irrigation infrastructure. The two banks, together and separately, initiated irrigation sector reviews to explore possibilities of assisting governments in such countries as the Philippines and Indonesia in the development of medium- and long-term food production strategies and policies for irrigated agriculture. Earlier, in February 1983, the ADB initiated a study focused on the operational aspects of satisfying future requirements of food consumption and developing suitable approaches and methodologies for use in the analysis and determination of optimum strategies for agricultural development. The study, which was undertaken jointly by the International Food Policy Research Institute (IFPRI) and IRRI and completed in May 1984, used the Philippines as a model to develop a methodology by which to analyze other countries. The study concluded that the Philippines had a comparative advantage, relative to imports, in the production of both irrigated rice and some non-rice crops. It identified as one viable alternative the shifting of any "excess capacity" in irrigation from rice to the production of corn, soybean, cotton, etc., where soils permit. The study also revealed the availability of an area of about 270,000 hectares (ha) of lighter soil types within currently irrigated areas that would be suitable for diversified crop production during the dry season.

A critical issue identified in that study is the need to examine the technical and socioeconomic constraints to profitable production of irrigated upland (diversified) crops. This became the basis for a technical assistance grant (TA 564 PHI) by the ADB to the Government of the Philippines to collaborate with IIMI on a "Study on Irrigation Management for Crop Diversification." The study was started in early 1985 with the appointment of an IIMI resident scientist in the Philippines.

In Indonesia, the ADB Sector Review and Contact Mission in mid-1984 reached an agreement with the Government of Indonesia to conduct a two-year five-component study on food production and irrigation strategies in Indonesia. It was agreed with the Indonesian Government that the first three components of the study, dealing with the macroeconomic aspects of food demand, supply, and substitution as related to the Government's food crop market interventions and pricing policies and to regional comparative advantages, should be undertaken by IFPRI. The remaining two components, dealing with the technical, socioeconomic, and institutional aspects of irrigation management and crop diversification, were to be studied by IIMI and got underway in late 1985 with the appointment of an IIMI resident scientist in Indonesia. Both studies in the Philippines and in Indonesia have been extended for a second two-year phase, and are due to be completed by this year.

In the case of Sri Lanka, the National Agriculture, Food, and Nutrition Strategy emphasized the importance of crop diversification and regional specialization to increase the profitability of farm enterprises, and the need for government services in research and extension, supporting the transition through multidisciplinary research programs. Under crop diversification, aspects to be emphasized were the need for a marketing program to ensure the commercial viability of non-rice crops, and greater attention to policy review and assessment of other field crops to ensure that producer incentives were maintained. The members of the IIMI-Sri Lanka Consultative Committee, being fully aware of the National Agriculture, Food, and Nutrition Strategy, and after being briefed by IIMI on the newly initiated study on irrigation management for crop diversification in the Philippines, requested IIMI to conduct a similar study in Sri Lanka beginning in the dry season of 1985. Unlike the studies in the Philippines and Indonesia, IIMI had to rely on the limited unrestricted portions of its budget in funding the work in Sri Lanka.

Although IIMI had hoped to develop a unified overall approach for the three country studies, financing and other problems forced it to adopt a variety of strategies in the conduct of the research for each country. While the objectives are very similar, the methodologies used and, consequently, the data collected have varied. As a whole, the research objectives by country (as listed in Annex A) are focused on the examination of the technical and socioeconomic constraints and potentials to more intensive non-rice cropping in irrigated land during the drier part of the year when there is insufficient water available to grow rice throughout many systems. The findings would serve as a basis for developing and recommending policies and practices, including appropriate water control, to promote more intensive diversified (non-rice) cropping.

The research methodologies, albeit different, paid special attention to physical, social, economic, and agricultural factors relevant to a better understanding of irrigation management technologies. The technologies permit seasonal shifting from rice to non-rice crops in areas particularly well-suited to non-rice crop production. Physical factors, such as water supply, drainage, soil characteristics, and climate; biological factors, such as type of non-rice crops, length of growing season, and water requirements; institutional factors such as requirements for labor, technology, water, and farmer-agency interventions; and economic factors such as profitability of cultivation practices and yield risk were examined. Decision-tree analysis was used in two countries in identifying which of the foregoing factors were most important and under what circumstances with respect to farmers' decisions to grow rice versus non-rice crops.

CHAPTER 3

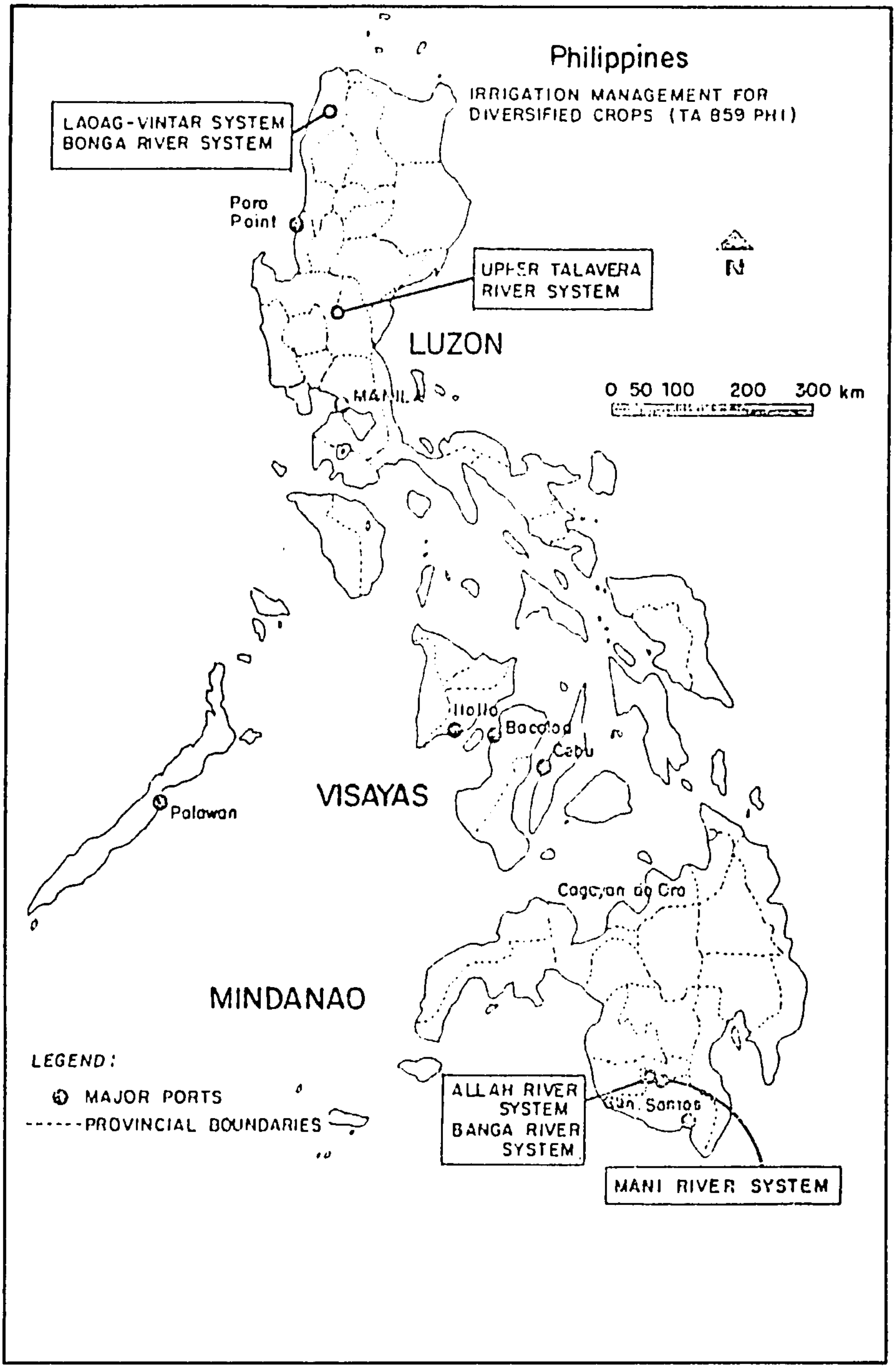
Research sites

CRITERIA FOR SITE SELECTION

THE CRITERIA APPLIED in the selection of research sites varied across countries. In the Philippines, the Allah River Irrigation Project site in South Cotabato was essentially chosen because the Technical Assistance grant was justified by citing the need for the development of an appropriate water management scheme for the proposed rice-based cropping pattern for the project. This Project was designed to accommodate non-rice crops such as corn in the coarse-textured sandy areas during the drier second season. As the Project was still under construction, only the Lateral "A" Extra, where the Pilot Testing and Demonstration Farm Number 2 was to be located, was selected in conducting the research. The adjacent Banga River Irrigation System and the nearby Mani Communal Irrigation System were chosen to understand how they were being managed as fully operational systems in accommodating irrigated corn. The Cavite site, the Second Laguna de Bay Irrigation Project of the National Irrigation Administration, was envisioned to have 2,500 ha out of an aggregate area of 13,160 ha programmed for vegetable production using water to be pumped from the Laguna de Bay Lake. A whitebean production promotion project was in progress when IIMI began its work. The Magat River Integrated Irrigation System in Isabela, which is one of the two biggest systems in the country, has about 11,000 ha of diversified land class in which the Ministry of Agriculture and Food was trying to promote hybrid yellow corn production under its *Maisagana* program. This system's initial rehabilitation was funded by ADB and so was the construction of the Second Laguna de Bay Irrigation Project, Banga River Irrigation System, and Allah River Irrigation Project. The other sites such as the Laoag-Vintar River Irrigation System, San Fabian River Irrigation System, Upper Talavera River Irrigation System, etc. were added much later to gain more insight into why crop diversification has been successful in these systems. Figure 3 shows the location of the Philippine sites. Annex B provides brief descriptions of some of the key sites.

In Indonesia, the research sites were selected in relation to the following criteria: 1) they either have non-rice *(palawija)* crop production – palawija crop production is high on neighboring fields – or have very high potential for diversified cropping in the area; and 2) they are perceived by the staff of Provincial Department of Public Works to have above-average quality of irrigation management – defined in terms of the decision-making process for the allocation of irrigation water, not in terms of the available water supply – or to have the potential for high quality of irrigation management in the area. Because the type and quality of the physical infrastructure are

Figure 3. Location of study sites for TA 859 PHI in the Philippines.



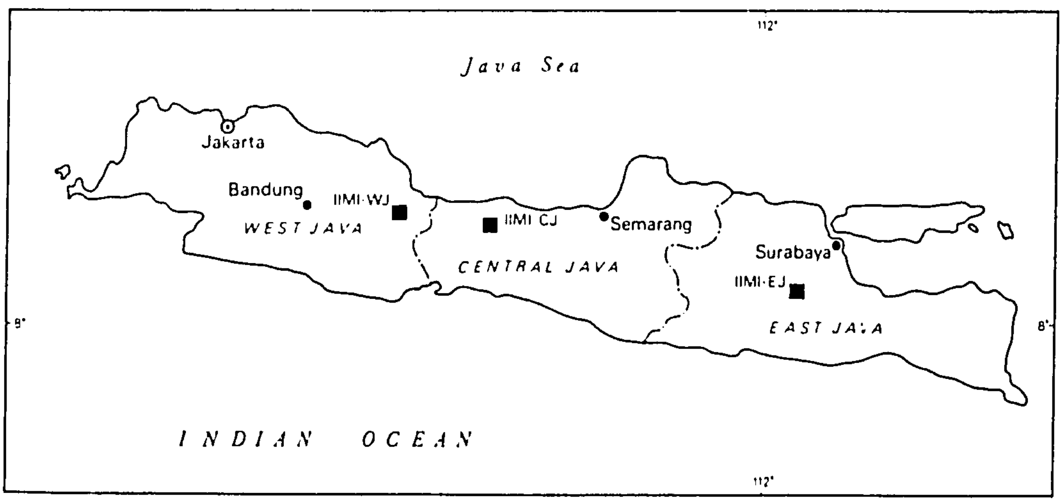
Source: IIMI (1988a)

directly related to the capacity for controlling water deliveries, only "technical" irrigation systems were considered for selection. Further, it was decided to include at least two sites in projects financed by the ADB.

Following extensive discussions and field visits, three irrigation projects *(wilayah)* were selected in Java. Within each of these projects, two research irrigation systems *(daerah irrigasi)* with less than 2,500 ha (except in East Java where a larger system was chosen) were selected. These projects are Waru Turi in East Java, Pemali Comal in Central Java, and Cirebon in West Java. The location of study sites is given in Figure 4 and brief descriptions of these sites are in Annex C.

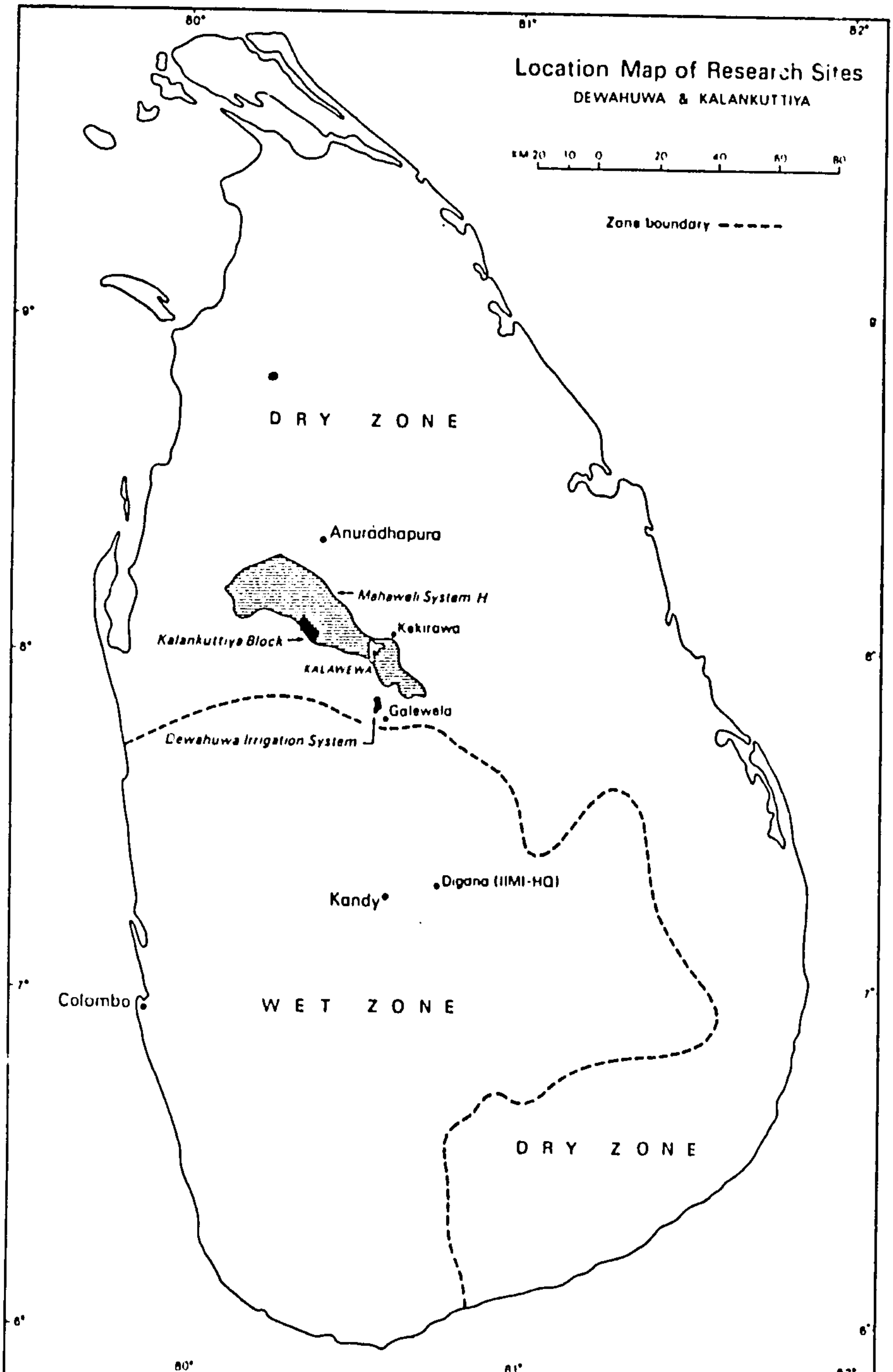
In Sri Lanka, the selection of the research sites considered factors such as presence of other food crops or non-rice crop production during *yala* (dry season), type of administration of the system, nature of the water source, and size and age of irrigation systems. These factors were considered because they cut across a wider range of irrigation systems found in the country than other factors such as design, layout, and manner of regulation. Two reservoir schemes located in the Dry Zone of the North Central Province were selected: the relatively new Kalankuttiya Block of the large Mahaweli H system under the Mahaweli Economic Agency, and the older medium-sized Dewahuwa Irrigation System under the Irrigation Department and the Irrigation Management Division. Kalankuttiya System was intentionally designed to accommodate other food crops in the well-drained reddish-brown earth (RBE) during the dry season, while Dewahuwa Irrigation System is a traditional rice irrigation system in which diversified crops were being introduced to rationalize the use of the limited water stored for the dry season. Figure 5 shows the location of these two research sites and Annex D gives the brief descriptions.

Figure 4. Location of stufy research sites in Java, 1986 to 1987.



Source: IIMI (1987b).

Figure 5. Location map of research sites in Sri Lanka.



Source: Miranda and IIMI Irrigation Management for Crop Diversification Group (1988).

A summary of some important characteristics of all selected irrigation research sites which include location, type of system, service area, crops and cropping patterns, soils, and rainfall patterns is given in Table 6.

Table 6. Irrigation research site characterization.

Location	Type of system	Service area (ha)	Crops and cropping pattern [b]	Soils/ texture	Rainfall pattern [a]
INDONESIA					
			R-R-R		
			R-R-P		
East Java			R-P-P[c]		
Waru-turi	Run-of-the river diversion scheme (technical)[d]	1366	WS-rice	Alluvial soils	Annual-1700mm
			DSI-rice	Clay, Clay	Wet-100-200mm/mo
			Soybean	loam to	Dry-100 mm/mo
Nganjuk			DSI-rice	sandy loam	Convective storms
Section			Soybean		of short duration
3 Research			Maize		usually in the
blocks			Groundnut		afternoon
			Sugarcane		
Central Java					
Pemali Comal	Run-of-the river diversion schemo (technical)		WS-rice		
			DSI & DS2	Aluvial soils	
			Rice	Clay and	
Gung Section			Soybean	clay loam	
Jarot Conkring			Sugarcane		
Gung Upper			Mazie		Annual-1900 mm
Gung Lower		1624	Peanuts		
		1885	Chili		
			Mungbean		
			Sweet potatoes		
West Java					
Cirebon	Run-of-the river diversion scheme		WS-rice	Alluvial soil	Annual-2300 mm
			DSI & DS2	Clay	Coastal-1200mm
Cirebon-	(technical)		Rice	Clay loam	2700mm
Kuningan			Maize	and loam	Hilly area>
Section			Onion		2000mm
Jasem			Chili		
Ciwaringin		2417	Peanuts		

Location	Type of system	Service area (ha)	Crops and cropping patterm[b]	Soils/ texture	Raintall pattern[a]
		519	Mungbean Sugarcane		
THE PHILIPPINES					
South Cotabato					
Allah Valley IP[e]	Run-of-the river diversion scheme	8000	Sandy loam	Alluvial soils 1800 mm	Type IV
Banga RIS[f]		1930	R-R R-Corn R-R-Corn R-R	to	
Mani Communal IS[g]		700	R - Corn	clay loam	
Isabela					
MRIIS[h]	Reservoir river	97000	R-R R-Corn R-Peanut	Alluvial soils Clay loam to loamy sand	Type III 1900 mm
Cavite					
Second Laguna De Bay IP	Puming scheme	13120		R-R R-Whitebeans	Clay Type I 2000 mm
Tarlac					
Tarlac-San Miguel O'Donnel RIS	Run-of-the river		R-R R-Corn	Alluvial soils Sandy to clayey	Type I 2000mm
Nueva Ecija					
Upper Talavera	Run-of-the river		R-R R-Onion R-Garlic	Alluvial soils Sandy to clayey	Type I 2000mm
Pangasinan					
Agno RIS	Run-of-the river	12130	R-R	Alluvial soils	Type I
San Fabian RIS	Run-of-the river	4265	R-Mungbean R-Tomato R-Tobacco R-Cotton	Sandy to clayey	1900 mm

Location	Type of system	Service area (ha) pattern[b]	Crops and cropping	Soils/ texture	Rainfall pattern[a]
Ilocos Norte					
Laoag-Vintar RIS	Run-of-the river	2377	R-R-Mungbean	Alluvial soils	Type I
Bonga Pump IS	Pumping scheme	620	R-Garlic -MB	Sandy to clayer	2300 mm
SRI LANKA					
North Central Province					
Dewahuwa	Reservoir scheme	1215	Rice-rice	Residual	Bimodal rainfall
Irrigation Scheme			Rice-chilli -soybean -mungbeam	soils Sandybeam	1500 mm Wet from October to mid-January and from mid-March to August
Kalankuttiya Block Mahaweli H	Part of reservoir scheme	2040	Rice-rice Rice-chili	Clay loam	Dry in February June to September

[a] Type I - two pronounced seasons: dry from November to April and wet during the rest of the year.
Type II - nc dry season with very pronounced maximum rainfall from November to January.
Type III - season not pronounced and relatively dry from November to April and wet during the rest of the year.
Type IV- rainfall more or less evenly distributed throughout the year.

[b] WS = wet season - November to March.
DS 1 = first dry season - April to July.
DS 2 = second dry season - August to November.

[c] R = rice
P = palawija

[d] Technical - irrigation systems in which irrigation flow can be measured and controlled.

[e] Irrigation Project.

[f] River Irrigation System.

[g] Irrigation System.

[h] Magat River Integrated Irrigation System.

Source: Various IIMI reports.

CROPS AND CROPPING PATTERNS

During the first wet-season cropping, rice which is basically an aquatic plant, is primary crop grown as is to be expected in all three countries. Some patches of vegetables, however, are raised in the higher areas. Sugarcane, being a 16 - to 18 - month crop which by law is required in the crop ratation in Java, is grown through the year.

During the second or third cropping season, when water supply becomes relatively scarce, the irrigation and cultivation practices observed vary across countries and sitations. In the Philippines, which basically has only two cropping seasons excepted in the Laoag-Vintar River Irrigation System and recently, Banga River Irrigation System, the service area is reduced to a fraction of the area served during the wet season. The area is normally rotated every year with the area served in one year receiving water again in the third or fourth year depending on which area is covered during the dry season. Exceptions are the Laoag-Vintar Irrigation System and Upper Talavera River Irrigation System (Figure 6) in which about the same areas are served every dry season.

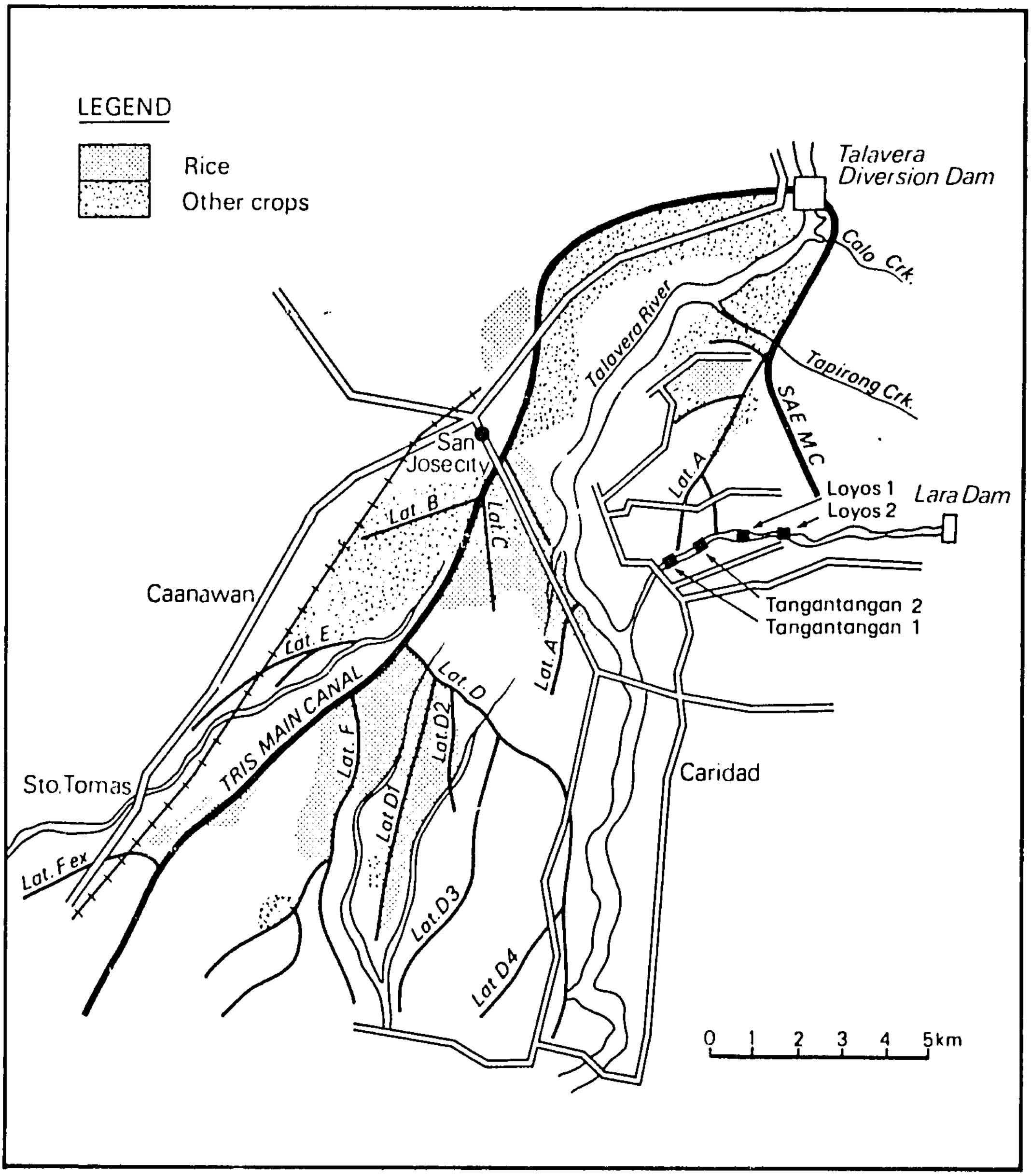
This is similar to the practice in Sri Lanka, in which the reduced upper portion of the service area is scheduled for cultivation. The farmers from the lower portion share in the cultivatin of the irrigated upper portion. This institutional sharing of reduced irrigated land is called *bethma*. Rice is still grown especially in the poorly-drained low-humic gley (LHG) soils in the lower portion of the toposequence, but non-rice crops are now being promoted in the well-drained, higher RBEs.

A similar trend is occurring in the Philippines. It involves targeting the cultivation of non-rice crops which grow best under aerated and well-drained conditions on diversified and dual land class soils with high seepage and percolation rates. These are coarse-textured alluvial soils found along river levees. Crops with import substitution potential such as corn and soybeans for livestock feeds are being promoted. The same crops are being emphasized in Indonesia. In all three countries, onion is grown as a cash crop. The other cash crops are chili in Sri Lanka, cucumber in Indonesia, and garlic in the Philippines.

In Indonesia, where the cropping intensity is highest (often over 240 percent), the third cropping or second dry season has been decreed by the Government of Indonesia to be devoted only to the cultivation of palawija crops. Rice, however, is still being grown (Table 7) in the poorly-drained, low-lying areas where the groundwater table is high. In the Philippines, if a third crop is grown, it is usually mungbean. Mungbean, which is a short duration and relatively drought-resistant crop, is grown in all three countries.

Specifically in Indonesia, the *golongan* system is used as a procedure for scheduling cropping patterns and planting dates for given secondary or tertiary blocks of irrigation systems. The practice of minimizing water demand through staggering planting dates preceded even the Dutch period, but the Dutch elaborated on the *golongan* system, particularly the scheduling of cropping patterns to permit sugarcane and rice rotation. This system permits the staggering of land preparation and planting dates within and between irrigation systems in order to spread out water demand so as not to exceed canal capacities and water availability. The system also reduces excessive water demand on irrigation systems by scheduling only as much dry-season rice as can be assured on the basis of irrigation staff estimates concerning adequate water deliveries. Different cropping patterns may be assigned to different blocks and these may or may not be rotated spatially each year. For example, in one year a given block may be scheduled for a rice-rice-palawija pattern, and the next year from a rice-palawija-palawija or perhaps, rice-sugarcane pattern.

Figure 6. Map of the Upper Talavera River Irrigation System (UTRIS) in Nueva Ecija showing cropped areas for dry season 1987-1988 and critical points of water distribution.



Source: IIMI (1988a)

Table 6 shows the typical cropping patterns observed in all research sites.

Table 7. Crop mix for first and second dry seasons, 1986 - Jarot 2 and 5, Gung Section, Central Java.

	Jarot 2		Jarot 5	
Crop	First dry season	Second dry season	First dry season	Second dry season
Rice	XX[a]	XX	XX	
Soybean	XX	XX	XX	XX
Sugarcane	XX	XX	XX	XX
Maize	XX	XX	XX	XX
Peanuts	XX	XX	XX	XX
Long beans	XX	XX	XX	
Cassava	XX	XX	XX	XX
Sweet potato	XX	XX	XX	
Mungbean	XX	XX	XX	XX
Chili	XX	XX		
Tomato			XX	
Intercropped			XX	XX
Squash			XX	XX

a XX = crop was present in the block that season

Source: IIMI (1987b).

RAINFALL PATTERNS

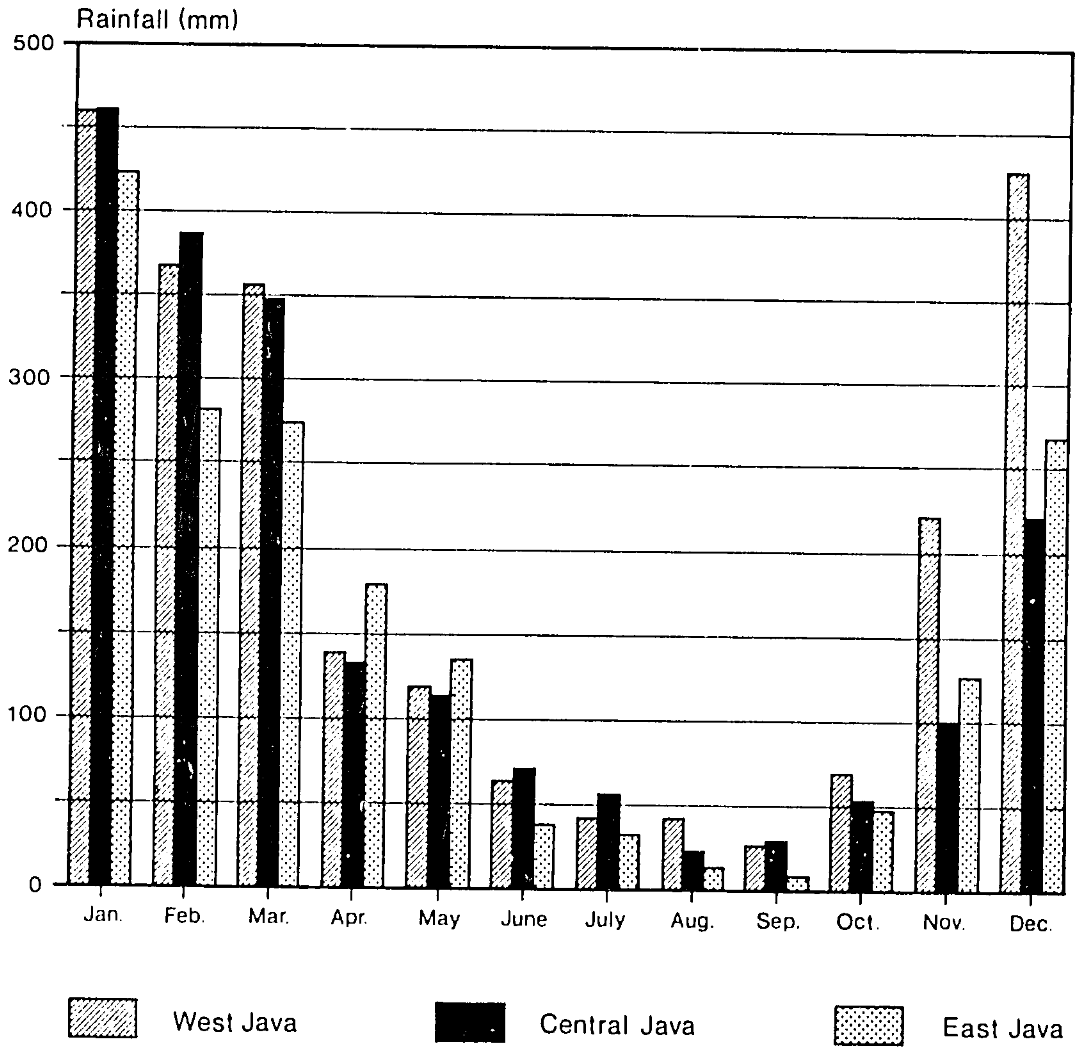
It became apparent early in the conduct of the research that rainfall distribution, and not so much the annual total, significantly influences the cropping pattern. The rainfall pattern itself is determined by the prevailing monsoons and the presence of mountain barriers. The Philippines and Sri Lanka, being located north of the Equator, experience more rainfall from May to October when the warmer and more moist Southwest monsoon is active than during the colder Northeast monsoon from November to February. Exceptions in the Philippines are sites in the South and Northeast in which the rainfall is more evenly distributed rather than being distinctly unimodal. Because the sites in Indonesia are located south of the Equator, the seasons are reversed. The wet season is also somewhat extended. The Sri Lankan sites, which are shielded from the Southwest monsoon, have the same wet season as Indonesia, from November to February when the Northeast monsoon is on. Another difference is the bimodal nature of the rainfall in Sri Lanka with the lower peak occurring in April and May. Figures 7, 8, and 9 illustrate the mean monthly/weekly rainfall distribution for the different research sites.

SOILS

Except for the residual soils in the research sites in Sri Lanka, those in Indonesia and in the Philippines are all water sorted or alluvial soils. The coarsest are found in the Allah River Irrigation Project in the Philippines, and the finest in the Java sites, with the well-drained soils in Sri Lanka being more on the coarse side. Using the new soil taxonomy, the texture varies from sandy entisols and inceptisols in the Philippines, to alfisols in Sri Lanka, to clayey vertic inceptisols in Indonesia. In each site in all three countries, there is a range of soil textures. In Sri Lanka, it is from sandy-loam to clay-loam, in Indonesia from loam to clay, and in the Philippines from coarse sand to clay.

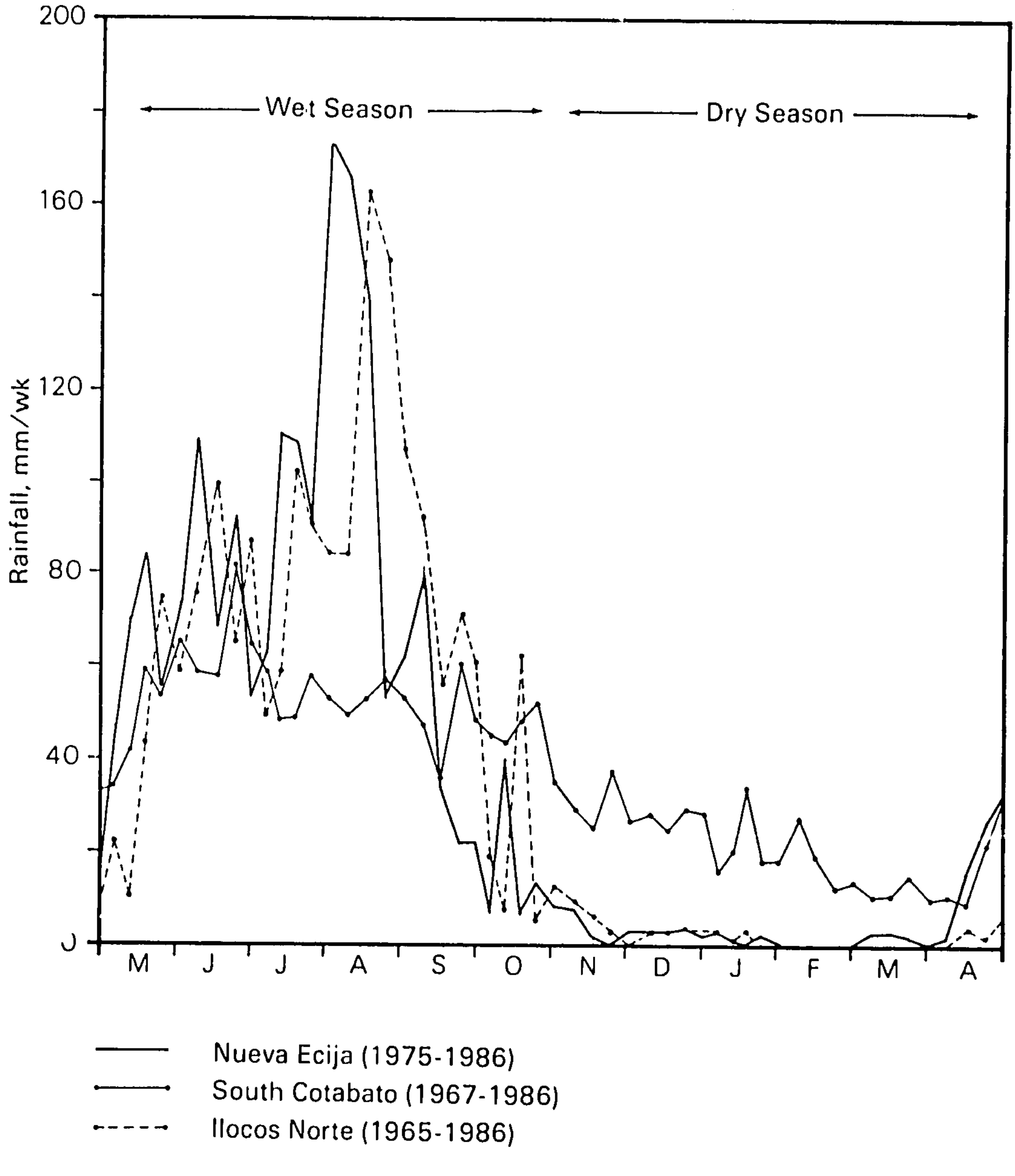
The soils in the Sri Lanka sites occur in a catenary sequence with the well-drained RBEs in the upper slopes of the undulating or rolling landscape, and the poorly drained LHGs in the valley bottoms (Figure 10). In the case of the Philippines, the diversified land class soils which have see page and percolation rates greater than eight millimeters per day are found along the river levees and the fine-textured good riceland class at the lower elevation further from the river where the water table is also high. The situation in Indonesia is somewhat similar to the Philippines, especially at the Laoag-Vintar River Irrigation System. The Philippines is trying to encourage the use of the diversified and dual land class in growing non-rice crops in the dry season in much the same way that Sri Lanka is pushing the growing of other food crops in the well-drained RBEs. In Indonesia all types of soils, provided they can be drained, are being used for palawija crops. Raised beds and deep drains are frequently resorted to as a means of providing the well-aerated condition required by the palawija crops. In some cases shallow rooted crops like onions which are irrigated twice daily are grown to take advantage of the high (shallow) water table conditions, especially in the West Java sites.

Figure 7. Mean monthly rainfall for East, West, and Central Java, Indonesia (20 years's average).



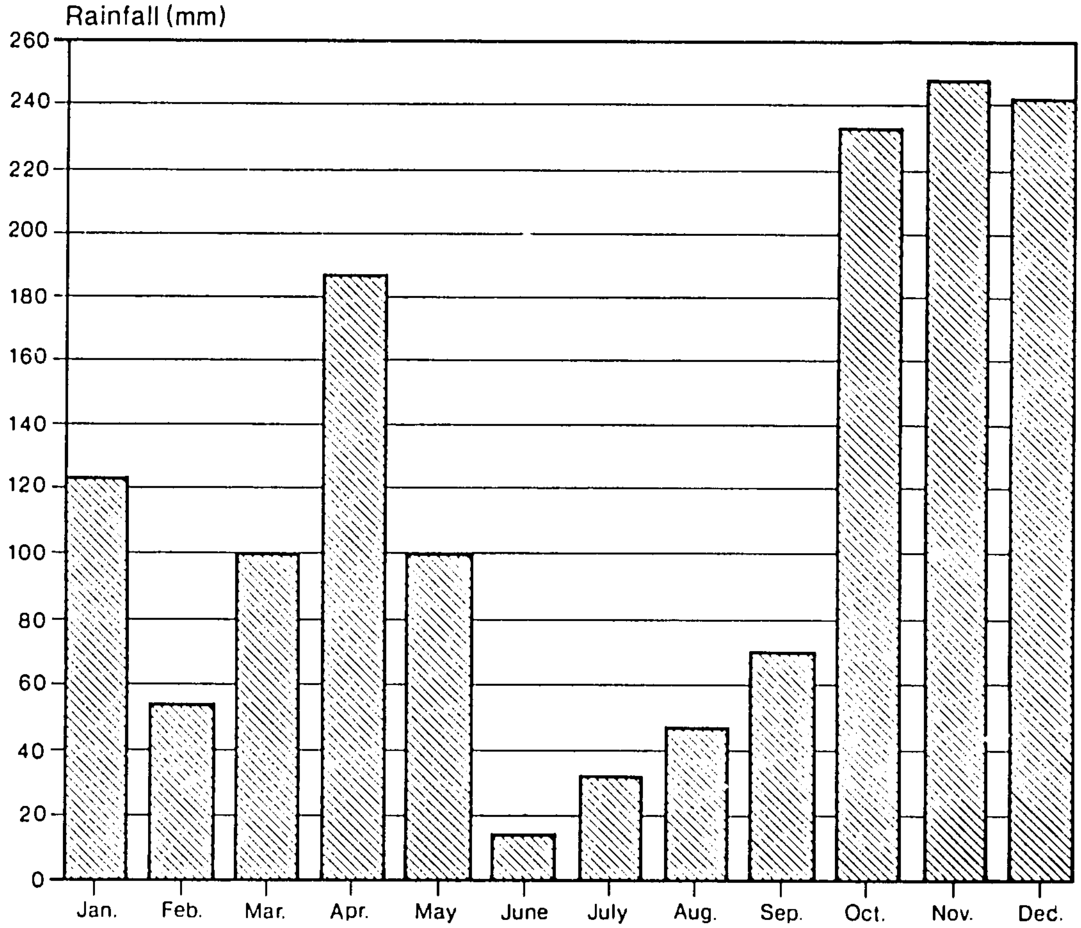
Source: Data from IIMI (1987a).

Figure 8. Mean weekly rainfall, for South Cotabato, Nueva Ecija, and Ilocos Norte, the Philippines.



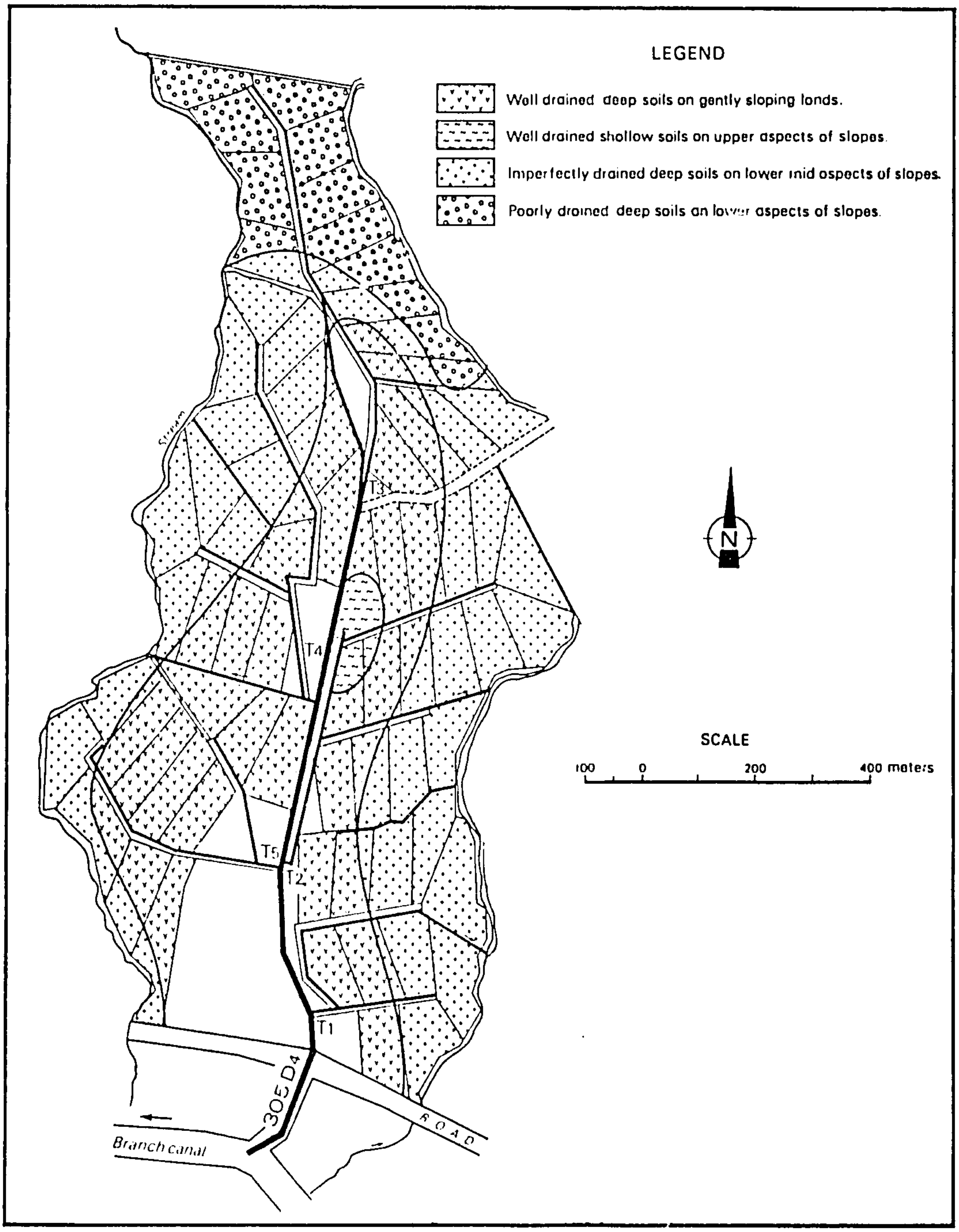
Source: Valera et al. (1988).

Figure 9. Mean monthly rainfall for North Central Province, Anuradhapura, Sri Lanka (30 years' average).



Source: Dimantha (1987).

Figure 10. Soil map of Mahaweli area, 305-D4



Source: Panabokke and IIMI Irrigation Management for Crop Diversification Group (1988).

CHAPTER 4

Emerging Research Results And Their Implications

IRRIGATION MANAGEMENT PRACTICES

In the management of the irrigation systems selected in the three countries, the intensity of operational planning and the implementation, monitoring, and evaluation of the plan vary across countries and sites within each country.

Planning

The basic principle in any case is simply to match as closely as possible the water supply with the water demand or soil crop requirements. The planning process observed can be very simple or complex, depending on the scope for manipulating supplies according to the demand. It can be as simple as the farmers being informed by their association officers about the availability of water and the time of its distribution, as in the Mani Communal Irrigation Systems or the Bonga Pump Irrigation System in the Philippines. Or, it can be very elaborate as in relatively large schemes such as the Mahaweli System H in Sri Lanka or in the Magat River Integrated Irrigation System in the Philippines. In the Magat River Integrated Irrigation System, planning can mean estimating the future water supply and the water demand of the expected cropping pattern, and then matching the two. This procedure of matching the water supply and demand is routinely done in all irrigation systems in Indonesia, and to a lesser degree in the Philippines and in Sri Lanka.

In *estimating the future supply*, the factors considered by the irrigation staff include anticipated rainfall distribution during the wet and dry seasons by using past records; type of water capture, diversion, and storage systems used; and reliability of hydrologic and climatic data. The situation varies from no records kept of rainfall and river and diversion flows, to 5-year moving average for national systems in the Philippines, 10-year records for the "technical" systems in Indonesia, and even longer records of about 30 years as used by the Water Management Secretariat for Mahaweli System H, using a main frame computer to estimate probabilities of flow during the on-coming season. The estimate often becomes pure guesswork in which the future supply is variable and unpredictable, as in some run-of-the-river schemes.

The *water demand is determined*, when this is done, by estimating the cropping patterns, the cultivation extent, and irrigation efficiencies at the on-farm and main systems. The efficiencies used are assumed rather than measured in all countries. The magnitude of the efficiency value used gives some indication of the permeability of the soils in which the canal network is built, the value being lowest in lined channels. Most of the main canal and secondary channels in systems in Indonesia and in the Allah River Irrigation Project and the Banga River Irrigation System in the Philippines are lined. For unlined canals as in Sri Lanka, a uniform value of 25 percent conveyance loss is used in the two sites. To make an accurate calculation of the system's water requirement, information is needed not only on the expected but also the actual water requirements (which vary according to type of field or farm operations, the stage of crop growth, etc.) of different crops under different soil conditions. In theory, this is done in Indonesia as indicated in the water-requirement coefficients (derived from *pasten*) used by provincial irrigation officers (Table 8). Crop-growth stage, however, is only considered for rice and sugarcane but not for different palawija crops. Based on past experience, tentative assumptions are made by the irrigation staff regarding the start of the cropping season, the crops to be grown, length of land-preparation time, the start of normal irrigation, and the end of season.

Table 8. Water requirement coefficients used by the Provincial Irrigation Service (PRIS) in study sites by crop and growth stage, 1986-1987.

	Central Java		West Java				East Java	
Location	Comal section		Gung section		Cirebon section		Heavy soils	Light soils
Units	l/s/ha[a]		l/s/ha		l/s/ha		l/s/ha	l/s/ha
	WS[b]	DS[c]	WS	DS	WS	DS		
Crop and stage								
Rice								
Seeded nursery	1.12	1.20	1.08	1.20	0.78	1.00	na	na
Land preparation	1.12	1.20	1.08	1.20	0.78	1.00	0.64	2.12
Tillering	0.65	0.73	0.65	0.73	0.39	0.55	0.46	1.40
Flowering	0.71	0.79	0.71	0.76	0.52	0.73	0.48	1.44
Ripening	0.46	0.52	0.46	0.52	0.00	0.00	0.31	0.94
Sugarcane								
Land preparation	0.30	0.30	0.45	0.45	0.39	0.55	na	na
Young cane	0.45	0.45	0.36	0.36	0.20	0.27	na	na
Mature cane	0.30	0.30	0.00	0.00	0.00	0.00	na	na
Palawija								
Much water	0.30	0.30	0.30	0.30	0.20	0.27	na	na
Less water	0.15	0.15	na	na	0.07	0.10	na	na
Water shortage	0.15	0.15	0.30	0.30	0.07	0.10	na	na

[a] Liters per second per hectare.
[b] WS = wet season.
[c] DS = dry season.

Source: IIMI (1987b).

Once calculations of the supply and demand are completed, the *appropriate allocation and distribution practices* or other measures are considered to determine the target flows at various levels of the irrigation system. The final choice of distribution method depends very much on the characteristics of the physical system in terms of capacity of the canal network, flow regulation available, and the managerial capacity of the irrigation staff and water users. Planning of the delivery schedule when done deliberately is normally tempered by experience gained through some form of monitoring, however crude, of the results of previous cultivation seasons.

Before the plan is finalized and operationalized, irrigation and other associated government officials meet with farmers or their representatives or both to decide formally on: a) the start of the season; b) areas and types of crops to be cultivated; c) length of land-preparation period; d) the start of normal irrigation; e) the end of the season; f) distribution method, whether continuous or intermittent; and g) the maintenance schedule and responsibilities.

At this meeting, the irrigation staff presents the plan for the season, based on whatever information is at hand and the experience accumulated in operating the system. Discussion of the plan is usually invited before the final decision is made. The suggestions of farmers may or may not be entertained in the process. This type of cultivation meeting is legally required in Sri Lanka, and is now becoming institutionalized in the Philippines. In Indonesia, the plan is approved by the Irrigation Committees at the regency and district levels.

Implementation

The agreed plan is used as the basis for the release and delivery of irrigation water. In most systems field staff have acquired experience in estimating water adequacy by simply observing elevations at intake and diversion structures, and canals. This is practical, but more reliable and accurate measurements are needed to assure adequate water supply. In implementing the plan for the main season or wet season in which the crop is basically rice, the starting date and the choice of the distribution method for land soaking and land preparation are dictated by the availability of water at the start of the main season. In run-of-the-river, direct diversion systems, the water flow increases with the relative activity of the monsoon. In this situation, a staggered schedule of delivery is usually chosen by serving gradually increasing acreage in accordance with the flow and rainfall pattern. The diverted flow is concentrated or rotated among sections of the canal service area. This is routinely done in the Banga River Irrigation System and the Laoag-Vintar River Irrigation System in the Philippines, in most of the sites in Java, and even in the Dewahuwa Irrigation System in Sri Lanka.

In the systems with storage facilities where stored water is adequate at the start, the water is delivered continuously to the whole service area simultaneously for a planned 30-day period although this is almost always exceeded. This is the practice in the Mahaweli System H in Sri Lanka and in the Magat River Integrated Irrigation System in the Philippines. After planting is over and normal irrigation commences, these systems have the flexibility to deliver water continuously or intermittently, depending on the canal network configuration and flow regulation present.

In the direct diversion type, continuous water supply is adopted for as long as the diverted flow can meet the requirement of the cultivated service area. When water becomes short as caused by the failure of the monsoon or overdiversion by systems located upstream along a river course, however, the reduced flow is rotated among sections of the system. The level of rotation can be below or at the tertiary, secondary, or along sections of the primary canal, depending on the severity of the water shortage. If the value of Faktor K which is the ratio of the water supply and demand falls below 0.6 to 0.7, rotational water issue is followed in Indonesia. The other alternative is to tap a supplementary water source upstream, or *suppletion* as the practice is called also in Indonesia. At the field level, enterprising farmers who have installed their own shallow tube or open wells use these to augment their water supply. This is routine at the Laoag-Vintar River Irrigation System and the Upper Talavera River Irrigation System in the Philippines, and in several sites in Java, but is seldom seen in Sri Lanka. In really severe cases of water shortage, agreement is sometimes reached in many systems to deliver the limited water according to the sensitivity of the crop and crop-growth stage; the more critical the stage, as in the reproductive stage, the higher the priority of water. Very often, however, the decision is made to deliver the water to areas easy to irrigate.

Interruption of water flow to the canal network for varying periods is normally practiced whenever sufficient rainfall is received in the service area of a storage system. In the direct diversion type, the flow is usually interrupted only if the rainfall is observed to be so heavy as to cause flooding in parts of the service area when combined with the irrigation supply. The other reason advanced for closure of the headworks is to avoid breaching and silting of the canal network. Drainage of excess water flow is practiced extensively, although drainage facilities are generally inadequate or are not properly maintained.

During the second or third cropping season when water supply becomes relatively scarce, the irrigation and cultivation practices observed vary across locations and situations. In the Philippines, which has only two cropping seasons, the service area is automatically reduced with rice being grown in the reduced area and other crops grown in unirrigated portions, except in the few systems selected for this study, especially in the Northwest area of the country. The government has attempted to promote cultivation of a greater, if not the whole, service area with a combination of less water-consuming non-rice crops in the well-drained higher land, and rice in the lower-lying lands with high groundwater tables. This situation of having a greater area cultivated already prevails in all of the sites in Java, and to a lesser extent in the Sri Lanka sites. But, during the second season, if the water, though limited, is still adequate and assured, farmers tend to prefer rice cultivation in all three countries. During the third season, and this is true in all sites in Indonesia, most of the area that could be irrigated is planted to palawija, except the lower-lying, poorly-drained areas. In the Philippines, it is only in the Laoag-Vintar River Irrigation System that a very limited area is planted during the third season and only with mungbean.

Monitoring and evaluation

The monitoring process leaves much to be desired. It tends to break down as it goes lower in the system. It is more geared towards office reporting rather than for day-to-day operations. Consequently, it is generally found that the tail-end portions of the systems suffer from deficiencies of water, whereas the head or upper portion has excess water. This inequity is shown by the water-use efficiency obtained at the head and tail sections in the Upper Talavera River Irrigation System in the Philippines (Table 9) and in the Central Java sites (Table 10). In the Java sites, for example, gate tenders generally favor their areas at the expense of downstream farmers. This is illustrated by the value of the management performance ratios (ratio of planned and actual discharge arriving at the division structure) in Figure 11. In Sri Lanka, there is more variation of flows (Table 11) at lower levels of the system with the magnitude being greater in the older Dewahuwa Irrigation System. The Kalankuttiya System which has constant head regulating structures in the form of duck-bill weirs along the branch canal has much less flow variation at the head of distributary canals. While the key requirement of farmers interviewed is for reliable and adequate supply to their fields, less availability and greater variation of water is shown in Tables 9, 10, and 11. The rotation of the water supply is a serious attempt to improve reliability and equity of the water supply in all sites. Where canal regulation is deficient, farmers themselves put up temporary checks to head up the water so it can flow in the canals serving their areas.

Table 9. Mean water use efficiencies (WUE) and actual irrigation diverted (AID) by section of systems for all Philippine study sites, dry season, 1987-1988.

Site	Section	AID (mm)	WUE (%)
LVRIS[a]	Whole system	2086	60
	Division I	2828	56
	Division II	1694	67
	Division III	2324	49
	Division IV	1540	59
UTRIS[b]	Whole system	1864	72
Upstream area		1965	64
Downstream area		1335	89
ARIP[c]	Whole system	4431	41
Upstream area		4554	42
Midstream area		5324	37
Downstream area		3344	57
BARIS[d]	Whole system	1838	85
Division A		3718	60
Division B		1300	85
Division C		2158	83

[a] Laoag-Vintar River Irrigation System.
[b] Upper Talavera River Irrigation System.
[c] Allah River Irrigation Project.
[d] Banga River Irrigation System.

Source: Adapted from Valera et al. (1988).

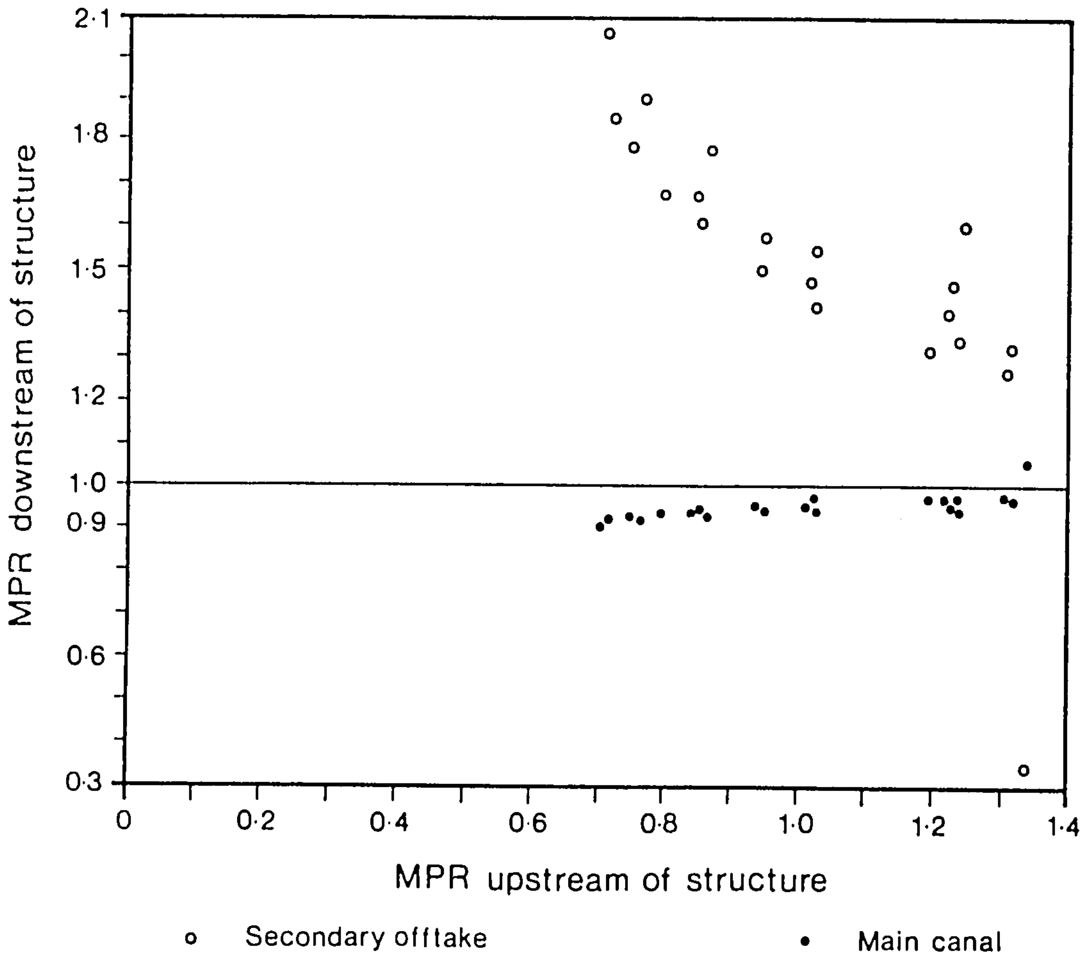
Table 10. Seasonal water availability and water use efficiency during the first and second dry seasons, Indonesia study sites, 1986.

Season / Location[a]	First dry season		Second dry season	
	Water available (mm)	Water efficiency (percent)	Water available (mm)	Water efficiency (percent)
East Java				
B-2	1103	47.3	976	31.2
B-3	1778	34.1	1422	20.6
B-4	1079	27.0	1079	31.0
B-15	743	74.5	839	39.9
B-17	1036	52.1	1219	27.5
B-19	990	70.0	990	33.8
B-21	955	42.2	1069	31.0
B-23	1027	na	1107	30.3
B-24	911	47.9	1341	22.6
B-25	1409	33.8	1333	20.1
a99	708	31.3	554	64.5
B-29	721	45.2	869	26.8
Average		45.9		31.6
Central Java				
Jarot 2	432	55.4	407	72.3
Jarot 5	409	38.4	442	64.2
Cangkring 3	463	73.4	259	69.5
Cangkring 7	402	74.1	257	91.7
Average		60.3		74.4
West Java				
Mirat I	1175	38.7	1286	18.7
Mirat IIb	2240	25.5	726	37.3
Jasem II	1228	48.9	749	12.9
Average		37.7		23.0

[a] Location is usually in order from source, although a99 and B-29 are tertiary blocks off the main canal and secondary canal B-21, respectively.

Source: IIMI (1987b).

Figure 11. Actual and planned gate operations at MPR 4, Cirebon, West Java.



Source: Colmey, Murray-Rust, and Vermillion (1988).

In the management of an irrigation system, even in its simplest form, the mechanism for delivering and applying water to farmers' fields can be considered to consist of three parts: 1) a set of physical works that moves the water from its source to the crop, 2) a plan that defines the activities to be undertaken, and 3) the people individually and in groups who implement and monitor the plan. Using the new computer lingo, the physical infrastructure is referred to as hardware, and the nonphysical managerial inputs as software. Up to a certain point, as Levine (1980) puts it, some degree of substitution between the hardware and software elements in each of the basic functions of water delivery, maintenance, and conflict management of irrigation systems is observed. Any gap between the irrigation management practice that is desired and that which exists seems to be caused by one or more of the following:

Table 11. Variations in water delivery at various levels in the Sri Lanka study sites, 1985-1986.

Season	Delivery points[a]	Number of observations	Mean delivery (mm)	Standard deviation	Range (mm)	Coefficients of variation
Dewahuwa						
1985 yala	DC	5	686	302	310-1228	44
	DT	14	661	306	301-1321	46
	TO	3	474	172	240-652	36
1985/86 maha	DC	7	1087	171	766-1373	16
	DT	20	956	448	339-2050	47
	TO	17	1129[b]	515	438-2571	46
1986 yala	DC	9	1030	355	412-1809	34
	DT	20	703	394	190-1846	56
	TO	10	570	227	313-1018	40
Kalankuttiya (Mahaweli H)						
1985 yala	DC	3	886	96	880-1006	10
	TO	11	755	128	624-1037	17
1985/86 maha	DC	5	688	99	513-797	14
	TO	28	534	192	104-859	36
1986 yala	DC	5	907	100	766-1022	11
	TO	29	757	259	167-1223	34

[a] DC = Head of distributary channel.
DT = Direct turnout from main canal.
TO = Turnout from DC.
[b] Increased by inflow from local runoff.

Source: Miranda and IIMI Irrigation Management for Crop Diversification Group (1988).

* poorly maintained and deteriorated condition of the physical system;
* incomplete or inappropriately designed and constructed physical works such as lack of functional flow-regulating and measuring facilities or inadequate canal capacity;
* lack of accountability and motivation of irrigation staff due to weakness in the management system, especially in performance monitoring and feedback for the decision-making process, interference by politicians and influential people; and
* uncooperative behavior and attitude of many farmers, probably caused by their noninvolvement and lack of appreciation and trust in system management.

The end result of deficiencies in the hardware-software mix is unstable water supply to various parts of the irrigation system. This problem is common in whole systems or parts of systems included in the study. It may be remedied by timely evaluation and use of monitored information at various levels of the system management as indicated by operational research conducted in the Mahaweli H site with the participation of agency staff and farmer leaders. Regular meetings between the irrigation officials and the farmer leaders after each rotational water delivery proved to be an effective way in improving communication between them and in identifying specific water problems and their solutions at the secondary and tertiary levels. To improve the collection and information needed for management decisions, new procedures tested are now being recommended to Indonesia. This includes the use of a pocket-size book by the gate operator to record discharges, the use of the management performance ratio to monitor and respond to variation in planned and actual discharges, and the making and using of tertiary block maps to improve information on actual crop areas.

Annexes E, F, and G describe the irrigation system management in Indonesia, the Philippines, and Sri Lanka research sites, respectively.

ON-FARM IRRIGATION PRACTICES

On-farm operations are relatively flexible in terms of the farmers' capability to adjust to different conditions of water availability. The reliability of water supply on the farm depends on the supply situation in the main system. With reliable water supply at the turnout, sharing of the water among farmers is better organized, with greater equity and fewer conflicts arising. The reverse situation at the turnout tends to trigger a chain of undesirable reactions and behavior from the farmers which are prompted by their desire to have a more assured water supply to protect their investment in their crops.

Basin-to-basin flooding, which is the basic water application method for rice, is also used in irrigating non-rice crops but with a difference. Instead of the supply being continuous and simultaneous, it is intermittent and mostly rotational. The specific method of water application, however, is closely related to the type of seedbed that is prepared and the kind of crop that is grown. There are at least four application practices commonly used in all locations: 1) flush basin flooding with rudimentary field ditches for soybean and mungbean; 2) broadbed and furrow for chili, garlic, and cucumber; 3) raised beds for onion; and 4) furrows for corn, as shown in Figure 12 and Table 12.

In Sri Lanka the flush flooding from basin to basin is carried out by starting from the upper basin *(liyadde)* and ending at the lower one. In this method, the entire basin is flooded in one operation by turning the irrigation stream along the rudimentary ditches that are fashioned within the basin. The first basin to receive a stream size of 4-20 liters per second is impounded by blocking the basin bund spillway or check at the exit. Soon afterwards, the remaining impounded water in the upper basin is released and directed to the adjacent lower basin to irrigate it. With this method, overirrigation of the basins located close to the farm inlet results. Considerable soil loss through erosion also occurs.

The broadbed and furrow method is essentially like flush flooding, except that broadbeds with

Table 12. Irrigation field application practices for rice and non-rice crops by country.

Application practice	Indonesia	Philippines	Sri Lanka
A. Basin flooding	Rice	Rice	Rice
B. Flush basin flooding with rudimentary field ditches	Soybean Peanut Mungbean Corn	Garlic Mungbean/ whitebean Onion (with mulch)	Soybean Mungbean
C. Broadbed and furrow	Cucumber	Garlic Onion	Chili
D. Raised beds	Red onion	Onion	Bombay onion
E. Furrow	Corn Cassava	Corn Whitebean	Chili

Source: Various IIMI reports.

furrows serving as small ditches are created in the basin. Farmers tend to aid this method by splashing water on the chili beds as is done in Sri Lanka, or on garlic and onion plots in the Philippines.

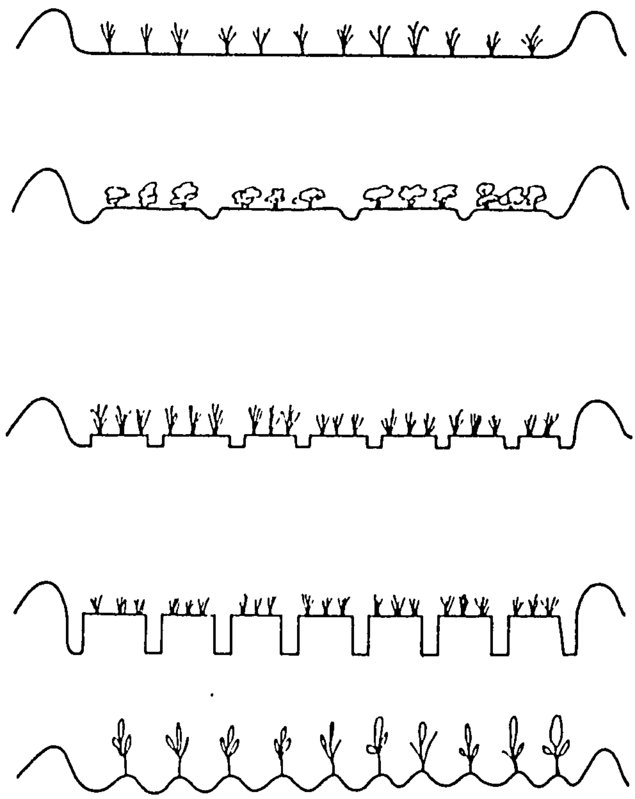
The raised bed method is identified with onion cultivation, especially in fine-textured soils and under high groundwater table conditions. The water impounded in the deep ditches on the side of the beds is scooped and sprinkled or splashed in the beds twice daily in Indonesia, and less frequently in Sri Lanka and the Philippines.

The furrow, the narrow ridge and furrow, or furrowed basin system is extensively used for row crops such as corn and cassava in Indonesia and chili in Sri Lanka. In the Philippine studies, furrow irrigation is proving to be suitable for irrigating corn in coarse-textured soils in the Banga River Irrigation System and the Allah River Irrigation Project by cutting down the irrigation time by at least a third compared to what it takes when flush basin flooding is used.

The amount of labor used in preparing the seed beds for the different water application differs; it is highest in raised bed and hilling up from furrows conditions which can be 50 to 100 percent more than for flush basin flooding method.

In terms of water applied, it tends to vary according to type of crop, rainfall and drainage, and water table conditions. Table 13 shows the contribution through capillary action of groundwater in the poorly drained areas planted to maize and soybean in Indonesia. Cropwise, the short-duration soybean requires the least water, followed by peanut and maize. In the Philippines, dry-season rainfall in the Magat River Integrated Irrigation System makes it possible to grow a good crop of corn with one to three irrigation applications only. On the other hand, Table 14 shows that short-duration mungbean needs the lowest amount of water, while onion, more frequently irrigated, needs the highest, with garlic requiring somewhat less.

Figure 12. Non-rice crop field irrigation application practices.



A. Basin flooding

B. Flush basin flooding with rudimentary shallow field ditches

C. Broad bed and furrow

D. Raised beds

E. Furrowed basin

Source: Adapted after IIMI (1987b).

In Sri Lanka, it is not obvious from Table 15 which crop requires more water. Five-month chili varieties that are grown, theoretically, have to require more water than mungbean and soybean. It should be noted that no soil moisture stress was detected in the sample areas, indicating a relatively liberal application of water exceeding crop demand. Yieldwise, chili, mungbean, and soybean fared better under well-drained soils with soybean showing the best tolerance for poorer drainage conditions.

CROP DECISION-MAKING CONSIDERATIONS

In order to understand the potential for irrigation in the process of supporting and intensifying non-rice crop production, it became necessary to identify the full range of constraints and incentives involved in the process, both those which are directly related to irrigation and those which are not.

Table 13. Field irrigation rates and yields for selected non-rice crops at IIMI research sites, Indonesia, 1986.

Crop	Location	Amount of water (mm)	Yield (kg/ha)
Soybean	Nganjuk, East Java	85	828
		81	380
		53	780
	Gung, Central Java	0[a]	818
	Cirebon, West Java	376	
Maize	Nganjuk, East Java	211	2946
		63	2688
		26[a]	3091
	Gung, Central Java	242	2418
		138	775
		131	2676
		32[a]	3478
		29[a]	1785
	Cirebon, West Java	259	688
Peanut	Gung, Central Java	100	2446
	Cirebon, West Java	173	1297
		120	1216

[a] Poorly drained fields.

Source: IIMI (1987b).

In attempting to do the foregoing, two different decision-tree models were derived and developed. The descriptive model of crop decision making under uncertainty, which was used in the Philippines, is a modified version of Gladwin's (1983) decision-tree model presented in Figure 13. The one developed in Indonesia is made up of a number of models derived from interviews with individuals and groups of farmers in their homes and fields to elicit what local decision criteria are relevant within given irrigation blocks. The models for first and second dry seasons for Jarot 2 Block in Central Java are illustrated in Figures 14 and 15.

In the Philippines, the study examined and documented six cases of successful crop diversification in irrigated rice lands, focusing particularly on the economic and institutional and, to a lesser extent, the physical and technical factors that have been supportive of the crop production. Non-rice crops included tobacco, cotton, tomato, mungbean, onion, garlic, corn, and peanut in four systems with Type-I rainfall pattern located in Luzon. The following conditions were found to be conducive to the adoption of crop diversification during the dry season (Gonzales-Intal and Valera 1988):

1. Irrigation water supply for rice in the dry season is insufficient.
2. Level of income from other sources is low.
3. The farmer has seen other farmers reap profits from the crop.

Table 14. Field irrigation rates for selected non-rice crops at IIMI research sites, the Philippines, 1986-1987.

Year	Crop	Location	Total water applied (mm)	Yield (ton/ha)
1985-86	Corn	*MRIIS*[a]		
		Sibester IA[b] (San Mateo)	41[c]	4.70
		CPPL IA (Luna)	125[d]	4.65
1986-87	Onion	*UTRIS*[e]		
		Tayabo	494	17.42
			451	15.54
		Sibot	391	27.00
			543	37.00
		Mean	470	24.24
	Garlic	*LVRIS*[f]		
		Vintar	576	2.28
		San Mateo	298	2.21
		Dibua	405	1.72
		Navotas	246	1.62
		Santa Maria	299	1.75
		Mean	406	1.93
	Mungbean	Vintar	159	1.04
		Navotas 1	211	1.10
		2	229	1.30
		Mean	204	1.17

[a] Magat River Integrated Irrigation System.
[b] Irrigation Association.
[c] One irrigation application only.
[d] Three irrigation applications.
[e] Upper Talavera River Irrigation System.
[f] Laoag-Vintar River Irrigation System.

Sources: IIMI (1986a) and IIMI (1988b).

4. Farmers in nearby fields are planting the crops.
5. There is no better alternative (i.e., it is the best under the circumstances).
6. The family's rice consumption requirement for the year is met by its wet-season rice crop and other sources of income.
7. The crop is perceived as technically feasible by the farmer (i.e., it is suitable to the soil and topography of his farm, the timing of the cropping season is "right," and the irrigation water

Table 15. On-farm water delivery rates, drainage class, and dry-season crop yields in research sites, Sri Lanka, 1985-1986.

Location	Season	RF[a] (mm)	ET[b] (mm)	Crop	Drainage class	Water delivered (mm)	Yield kg/ha
Dewahuwa	Yala 1985	136	633	Chili	WD[c]	597	1020
					ID[d]	439	876
				Mungbean	WD	620	756
					ID	351	616
				Soybean	WD	573	1363
					ID	425	1693
Kalankuttiya	Yala 1985	177	704	Chili	WD	432	1951
					ID	338	1545
Dewahuwa	Yala 1986	53	531	Chili	WD	438	1030
					ID	567	827
					PD[e]	301	131
				Mungbean	WD	467	691
					ID	450	458
					PD	305	675
				Soybean	WD	503	1709
					ID	444	1540
Kalankuttiya	Yala 1986	10	525	Chili	WD	554	718
					ID	349	559

[a] Rainfall.
[b] Evapotranspiration.
[c] Well drained.
[d] Imperfectly drained.
[e] Poorly drained.

Source: Panabokke and IIMI Irrigation Management for Crop Diversification Group (1988).

available is sufficient to support the crop).

8. Seeds are available.

9. The crop is perceived as economically feasible by the farmer (i.e., his produce will be bought, there will be a source of credit if needed, and the labor required for the crop whether family or "hired" is available).

10. The farmer is convinced that the crop will yield high returns, and not just marginally higher returns than rice, a˙ farmers tend to have high minimum-profitability requirements for diversified crops.

Figure 13. A descriptive model of cropping decision making used in the Philippines.

Stage 1. Satisfaction of Basic Needs: Assuring rice consumption requirements

Q: Will the family's rice consumption requirements be met if the farmer plants other crop(s)?

YES — (Move on to Stage 2)

NO — Is (are) there non-rice crop(s) with possible returns that will allow the family to meet its rice consumption requirements?

- YES (Move on to Stage 2)
- NO (Plant rice only)

Stage 2. Testing for Feasibility: Satisfaction of technical constraints and economic feasibility

Technical Constraints:

* Soil, topography
  (Does crop X yield well at farmer's soil, topography?) ==== if no ==== eliminate crop X

* Water requirements
  (Does farmer have irrigation or is the water enough to meet the requirements of crop X?) ==== if no ==== eliminate crop X

* Timing of farm operations
  (Is the timing of farm operations for crop X acceptable to the farmer?) ==== if no ==== eliminate crop X

* Knowledge
  (Does farmer know now to plant crop X or will he be able to obtain information?) ==== if no ==== eliminate crop X

Economic Feasibility:

* Demand

(Can the farmer sell crop X in a nearby market or to a merchant?) ==== if no ==== eliminate crop X

* Time, labor
  (Does the farmer have the available time and accessible labor to help his plant crop X?) ==== if no ==== eliminate crop X

* Capital, credit
  (Does the farmer have the capital or accessible credit to buy inputs for crop X?) ==== if no ==== eliminate crop X

Note: In Stage 2, there is no one particular sequence in which the farmer processes each alternative crop vis-a-vis the technical constraints and economic feasibility. Suffice it to say that any alternative crop that fails to meet any one of the above-mentioned four technical constraints or three economic feasibility requirements is eliminated from consideration.

Stage 3. Cost-Benefit Analyses

Examination of the expected returns of each alternative crop vis-a-vis costs.

Q. Are returns from crop X n times greater than returns from previous crop (rice)?

YES	NO
Plant crop X	Stick to old crop (rice)

Note: n is a value which represents the minimum profitability of crop X over the previous crop for which the farmer will be willing to take risk of planting crop X. n is an empirical value that is greater than 1.

Source: Gonzales-Intal and Valera (1988).

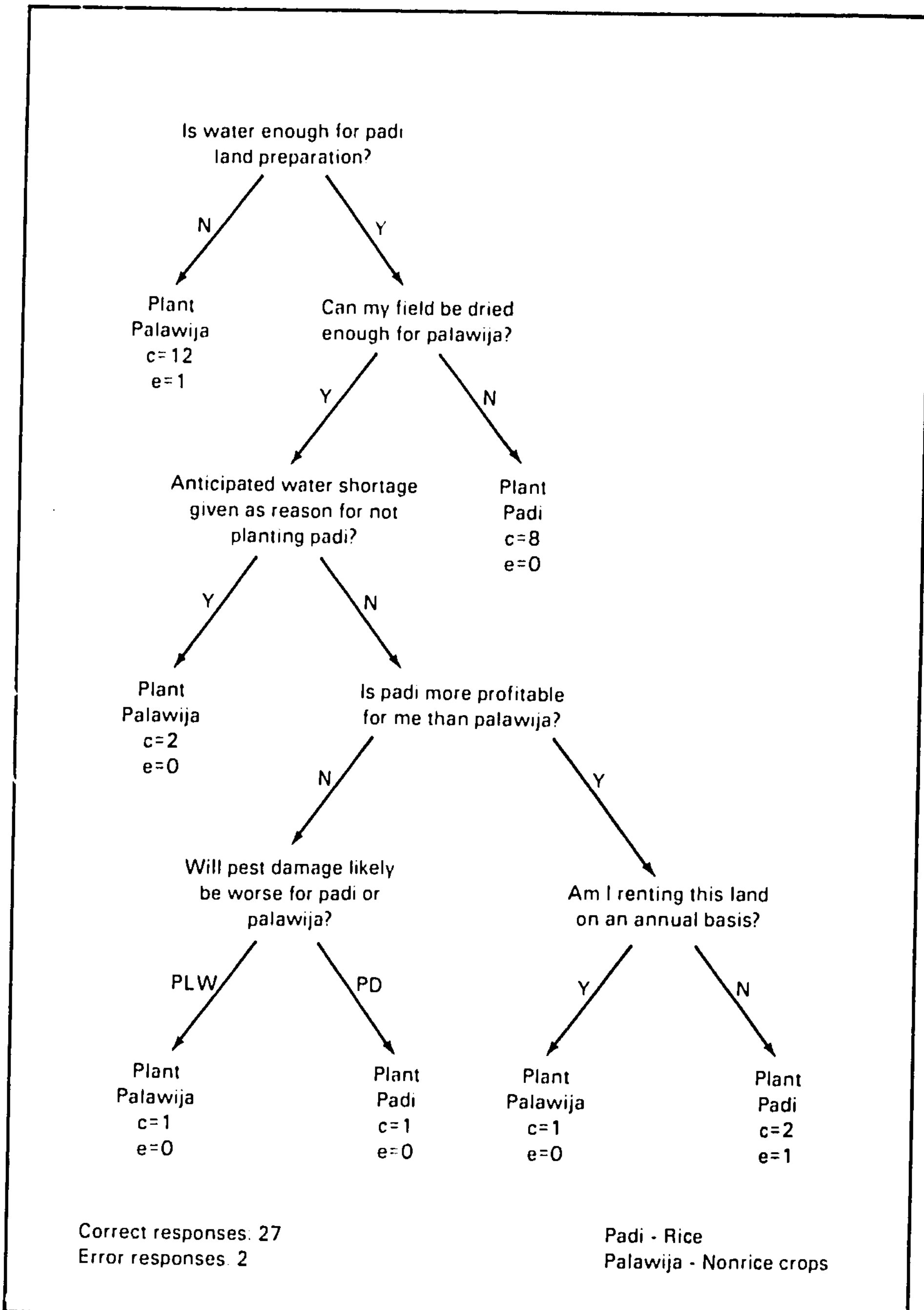
11. The sale price of the produce is assured (as in a contract growing scheme) or the market price of the crop does not fluctuate too much (i.e., it is not a "price-risk" crop).

12. The support structures are present, namely, technical assistance, good credit mechanisms, and viable marketing systems.

In the models derived in Indonesia, questions were posed according to the actual criteria identified by farmers, reflecting the same level of abstraction expressed by them. They are listed in order of frequency of relevance, determinacy, or logical relatedness – according to the local logic of farmers. In general, the models are not very complex, and the range of decision criteria not very broad.

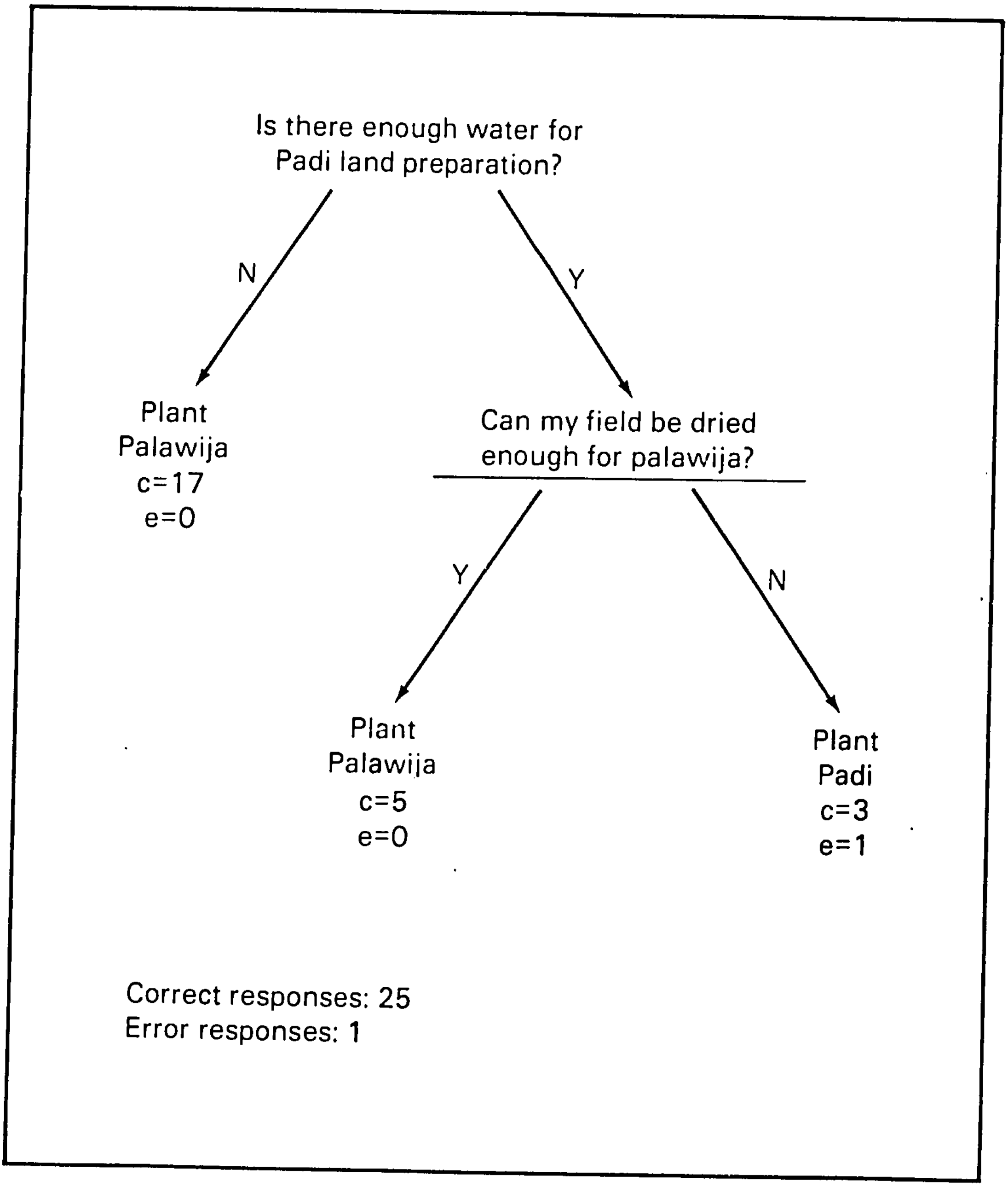
The timely availability and drainability of water figure prominently in the farmers' decisions whether to plant palawija or rice. Not surprisingly, in all three provinces of East, Central, and West Java there is a marked tendency to plant rice during the rainy season (November to April), and palawija during the second dry season (August to October), except for a few extenuating circumstances specified in the models. The first dry-season planting period is more problematic.

Figure 14. Farmer decision model to plant padi or palawija, Jarot 2 Block, Central Java, first planting period of 1986 dry season (Gadu 1).



Source: IIMI (1987b).

Figure 15. Farmer decision model to plant padi or palawija, Jarot 2 Block, Central Java, second planting period of 1986 dry season (Gadu II).



Source: IIMI (1987b).

During this season, it appears that farmers often identify the availability of water at the desired time for rice land preparation as a key factor in deciding to plant rice. If experience tells farmers that there is usually enough irrigation or rain water or both for rice cultivation during the first dry season, farmers use as a seasonal decision criterion the availability of water at the desired point in time to begin rice land preparation (with a range of two weeks generally being the maximum tolerable time for farmers to wait and see if irrigation water or rainfall will be enough). During the second dry season, inadequately drained soils are sometimes a constraint to planting palawija. Also during this season, the prevalence of off-farm work, the high risk of crop damage by rats, and the relative insecurity of water supplies, all contribute to prompt farmers to leave their fields fallow or permit landless villagers to cultivate the land free of charge.

In the case of the Sri Lanka sites, no decision-tree model was derived or tried in understanding the crop decision making of the farmers, except by simple observation and documentation of what farmers do within the two schemes. In principle, the cropping decisions are reached at the pre-cultivation meetings. *Bethma* farmers are able to make their decisions only after they know the location of their farm lot within the farm allotment, its soil and drainage characteristics, and its access to irrigation supply. Although the drainage class of the soil has a significant influence on selecting the land for either non-rice crops (other food crops) or rice during the dry season, it is not the sole criterion. In the tail end of the longer field channels where water supply tends to be limiting, farmers are able to raise other food crops in imperfectly drained soils, and to some extent, in poorly drained soils.

Market availability, profitability as well as experience in growing another food crop influences farmers' cropping decisions. In both sites farmers give preference to chili because of higher returns and certainty of the market. They often find it difficult to sell crops such as mungbean, soybean, and black gram. Availability of credit is an important consideration in growing chili because the cash cost required is about three times that of rice. As many farmers have defaulted on their previous loans, they are at the mercy of private money lenders who charge an interest rate of 15-20 percent per month.

CHAPTER 5

Preliminary Conclusions and Recommendations

POTENTIALS

IRRIGATED CROP DIVERSIFICATION has the potential for increasing rice farmers' incomes, achieving stable food supplies in the country, and earning and/or saving foreign exchange. It may be a starting point to a more general and encompassing agricultural diversification program. It can lead to the development of relatively more income-elastic agricultural production like livestock and poultry (because of the successful production of feedgrains such as corn and soybeans), and fruits which may have greater market demand and higher potential for increased farm incomes.

There are non-rice crops grown in each country showing higher and consistent profitability compared to rice (Table 16). There are well-drained and coarse-textured soils present which are well suited to diversified crops. A limited water supply cond'ion not adequate to meet the requirements of rice during the dry season is experienced in many schemes with favorable soil. Related to this is the distinct unimodal dry-season rainfall pattern which makes it possible to have the desired well-aerated soil conditions. These factors all contribute to a favorable environment for irrigated crop diversification.

Moreover, no major land movement or landshaping is needed to irrigate non-rice crops, although farmers have to introduce a rudimentary system of on-farm supply and drainage ditches to their plots to facilitate the timely application of water to their fields and removal of water (Figure 16). Rice basin bunds are retained when the appropriate seedbeds are prepared to fit the requirements of specific non-rice crops. Furthermore, irrigation systems properly designed for supplementary irrigation for wet-season rice which can meet land soaking and land-preparation requirements, do have enough canal capacity for the desired intermittent flow for irrigating non-rice crops. The placement of additional checks by farmers in the main delivery system to enable the regulation and delivery of a limited water supply up to the turnout level during the dry season, however, is observed.

Greater interest among all concerned from farmers to policy makers and the donor community is now being generated, and attention paid to the various issues in evolving a viable strategy for rural diversification of which irrigated crop diversification is a key ingredient. While the potential for irrigated crop diversification has been pointed out, there are a number of constraints which have to be mitigated.

Table 16. Average rice production costs and returns compared with other crops by the ratio of non-rice crop/ rice crop.

Indonesia: dry season 1, 1986 (in Rp[a]/ha)

Cost Item	Rice[b] (East Java)	Maize (East Java)	Peanut (East Java)	Shallot (Central Java)	Soybean (Central Java)	Cucumber (West Java)
Labor	237792	0.86	0.97	2.60	0.41	2.53
Seeds	16500	1.13	1.00	13.33	2.29	1.90
Fertilizer	51770	1.20	0.12	2.61	0.39	1.30
Chemicals	13000	0.50	1.33	0.70	4.43	2.02
Equipment	35000	0.36	-	-	0.21	1.43
Rent, taxes, etc.	50638	0.76	0.83	0.46	1.02	1.57
Total cash cost	404700	0.87	0.79	2.50	0.71	2.17
Gross returns	688578	0.78	0.89	3.60	1.29	2.90
Net returns	283878	0.64	1.04	0.52	2.12	3.90

[a] Rp 1514 = US$1.
[b] Wet season.

The Philippines: dry season, 1986 (in Pesos[a]/ha)

Cost Item	Rice	Tobacco	Cotton	Tomato	Mungbean	Onion	Garlic
Hired labor	2842	0.60	0.78	0.53	0.22	2.56	1.39
Seeds	435	0.00	0.00	1.15	1.79	9.84	29.17
Fertilizer	1243	1.82	1.51	1.95	.00	.00	1.25
Chemicals	290	5.60	8.57	9.15	2.00	3.72	1.78
Total cash cost[b]	7507	1.22	1.39	1.26	0.39	3.22	1.94
Gross returns	11035	1.86	1.89	0.62	0.25	3.70	2.19
Net returns	3528	3.48	2.59	-	-	4.77	2.69

[a] Pesos 20 = US$1.
[b] Including other cash costs.

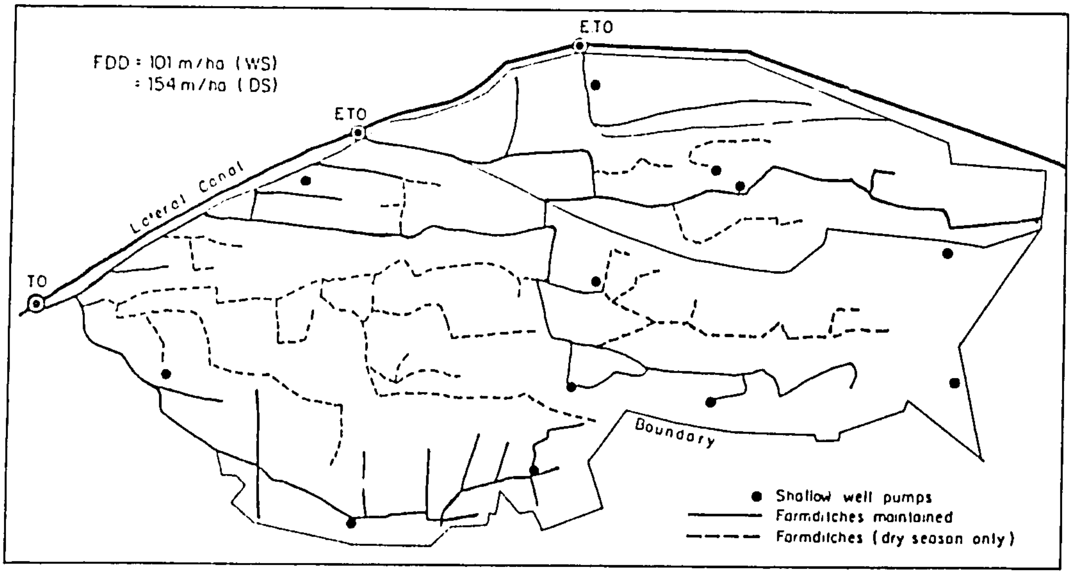
Sri Lanka: dry season, 1986 (in Rs[a]/ha)

	Dewahuwa				*Kalankuttiya*	
Cost Item	Rice	Chili	Mungbean	Soybean	Rice	Chili
Hired labor	1345	4.70	1.80	1.80	1432	3.40
Seeds	406	1.40	2.00	1.80	671	0.90
Fertilizer	788	2.60	0.10	0.20	804	2.50
Chemicals	181	14.30	5.80	2.10	420	5.20
Equipment	1323	1.10	1.00	1.30	1930	0.80
Irrigation water[b]	7	11.10	-	-	56	1.00
Total cash cost	4050	3.20	1.40	1.30	5313	2.10
Gross returns	7814	3.36	1.64	2.16	10436	2.43
Net returns	3764	3.60	1.94	3.00	5123	2.76

[a] Rs 30 = US$1.
[b] Fee not included.

Source: Various IIMI reports (1986).

Figure 16. Layout of rotation area in the Upper Talavera River Irrigation System (UTRIS) showing additional farm-level facilities used by farmers during the dry season.



Source: Tabbal et al. (1988).

CONSTRAINTS

The constraints to more effective irrigated crop diversification can be classified as irrigation-related, agronomic, and economic.

Irrigation-related (including institutional) constraints

Water control is more demanding in terms of supply or removal of water for non-rice crops due to their far stricter requirements for soil water. In contrast with the continuous supply for rice, water must be delivered intermittently for non-rice crops. Intermittent or rotational supply requires the presence of the farmer to receive and apply the water to his fields. This is further complicated during the dry season when the limited and uncertain water supply has to be delivered by rotational distribution which requires greater joint management effort and, in turn, needs effective communication between the irrigation staff and the farmers. Changes are very often not communicated properly to the farmers and sometimes not even to the field-agency personnel, with the result that confidence in the reliability of water delivery erodes. Irrigation control and measurement facilities to deliver the required intermittent water supply are frequently inadequate, nonfunctional, or absent.

The crop decision-making study in Indonesia indicates that the water environment is a crucial element in farmers' decisions to plant rice or palawija, being even more determinative than other factors such as the market, prices, and land tenure. This means that without strict control over allocation and distribution of water, crop diversification will not become widespread. Where there is liberal water supply in the dry season, even though non-rice crops return higher net profits than rice, farmers are inclined to grow rice.

Agronomic constraints

Farmers who have grown only irrigated rice before are usually unfamiliar with agronomic practices for non-rice crops. This is particularly true in places where crops such as corn, mungbean, and peanuts are grown only under rain-fed conditions. Farmers are also relatively unfamiliar with the crop husbandry of some important crops such as soybeans. Short-duration and high-yielding varieties of non-rice crops are needed to provide greater flexibility and more productivity to cropping patterns to fit scarce water supply situations.

Economic constraints

There are greater economic risks associated with many non-rice crops than with rice. Cash and labor inputs can be three or four times higher for non-rice crops than for rice crops. Cash inputs -- fertilizers, pesticides, and hired labor for weeding and harvesting -- are much higher for non-rice crops (Table 16). Institutional credit is scarce while noninstitutional credit carries interest rates as high as 20 percent per month.

Unstable prices and lack of organized marketing structures for non-rice crops increase the risks for farmers involved in their production. Otherwise, there are indications that farmers who had grown good crops of corn in the Magat River Integrated Irrigation System in the Philippines and soybean in Sri Lanka, are more than ready to shift to these crops, if assured of a reasonably competitive price and market for their produce.

To summarize, the following are general conclusions and recommendations that can be considered by policy makers involved with irrigated crop diversification.

* For diversified cropping those irrigation systems with a limited water supply condition not adequate to meet the requirements of rice for the whole command during the dry season, and which have substantial areas of well-drained, coarser-textured or diversified land class of soils should be selected first.

* The irrigation system should be at least in a physical condition that would enable a satisfactory level of water delivery and control at various levels of the system.

* There is an urgent need to improve the interaction between irrigation staff and farmers in irrigation system management, from planning and implementation to monitoring of irrigation

deliveries. Some form of joint management by encouraging increased organized farmers participation in the irrigation management process is needed to meet the more demanding requirements of non-rice crops in a situation of limited and uncertain water supply.

* A more vigorous extension program to disseminate the irrigation as well as agronomic practices for non-rice crops showing potential profitability is suggested to help farmers consider options on what non-rice crops to grow.

* An assured and stable market, competitive price, and ready availability of credit are a must in promoting and sustaining irrigated crop diversification.

CHAPTER 6

Indicative Research Agenda

TWO BASIC QUESTIONS were addressed by IIMI in analyzing the implications of crop diversification for irrigation management. First, what are the potential incentives for, and constraints to, increased production of non-rice crops in an irrigated, rice-based cropping system? Second, what are the appropriate irrigation management practices where diversified cropping already exists? Until lately, more attention has been given to the first question, which includes how current irrigation practices may constrain crop diversification. More recent work is being directed to address the second question which involves the comparison of the performance of different irrigation management practices for diversified cropping. This comparative analysis on the findings of the three country studies is a part of this emerging trend. This move is shared specifically by the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD 1988), which in the light of information, knowledge, and practices it reviewed on the subject, pointed out that efforts would have to be directed to looking into the following in enhancing irrigated crop diversification:

* The research agenda should focus more on irrigation systems in which management manipulations, practices, and technologies can be applied with the least cost and high efficiency to an alternate rice and non-rice cropping pattern, bearing in mind the following:
  1. New water application methods or modification of the existing ones must be tried at the farm level.
  2. Management of small, successful irrigation units or systems must be studied, particularly their advantages, for possible transfer of technology to other areas.
* Only critically needed data in the design, planning, and operation of irrigation systems for upland crops must be attended to.
* Doubtful information/data on the design and operation of an irrigation system should be verified.

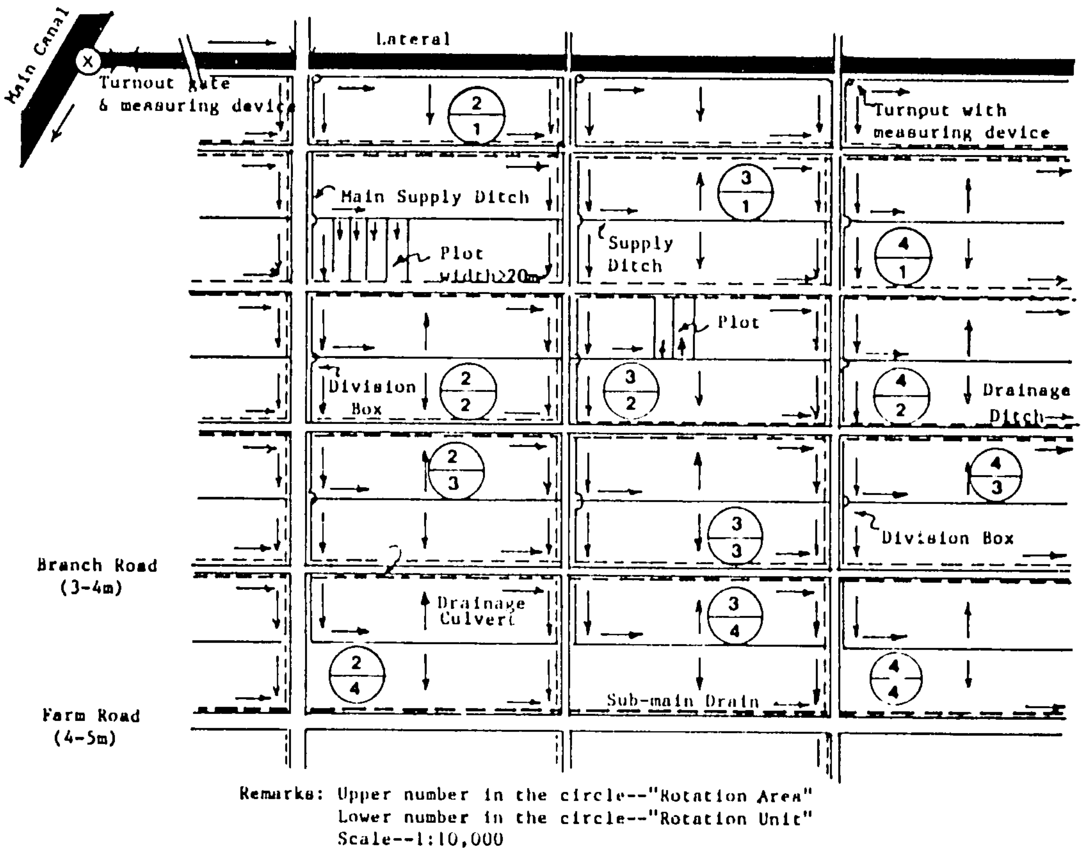
Unreliable water supply serves as a disincentive for the farmer by increasing labor costs because the additional time he spends in waiting for the water reduces his opportunities for off-farm employment. His anxiety is also increased because of the risk of losing his heavy investment on cash inputs and labor, resulting from reduced crop yield if he does not get his water supply on time. One answer appears to be better communication between irrigation staff and farmers. What seems to be needed is the introduction of an effective process of bringing about the desired improvement in communication through some form of joint agency-farmer management of the irrigation delivery. More organized farmer participation is implied.

Improved assessment of both water supply and demand needs to be done to better match the two under diversified cropping conditions. For non-rice crops the supply includes not only canal flow and rainfall but also subsurface supply from the soil profile and the groundwater table. The contribution from the fluctuating water table is harder to estimate. On the water demand, more information needs to be collected periodically in the field on the type and extent, and growth stage of non-rice cropping. The assessment of the water supply and demand needs could be facilitated with active participation of farmers, especially if they are organized.

Reduction of excess moisture and better drainage have been indicated to encourage more crop diversification. Stricter control over water deliveries is implied which may require additional management inputs. Complementary on-farm drainage facilities for fast removal of excess water and lowering of the water table may have to be installed and integrated with the main drainage system. Appropriate alternative designs of irrigation and drainage systems which enable the timely application and removal of water will need to be worked out. The farmers are already seen trying to provide these facilities by a rudimentary system of farm ditches and beds. In Japan and in Taiwan where land consolidation of cultivated areas (shown in Figure 17) is being practiced extensively, consisting of each field plot being served directly by an irrigation ditch, a drainage ditch, and a farm road, can be considered as the ultimate in a spectrum of on-farm development possibilities and also not a distant reality.

IIMI, whose primary mission is "to strengthen national efforts to improve and sustain the performance of irrigation systems, through the development and dissemination of management innovations," has tried to contribute its share in addressing the issues on the subject by working with both irrigation agencies and research organizations in the three countries. As mentioned earlier, it has also initiated an ongoing collaborative project with IRRI on problems of irrigation management for rice-based farming systems in the Philippines, Indonesia, and Bangladesh (Annex H). In this project IIMI is concentrating on the main system aspect, in which it has comparative advantage, by looking at the various factors that may influence the management decision-making procedures at all levels for irrigation systems with diversified cropping, and IRRI is looking at the on-farm concerns. In its newly completed strategy, IIMI has chosen to focus on seven thematic areas in fulfilling its mandate. Four of these themes, management of water resources for irrigation, management of irrigation facilities, management of irrigation organizations, and management of change in the institutions for irrigation, are involved in this venture. There are a number of technical, socioeconomic, and institutional issues that have been identified to be as important as, if not more vital than, irrigation management under many situations in enhancing cultivation of non-rice crops. Some of these are better addressed by national agricultural research systems or by international crops research institutes because they are endowed with the human, infrastructural, and other resources to do so. On the other hand, through the newly organized research network on irrigation management for crop diversification in rice-based systems, IIMI will be able to collaborate with irrigation management agencies and research organizations in finding relevant solutions to the outstanding problems of crop diversification through the development and dissemination of irrigation management innovations.

Figure 17. Typical layout of water distribution system in a land consolidated area.



Source: Li-Jen (1986).

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ANNEX A

Research Objectives by Country

Country	Research objectives
1. Indonesia	* To examine the constraints to more intensive non-rice (palawija) in irrigated areas. * To explore ways of alleviating the above constraints, taking into account associated costs and benefits at the system and farmer levels, social factors, and different soil and topographic conditions. * To assess existing and potential irrigation management practices at the field-, tertiary-, and main-system levels for their effect on the extent and performance of palawija crops. * To recommend policies and practices which will support more intensive palawija cropping in irrigated areas and assess the likely impact of such measures on irrigated cropping patterns.
2. The Philippines	*Phase I* * To identify technical and socioeconomic constraints to irrigated crop diversification with special attention to: - irrigation management constraints to crop diversification, - agronomic and economic comparisons of different irrigation management alternatives, - assessment of institutional aspects relating to crop diversification, and - general implications emerging from the above findings. *Phase II* * To determine irrigation management practices most likely to enhance cultivation of selected non-rice crops in limited parts of the irrigation systems during the dry season and to field-test the most promising of these practices. The associated objectives are to:

Country	Research objectives
	- develop a methodology or criteria for identifying parts of the irrigation systems most suitable for selected diversified crops, - compare the profitability and performance of selected diversified crops under irrigated conditions, - identify the primary factors and their interaction which condition how farmers prepare their land for irrigated rice in the wet season and for one or more diversified crops in the dry season, - develop on-farm irrigation methods for at least one upland crop, - design and field-test operating procedures for publicly managed portions of irrigation systems, and - recommend policies most likely to support profitable farming practices and investment in irrigation development for diversified crops and to suggest guidelines for irrigation management practices.
3. Sri Lanka	* To identify and develop strategies to facilitate more intensive diversified cropping in areas that have been primarily developed for producing flood irrigate rice. The specific objectives are to: - identify existing and potential irrigation practices for non-rice crops at the main system, tertiary system, and farm or field levels; - identify incentives for and constraints to further expansion of non-rice crops; - identify and pilot-test possible improvements in irrigation management to facilitate the growing of non-rice crops in areas where soil conditions, topography, crop profitability, and other factors generally favor non-rice crops; and - make recommendations concerning the adoption of improved irrigation practices in irrigated non-rice crop production based on an assessment of the impacts on irrigation and crop production performance of the pilot-tested irrigation practices.

Sources: IIMI (1987b), IIMI (1986a), IIMI (1987c), and Miranda and IIMI Irrigation Management for Crop Diversification Group (1988).

ANNEX B

Research Sites In The Philippines

Some of the Philippine irrigation systems where IIMI conducts research are the Laoag-Vintar River Irrigation System and Bonga Pump No. 2 in Ilocos Norte, the Upper Talavera River Irrigation System of the Upper Pampanga River Integrated Irrigation Systems in Nueva Ecija, and the Allah River Irrigation Project and Banga River Irrigation System in South Cotabato.

The following are brief descriptions of the provinces and the irrigation systems used as research sites located in them.

Ilocos Norte

The province of Ilocos Norte is located at the northwestern portion of Luzon, the largest island of the Philippines. It has a total land area of 339,934 hectares (ha). It consists of alluvial plains (21 percent), hills (31 percent) and mountains (41 percent), and coastal and miscellaneous land types (7 percent).

Typical of the Ilocos Region, the extent of flat, lowland area is limited to the farming population. Relatively fertile lowlands are limited to the narrow coastal plains and inland valleys, plains, and alluvial fans. An extensive alluvial fan is located at the southern part of the province, which is dissected by a wide meandering river.

The alluvial fans have generally coarse-textured soils (sometimes stony) while the lower-lying alluvial plains have fine, clayey soils. Aside from the relatively low inherent fertility other soil properties are generally favorable to plant growth.

The most common crop cultivated is rice. Corn, tobacco, garlic, onion, and cotton are the major secondary crops. The most common cropping patterns practiced are rice-rice, rice-tobacco, rice-garlic, rice-cotton, and rice-vegetables.

The most limiting factor for agricultural development in the province is its rainfall pattern. Although average annual precipitation is relatively high (more than 2,000 millimeters [mm]), it falls only within a 6-month period (May to October). Monthly rainfall in general shows that August has the highest rainfall while February has the lowest. It is too wet for most crops during the wet season and too dry during the dry season.

The mean annual daily temperature is 26.8°C. January is the coolest month while April, May, and June are the hottest.

Seasonal variation in relative humidity is light, the annual mean being 77 percent. The highest average relative humidity is 86 percent in August, and the lowest is in March.

Evapotranspiration in Ilocos Norte is generally high. This is due to the effects of high temperature, low relative humidity, long hours of sunshine, high wind speed, and relatively many windy days. Generally, 31 to 40 percent of all tropical cyclones entering the Philippine area of responsibility affect Ilocos Norte. The average annual cycle ranges from six to seven. There were 50 major storms that affected the province in an 8-year series (1968-1975).

The Laoag-Vintar River Irrigation System

This is a run-of-the-river type irrigation system located in Ilocos Norte. It is one of eight national irrigation systems comprising the Ilocos Norte Irrigation Service. Its total service area is 2,377 ha and it can serve the whole service area during the wet season. Lowland rice is planted in the whole service area during the wet season. In the dry season, only 900 to 1,100 ha are planted of which 400 to 700 ha are planted to diversified crops, mostly garlic. The latter area is located mostly in the lower reaches of the system.

The system irrigation network consists of 27.5 kilometers (km) of main canals. It has 7 main laterals and 5 sublaterals with a total length of 72.98 km. The Laoag-Vintar River Irrigation System which is headed by an irrigation superintendent has four divisions: 1, 2, 3, and 4. Each of the four divisions of the system is supervised directly by a watermaster. Each division is divided into sections supervised by a ditchtender.

Mean farm holding in the area is small ranging from less than half a hectare to a little over a hectare, averaging 0.86 ha. The majority of the farmers cultivate several parcels of land under leasehold tenancy. The main reasons given by farmers in selecting garlic as a dry-season crop are: it is a good source of income; it is profitable, commanding a high price; it is suitable for the area; and water is available for its cultivation.

Of the two irrigators' associations working in the command area, the Laoag-Bacarra-Sarrat Irrigator's Association (LABASA) found downstream, with rice-garlic-mung cropping pattern, is more cooperative than the Vintar Irrigators' Association located upstream, using a cropping pattern of rice-rice.

Nueva Ecija

Nueva Ecija is located at the central part of Luzon. The irrigated area consists of 112,136 ha, or 61 percent of the total cultivated area.

Climatic conditions in the province show a distinct wet and dry season and fairly uniform temperature. The months of January to April are generally dry, and the rainy season occurs from May to December. Rainfall is usually intense from May to October, the heaviest rainfall being in August. Annual rainfall over the province is about 2,000 mm.

Average monthly temperature ranges from a maximum of 32°C to a minimum of 21°C. Annual mean temperature is 27°C. Data indicate that the coolest months are from December to February while the warmest is May.

The range of relative humidity is 59 to 96 percent with an annual mean of 75 percent.

Monthly pan evapotranspiration is minimal in August at 93 mm and maximal in April at 252 mm. Estimated annual mean is 1,904 mm.

Over 70 percent of the area has slopes ranging from 0 to 3 percent. These areas are mostly suitable for irrigation due to their relatively flat terrain. The rest are almost equally divided among gently sloping areas, moderately sloping areas, and mountains.

Forty-two percent of the province was formed from alluvial deposits of sand, silt, gravel, and clay. These occur in the eastern side of the province. The western side consists of undifferentiated volcanic rocks.

About 46 percent of the province is classified as good cropland which is highly suited to rice production. The soils in this class can be adopted to almost any crop. Fifteen percent is classified as moderately good cropland. This is suited to diversified cropping. It has some slight limitations which may include gentle slope, moderate susceptibility to erosion and slight salinity.

The Upper Talavera River Irrigation System

This is also a run-of-the-river type irrigation system. It has intake structures on both banks. One intake serves the main system while the other serves the San Agustin Extension area. The main system is about 10,000 ha (5,000 ha served by the Talavera River Irrigation System Dam and 5,000 ha served by the Diversion Canal No. 1 coming from the Rizal Dam which is served by the Pantabangan Reservoir). The San Agustin Extension is about 500 ha.

The Upper Talavera River Irrigation System is supervised by a Zone Engineer for the irrigation water allocation and minor maintenance work. It is further divided into areas covering 700 to 1,000 ha under an assistant water management technologist. These technologists are assisted by ditchtenders who help in the cleaning of laterals and main canal. In areas where irrigators' associations are operational, maintenance work is contracted to the associations. During the wet season, the whole area is programmed for lowland rice and water flow is continuous in all canals unless shortages occur when rotation is resorted to. Rotation is done by sections of main canal. Rotation period is usually one week. Water delivery is also cut off when there is enough rainfall to prevent damages in the system or flooding of rice fields following the National Irrigation Administration schedule for accommodating effective rainfall.

During the dry season, normally only 500 ha are programed for irrigation to be planted to diversified crops for this system. No action is taken to prevent farmers from planting lowland rice because some areas are not adaptable to upland crops. There are even adaptable areas also planted to rice. Usually only 50-60 percent are planted with irrigated upland crops.

Most of the farmers now residing in the system's service area are from other parts of the country who had settled in the area before the second world war. A majority of them comprised Ilocanos (those from Ilocos Region) from the North who brought their knowledge of growing diversified crops such as onions and garlic.

Most of the Ilocanos planting onions and garlic settled in the Munoz area. The crop was adopted by other farmers. The area became accessible by train in the early 1960s for cheap transport of products to Manila. This contributed to better profitability of cash crops such as onions and garlic.

There were some cases where farmers harvesting early hit the jackpot and grossed in excess of ₱100,000 per ha in the late 1970s. This encouraged wider adoption of the crop.

At present, the major buyers of onion are the owners of cold storage facilities in the nearby towns of Bongabon and Palayan City, both of which are located in the western section of Nueva Ecija. Traders from other places also come before or during harvest time to buy the crop. Some enterprising local traders provide seeds and loans to farmers with a contract to buy the product at an agreed price.

The main reason given by the farmers for planting onion is its profitability. Other reasons are because onion is the only crop which they know how to grow that can give them a reasonable profit and insufficient water to grow a second crop of rice. Mean farm sizes in the area range from a little over 1.0 ha to 8.6 ha. Most farmers cultivate one to two parcels of land. The prevailing tenure status is leasehold with a few owner operators and Certificate of Land Transfer awardees.

South Cotabato

South Cotabato is located in the southern part of the Philippines. The irrigated area consists of 24,694 ha, or 9.9 percent of the total cultivated area.

The rainfall pattern of the province is classified as Type IV which is characterized by more or less even distribution of rainfall throughout the year. Rainfall record shows that the province has an annual rainfall of about 1,800 mm.

Average monthly temperature ranges from 26.6°C to 28.2°C. Temperature throughout the year is fairly uniform, with the summer months of March, April, and May registering relatively higher temperatures.

The range of the relative humidity is 76 to 83 percent with an annual mean of 80 percent.

Monthly pan evaporation ranges from a minimum of 105 mm in February to a maximum of 127 mm in May. Mean annual evapotranspiration is placed at 1,409 mm.

The area is relatively free from tropical cyclones which affect the central and northern part of the country.

Rice and corn are the major agricultural products of the province. Rice generally yields more than 4.4 tons/ha, and hybrid corn more than 4.0 tons/ha.

Dominant cropping patterns are rice-rice for irrigated areas, and rice-corn or corn-corn for rain-fed areas.

Banga River Irrigation System

This is also a run-of-the-river type irrigation system. It has a reported irrigable area of 2,500 ha out of a designed command area of 3,360 ha, partially irrigating the villages *(barangays)* within the municipalities of Banga, Norala, and Santo Nino in the province of South Cotabato.

The dominant problem is the high amount of silt carried by the river flow. To minimize the entry of silt, the spillway gates are opened twice daily for two hours to clear the entrance to the main canal. This system also has a silting basin into which the water is diverted before entering the main canal. Despite these measures, the main canal still needs annual desilting in April.

It is noted that heavy siltation of the irrigation canals causes shortage of irrigation water. Only about 20 percent of the river discharge can be diverted at the main-canal intakes. Also the volume diverted fluctuates from 0.80 to 1.80 cubic meters per second (m3/sec). As a consequence, the service area has been reduced to 2,110 ha in which only 1,600 ha can be irrigated during the wet, season, and 1,300 ha during the dry season.

The whole system is headed by an assistant irrigation superintendent, and is divided into three watermasters' divisions. The system has nine irrigators' associations which have been federated into one in 1985. The federation assists the National Irrigation Administration in the operation and maintenance of the system.

For water distribu.ion purposes the system is divided into six hydrologically separate sectors. These sectors are grouped into corresponding water management technician divisions (A, B, and C). The sectors with their different areas and other descriptions are presented in the following table.

Sectors with their different areas and other descriptions.

Sector group	Irrigable area	Water Management Technician Division covered	Number of irrigators' associations	Laterals covered
I	250	1(A)	4	A, B, C
II	400	2(B)	1	D
III	360	1(A)	1	E
IV	300	1 & 2 (C)	1	Main canal (E-F)
V	350	3(C)	1	F
VI	270	3(C)	1	G
Total	1930	3(C)	9	7

Federation board members hold monthly meetings with the National Irrigation Administration personnel to discuss problems and plan short-term strategies. Each irrigators' association also has a monthly meeting with farmers to serve as a forum for gathering feedback from them. Some of the irrigators' associations have a contract with the National Irrigation Administration for maintenance of the laterals serving their area. Other laterals not contracted for maintenance by the farmers including the main canal are maintained by canal tenders paid by the National Irrigation Administration as regular personnel.

Mani Communal Irrigation System

This communal irrigation system with a diversion dam located in Esperanza, Koronadal, South Cotabato serves two villages, Mabini and Barrio 5, also of Koronadal. Its total service area is 700 ha but only 200-400 ha are served each season, depending on water availability. It is managed by a communal irrigators' association through its President and the nine members of the Board of Directors. The system is divided into five sectors, each having a sector leader and other officials responsible for distributing water within their sector. There is a hired canal tender to oversee the distribution of water to the different sectors, and a hired gatekeeper at the main diversion point who is responsible for closing and opening the gates of the dam.

The Allah River Irrigation Project I

The Allah River Irrigation Project I covers a design area of 18,800 ha which is served by two dams on the Allah River. Dam No. 1, located at Surallah, South Cotabato, serves the towns of Surallah, Norala, Santo Nino, and Banga, and has a service area of 7,300 ha. Dam No. 2 is located in Santo Nino, and will serve part of Santo Nino and Norala in South Cotabato, and the municipality of Isulan in the province of Sultan Kudarat.

Dam No. 1 is the study area. It has eight main laterals and five sublaterals. The service area of laterals A-extra, B-extra and C-extra, located along the banks of the Allah River, and which has very light soils, was designed to adopt crop diversification during the dry season. The combined area of these laterals is about 1,000 ha.

The Allah River Irrigation Project operation is headed by an irrigation superintendent. He is assisted by an assistant irrigation superintendent at each dam. In Dam No. 1 of the Project, there are eight watermasters with each watermaster covering an area of 700 to 1,000 ha. The farmers are being organized into farmer groups. No ditchtenders are employed in the system. Canal maintenance is contracted to informal farmer groups.

The rainfall distribution pattern at Allah Valley is relatively even. There is significant rainfall even during the dry season. The range of pan evaporation is 3-6 mm/day while seepage and percolation is about 10 mm/day. Significant features of the site are the relatively porous (sandy) soils and their low organic matter content. The presence of semipermeable layer of 'sandstone-like' material that ranges from 0.5 to 1.5 meter depth, however, reduces the percolation.

In the project site, there are six soil types; three are diversified crop lands and the rest, ricelands. In both classes there are three subclasses: highly suitable, moderately suitable, and marginally suitable. Marginally suitable diversified crop lands are found near the banks of the Allah River. These are very light-textured soils (sandy loam), with slopes of 0 to 2 percent. With adequate irrigation, these can become highly suitable lands for diversified crop during the dry season and moderately suitable rice lands during the wet season. The moderately suitable diversified crop lands are sandy clay-loam textured with slopes of 0 to 1 percent. Highly suitable diversified crop lands are clay-loam textured with slopes of 0 to 1 percent, and will have the same classification under irrigated conditions.

The marginally suitable rice lands are clay to clay-loam textured, and are either low lying flat lands located near drainage waterways or with very steep slopes needing leveling before they can be planted to lowland rice. The moderately suitable rice lands are clay-loam to sandy clay-loam textured relatively flat lands, and have poor to good drainage with high water tables during the wet season. The highly suitable rice lands are clay to clay-loam textured with good drainage.

ANNEX C

Research Sites In Indonesia

The research sites are located in three provinces of East Java, Central Java, and West Java. A brief description of each site is given below.

Waru Turi, East Java

The project area is located in the alluvial plain formed by the Brantas River, one of the largest in Java, and its tributaries. The three main soil series in Waru - Nganjuk, Sentul, and Kertosono - have infiltration rates ranging from 0-2 to 5-12 millimeters (mm) per day. The soils along the Brantas River tend to be lighter than those further west. The Project area consists of three subproject areas: Waru Jayeng (Waru) and Turi-Tunggorono (Turi), which are mostly served by existing schemes drawing water from the Brantas River with flow released from the Karang Kates Reservoir; and Papar Peterongan, which is now partly irrigated by several schemes supplied by local streams and the Selorejo Dam. The Papar Peterongan is to be integrated into the project.

Waru is a run-of-the-river system whose main intake is at Mrican near Kediri. In Waru the irrigated area *(sawah)* is 13,366 hectares (ha) - Waru System 12,827 ha and Besuk System 539 ha; both located in Nganjuk Section. There are three subsections: Waru Jayeng, Kertosono, and Lengkong, and a total of 94 villages. The main irrigation canal from the Mrican headworks has a length of 21 kilometers (km). It feeds a network of 29 secondary canals. The lengths of these canals range from 0.8 to 15.5 km. The total length of the canals is 155 km. Each secondary canal is equipped with a measuring device. The total number of irrigation districts (Daerah Irigasi) in the Waru area is two. The Table below shows the details of these irrigation districts and their respective areas. The Waru systems were developed during the Dutch colonial era, with water supply from run-of-the-river flows in theBrantas River. Over the past years, since World War II, due to the steady increase of sediment entering the canal from the Brantas River and the gradual deterioration of irrigation facilities, both Waru and Besuk systems have required extensive rehabilitation and upgrading.

The Waru area also suffers from periodic inundations over an area up to 2,000 ha in an average year. This is a result of floods mostly originating from the Widas River and its tributaries. On the other hand, there have been threats of flooding to both areas by the Brantas River in the past. Furthermore, the internal drainage condition in the Waru area is poor, due to heavy silt deposits, lack of regular maintenance of drains, and some inadequacy in the drainage systems.

The climate of the Project area is tropical, with distinct wet and dry seasons in normal years.

Breakdown of irrigation districts in the project area, in hectares.	
Waru Sub-Project *Daerah Kediri* *Seksi Nganjuk:*	
1. Cabang Seksi Waru Jayeng	: Daerah Irigasi Waru-Kertosono System - 5628 ha
2. Cabang Seksi Lengkong	: Daerah Irigasi Waru-Kertosono System - 3558 ha
3. Cabang Seksi Kertosono	: Daerah Irigasi Waru-Kertosono System - 3641 ha
	Daerah Irigasi Besuk - 539 ha
Total in Waru Sub-Project	13366 ha

Mean annual rainfalls vary from about 1,800 mm over the Waru area to about 1,700 mm over the Turi area. At the 80 percent exceedence level, these figures reduce to 1,400 mm over the Waru area and 1,300 mm over the Turi area. Rainfall usually occurs in the late afternoon or evening. Storms are convective and of short duration, seldom lasting for more than a few hours. Intensities are high and, when strong and heavy storms occur, more than 50 percent of the storm total may be expected to fall in one hour. This situation often causes local submergence due to slow drainage capacity in the area.

A review of monthly rainfall records of more than 20 years shows that, on the average, there is a significant decrease in rainfall from March or April, followed by a dry season with little or no rainfall, and then a substantial increase in December. Mean monthly rainfall in the two areas, equalled or exceeded in 80 percent of the years, ranged from about 100-250 mm in the wet season to less than 100 mm, and in some months (June-October) even to almost zero, in the dry season.

Monthly temperatures vary little throughout the year, from about 26°C to 28°C, while daily temperatures vary between 22°C and 33°C, approximately. Solar energy is higher in the dry season than in the wet season as there are about five to seven hours of sunshine in the dry season as compared to four to five and a half hours in the wet season. Relative humidity is rather high in the two areas, with 80-90 percent in wet seasons and 70-80 percent in dry seasons. Potential evapotranspiration is about 1,660 mm per annum, and shows little change between the months.

In the Project area average farm holding per farm family is about 0.45 ha in Waru. Seasonal crops are grown on the farm land, or replacement with one long-term crop-sugarcane is also practiced. The seasonal crops include rice in the wet season (November-March), and rice and palawija in the early or first dry season (April-July) as well as in the late or second dry season (August-October). There are two categories of dry rice *(padi gadu)*: authorized, which has the right to get irrigation supply as required, and unauthorized, which is provided irrigation supply on a par with palawija water requirements. Palawija planted in the research area consists of soybean, maize, and groundnuts, with the first two crops being the major ones as they occupy more than 90 percent of the palawija area. Sugarcane occupies about 15 to 20 percent of the total area. There exists some fallow land in the wet season owing to the poor drainage and floods, and in the dry season due to water shortage. During the first dry season (April-July), about two-thirds of the harvested area is on rice, and about one-fourth on palawija crops (mostly soybeans). In the second dry season (August to November), nearly all the non-sugarcane area is on palawija crops (mostly maize). No tobacco is grown in the Waru area. Some areas have recently experienced a switch from rice-rice-rice to rice-rice-palawija.

Pemali-Comal, Central Java

In general, rainfall and available water are higher as one moves farther toward the eastern part of the Pemali-Comal area. Irrigation in Pemali-Comal can be traced back approximately 85 years, to an initial 7,500 ha under Sungapan Weir. Before 1940, the canals and structures were well-maintained, irrigation rules enforced, and water deliveries regulated according to plan. The facilities, however, were allowed to deteriorate like most irrigation systems in Indonesia during and immediately after World War II. Consequently, during Repelitas (National Plans) I and II, Pemali-Comal was selected to be rehabilitated, and additional drainage was provided for coastal fields. Beginning in 1970/1971, the Project was rehabilitated with the aid of a World Bank loan.

Irrigation in the Pemali-Comal Project is primarily run-of-the-river diversion (over 40 major diversion points), although there are three reservoirs in the Project. The irrigation systems tend to be somewhat above average in size, and many are interconnected with each other. In addition to the diversion points, there are three reservoirs *(waduk)* - Cacaban, Melahayu, and Penjalin - with holding capacities ranging from 60-86 million cubic meters.

The irrigation canal network consists of 169,300 km of intake channels *(saluran induk)* and 817,110 km of secondary canals. The tertiary water distribution system was rehabilitated beginning in 1974/1975. About three-fourths of the tertiary networks in the 124,060 ha of technical irrigation systems in Pemali-Comal have since been rehabilitated. Beginning in 1975, efforts have been exerted to develop *Perkumpulan Petani Pemakai Air* (P3A) or *Dharma Tirta* in the project area.

The general water supply in the central and western sections of the Pemali-Comal Project is definitely less than farther east in the project area. This encourages the production of palawija crops in the central and western parts, but only mono-crop rice in most of the east. The overall cropping intensity throughout the Pemali-Comal area is 180-200 percent. In the Comal and Gung irrigation sections, the cropping intensity is roughly 240 percent.

Within Wilayah Pekalongan, two research sites in Irrigation Section Gung have been selected. In this section there is a design irrigation area covering about 41,853 ha. This area includes 9 technical irrigation systems, 2 semitechnical systems, and 11 simple systems. These systems are served by a reservoir, 20 diversion weirs, 38 km of main canals, 270 km of secondary canals, and 2,231 km of tertiary canals. In the section there are 391 employees, with more than 80 percent of them being permanent employees of the Government of Indonesia.

Cirebon, West Java

The research area is administratively situated in the district area of Cirebon in the north-eastern corner of the Province of West Java. Cirebon *Wilayah* consists of two of Indonesia's largest irrigation sections: Cirebon- Kuningan with 71,000 ha and Sumedang-Majalengka with 67,000 ha. Irrigation was first developed in this area during the second half of the 19th century.

The elevation of much of the area is less than 20 meters above sea level. It becomes flat as it approaches the sea. *River alluvium* soils dominate the area. The climate is characterized by the prevalence of monsoons. The west monsoon, which is the rainy season, lasts from December to

March, and the east monsoon or dry season lasts from June to about October. In the coastal area the annual rainfall varies from 1,200 mm to 2,700 mm. In the hilly area rainfall is generally more than 2,000 mm.

Both research sites are located in the Irrigation Section of Cirebon-Kuningan. The total irrigated area in the district is about 71,000 ha. This area includes 115 irrigation systems *(daerah irigasi)* that range in size from 30 ha to 8,000 ha. In the section there are 3 reservoirs, 102 weirs, 407 km of main and secondary canals, and over 1,200 km of tertiary canals. Fifteen irrigation watermasters *(pengamat)* work in the section, with areas of responsibility ranging from 825 to 5,780 ha each. The 96 irrigation inspectors *(juru pengairan)* in Cirebon Kuningan serve an average area of 705 ha each, with the range of areas being 240 to 2,300 ha each. Over 690 employees work in the section, with approximately 45 percent permanent, and the rest divided between permanent and temporary daily employees.

Food crops, although still dominated by rice, are highly diversified. In addition to wet- and dry-season irrigated rice, variations of the cropping system exist which are influenced by the variability of water status in the field. The *Gogorancah* system, which is practiced quite extensively in the District of Indramayu, is also followed in some subdistricts in the eastern part of Cirebon. Another variation, the wide-bed system *(Sorjan)*, is quite extensively practiced in the coastal area. It is used either to solve the problems of floods or drought. When it is used to reduce the risks of floods as in the subdistrict of Kapetakan in the eastern part of Cirebon, rice is planted at the top of the bed. The lower part is used for a fish pond. In contrast, when it is used to reduce the risk of drought, rice is planted in the lower part and secondary crops at the top of the bed. This is practiced in the subdistrict of Gegesik and Susukan in the western part of the district. There are about 2,000 ha of Sorjan system cultivated in almost all subdistricts in the coastal area of Cirebon.

Sugarcane has long been cultivated in this area largely to serve the demand of the sugarcane factories. This crop is planted in rotation with rice and palawija crops. During the colonial period, and until quite recently, the area planted for sugarcane was decided by the government. About one third of the area of the proposed village was always in sugarcane and the farmers were forced to rent this land to the factory. There are also private individuals that plant cane to serve local needs. Most of the secondary crops are grown during the late wet season and during the dry season.

ANNEX D

Research Sites In Sri Lanka

The two research sites in the North Central Province, Kalankuttiya and Dewahuwa, are situated in the dry-zone low country of Sri Lanka where most of the major irrigation schemes are located. Nearly 60 percent of the total irrigated area of the country falls within the category of major irrigation systems and the two research sites represent the two administrative departments in the Mahaweli and Lands Development Ministry. The Dewahuwa site is under the authority of the Irrigation Department, which was the sole authority over the major irrigation schemes until 1970, and presently under the Irrigation Management Division as well. The Mahaweli Development Authority, established with the Mahaweli Project in 1970, has taken control over all the areas scheduled to benefit from this river diversion scheme. The Kalankuttiya site, representing the Mahaweli System, consists of a large local irrigation reservoir linked to a substantial outside river diversion. In contrast, the Dewahuwa site has an independent local storage reservoir within its own catchment supplemented occasionally by diversions.

Both field research sites are characterized by a bimodal pattern of monthly rainfall distribution with two distinct dry periods, one short and the other prolonged. The annual average rainfall is 1,500 millimeters (mm). Nearly 70 percent of the annual total rainfall occurs in the period October to mid-January, the *maha* (wet) season. The remaining rainfall occurs in the period mid-March to mid-May, the *yala* (dry) season. February, June, July, August, and September are relatively rainless. The 75 percent probability of rainfall expectancy in the maha season is 430 mm, and 200 mm in the yala season.

The pan evaporation measured from a Class-A pan varies from 3.5 to 7.5 mm/day. From the first week of October to the end of January, the pan evaporation is less than 5 mm/day. The pan evaporation from June to the end of September is over 6 mm/day.

The annual average temperature is 26°C. The minimum temperature varies between 20°C and 25°C over the year while the maximum temperature varies between 27°C and 34°C. The daily temperature fluctuation over 10°C occurs during the period mid-February to end of April.

Solar radiation is quite low during the maha season. This is mostly due to the cloud cover during this period. The lowest value of the solar radiation is 300 calories per day which occurs during the month of December.

The soils in the irrigation command areas occur in a catenary sequence in the undulating landscape. The well-drained and imperfectly drained reddish-brown earths (RBEs) are found in the convex uplands and mid-slopes respectively. Poorly drained low-humic gley (LHG) soils occur in the concave valleys and bottom-lands.

In the past the LHGs were used for continuous cultivation of rice under both rain-fed and irrigated conditions. With the development of new irrigation schemes, all the soils in the catena were brought under cultivation. Rice was the only crop grown in these lands in the beginning. Loss of excessive quantities of water was observed owing to the high seepage and percolation rates in the RBEs when standing water was maintained for rice. Other field crops were therefore introduced to overcome the situation. Consideration of ground water table behavior and drainage became increasingly important as other field crops proved to be intolerant of excess moisture conditions.

The Kalankuttiya Block of the Mahaweli H system was initially designed to accommodate other food crops in the well-drained RBEs during the dry season. The Dewahuwa site, which is an old and medium-sized irrigation scheme, is a traditional rice irrigation system into which diversified crops are being introduced.

Dewahuwa

Dating to the third century A.D., this ancient tank had been abandoned for centuries when it was reconstructed in the 1950s. Farmers from the reservoir area, from surrounding villages, and from more distant regions were allotted 2.0-hectare (ha) parcels of irrigated land plus 1.2 ha "highland" plots near the command area. By 1970, the new system had fallen into a state of disrepair and was rehabilitated under a Japanese aid project. Today the designed command area has been expanded by nearly 20 percent by unauthorized encroachments; the lands originally allotted to families have been subdivided several times. While most household economies remain primarily agricultural, many of the second and third generations rely on rain-fed agriculture outside the scheme, supplemented by off-farm employment. Land tenure is fluid, with about half the operators farming land which they do not own. Some nonowners are family members who may someday inherit the land they now lease. Others who are classified as owners have taken mortgages and are actually tenants on their own land. Hidden tenancies are common as land transfers through either lease or sale are prohibited by law in Sri Lanka's settlement schemes.

The system is composed of the Dewahuwa Reservoir, a main conveyance canal with a single embankment, distributaries to nine tracts (1-9), and field channels serving individual farm allotments of two hectares each. The total command area which was initially 943.7 ha (2,336 acres) has now increased to 1,215 ha (3,000 acres).

The Dewahuwa Reservoir spreads over a 392 ha (980 acres) area at full capacity level. It is augmented by flows from Nawakka Ela, Kuda Oya, and Kalugal Oya which are ephemeral streams, and from the Nalanda Reservoir. The catchment area of the reservoir is 67 square kilometers (sq km) (26.0 square miles [sq miles]). The main features of the Reservoir are:

Full storage capacity – 1,197 hectare meters (9,700 acre-feet)
Area at full supply level – 396.7 ha (980 acres)
Bund length – 583 meters (1,914 feet [ft])
Length of the spill – 184 meters (604.75 ft)
Bund top width – 5.5 meters (18.0 ft)
Free board – 1.4 meters (4.6 ft)
Head at full supply level – 8.7 meters (28.5 ft)

The spillway is a clear overfall of natural rock with a concrete crest wall built to pass cyclonic flood of 301 cubic meters per second (m3/sec) (10,630 cubic feet per second [cusecs]).

The 16.09 km single embankment earthen main canal has a capacity varying from 3.2 m3/sec (113 cusecs) at the head to 0.2 m3/sec (7.0 cusecs) at the extreme end. It has a gradient of 0.00035.

The main canal has flow regulating and measuring provisions, such as cross-regulators of the underflow and overflow type, and also combinations of these two types. Moreover, there are slope protection structures like retaining walls and channel shape guides for maintenance. There are 12 cross-regulators at about 1.6 km intervals. Five of them are with vertical sliding steel gates and the rest are checks with simple wooden flush boards.

Along the main canal, measuring devices like parshall flumes and rectangular contracted weirs can be found. One parshall flume is located at the head of the main canal and the other about eight kilometers downstream.

There are 11 distributaries in addition to several direct turnouts which take off from the main canal, commanding areas ranging from 14 to 180 ha. Most of these distributaries have functioning sliding gates but with no facility for monitoring flows.

The direct turnouts (direct offtakes) serve areas varying from 2 to 18 ha along the main canal. They have sliding steel control gates and contracted weirs with baffles as measuring facilities.

There are division boxes, chutes, and drop structures along the distributaries. The turnout gates to field channels are made of wooden planks with padlocking arrangements but with no provision for flow measurement. Most of them are not in good condition. Even some of the gates that are in good condition can be tampered by farmers whenever they want to take water illegally.

Kalankuttiya

This is a part of the country's largest irrigated settlement scheme, a greater part of which is still under construction. System H was completed in 1975. It is the oldest of five separate systems within the scheme, all fed by waters from the Mahaweli River as well as from smaller streams. Prior to its construction, much of the 27,000 ha which comprise the irrigated area of System H was jungle, with scattered villages based on irrigated agriculture from small village tanks and swidden plots. The new canal system and associated land development obliterated many of these tanks and incorporated others into on-line reservoirs fed by the main-canal system. Settler families from the area, as well as from outside the region, were allotted one-hectare parcels of irrigated land and 0.2 ha for house plots and gardens. Following the precedent of other settlement schemes, the government constructed all irrigation facilities, and cleared and leveled the fields.

The Kalankuttiya Block is located within the H-2 subsystem of system H area. It falls under the Kalawewa Resident Project Manager's Region. The Kalankuttiya Administrative Block consists of the irrigation blocks 305, 306, 307, 308, and 309, covering approximately 2,021 ha. The whole block is bound by two drainage channels: Kala Oya, the major drainage line in system H and, Kalankuttiya Ela, running in the east-west direction forming the northern and southern boundaries. The water-distribution system consists of a storage tank known as Ihala Kalankuttiya Tank with a maximum capacity of about 190 hectare meters (1,540 acre-feet), of which about 184 hectare meters (1,490 acre-feet) are effective for irrigation. A main canal known as Branch Canal No. 1, which is 11.5 km long, takes off from the tank.

The tank has its own catchment area of 68.86 sq km (26.6 sq miles) but generally, it is replenished from the Kalawewa Right Bank Canal through the Mulanutuwa Tank. To meet the present demand it normally receives about 12-24.5 hectare meters (100-200 acre-feet) per day throughout the season. Water issue from the tank is regulated at the main sluice which consists of three vertical adjustable gates. Two spillways in the tank avoid the possible unexpected overload with the crest level located 10 ft above the sill level.

The Branch canal, which has a maximum design capacity of 5.65 m3/sec (200 cusecs) at the head-end area, traverses the higher aspects of the land-scape and hence, there is no incoming drainage water to the main system. The distributaries are stretched to either side. Two types of cross-regulators can be identified in the main system. One adjustable cross-regulator, which consists of two wooden undershot gates located just below the first two head-end distributaries and nine fixed overflow type cross-regulators known as duck-bill weirs, are located in varying places between the first five and last three distributary offtakes, helping to maintain the desired hydraulic head at different sections of the channel. Flow monitoring in the branch canal is done at the head reaches just after the first two distributaries, using a calibrated staff gauge with an automatic water level recorder.

A total of 20 distributary channels with varying design capacities depending on the extent of the command area (which varies from 35 to 310 ha) but adequate to carry the peak requirements of all turnouts to field channels in a distributary, is located along the secondary spurs that traverse the landscape. All the distributary offtakes consist of adjustable steel sliding control gates. Except in one distributary, all the others are provided with a monitoring device. In most cases, the device consists of a hump structure and a gauge, except a Cipoletti weir in one distributary. Another distributary is equipped with an automatic water level recorder. A locking mechanism is also provided in some distributary gates to avoid unauthorized adjustments. As there is no drainage system coupled with the branch canal, the last distributary channel functions as a drainage channel during heavy rainy days. To facilitate this, one gate of this listributary has been removed.

Offtakes (turnouts) from the distributary to fields channels generally serve 4-20 farm allotments of 1 ha each, located along the tertiary spurs of the landscape. The command area of such a field channel is about 16 ha. In general, these field channels are designed to carry a flow of 28.3 liters per second (1 cusec).

There are no direct farm offtakes (outlets) to farms from the branch canal. Generally, all the outlets originate from the field channels, except for a few direct ones identified in some distributaries. The outlets consist of a 15 cm (6 inches) diameter pipe designed for a flow of half a cusec (14.15 liters per second). The irrigation system has been designed to accommodate rotational water issues.

ANNEX E

Irrigation System Management In Indonesia

Organizational Setup

Within the Provincial Public Works Department, the Provincial Irrigation Service is responsible for operating and maintaining public irrigation systems. The most junior permanent member of the Pro' ' .cial Irrigation Service staff, the irrigation inspector *(juru pengairan)* is not only responsible for irrigation facilities serving approximately 1,000 hectares, but also oversees the setting of 15-25 main and secondary gates. He also records hydrologic and crop data, arranges for regular and emergency maintenance, works with water user associations and village watermasters *(ulu-ulu)* to maintain tertiary and quaternary distribution canals and arranges for staggered planting dates and water rotations. He is assisted by a few gatekeepers and laborers. The inspector is directly answerable to the subsection chief *(Pengamat or Kepala ranting)*.

The subsection chief has a direct role in managing funds and personnel for maintenance activities. His role with respect to operations, however, is more supportive. Usually, the working out of the crop water-requirement estimates, discharge schedules, and calculation of *Faktor-K* and *Palawija Relatip Faktor* (FPR) are delegated to the inspectors. Frequent meetings with inspectors and water user associations facilitate discussions of crop schedules, planting dates and rotations, etc.

The operation process could be categorized into five sections: 1) estimation of the availability of irrigation water at the respective diversion points; 2) estimation of irrigable area, type of crops and the growth stage of the crops; 3) calculation of the required discharge; 4) setting of gates to deliver the discharge; and 5) monitoring of the discharge flow and feedback for necessary adjustments.

The decisions regarding irrigated area are taken at the regency and district levels by Irrigation Committees: once the available water for irrigation is estimated, the crop area and the cropping patterns are determined to optimize the irrigation water use. Estimation of available water is done with the help of the historic records of the flow-discharge curve. Operational decisions on water allocations and distributions to planted areas during a fixed time period are taken at the subsection and with the help of day-to-day records of flow discharge.

In Indonesia, especially in Java, planning and operational decisions revolve around the basic concept of *pasten*, where the relationship is between the water supply that is available at the intake gate and turnouts and the crop needs. The modern derivative of pasten is *Faktor-K*.

Twice each month, the village watermaster assesses and reports to the irrigation inspector the expected area and growth stage of each crop over the next two weeks. This enables the inspector to calculate the field requirement in liters per second per hectare using accepted formulas provided for each crop and growth stage. A constant of 1.20 to 1.30 is used for conveyance losses.

The demand (D) for irrigation water at the diversion point (headworks) is calculated by the subsection chief by aggregating data received from all tertiary blocks served by each diversion point and adjusting it for intake losses and secondary channel losses. The recorded daily average at the diversion points becomes the supply (S). The expected value of Faktor-K = S/D for the next two weeks. This information is passed down so that the respective gates at each level can be adjusted accordingly. The value "K" is exhibited on signboards adjacent to the control structures.

During drier parts of the year gatekeepers at diversion points have to calculate the Faktor-K as often as once a day, taking into consideration the actual flow. Changes if required at the various gates downstream are thus notified; as long as the value of Faktor-K remains above 0.6 to 0.7 continuous supply is assured. But, if the value falls below this level, rotational water issue system is followed.

The assumptions underlying the operational tool-pasten system:

a. The actual number of hectares under each crop and its growth stage is known.

b. The actual flow at the intake is measured.

c. The quantity of water diverted can be measured accurately.

d. The rate of canal and distribution losses is known.

e. Proper control over the gate settings is possible.

If any of these assumptions are violated, the operational value of the system for calculating required discharge is drastically reduced. Data collected in the research sites show that actual irrigation management practices often diverge from prescribed practices. It is not unusual for shortcut methods and rough approximations to be followed. These divergences are related to:

a. lack of field operational staff,

b. lack of trained staff,

c. lack of measuring instruments and structures,

d. decentralized control over diversions,

e. diversity within the tertiary blocks regarding crop type and growth stage,

f. prevalence of unmeasured supplementary water supplies,

g. extension of tertiary blocks across more than one village, and

h. alternative arrangements for water distribution being made between farmers and inspectors.

Determining irrigation water requirements for the tertiary block, whether the availability meets the demand or not and the future deliveries, depend on the information flows. The irrigation inspector initiates the largest number of information paths. The information flows and related calculations at the level of the village watermaster, however, is usually based on his own observations and estimates. The second vital point is the discharge data from the gate keeper. If either of these is faulty, it affects the rest of the analytical procedure.

Planning Process

The process of planning annual cropping patterns and planting dates begins with the report from the irrigation inspector on the expected cropping pattern at village level and at tertiary block level. The village-level officials are consulted in formulating this report. Before each rainy season Irrigation Committees at district (subsection) level and regency (section) level then meet to decide the crop plan. This information is then sent back down to the village level.

Estimating crop areas

Every year the Provincial Irrigation Service staff must check the area of each block to determine the land which has gone out of production due to development activities. Owing to administrative difficulties and budgetary disincentives, however, it is apparent that these figures are not updated regularly.

On the other hand, the estimations of crop area by the village watermasters and the inspector of a particular block are found to be often different from each other, although theoretically they should be the same.

Calculating the irrigation requirement

The calculation of irrigation requirement is done in three ways:

1. The pasten method.
2. The Faktor-K method.
3. The Palawija Relatip Faktor method.

Setting the same Palawija Relatip Faktor for all turnouts along a secondary canal tends to ignore the nonhomogeneous features of the various tertiary blocks and, thus introduces a wide margin for error. This is particularly true when wide soil differences exist between blocks.

The main difference between the Palawija Relatip Faktor calculation and the pasten calculation is that the former is based on the water available at the turnout, while the pasten examines water requirement at the rice field *(sawah)* itself. Apparently, the introduction of the Palawija Relatip Faktor method makes turnout operation easier than the pasten because it directly gives the required flow at gated turnouts where the flow can be adjusted as required. However, if the actual losses in each tertiary and secondary canal are known, starting at the sawah requirements and adding losses is more rational than the current use of the Palawija Relatip Faktor method.

Implementation

Measuring irrigation discharge

The level of efficiency under which the irrigation system operates depends greatly on the flow-monitoring aspects at primary, secondary, and tertiary discharge levels. At the IIMI research areas it has been found that 39 percent of the offtake structures were not measurable either due to construction faults or due to missing gauges; often the gatekeepers or irrigation inspectors who were responsible for taking measurements, determine the flow either using a wooden stick and a table from another gate or using an eye estimate. In addition, problems encountered with the establishment of a steady flow owing to inordinate amounts of flow in the canals are reported.

The research staff have also reported that there are wide discrepancies in the reported figures to the subsection chief by irrigation inspectors and the actual measurements or recordings. Therefore, it is apparent that, sometimes, reported data are poor and unreliable to be used effectively at top levels.

Adjusting gate settings

In many parts of the public irrigation systems in Indonesia, check structures and irrigation gates are not readjusted daily in response to frequent discharge fluctuations, although it is recognized that these adjustments are needed to keep actual deliveries in line with planned deliveries. Gate or checking readjustments are made more frequently along main canals and, often within tertiary blocks, than along secondary canals. In some cases, gatekeepers seem to lack skills and seem to perceive that the right to readjust gates has not been fully delegated to them. On the other hand, some gates do not function properly; the gates are fixed and used in such a manner that the water flowing through them approximates a proportional division along the secondaries. In general, the coefficient of variation is directly proportional to the distance from the main gate and it is of a higher magnitude in the second dry season than in the first dry season.

Levels and Trends of Irrigation System Performance

Management intensity of distributing water

IIMI research indicates that there is a tremendous amount of fluctuation within almost all the irrigation canals. Most irrigation systems being run-of-the-river systems, some degree of variation is expected. It is the adjustments at the gates which are important in controlling the flow. The relative frequency at which the gates are being operated provides a measure of performance: the number of times the intake was adjusted during the period and the average number of days between the adjustments (indicator of intensity or responsiveness of management). The average number of days between adjustments in the dry season have been two to five days compared to the range of three to seven days in the wet season. There is little difference in gate adjustment responsiveness between upper- and lower-end gates in East Java, but there is a significant difference between upper- and lower-end gates in Central Java.

Management performance ratio

Management performance ratio is a direct comparison of actual irrigation water deliveries with planned deliveries: the ratio of actual delivery (supply) to the planned delivery (demand).

$$\text{Management performance ratio} = \frac{\text{Actual measured discharge}}{\text{Planned discharge}}$$

Good management results in a management performance ratio of 1.0, which is a measure of efficiency (i.e., determining how close a system, during each planning period, is operating to its stated goal). Uncertainties with respect to water supply and rainfall make it difficult for the management performance ratio to be always 1.0. Therefore, there is an acceptable range around the management performance ratio of 1.0 (0.75 to 1.50). When variability is expressed in terms of the coefficient of variation values, comparison between areas, seasons, or systems becomes possible.

The problem is that the field officers do not use actual field data when reporting deliveries but instead, report planned discharge as delivery discharge which provides a very impressive management performance ratio of 1.0. The wide discrepancies between the results of IIMI data and the Provincial Irrigation Service data confirm the above anomaly. The results of the above study reveal that management performance varies widely from province to province and even from one irrigation system to another within provinces. Central Java shows the best management performance.

Data from Cirebon-Kuningan in West Java are more erratic, while data collected in East Java indicate that there is a consistent pattern of overdiversion from the Brantas River into Waru Jayeng Irrigation Scheme. Such haphazard variation in the management performance ratio implies weaknesses in training, monitoring and supervision, and problems in the physical condition of structures.

Although these values serve as a good indicator of management performance, the use of seasonal averages tends to mask interseasonal variation. The range and magnitude of seasonal variation when shown graphically indicate that even irrigation systems that have a seasonal management performance ratio close to 1.0, could have considerable variation from period to period (where irrigation periods are different).

Monitoring and Evaluation

Spatial variation in water delivery

Use of the Faktor-K or Palawija Relatip Faktor method is designed to ensure equity throughout the irrigation system. IIMI studies reveal, however, that there is an extremely wide variation of allocation of water within the system. Except for East Java, availability of irrigation water, in liters per second per hectare, especially during the two dry seasons, tends to decline with distance from the water source. In East Java, the security of overall flow in the Brantas River as well as Waru Jayeng's favorable location along the river illustrates that water is abundant in the head and tail, but tends to be less abundant in the middle of the system. In Central and West Java, availability in the head and middle is better than in the tail end. Relatively low coefficient of variation values in the tail end during the rainy season indicates that many of the systems become drains during part of the year.

Water availability

Locationwise water availability per hectare (in millimeters) compared to actual water required per hectare during each season offers another means of evaluating system performance: measure efficiency at the canal or block level. When effective rainfall is practically zero, this statistic becomes more meaningful, as for the second dry season. IIMI studies have mapped actual crop patterns using standard crop coefficients, and have calculated water requirements. These water requirements have been compared with water provided by the irrigation system to determine how close the irrigation system is able to match plant-water requirements. Given that a fixed amount of additional water has to be applied to cover tertiary and secondary canal conveyance losses, efficiency value in the range of 70-80 percent are considered excellent. Values above 85 percent indicate that, unless additional water is supplied from rainfall or another source, the plant may not have been provided with its full requirement due to distribution losses. Higher efficiencies found in Central Java confirm the higher level of management.

Cropping intensities

An improved irrigation system management would lead to increased cropping intensities. Although the Faktor-K and the Palawija Relatip Faktor methods are designed to provide equity along a single water system, IIMI data indicate that there often is significant variation in cropping intensities from system to system and from block to block within various systems. There is significant room for improvement both in the levels and in the equity of cropping intensities along the two major watersheds in West Java where IIMI research sites are located. Along the Ciwaringin River cropping intensities tend to drop markedly downstream. Along the Cisangarrung River, the three systems with the lowest cropping intensities are in hilly areas with uneven topography.

Maintenance

It is recognized that maintenance is generally underfunded. It is the duty of the irrigation inspector to identify the nature and the cost of maintenance required within the year, such as:

* length and width of canals requiring maintenance,
* number of major and minor installations needing repairs,
* number and type of gates not functioning,
* primary and secondary banks that have slipped,
* estimating areas where cutting grass and other plants would improve water flow,
* estimating the amount of sediments to be removed from canals, and
* listing the number of canal walls that need repairs.

The cost estimates are done according to the standards for operation and maintenance cost analysis suggested by the Directorate General for Water Resources Development. It is not unusual for the central government, however, to provide far less than the requested amount.

Based on their extended work in East Java, MacDonald and Partners have recommended the following order of priority for selecting maintenance tasks.

* *Preventive maintenance*: prevent further deterioration of canals, structures, and mechanisms.
* *Desilting and bank repairs:* ensure that sufficient water can flow through the canal system and can be removed by the drainage system.
* *Reduce seepage:* line canal banks where losses are high.
* *Measure flows:* repair or construct measuring devices.
* *Maintain display boards, etc.:* attend to the appearance of the system.

ANNEX F

Irrigation System Management In The Philippines

Planning

Planning is an essential and critical stage in irrigation system operation in the Philippines. In planning, the potential availability of irrigation water and appropriate cropping calendars are determined to optimize the use of the available water supply. Concerning optimization, the timely and sufficient allocation and distribution of irrigation water where it is needed are of utmost importance.

In planning the cropping calendar, the supply of water (irrigation and rainfall) is matched to demand (soil and crop water requirements). In run-of-the-river diversion-type irrigation systems, the amount of water expected to be available for the system during an operational year is determined using a five-year moving average. In this scheme, the most recent five-year data are used as an estimate of the potential availability of water for the system for a particular year, regardless of the data available. The expected rainfall occurrence is likewise determined using the five-year moving average. The demand for irrigation water depends on the crop to be irrigated and its growth stage. Other water requirements are the amount required for land preparation and other farming activities, and the amount lost through evaporation, seepage, and percolation. The latter two factors depend on the soil characteristics.

For rice, the value of 13 millimeters per day or 1.5 liters per second per hectare is generally used as the on-farm water requirement. In systems with lighter soils, the figure may be higher. For secondary crops, the usual irrigation water requirement can be four times less than that of rice although 60 percent is sometimes used.

The weighted average of the irrigation water requirement for both rice and non-rice crops on a given system determines the area that could be irrigated during any given time.

Before the start of every season, a meeting between the irrigators' associations and the National Irrigation Administration staff is nominally held to discuss a tentative plan that includes the program area and the subsequent water-delivery schedules. The degree of participation by the irrigators' associations is dictated by the level of involvement and functionality of the different irrigators' associations in each of the sites. Among the sites, the irrigators' associations at Banga River Irrigation System are observed to be very much involved and committed to observe equitable sharing of water in the dry season. The areas programmed for rice in the dry season are rotated on a yearly basis giving an opportunity for all areas to be irrigated in the dry season for rice. The areas not programmed for rice are encouraged to plant corn and other upland crops. These are only irrigated upon signing a request for irrigation. This request is needed in order that collection of irrigation fees at the end of the season is facilitated. Moreover, the programmed rice areas get the first priority in case of water scarcity.

At the Laoag-Vintar River Irrigation System, the locationally favored (upstream) Vintar Irrigators' Association is not as interested in equitable sharing of water, particularly in the dry season. Thus, only the Laoag-Bacarra-Sarrat Irrigator's Association (LABASA) is really involved in the water allocation activity. Only the areas near the canals and located at lower elevations are programmed for rice. Areas programmed for non-rice crops are located at the tail end of lateral and sublateral canals, and with coarse-textured soils. A third crop of mungbean is usually programmed, depending on the available residual water at the end of the dry season. Usually two to four deliveries are available after the regular second crop. At Bonga Pump (BP) No. 2, water allocation is relatively simpler as the system is partially turned over to the irrigators' associations with no direct intervention of the National Irrigation Administration staff. Notwithstanding this arrangement, not all areas are irrigated for rice because water supply is also limited. Location of the farms, soil suitability, and payment record are the criteria used in allocating water for rice in the dry season. Non-rice crops, mostly garlic and water melon, are also programmed.

At the Upper Talavera River Irrigation System which is a part of the Upper Pampanga River Integrated Irrigation System the seasonal irrigation plan is theoretically made by the Agricultural Development Coordinating Council. This Council is chaired by the Provincial Governor of Nueva Ecija. The members are the Operations Manager of the Upper Pampanga River Integrated Irrigation System and representatives from the local government, the Department of Agriculture, and private enterprises involved in agriculture, such as rural banks and agricultural chemical companies. The Council meets at least one month before the start of the wet season to prepare the irrigation plan for the whole of the Upper Pampanga River Integrated Irrigation System, including the Upper Talavera River Irrigation System, for the following wet and dry seasons.

Actually, however, only the upstream irrigators' associations are involved in water allocation. Nominal participation of the other irrigators' associations are observed with no actual involvement in terms of group work activities and frequency of attendance in meetings called by the National Irrigation Administration staff. The major reason cited by farmers is the uncooperative behavior of the farmers from the upstream irrigators' associations. This situation is the reverse of that at the Laoag-Vintar River Irrigation System, where the downstream irrigators' association is the one functional. In this situation, allocation of water at the start of the season is difficult to implement. Farmers are given the option to plant the crop of their choice. The National Irrigation Administration staff, however, caution the farmers that water will only be sufficient for those areas near the source, particularly for irrigating rice. Consequently, non-rice crops (mostly onions) were not programmed until about two years ago when the differential billing of 60 per cent of the fee for rice was implemented for non-rice crops. Whatever areas are planted to rice and non-rice are billed accordingly, when the list of planted areas is prepared. The non-rice crops at the Upper Talavera River Irrigation System are planted only in those areas with medium-texture soils. These areas are located mostly in the upper and middle portions of the service area.

At the Allah River Irrigation Project, the participation of the irrigators' associations in the water allocation activity is just starting to evolve. The irrigators' associations of laterals A, B, and C extra are not fully convinced that their areas should be programmed for non-rice in the dry season because they were already planting two rain-fed crops of corn every year before the Project was initiated. Most farmers in these areas prefer to plant rice even without the assurance of irrigation water in the dry season. To these farmers, irrigation is synonymous to irrigated rice production owing to the misleading abundance of irrigation water as observed in the main canal and the occasional rainfall during the dry season.

Implementation

The approved plan becomes the primary basis for water allocation and distribution in an irrigation system.

The plan is revised when the actual supply falls short of the expected water supply. This occurs due to the probabilistic nature of the hydrometeorological factors involved in the plan. Any changes or deviations from the plan have to be approved jointly by the National Irrigation Administration staff and the irrigators' associations concerned.

If the actual water flow measured at the intake falls short of the expected value, a system of rotation is enforced. The rotational scheme depends on the severity of the water shortage. Rotational schedule is resorted to as the reduced available water supply can then be directed among sections with greater control and precision.

At the Upper Talavera River Irrigation System, the diversion of water from the dam is continuous even during the scheduled cut-off period, according to the irrigation plan prepared by the Agricultural Development Coordinating Council. During the scheduled cut-off in the month of May, there is minimal flow from the river, which can only irrigate a small portion of the upstream area. This area is planted to lowland rice. Water delivery is only suspended when rehabilitation work is needed. Even desilting the main canal of the Upper Talavera River Irrigation System, which is an annual operation, is done without shutting off water delivery. Water at the low diversion dam cannot be stored and, if not diverted, is considered lost. Diversion of water is therefore done as long as it can be used in the system.

The diversion of water from the dam at the Upper Talavera River Irrigation System is continuous except during the rainy season when the rainfall is high, requiring the closing of the main canal to prevent flooding of the service area and damages to canal structures. But even then, there is still a water flow from drainage entering the canals from adjacent high areas.

During the wet season, the whole area is programmed for lowland rice and water flow is continuous in all canals unless shortage occurs where rotation is resorted to. Rotation is done by section of the main canal. The rotation period is usually one week.

During the dry season, only 500 hectares (ha) are programmed for irrigated diversified crops in the Upper Talavera River Irrigation System. Nothing is done to prevent farmers from planting lowland rice because some areas, owing to their low elevation, are not adapted to upland crops. There are also areas suitable for upland crops planted to lowland rice. In most years only 50-60 percent of the programmed area is planted to upland crops. As the agreed program is to plant irrigated upland crops, farmers following the program are given first priority in getting water. When the rice survives, however, the area planted to it is also billed at the same rate as the scheduled lowland rice during the dry season. The area planted to diversified crops is billed at 60 percent of the rate charged to rice.

In some years when water from the river is more than enough for the programmed areas, especially during the start of the season, the planted area reaches 700 ha. This causes water shortage later in the season. Thus, instead of cutting off water supply to unprogrammed areas, rotation by sections of the main canal is done to enable all the planted areas to have water. This happened during the dry season of 1986. Some tail-end areas which could not be irrigated used small shallow tube well pumps.

Because there are areas planted to lowland rice, it is very hard to enforce the planned rotation schedule. Lowland rice is planted in low areas upstream. The rotation schedule is hardly implemented especially at night. Close guarding of the checkgates is necessary to enforce the rotation schedule. Tail-end farmers planting onions sometimes have crop failures owing to unavailability of water.

Upstream farmers can easily get water. This easier availability of water encourages upstream farmers to plant onions in unmulched plots to produce better quality bulbs. Downstream farmers plant onions in mulched plots because irrigation in the tail-end portion is made available only during their scheduled time. When the tail-end farmers are scheduled to receive water, guarding of checkgates is necessary to prevent theft by upstream farmers. It is not infrequent that tail-end farmers can only get water during daytime when watermasters and ditchtenders are on duty to enforce the schedule.

The duty of the watermaster is to distribute water throughout his service area up to the turnout level. At times when rotation is resorted to, night patrolling is done to ensure that there is no theft of water. Below the turnouts, the farmers share the water among themselves.

Another example is at the Laoag-Vintar River Irrigation System. If there is any acute water shortage in the dry season, priority is given to crops with the most need for water. The district officers and the Board of Directors of the Laoag-Bacarra-Sarrat Irrigator's Association (LABASA) have to meet to change the schedule if necessary.

The watermaster is involved in the distribution up to the point of determining the priorities among farmers' fields. In case of illegal water use by farmers, association members and the watermaster conduct an investigation and, if found guilty, water delivery in the area concerned will be suspended for the next water schedule.

The watermasters and the ditchtenders supervise water delivery to turnouts. The farmers share the water at the turnouts. The watermasters help, however, to determine the priorities. Watermasters and ditchtenders collect the irrigation service fees. Their performance is evaluated partly on the irrigation service fee collection.

The water duty for non-rice crops is 60 percent that of rice. Irrigation rotation for other crops is once a week for light soils, and once in two weeks for heavy soils. During heavy rains, water delivery is suspended to avoid canal wash-outs and flooding of fields. Even if the sluice is closed, runoff from side hills enters the canal. Ditchtenders are responsible for the upkeep of the canal system up to the laterals. Farmers have to maintain the farm ditches.

At the Banga River Irrigation System, the water supply is rotated among the sectors of the system, on a weekly schedule, decided at the preseasonal farmer meeting. The schedule cannot be altered by the irrigation staff without consultation with the farmer associations. The irrigation agency's role is to implement and enforce the rotation schedule. To prevent unscheduled water deliveries, unauthorized checks are removed and confiscated by the agency personnel during their daily rounds. Unscheduled sections are sometimes closed with concrete.

In the case of the Mani Communal Irrigation System, control of water distribution is done through the canal tender who patrols the canal every day to ensure the scheduled delivery. In times of water shortages, weekly rotations are practiced. It is observed, however, that upstream farmers resort to unauthorized diversions, causing shortages of water to the downstream farmers.

Monitoring

In the National Irrigation Administration systems, the evaluation of the physical performance of the system is reflected in the area irrigated and benefited, and the equity of water distribution. The economic indicators are the irrigation service fee collection efficiency and financial viability of the system.

There is an attempt to utilize data on water flows to determine shortfalls so that preventive measures or action can be planned and instituted during the following season. The different indicators are considered during an overall assessment of system performance.

Specifically, on the Laoag-Vintar River Irrigation System operation as an example, there are seven rain gauges being observed. During heavy rains, there is suspension of water delivery following the National Irrigation Administration's practice to avoid canal wash-outs and flooding of fields. But even if the dam is closed, there is water flow in the canals because of runoff as indicated earlier from side hills entering the canals.

There are water-measuring structures (staff guages) at major sections of the main canal and at headgates of laterals. Often these are not calibrated properly. Mostly, the rate of water flow is assessed in terms of depth of water in canals. This may have been caused by the helplessness of the National Irrigation Administration personnel in increasing supply when there is shortage and nonstorability of water when there is excess. The main performance measurement used is that water should reach areas where they are scheduled to receive it.

More recently, however, under the World Bank-assisted Irrigation Operations Support Project, the National Irrigation Administration is currently pilot-testing an irrigation management information system (monitoring and evaluation) program to help irrigation superintendents manage their irrigation systems more efficiently to bring about a high level of satisfaction to all irrigation water users. The program aims to provide irrigation superintendents with timely monitored information on:

* needs of farmers in complying with programmed water deliveries, so that these can be attended to by the irrigation system or coordinated with concerned agencies;
* the condition of irrigation facilities which are likely to affect water-use efficiency and cropping intensity;
* farming activities to guide adjustments in water deliveries; and
* problems which are likely to affect irrigation service fee collection and financial viability of the irrigation system.

The monitored information is intended to be used to evaluate differences between targets and accomplishments so that appropriate management action to correct the causes of the deficiencies can be instituted.

ANNEX G

Irrigation System Management In Sri Lanka

Organizational Setup

The program for Integrated Management of Major Irrigation Schemes seeks to establish a harmonization of the various inputs and services necessary for increasing agricultural productivity with special focus on the use of irrigation water. An interdisciplinary group with experience in agriculture, irrigation institutional development, and management at the Irrigation Management Division functions as the administering authority for the program. Policy guidelines and direction for the program are set by the Central Coordinating Committee consisting of the Secretaries, Ministry of Lands and Land Development, and Agricultural Development and Research, the Department Heads of Irrigation, Agriculture, Land Commission, and Agrarian Services, and the state banks.

At the district level, the instrument for implementation and monitoring is the subcommittee of the District Agricultural Committee set up to direct this program. The District Agricultural Committee comprises the Government Agent (Chairman), the District Heads of all the different agencies involved in the programs, and the Project Managers of projects falling within the district. The subcommittee would identify and implement projects, monitor and review the programs, and also evaluate the previous seasons' performance.

At project level, a project committee consisting of field staff of all agencies involved in agricultural production and farmer representatives, headed by the project manager, determines the program for implementation in the project. The main functions of the Project Committee are to formulate and implement a cultivation program for both *yala* (dry) and *maha* (wet) seasons, ensure proper distribution of water, arrange timely provision of inputs and sale of products, arrange operation and maintenance programs of the irrigation system, and increase agricultural production.

Under the Mahaweli scheme, lands developed for irrigated agriculture are zoned as systems, each being completed at various stages. The systems are in turn divided into projects, each under a resident project manager. The resident project managers are mainly responsible for the overall management of their respective project areas. At the project level, there are four deputy resident project managers to assist the manager, each for varying disciplines: water management, agriculture, community development, and lands.

A project is further divided into blocks, consisting of about 2,000-2,500 farm families, each under a block manager. The block-level management staff consists of an irrigation engineer, an agriculture officer, a marketing officer, a land officer and other supportive staff under the block manager who is responsible for the overall coordination at the block, and who reports to the resident project manager. The irrigation engineer is responsible for water deliveries and scheduling, and all irrigation maintenance work within the block. Block-level agriculture plans are prepared and implemented by the agriculture officer. Arrangements for necessary marketing facilities and supply of relevant information are the main tasks of the marketing officer. Land officers are responsible for keeping records of titles, distributing lands, and solving local problems.

The blocks are further divided into units comprising 200-250 farm families under a unit manager in charge of a unit who is the most important element in the management setup. He is the only representative of the government who has direct contact with the farmers. He is in charge of coordinating the timely supply of agricultural input to the farmer, communicating with the line agencies at the block and project level on behalf of the farmer, attending to the health and welfare needs of the farmer family, and water management within the unit.

Farmer organizations provide the forum for dialogue and interaction among farmers and between farmers and officers working in the project. In the establishment of farmer organizations, the following guidelines are emphasized:

> They should represent a distinct hydrological area, should be *bona fide* cultivators within the area they represent, and should represent all cultivators within the area.

Turnout groups constitute the lowest level of organization. They form the base on which the higher level-organizations are built.

Planning Process

Dewahuwa

There are two cultivation seasons in a year. Planning for the upcoming season generally begins during the last two months of the preceding season. The officials of the Irrigation Department estimate the available amount of water for irrigation and the effective command area, for which the water level in the storage tank at the time and what is expected to remain at the end of the season are estimated. Then, the anticipated rainfall, estimates through a 75 percent probability, and the expected amount from supplementary sources, if any, are taken into consideration.

The next phase is communicating the above findings to farmers through their representatives at the fortnightly committee meetings. Their opinions are solicited with regard to selection of crops and varieties, especially during the dry season as crops other than rice are involved. This is not a one-shot process. Given its dependence on rainfall, the amount of water available for cultivation may change. Besides, there is always the possibility of an additional water issue being given to offset tail-end problems, late start, etc. As a result, this process of exchanging information continues over a few weeks.

In the preseasonal (*kanna*) meeting the field-level representatives of all line departments and the farmer representatives meet to formulate the cultivation program. The planned program on water issues such as the first and last dates of water issues, rotation pattern, irrigable land area for the season or land area for bethma, etc., is prepared by the technical assistant. The appropriate line agencies are consulted on input supply, crop selection, credit procurement, etc. Resolutions with regard to irrigation system maintenance, channel clearing, etc. are also passed during this informal plenary session.

The next stage of the planning process is the kanna meeting which is held to formalize the decisions taken at the pre-kanna meeting. Under the Irrigation Act of 1968, these decisions become law. The meeting is chaired by the government agent and attended by all the district-level officers of the line agencies and farmer representatives.

Kalankuttiya

The head office of the Mahaweli Economic Agency initiates the top-level planning about two to three months before the season, with an estimate of the available irrigation water for the forthcoming season. The Central Water Panel, functioning in Colombo (head office), decides and allocates quantities to each project area. The Panel allows each project management to decide on the crops to be cultivated on a land area determined by the quantity of water that is allocated to them. During the initial discussions at the project and block levels, suitable alternative cropping patterns are suggested in order to maximize the land use with the available water supply. The information is then fed back to the Water Panel Board to formulate a tentative cultivation program for the entire system.

At the project level, the season begins with the resident project manager requesting his block officers to submit a cultivation plan for the season. This generally occurs around the last six weeks of the preceding cultivation season. The block- and unit-level officials review and discuss the proposed cultivation program with farmer representatives during their usual weekly meetings and refer their views back to the resident project manager. A preseasonal meeting with all unit-level field officers is held to formulate the cultivation plan.

Based on the premise of a minimum adequate water supply, the agriculture officer prepares the cultivation plan. This information includes the land extent to be cultivated and acreage under each crop. In case of rice, the agricultural officer will recommend longer-duration (four and a half month) or shorter-duration (three to three and a half month) varieties depending again on the amount and timing of the water supply. The unit manager makes his estimate based upon the previous season and contact with farmer representatives.

At least about two weeks before the season starts, the resident project manager calls the cultivation meeting (kanna meeting) in accordance with the Irrigation Act of 1968, which is attended by farmers, farmer representatives, unit- and block-level officials, project-level officers, and representatives from the other institutions responsible for support services. The primary purpose of the kanna meeting is to provide information about the coming season's cultivation calendar, type of crops to be grown, irrigation schedule, and to get farmers' approval for the plan.

Planning during continuous issue

Planning during the continuous water issue period is mainly based on the Unit Manager's cultivation progress report submitted at the weekly block meeting. Block-level officials make use of this information to estimate the requirements of inputs and services including water issues and seeds. In the case of irrigation supplies, day-to-day adjustments in response to farmers' requests are needed.

Planning during rotational issues

Once the land preparation is completed, planning for the rest of the period is as follows:

1. Formulation and implementation of a rotation system:
   a) irrigation intervals and frequency of water issues,
   b) main-canal distributions, and
   c) secondary- and tertiary-level distributions.

2. Flow adjustments during rotational issues according to the demand and availability of rainfall.

3. Review of previous rotational issues.

4. Shortcomings.

Further planning for clearing distributaries and field channels and distributions along the distributaries and field channels is done by the Unit Manager, who, assisted by field officers and farmer representatives, selects turnouts to receive water. Selection is based on:

1. Closeness to the distributary gate.

2. Soil type.

3. Ease in distributing water.

Selection of bethma partners

Owners of the allotments in the area to be irrigated are allowed to select their partners with the consent of the proposed partner. In case of difficulties, the Unit Manager's assistance is sought.

Implementation

Dewahuwa

The implementation of water delivery along the main canal, especially to the tail-end tracts, is beset with several problems. The main canal is presently in a poor physical shape because of a lack of maintenance over several years. It is silted up in several portions along its length and has a very small gradient beyond tract 6. The few regulators along its length are in poor working condition and can be easily tampered with by farmers. Pushing a reliable supply of water down the main canal to the lower tracts is therefore difficult. It is also further complicated by farmers at the direct turnouts in the head end of the main canal illegally opening the offtake gates. Nonetheless, the management has been able to resort to rotational deliveries between the tail-end and head-end tracts to bring about a reasonable measure of allocation between the tracts. During the yala season, when a bethma is practiced over half or one-third extent, management of the main canal has proved to be less difficult.

Sharing of water between turnouts to field channels does not normally follow the stated plan. The designated farmer representatives are not able to perform their allocated task of closing and opening the gates as scheduled. However, most gates lack locking devices or even control rods and flash boards. Farmers at the head end of the distributary usually tend to take an over supply during the day time while those at the tail end have to manage with the night flow which, at times, can be very high and erosive. This is reflected in the high degree of variation observed for deliveries between turnouts in all seasons.

Following the land-preparation phase, the management of rotational issues during the crop-growth phase has settled down to a workable procedure especially when there is sufficient water at the source. The rotational intervals both for rice in maha and other food crops in yala have been accepted by farmers. Some modifications are however made during very dry periods in yala. Rotational issues between distributaries are mainly managed by the agency staff and operated according to the planned schedule. Rotational sharing of water between field channels along a distributary, however, does not work out so smoothly. For instance, in a four-day water issue period when it was agreed that the tail-end turnouts in the lower half of the distributary will take water for the first two days, followed by the head-end turnouts for the third and fourth day, many disruptions were caused by farmers. Rotational sharing of water in long field channels is also beset by similar problems.

During one season, for example, within certain distributaries, a rotation was planned to divide the head-end portion from the tail-end and deliver water at separate times. According to the plan, the head-end turnouts were to be closed during the first day of water issue to allow water to flow to the tail, and would then reopen on the second day. There was no plan for the third day which was considered an ''off'' day, as the sluice was closed. But because of the time lag in water conveyance and variations in the exact time the sluice was closed, water flowed in the distributary on the third day as usual. Within the turnout areas, no rotations were planned; farmers were expected to take water continuously, or to work out ad hoc arrangements for sharing the flow.

Kalankuttiya

The irrigation channel system consists of:

- open single bank earthen main canals with intermediate regulating reservoirs,
- unlined branch canals,

- unlined distributary channels starting from a branch canal or the main canal, and
- unlined field channels of one-cusec (28.3 liters per second) capacity feeding on average of 16.2 hectares (ha) (40 acres).

The control devices consist of:

- main sluice from reservoir,
- branch canal regulation with manually operated slide gates and duck-bill weirs,
- weir type regulators in distributary channels, and
- off-take gates to control issues from:
  a) branch canal to distributary channels and
  b) distributary channels to field channels.

The supply system is designed in a way that the institutional managers have control over the issues of water up to one cusec to the head of the field channel. Measurement of water is possible from main canal up to the field turnout. Field channels vary in size and length. The farm outlet consists of a 10-centimeter (cm) internal diameter concrete pipe. The command area under each turnout varies from 6-50 ha according to the size and number of allotments.

At the commencement of the cultivation season, water-issue schedules are prepared taking into consideration the water requirements for the period of land preparation and crop growth. The land-preparation schedule for maha season (rice) is based on a theoretical water requirement of 12.7 cm (5 inches) in the first week and another 5.08 cm (2 inches) during the second week. An additional week is provided for land preparation during which another 6.35 cm (2.5 inches) of water is delivered. Water-distribution schedules for issues during both yala and maha crop-growth periods as well as the yala land-preparation period are based on 6.35 cm (2.5 inches) per week.

The weekly requirement at the heads of each distributary channel and field channel is thus computed, assuming conveyance losses of 15 percent for distributary channels and field channels, and a total of 25 percent at the head of the main canal.

The operational staff of the system can be broadly divided into three major categories:

1. Main- and branch-canal operational staff consisting of irrigation engineers, assisted by engineering assistants and water management supervisors. Their main function is monitoring, regulating, and issuing water to distributary-channel heads.

2. Distributary-channel operational staff consisting of an engineering assistant, project/unit manager, and field assistants. They are responsible for allocation of water at the field-channel head.

3. Field-channel operational staff consisting of a field assistant with the assistance of a farmer representative. They are responsible for the distribution of water to each allotment.

In Kalankuttiya, good control and regulation is provided along the branch canal because of the positive design features such as duck-bill weirs, and the good condition of distributary turnouts which have installed measuring devices of a robust nature. Flow measurements over the last 6 seasons show a good degree of equity in delivery between the 20 distributaries. Similarly, deliveries along the distributaries up to the field-channel turnout are not managed as well, especially in the case of very long distributary channels. When there is sufficient head at the main sluice of the Kalankuttiya Tank, the management has no difficulty in implementing the delivery plan according to schedule. When the water level at the main sluice falls below 1.524 meters (5 feet), appropriate modifications to the delivery plan have to be made on a day to day basis in order to ensure equity of delivery among the 20 distributaries. Also, during the land preparation period in the early phase of the cultivation season difficulties are experienced in meeting the total demand requirement for land soaking, plowing, and puddling. These difficulties are relaxed during the subsequent rotational issue period for crop growth.

Even with the good delivery system that is available in Kalankuttiya it has not been possible to keep to the scheduled 30 days allocated for land preparation either for the maha or the yala seasons.

Monitoring and Evaluation

Dewahuwa

The principal mechanism for monitoring organizational performance at the main-system level is to correlate performance with crop production figures. Yield per unit area is measured through crop-cutting surveys, and a comparison is made between the current yield and the yield during the previous season. At the meetings of the water management subcommittee, for instance, the additional government agent will inquire 1) whether the kanna meeting schedule with reference to water issues was adhered to (primarily to check on under-supply rather than over-supply); and 2) whether there is a drop in yield, and if so, whether this is correlated with inadequate water issues. (It has been pointed out that during the 1986/1987 maha, despite adherence to the schedule, the absence of anticipated rainfall during the flowering stage of the season resulted in stress to the crop, which in turn, resulted in a lower yield.) The philosophy of project management recognizes the importance of adopting other monitoring approaches and developing performance indicators suitable to an ongoing monitoring system on the assumption that initial improvement in management resulting in a 25 percent increase in yield could be achieved through a more accurate perception of issues.

Monitoring of water deliveries in relation to demand is carried out essentially at the point of the main-sluice issues. The evaluation of water deliveries is essentially based on farmer reactions expressed at the fortnightly Tract Committee meetings where farmers make quantitative statements on their perceptions of adequacy of supply.

Kalankuttiya

In the Mahaweli Project, plan implementation and monitoring are integral parts of the same process. Under the Mahaweli Authority of Sri Lanka there is a Performance Monitoring Unit. In the Kalankuttiya block, however, it is the Resident Project Manager, Galnewa, who is the key person. With the assistance of the Deputy Resident Project Managers for water management, agriculture, lands, and community development and the Progress and Program Control Officer, the Resident Project Manager, Galnewa, monitors the implementation of the cultivation program connected with the cultivation calender decided upon at the kanna meeting. This is done informally through site visits to the block office, and field and personal communication with block- and project-level officials.

Formally, there are management mechanisms set in place for program monitoring and ongoing evaluation. The weekly meeting of the Block Manager and his staff with the Unit Manager and their field assistants, and the monthly meeting of the Resident Project Manager and his key staff with the Block Manager and his staff, Unit Managers and Field Assistants belonging to the particular block, are two such examples. At both these meetings water issues at the unit level (daily or weekly or both) are monitored with reference to usage [cusecs released at the request of each Unit Manager, the extent of land area over which it was put to use, and for what purpose - this will vary with the stage of cultivation]. At the meeting of the Resident Project Manager, in particular, problems of interblock coordination of water releases from Mulannatuwa Tank are discussed. This is monitored next with the targets of the agricultural program. Finally, programs for the health and welfare of the settler (housing, sanitation, malaria control, etc.) are discussed and evaluated. Monitoring of the performance of the agency connected with the implementation of the workplan is carried out against the self-set targets by officials at the unit level.

In addition, program evaluation occurs on a biannual basis. The Resident Project Manager and his staff meet with the staff of all the block offices within the project. The manager of each block, with the assistance of the irrigation engineer and agriculture officer, accounts for the progress, or lack of it, of their programs. The Resident Project Manager and his staff then express in words the goals and directions they anticipate for the program for the next few months. Evaluation of the program is done against the set program and resources allocated. This exercise is referred to as progress control and program evaluation.

ANNEX H

IIMI-IRRI Collaborative Project On Problems Of Irrigation Management For Rice-based Farming Systems

1. National Partner Organizations

In Indonesia

Directorate General of Water Resources Development, Gadjah Mada University, and Agency for Agriculture Research and Development.

In the Philippines

National Irrigation Administration; Philippine Council for Agriculture, Forestry and Natural Resources Research and Development; Bureau of Agricultural Research, Department of Agriculture; and the Philippine Rice Research Institute.

In Bangladesh

Bangladesh Agricultural Research Council, Bangladesh Water Development Board, Bangladesh Rice Research Institute, Bangladesh Rural Development Board, and Bangladesh Agricultural University.

2. Donor

Rockefeller Foundation.

3. Program Themes of IIMI Involved

Management of water resources for irrigation, management of irrigation organizations, and institutions for irrigation management.

4. Field-Study Locations

In Indonesia

Mancungteung Irrigation System in Cirebon, West Java and Ciwaringan Irrigation System in Cirebon, West Java.

In the Philippines

Upper Talavera River Irrigation System, Upper Pampanga River Integrated Irrigation System, and Laoag-Vintar River Irrigation System.

In Bangladesh

Current IRRI research sites: Ganges-Kobadak (major lift system), Thakurgaon (deep tube well area), and a new major deep tube well site to be selected jointly by IIMI and IRRI.

5. Start Date

July 1 1987.

6. Completion Date

June 30 1990.

7. Objectives

1) To characterize the factors which influence 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 effectively incorporate changes in the farming systems;

3) to develop efficient and economical methods for managing irrigation water delivery and use of post-rice residual water for rice-based systems in which non-rice 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 policy makers to encourage informed and better decision making;

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

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

8. Brief Description of Activities

* The project is coordinated by Senen M. Miranda for IIMI, and by Sadiqul Bhuiyan for IRRI. The two are supported by interdisciplinary headquarters staff from their respective institutes.

* Beginning in early October 1987, consultation meetings were held with staff of national agencies in the Philippines and in Indonesia. Only a limited consultation in Bangladesh could take place in late January 1988.

* Active research started in the Philippines in December 1987, and in Indonesia in March 1988.

* The IIMI Head of Country Programs for each of the three countries has been requested to take on the role of overall country project coordinator.

* The point of integration among IRRI, IIMI, and national agencies involved in the project is the research sites (operating irrigation systems).

* Reporting and review meetings, scheduled twice a year, will be attended by the directly concerned headquarters staff.

* An annual review and planning meeting for each country will be held. During the meeting, the progress of all component studies, including the substantive accomplishments and problems, will be reported and discussed. Plans for the subsequent year may be altered to reflect agreements reached during the review.

* About three months before the end of the project (April 1990), a major workshop will be held to present the results of the project. Participants will include concerned staff of both institutions as well as key officials and researchers from national agencies involved in the collaboration. At the workshop a decision may be made whether to expand or discontinue the project.

Source: IIMI (1988c).