Management Arrangements for Accommodating Nonrice Crops in Rice-Based Irrigation Systems
Management Arrangements for Accommodating Nonrice Crops in Rice-Based Irrigation Systems

Proceedings of the First Progress Review and Coordination Workshop of the IMCD Research Network held in Quezon City, the Philippines, from 10 to 14 December, 1990.

Senen M. Miranda and Amado R. Maglinao, editors

INTERNATIONAL IRRIGATION MANAGEMENT INSTITUTE

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Cover photograph by Senen M. Miranda showing an irrigation infrastructure being managed to accommodate various nonrice crops in l a v a.
Contents

Foreword ................................................................. vii

OPENING ADDRESSES

Welcome Address .................................................. 3
Jose B. del Rosario

Keynote Address .................................................... 5
Manuel M. Lantín

COUNTRY REPORTS .................................................. 9

Management Arrangements for Accommodating Nonrice Crops in Rice-Based Irrigation Systems in Bangladesh ........................................ 11
M. A. S. Mandal, M. A. Ghani and M. Huq

Management Arrangements for Diversifying Rice Irrigation Systems in South India ........................................ 25
R. Kulandaivelu and K. N. Raja Rao

Management Arrangements for Diversifying Rice Irrigation Systems in Indonesia ......................................... 31
Suprodjo Pusposutardjo and Soenarno

Management Arrangements for Diversifying Rice Irrigation Systems in Malaysia ........................................ 53
K. F. Wong, B. Y. Shabrin and M. N. Mohd. Adnan

Management Arrangements for Diversifying Rice Irrigation Systems in Nepal ........................................ 67
Prakriti S. Rana, N. Ansari and Ram P. Satyal

Management Arrangements for Diversifying the Inherently Rice-Crop-Based Irrigation Systems in the Philippines ........................................ 83
National Committee on Crop Diversification (NCCD), Philippines .............................................. 83
(Presented by Jose A. Galvez)

Management Arrangements for Diversifying Rice Irrigation Systems in Sri Lanka .................. 97
Jayantha Jayewardene and Ananda Jayasinghe

Management Arrangements for Diversifying Rice Irrigation Systems in Thailand ...................... 117
Anchalee Ouraikul, Anan Lila and Lersak Rewtarkulpaiboon

Summary/Highlights of Papers/Discussions: Country Reports ............................. 133

SPECIAL PAPERS .................................................. 137

Irrigation Management for Rice-Based Farming Systems in Indonesia, Bangladesh and the Philippines: A Synthesis of Findings under the IIMI-IRRI Collaborative Project ............................. 139
Senen M. Miranda and Amado R. Maglinao

Policy and Research Issues in Irrigation Management for Crop Diversification: With Special Reference to Sri Lanka ................................................................. 153
Masao Kikuchi

Summary/Highlights of Papers/Discussions: Special Papers ............................. 175

WORKSHOP GROUP SESSIONS ................................ 177

Workshop Group Sessions .................................. 179

Summary/Highlights of Group Outputs and General Discussion ............................. 185

Summary/Highlights of the Steering Committee Meeting ............................. 187

Appendix A Workshop Program ............................................. 191
Appendix B Workshop Groupings ............................................. 195
Appendix C List of Participants ............................................. 197
Foreword

DURING THE ORGANIZATIONAL and planning workshop for a research network on irrigation management for crop diversification in rice-based systems (IMCD) held in late 1988 in Bangkok, Thailand, the participants agreed to establish a research network involving eight humid tropical Asian countries in which irrigated rice is the main crop during the wet season. The group also agreed to hold annual workshops to review the activities and results of the research network.

In the first meeting of the IMCD Network Steering Committee held in Kuala Lumpur in December 1989, it was further agreed to hold the First Progress Review and Coordination Workshop in the Philippines during 10-14 December, 1990. With the theme "Management Arrangements for Accommodating Nonrice Crops in Rice-Based Systems," the workshop took off from the earlier activities of the network.

The program of the workshop included the presentation of country reports, a session on special papers, small-group discussions, field visits, and the second meeting of the Network Steering Committee. The country reports focused on the experiences of the different countries on irrigation management for rice-based cropping as these relate to planning, implementation, monitoring and evaluation both at the system and farm levels.

The synthesis of the results of the three-year collaborative project on irrigation management for rice-based farming systems in Bangladesh, Indonesia and the Philippines between the International Irrigation Management Institute (IIMI) and the International Rice Research Institute (IRRI) were highlighted. In addition, another special paper discussed research and policy issues on irrigation management for crop diversification. The country reports and the special papers provided lead topics for further discussions in the small-group sessions.

The participant countries agreed on various plans relating to research and development, information dissemination and exchange, and funding and organization. Five research and development areas were identified a) drainage requirement for rice and nonrice crops in rice-based systems; b) techniques of quantifying water demand; c) on-farm water distribution facilities; d) development of flexible supplemental water sources; and e) farmers’ support services for diversified cropping in turned-over areas.

The group also recommended that the present annual workshop, the workshop proceedings and IMCD newsletter should be continued; a more responsive mechanism for soliciting contributions to the newsletter should be established; and a training curriculum on IMCD topics should be developed and incorporated into existing training programs such as that conducted by IRRI.
It was felt that each country should have a national committee or an umbrella organization to oversee/coordinate the activities on crop diversification. No standard objectives or rules were recommended but it was suggested that the National Committee on Crop Diversification in the Philippines could be taken as a model and modified as necessary.

The second meeting of the Network Steering Committee concluded with the anticipation that the proceedings of the workshop would be published. A new set of officers was selected and plans for the next workshop, to be held in Indonesia in September 1991, were firmed up.

IIMI wishes to thank the Government of Japan for its generous support; it was through its financial assistance that this coordination workshop was pushed through.

IIMI also extends its gratitude to the Philippine National Committee on Crop Diversification (NCCD) and the Japan International Cooperation Agency (JICA)-supported Diversified Crops Irrigation Engineering Project (DCIEP) of the National Irrigation Administration (NIA), for co-sponsoring the workshop and for making the necessary arrangements during the workshop and field trip.

Special thanks are due to Dr. Senen M. Miranda (Senior Irrigation Specialist, IIMI and IMCD Research Network Secretariat Coordinator) who was primarily responsible for organizing the workshop and to Dr. Amado R. Maglinao (IIMI-IRRI Collaborative Project Coordinator/Researcher in the Philippines) for his assistance in the conduct of the workshop and, especially, in the preparation of the workshop proceedings.

Khalid Mohtadullah
Director for Research
International Irrigation Management Institute
Opening Addresses
Welcome Address

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THE HONORABLE MANUEL Lantin, Dr. Senen Miranda, Dr. Rodolfo Undan, participants, resource persons, guests, ladies and gentlemen.

I am very pleased to welcome you to the Philippines, to the National Irrigation Administration (NIA) and more auspiciously, here, to the Diversified Crops Irrigation Engineering Center of NIA. This Center is a symbol of international concern on the very issue of nonrice crops in rice-based farming-systems a manifestation of our resolve and that of the Japanese government to move toward crop diversification in our irrigation systems.

The subject of nonrice crops in rice-based systems is a very timely topic to tackle especially here in the Philippines today. Our government has embarked on a nationwide agrarian reform program so that the farmers will own the lands they till. But the average size of farms continues to shrink and waters supplies in our rivers dwindle as a result of watershed denudation. And rice production alone may no longer be an adequate source of livelihood from the limited landholdings. In the circumstances there is an urgent need to identify alternative ways for the farmer to earn more from his agricultural production endeavors. Irrigation of nonrice crops in rice-based systems could well be just one of the prospects to answer this need.

However, before we can start a big program in crop diversification, we have to ask many questions which can be summarized into three basic queries, How?, Where? and When? "How?" refers to the technologies appropriate for specific irrigation standards and management modes and agricultural production patterns. "Where?" pertains to locations suitable for certain crops under specific agronomic and climatic conditions and with appropriate physical infrastructure. And "When?" addresses the timeliness of implementing the program considering its economic viability to the farmers as certain crops are influenced by availability of distinct support services, and the adequacy of marketing and pricing programs.

Indeed, we need to learn more: a lot of work lies ahead of us. In this workshop we may find some answers to our queries through the sharing of each other's experiences.
IRRIGATION MANAGEMENT AND CROP DIVERSIFICATION IN RICE-BASED FARMING SYSTEMS

It is my distinct honor to be among the best experts in Asia in irrigation and crop diversification and other guests who are gathered at this Progress Review and Coordination Workshop on Irrigation Management for Rice-Based Farming Systems.

I understand that this activity is the first of its kind jointly sponsored by the International Irrigation Management Institute (IIMI) and the Philippine National Committee on Crop Diversification. It is appropriate that we congratulate the organizers of this important undertaking. I sincerely hope that your activities for the duration of your stay here will turn out to be both productive and meaningful.

I would like to take this opportunity to share with you some experiences of our activities and current efforts in increasing production and farm profits as they relate to the theme of this workshop, "Management Arrangements for Accommodating Nonrice Crops in Rice-Based Systems."

As you may all know, agriculture still dominates the Philippine economy. Agriculture is the largest contributor to the Gross Domestic Product (GDP) and agricultural products contribute substantially to export earnings. About 70 percent of our population living in the countryside depend on agriculture and agriculture-related activities for their livelihood. In 1989, it was determined that a rural family earns an average of P2,401 a month. This is about 25 percent lower than the poverty line which is P2,700 as established by the National Economic and Development Authority (NEDA).

In our efforts to make Philippine agriculture a profitable venture, irrigation and crop diversification are both proven to be indispensable tools.

As in other countries in Asia, agricultural production in the Philippines is traditionally concentrated on a few main crops. Benchmark surveys conducted by the Department of Agriculture (DA) in 1981 indicate that the majority of Filipino farmers are monocropers with rice and corn as the traditional monocrops. Recent surveys confirm that this is still the case with a large number of farmers.

Monocropping may not be the problem per se. But as we face an intense race between population growth, spiraling prices, and food production. It becomes clear that monocrop-
ping is inappropriate for most of our farmers in addressing food and fiber scarcity. Under Philippine conditions, monocropping is inefficient as it does not maximize the use of farm labor or increase returns from the land. Also, it cannot provide our farmers insurance from the vagaries of weather, pests and diseases, and price fluctuations.

Indeed, crop diversification finds relevance in the need to increase agricultural production and farm income. The fulfillment of this need is at the heart of the DA’s plans and programs. Thus, in its medium-term plan, crop diversification is explicitly identified as one of the strategies in pursuing its objectives.

While crop diversification is an old practice in the Philippines, intervention by the government has helped spread its use among farmers. Current estimates show that of the country’s 3.2 M ha of potential irrigable lands, 1.47 M ha or 47 percent are provided with irrigation facilities. In some of these irrigation service areas, the National Irrigation Administration (NIA) has identified the following conditions which have brought about crop diversification to its present form:

1. Widespread inadequacy of water supply during the dry season to support the production of the high-water-requiring rice crop.
2. Natural necessity for vegetables as they constitute one of the components of the balanced diet of Filipinos.
3. Inherent better suitability, as regards productivity of nonrice crops over rice in certain soil types.
4. Higher profitability per unit area of nonrice crops versus rice crop, especially when harvest time is a particularly advantageous period.
5. Mutual desire between farmers and irrigation personnel to maximize utilization of available land and water resources.
6. Occasional very favorable price situations and attractive market facilities for the produce for particularly on-demand kinds of nonrice crops.
7. Adeptness of farmers in the technique of selecting and growing promising high-market-potential nonrice crops in rice fields.

The first official involvement of the government in promoting crop diversification as a strategy to increase farm productivity and income began in the early 1970s. Some of the more notable programs which included crop diversification as a strategy are:

1. The Asian Rice Farming Systems Network (ARFSN). This was established in collaboration with national programs to increase the productivity and income of small-scale rice farmers in different rice environments. The Philippine agency involved in this network is the DA. Results of ARFSN on-farm testing have proved that production in lands traditionally planted to rice alone can be intensified through planting of a variety of crops.
2. Irrigation Management for Crop Diversification Project. This is implemented by IIMI in collaboration with several local institutions like NIA and DA. IIMI’s studies are focused on: a) determining irrigation practices most likely to enhance cultivation of selected diversified crops; b) field-testing of the most promising practices in selected areas; and c) identifying various factors that may influence the
management and decision-making procedures at all levels for irrigation systems with diversified cropping.

3. Farming Systems Research and Development Project: Bicol Region (FRSDP-Bicol). This is a project of the DA funded by the United States Agency for International Development (USAID). Among the project's prominent activities that started in 1984 are: a) on-farm research on multistory cropping in coconut-based systems; b) cropping pattern trials and component technology tests for coconut-based areas, rain-fed rice-based areas and open upland areas; c) crop-livestock integration and goat production under coconut, supplemented by pasture lots of improved grasses and legumes; d) income-generating home industry projects focused on female labor; e) cash-generating activities targeted towards production of short-term, high-value crops; and f) multilocation testing and initial diffusion of information on promising enterprises and technologies. With these activities, the project developed several promising technologies, some of which include: a) direct-seeded rice grown in plots with sesbania (S. oleacea) as green manure; b) upland crops under coconut; c) peanut after rice; etc.

4. KABSAKA: The Rain-fed Farming Systems Project. Funded by the World Bank and implemented for a five-year period (1981-85), this project is considered as the first major effort to support multiple cropping as a means of raising agricultural productivity in the rain-fed areas.

There are numerous projects carried out in the Philippines showing great potential for crop diversification. Results of many of these projects conclude that crop diversification adds to the net benefits derived from the farm and we can readily say that technologies and experiences for increasing cropping intensity are available.

Promotion of crop diversification and its adoption, however, are not at all simple. There are several problems and issues which policymakers and administrators contend with which we have just begun to address. These issues involve: a) the need to increase investment for research and extension; b) inadequate and poor infrastructure facilities for marketing of farm produce; c) inadequate postharvest facilities; and d) availability of technologies for crop diversification with different crops under various agro-climatic conditions.

The other considerations for planning and implementation of crop diversification programs which researchers and policymakers should give careful attention to are: a) management capabilities of farmers; b) stability of water supply; c) socioeconomic considerations, i.e., profitability of the enterprise, availability of credits and inputs; d) acceptability of new crops; e) availability of postharvest facilities; etc.

It is readily admitted that the economics of crop diversification are enormous and so are the problems that need to be solved. Needless to say, success is linked with the overall socioeconomic and political spectrum and the commitment of policymakers, researchers and extension workers. It also depends on the willingness of farmers to adopt measures recommended for their benefit. To assure this, people of the community must be involved in and consulted on the identification of crop diversification programs that suit their needs.

Meanwhile, economic infrastructures need to be prepared to cope with second generation problems like marketing and distribution, resulting from increased production of agricultural goods.
I am certain that you will think through all the issues and problems confronting irrigation management and diversified cropping systems. I hope I have provided you some helpful ideas in your effort to plan your activities for resolving some of the significant problems on behalf of all concerned farmers.

Thank you.
Country Reports
Management Arrangements for Accommodating Nonrice Crops in Rice-Based Irrigation Systems in Bangladesh

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INTRODUCTION

AGROCLIMATIC CONDITIONS and agronomic factors remain extremely favorable for rice cultivation during the wet season in Bangladesh. Furthermore, people’s extreme dietary bias to rice as the staple food favors the dominance of rice-based farming systems in the country. Rice receives major support from government programs in terms of input distribution, price support and technological development. Seventy-two percent of the current total cropped area of the country is put to rice cultivation and 83 percent of the total irrigated land is covered by rice. A recent estimate based on field surveys in four different agro-ecological regions of Bangladesh reveals that 92 percent of total pumped water is consumed by rice alone, the remainder being used for irrigating nonrice crops (Biswas 1990). Rice also receives most of the agricultural loans. In 1988-89, 67 percent of the total loan from the Bangladesh Krishi Bank was disbursed for rice production.
Extent and Conditions of Crop Diversification

Agriculture in the country is highly diversified as it encompasses crops, livestock, fisheries and forestry in an interrelated fashion. The crop sector alone includes about one hundred crops grown in different seasons of the year. The agricultural census of 1983-84 documented 85 crops, which included 11 cereals, 10 pulses, 7 oilseeds, 7 cash crops, 31 vegetables and 9 spices. But cereals (rice, wheat and minor cereals) occupy about 77 percent of cropped land, the remainder is devoted to pulses, oilseeds, cash crops, vegetables and other crops (Table 1).

Table 1. Distribution of cropped area by crop, 1988-89.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Total cropped area (1'000 ha)</th>
<th>% of total area</th>
<th>% of irrigated area</th>
<th>Irrigated area as % of total cropped area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>10,225</td>
<td>72.4</td>
<td>83.3</td>
<td>19.3</td>
</tr>
<tr>
<td>Wheat</td>
<td>560</td>
<td>4.0</td>
<td>8.4</td>
<td>35.0</td>
</tr>
<tr>
<td>Other Cereals</td>
<td>115</td>
<td>0.8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pulses</td>
<td>535</td>
<td>3.8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Oilseeds</td>
<td>562</td>
<td>4.0</td>
<td>0.8</td>
<td>3.1</td>
</tr>
<tr>
<td>Cash Crops</td>
<td>808</td>
<td>5.7</td>
<td>0.5</td>
<td>9.2</td>
</tr>
<tr>
<td>Vegetables</td>
<td>459</td>
<td>3.3</td>
<td>3.8</td>
<td>7.3</td>
</tr>
<tr>
<td>Others</td>
<td>853</td>
<td>6.0</td>
<td>3.2</td>
<td>5.6</td>
</tr>
<tr>
<td>Total</td>
<td>14,117</td>
<td>100.0</td>
<td>100.0</td>
<td>16.7(27.0)*</td>
</tr>
</tbody>
</table>

*Indicates, irrigated area as proportion of 8.9 M ha net cropped area in 1987-88.


The rate of adoption of a few non-rice crops such as vegetables and banana is increasing, as these are being commercially grown in different locations of the country. For example, in areas such as Bogra Sadar, Gabtoli, Shibogoiij, Khetlal, Kalai. Dhaka Sadar, Mithapukur, Rangpur, Dinajpur Sadar, Rajshahi, Paba, Putia, Natore, Chandina, Comilla, and Feni, farmers have taken up commercial production of vegetables, especially potato, cabbage, cauliflower, cucubit, tomato, and aroid. Onion and tomato are grown widely in Iswardi, Pabna, while banana is adopted as a commercial crop in areas such as Shibgonj, Narshingdi, and Kaligonj, Jhenaidah. These vegetables and fruits are mainly disposed of through domestic markets all over the country. Some vegetables and fruits are exported.

Diversification of crops in different locations of the country is possible mainly because a number of high-yielding varieties of vegetables are available and also because the versatile use of minor irrigation equipment is spreading. Current research on irrigated crop diversification at Bangladesh Agricultural University (BAU) reveals that the extent of irrigated crop diversification was larger in shallow tubewell (STW) and hand tubewell (HTW)
schemes than in deep tubewell (DTW) schemes. This is because STWs and HTWs have smaller command areas and have more flexibility to adjust to variable water application required for accommodating both rice and various nonrice crops in the same commands. There are also areas where other forms of manually operated devices such as treadle pumps, rower pumps, dug wells, and swing baskets are also used extensively for irrigating crops such as vegetables and fruits.

**Agencies Involved in Crop Diversification**

A number of government and nongovernment agencies have taken up research and extension programs in order to promote diversified cropping. The most notable of them are: Multicrop Demonstration Programme of the Directorate of Agricultural Extension (DAE) for popularizing 49 noncereal crops; Bangladesh Agricultural Development Corporation (BADC)-sponsored Agro-Service Center for promoting vegetables, fruits, seeds/seedlings, fish and poultry; Horticultural Development Project of DAE-BADC-BAN; BRRI-BWDB-IRRI-IIM Project for improving irrigation effectiveness and diversified cropping; On-farm Research and Development Programme of BAR for diversified cropping; Crop Diversification research for improving irrigation water market, and Farming System Research and Development Project at BAU; Continuous Cropping System Management Programme of Bangladesh Rural Development Board and German Technical Assistance-sponsored Tangail Rural Development Project for demonstrating vegetables and fruits in the upland district of Shokhipur; Improved Vegetable Cultivation Program of Mennonite Central Committee in Feni; Changing cropping patterns with Treadle pumps under Rangpur-Dinajpur Rural Service; and Canadian International Development Agency (CIDA)-sponsored Crop Diversification Program using mostly manually operated shallow tubewells for irrigation.

**IRRIGATION PLANNING AND OPERATION FOR RICE-BASED SYSTEM**

**Practices in Rice Irrigation-Systems**

Irrigation is applied for high yielding variety (HYV) rice production during the dry months of January/February to April/May, but in areas where winter vegetables or short-duration oilseeds are grown, irrigation may start in February/March and continue up to May/June.

Planning for rice irrigation varies between lift-irrigation systems and large-scale gravity-cum-lift irrigation systems. For DTWs (usually 2 cfs capacity) and STWs (usually 0.5 cfs capacity) which are used for intermittent or continuous flood irrigation in the small-sized fragmented plots surrounded by dikes, major planning activities include decision making as to when to start pumps, which canal to be repaired and to what extent, who will put how much land for what crop, how much land to be covered in the command area, how much to
charge for water, how much diesel to buy, who will collect water fees in how many installments, and which mechanic to be contracted for pump repair in case of breakdowns and at what mode of payment. The dominant form of payment for water is cash at a fixed rate per unit of irrigated land for the whole season, but the rates vary depending on whether water suppliers or water users provide fuel. The other important form of payment is sharecropping with water, where one-fourth share of the crop is charged for water. In a normal year, on average, the full requirements for DTW and STW are about 3,000 and 600 liters of diesel, respectively, and the tubewell owners/managers have to purchase these with cash or on credit in several installments.

A recent field study at BAU shows that in the case of HYV rice, irrigation water is usually applied at 2-10 day interval with 30-50 mm average net depth per application, depending on variations in soil type, climate and irrigation plan. There are canal-wise rotations, and also management flexibilities to allow water to rice fields on demand from farmers. But the water sellers always prefer low-lying clay dominant plots which have high water holding capacity. Plots with light textured sandy soils, which require frequent irrigation or those plots where water delivery with the existing kucha canals is difficult or result in huge conveyance losses, are gradually “screened out” of rice irrigation and put to wheat or other low-water-consuming nonrice crops. This is one of the reasons why tubewell commands undergo contraction or expansion every year, resulting in increase or decrease in profits from the sale of water.

As far as irrigation planning is concerned, increased command area means increased hours of pumping and increased cash requirement for meeting energy costs; but, there are areas where increased pumping may not produce enough water for all the command-area plots because of reduced discharges, especially in the hottest months of March and April. A recent field research study in four sites in the country reveals that overall irrigation canal system efficiencies were 63 and 54 percent, respectively, for STW and DTW (Duna 1990). The same study also found that most of the irrigated rice and nonrice crops were underirrigated.

The Ganges-Kobadak (G-K) irrigation system, a large gravity-cum-lift irrigation system, was designed for providing supplemental irrigation to amin rice grown in the wet season, but nowadays farmers in the G-K irrigation system produce two rice crops, HYV aus and HYV amin, and most land remains either fallow or is used to grow low-value low-yielding pulses. The major planning elements involved in such projects are annual repair and maintenance of pumps, repair and dredging of intake channels and irrigation canals, selection of date of initiation of pump operation and pump suspension, and collection of water fees which is very negligible at present.

**Modified Practices to Accommodate Nonrice Crops**

Canal network facilities of well-functioning rice irrigation systems can adequately support the water delivery needs of both rice and nonrice crops in the dry season without any major redesign or upgrading specifically for that purpose (Bhuiyan 1989). At the farm level, water application and drainage functions for nonrice crops may require some additional facilities, mostly in the form of channels, but these can be normally handled by the farmers adequately.
These additional facilities are seasonal and disappear at the beginning of the wet season as the land is released for rice cultivation (Tabbal et al. 1990).

A recent field research at BAU reveals that farmers of an intensive lube-well irrigated area of Chandina, Comilla could successfully adapt the kutcha channels used for flood irrigation to rice fields for the purpose of providing furrow irrigation to vegetable fields. Farmers delivered irrigation water intermittently from kutcha farm ditches to furrows in plots in which potato was grown either as the sole crop or as an intercrop with other vegetables such as brinjal, yard-long bean, and bitter gourd. After the harvesting of potato, the ridges or furrows were leveled off through deeper plowing by tractor or country plows to allow land soaking and puddling for transplanting of HYV boro rice which could then be irrigated without difficulty by applying the usual flooding method. Such modifications of water conveyance structures and necessary adjustments of water delivery schedules were also observed in Jhenaidah, a relatively dry zone where irrigated nonrice crops such as potato, tobacco, papaya, tomato, brinjal and banana are grown simultaneously with HYV boro rice which is however grown on other plots of the same tube well commands (Mandal 1990).

**Constraints/Opportunities in Management Changes**

In Bangladesh, most soils are well-drained and groundwater is well beyond the root zone of most crops grown during the dry season. Therefore, land suitability and drainage are not major problems for crop diversification, except that temporary drainage congestion problems are artificially created by the unplanned construction of roads and embankments. Such congestion restricts or delays planting of Rabi crops such as pulses or oilseeds in many areas, because lands remain too wet to be planted. This is particularly the case in the G-K irrigation system where delayed suspension of pumps in mid-November is reported to be responsible for delayed seeding of Rabi crops and hence damage of these crops at mature stage because of early pumping in February (Ghani et al. 1990).

One of the agronomic opportunities for changing irrigation management for crop diversification is that a number of quick-growing high-yielding varieties of vegetables and oilseeds are available in Bangladesh. With the presently available cultivars, an opportunity for expanding cultivation of nonrice crops exists mostly in the winter and partly in the summer seasons. But to release land early in the winter months to facilitate timely seeding of the succeeding nonrice crops, presently grown photosensitive rice varieties need to be replaced by day-neutral to weakly photosensitive rice varieties in the wet season (Huq 1990). Besides, the very low yield potential of some nonrice crops, especially pulses and oilseeds, results in lower returns to farmers, compared to irrigated HYV boro rice. Both yields and profitability have been declining in recent years. This implies that more and more land is diverted to boro cultivation, pushing nonrice crops out of cultivation or to cultivation in poor quality soils.

From a technical point of view, different crops need different methods and different intensities of irrigation. Biswas and Sarker (1987), in a pioneering paper, illustrated the physical and technical potentials and constraints of irrigating nonrice crops commonly grown in Bangladesh and indicated that the existing rice-based irrigation distribution
systems are not appropriate for irrigating nonrice crops. But the level of technical adjustments needed to accommodate nonrice crops in the existing rice-based irrigation water distribution system is within the farmers' ability. The major input required for altering rice basin irrigation to furrow irrigation to suit line planted vegetables, and then for leveling off the furrows again for rice cultivation at the beginning of the wet season is human labor, which is adequately available in most areas during the early winter months. Whatever extra costs incurred in making such structural alterations are more than compensated for by savings made in terms of reduced costs of pumping water for nonrice crop irrigation.

A number of food items such as pulses (mostly lentils), spices (onion, ginger, turmeric, etc.) and edible oils are currently imported, although some of these imports are not officially recorded. These crops have been pushed out of cultivation by the singular emphasis on dry-season rice production with mechanized irrigation. The prices of these crops may have risen recently so that the cultivation of these crops appear to be profitable, temporarily, compared to irrigated rice production. But inter-year price fluctuations and inadequate transport, communication, storage and marketing facilities, restrict the expansion of these crops on a commercial scale. Furthermore, the farmgate prices which the growers receive during the harvest are much lower than market prices consumers actually pay. This is especially true for potato and vegetables which are perishable and need cold storage facilities.

The available institutional credit for nonrice crop production is inadequate, despite the fact that crops such as potato and leafy vegetables need considerably more cash inputs as well as timely cultural operations and timely processing, and transport and marketing facilities than rice. A three-country study by Miranda (1989) also corroborates this view. Another major institutional constraint is that the irrigation support services such as supply of fuel oil, electricity, machine spare parts and repair services are virtually not available for irrigating crops other than HYV boro rice grown in the dry season (Mandal 1988). This turns out to be a formidable problem for irrigation managers/tubewell owners to undertake canal repair or pump operation in the wet season to provide supplemental irrigation to aman rice, which is the major rice crop in terms of acreage and output. But a significant improvement in yield of this major rice crop appears to be a prerequisite for diverting lands from dry season boro rice to nonrice crop production.

The type of crops grown by neighboring farmers in adjacent plots is also an important consideration for growing nonrice crops in rice-based irrigation systems. For example, the D-N-D Irrigation Project of BWDB is very close to Dhaka City with a good market for vegetables, but the farmers in the farming system research block of the project did not respond to suggestions of growing vegetables. The main reason farmers reported was that they were unable to protect one or two plots of vegetables from theft (Huq 1990).
STRATEGIES TO ADDRESS CONSTRAINTS/OPPORTUNITIES

Improvement of Irrigation Facilities

The Fourth Five-Year Plan of Bangladesh has put increased emphasis on the improvement of irrigation facilities. It is expected that by 1994-95, the terminal year of the plan, 4.8 M ha (54%) of the country's 8.85 M ha net cropped area, will be under irrigation. While surface water irrigation will cover more than one-third of the area, groundwater lift devices such as DTWs, STWs and HTWs will be the dominant forms of irrigation in the future (Table 2).

Table 2. Irrigation achievement and targets in Bangladesh.

<table>
<thead>
<tr>
<th>Source of irrigation</th>
<th>Estimated achievement (1989-90) ('000 ha)</th>
<th>Target for FFYP* (1990-95) ('000 ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface water irrigation:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gravity flow</td>
<td>1,295</td>
<td>1,788</td>
</tr>
<tr>
<td>Low-lift flow pumps</td>
<td>212</td>
<td>500</td>
</tr>
<tr>
<td>Traditional lift</td>
<td>783</td>
<td>1,088</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>200</td>
</tr>
<tr>
<td>Groundwater irrigation:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>STW</td>
<td>1,805</td>
<td>3,017</td>
</tr>
<tr>
<td>DTW</td>
<td>1,251</td>
<td>2,200</td>
</tr>
<tr>
<td>HTW</td>
<td>500</td>
<td>700</td>
</tr>
<tr>
<td>FMTW</td>
<td>54</td>
<td>54</td>
</tr>
<tr>
<td>Total</td>
<td>3,100</td>
<td>4,805</td>
</tr>
</tbody>
</table>

*Fourth Five-Year Plan.

Source: Planning Commission (1990)

One encouraging feature of the proposed irrigation development is that greater emphasis has been put to small-scale lift irrigation devices, which offer better management opportunities for crop diversification. Therefore, it is also not surprising that the crop diversification programs of government and nongovernment organizations give preference to locations where farmers have more access to these flexible small-scale technologies, compared to large-scale irrigation projects.
Improvement in Procedures and Practices

While there will be horizontal expansion of irrigation facilities by installing additional capacities, there are also pronounced intentions to improve irrigation performance through improved water conveyance systems, improved canal layout and alignment, and motivation and training of farmers on appropriate water application methods. One of the improved water distribution systems currently being experimented is buried pipe irrigation, which allows greater flexibility in water management for growing rice and nonrice crops on fragmented plots simultaneously. Another experiment with respect to improved water distribution system is the rotational irrigation practices in the G-K irrigation system and the North Bangladesh Tubewell Project, which demonstrated feasible cropping patterns allowing growing of rice in the wet season and nonrice crops in the dry season. One of the encouraging aspects of irrigated cropping patterns is that these promise higher levels of grain output per hectare (Tables 3 and 4).

Growing nonrice crops in the winter season in sequence with aman rice in the wet season may be accomplished by selecting or developing rice varieties which are day-neutral to weakly photosensitive rice varieties so that lands put to these varieties can be released in early October and adequately dried to allow early seeding of nonrice crops. Another opportunity exists with the Flood Control and Drainage (FCD) projects which are expected to drain out land to the advantage of nonrice crop production (but to the obvious disadvantage of natural fisheries). Intercropping of pulses with wet-season aman rice provides another good opportunity; it is practiced in several parts of the country. In this case, pulse seeds are sown by draining out excess water after flowering of aman rice and the pulse seeds germinate and grow within the rice fields using residual moisture. Khesari (Lathyrus Sativus) is mostly grown in such intercropping systems.

DIRECTION OF IRRIGATION MANAGEMENT FOR CROP DIVERSIFICATION

Research and Development

The promotion of crop diversification in Bangladesh involves research in two major directions: irrigation management and crop development. A number of researchable issues relating to crop diversification were suggested by Mandal (1988). Some of the on-farim research studies on improved water management practices are currently being conducted by the engineering divisions of the Bangladesh Rice Research Institute (BRRI) and the Irrigation and Water Management Department at Bangladesh Agricultural University (BAU), Mymensingh. Rotational irrigation practices, improved conveyance systems, water quality, water balance studies of rice vis-a-vis nonrice crops, and improved water application methods are also on the current research agenda.
Research on improvement of crop varieties, to be included in crop diversification programs, is carried out by the Bangladesh Agricultural Research Institute (BARI), Bangladesh Institute of Nuclear Agriculture (BINA) and BAU. The Crop Diversification Program of the government envisages long-term, medium-term and short-term research strategies (Ministry of Agriculture 1989). Long-term research includes hybridization techniques while medium-term research strategy involves collection of local varieties, and import and screening of advanced breeding lines. Short-term strategies encompass collection of germplasm of vegetables, spices and fruits. Field research is needed for the adoption of improved technology packages for the improvement of local varieties such as ginger, turmeric, onion, garlic, chili, etc. Another urgent research is the development of high-yielding varieties of oilseeds and pulses.

Table 3. Average annual grain yield (t/ha) for selected cropping pattern in the Ganges-Kobadak Project (Phase I), Bangladesh, 1982-89.

<table>
<thead>
<tr>
<th>Cropping pattern</th>
<th>Total yield under recommended management</th>
<th>Total yield under farmer management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat-BR1-4</td>
<td>11.41 (8.93)</td>
<td>10.06 (7.63)</td>
</tr>
<tr>
<td>Wheat-BR1-BR1-1</td>
<td>11.80 (10.34)</td>
<td>10.41 (9.09)</td>
</tr>
<tr>
<td>Gram-BR3-BR11</td>
<td>11.77 (10.56)</td>
<td>9.94 (8.80)</td>
</tr>
<tr>
<td>Gram-BR3-BR1</td>
<td>11.81 (9.81)</td>
<td>10.44 (8.93)</td>
</tr>
<tr>
<td>Wheat-BR1-BR11</td>
<td>10.61 (9.88)</td>
<td>8.14 (7.76)</td>
</tr>
<tr>
<td>Wheat-BR6-10</td>
<td>11.7 (10.15)</td>
<td>10.28 (9.23)</td>
</tr>
<tr>
<td>Wheat-BR6-BR11</td>
<td>10.61 (9.88)</td>
<td>8.14 (7.76)</td>
</tr>
<tr>
<td>Gram-BR1-BR1</td>
<td>11.36 (10.15)</td>
<td>10.28 (9.23)</td>
</tr>
<tr>
<td>Kheshari-BR1-BR11</td>
<td>10.26 (10.26)</td>
<td>8.53 (8.53)</td>
</tr>
<tr>
<td>Dhaincha-BR3-BR11</td>
<td>11.64 (10.64)</td>
<td>10.17 (10.17)</td>
</tr>
<tr>
<td>Dhaicha-BR3-BR11</td>
<td>11.65 (10.65)</td>
<td>9.25 (9.25)</td>
</tr>
<tr>
<td>Sunhemp-BR1-BR11</td>
<td>10.5 (9.50)</td>
<td>9.24 (8.14)</td>
</tr>
<tr>
<td>Wheat-BR1-BR11</td>
<td>11.25 (10.30)</td>
<td>10.06 (9.40)</td>
</tr>
<tr>
<td>Gram-BR1-BR11</td>
<td>10.47 (9.36)</td>
<td>9.54 (8.46)</td>
</tr>
<tr>
<td>Cowpea-BR1-BR11</td>
<td>11.51 (9.99)</td>
<td>10.80 (9.56)</td>
</tr>
<tr>
<td>Kheshari-BR1-BR10</td>
<td>10.84 (9.95)</td>
<td>9.52 (8.72)</td>
</tr>
<tr>
<td>Kheshari-BR1-BR4</td>
<td>10.85 (9.78)</td>
<td>9.74 (8.72)</td>
</tr>
<tr>
<td>Keshari-BR14-BR11</td>
<td>11.12 (10.10)</td>
<td>9.63 (8.75)</td>
</tr>
</tbody>
</table>

*Crops* grown in rabi (winter), aus and aman seasons respectively, i.e., wheat is grown in rabi, BR1 in aus and BR4 in aman.

*Figures* in parentheses are the rice yield (t/ha) for the pattern.

*Source:* Ghani et al. 1990. Table 4. Average annual grain yield (t/ha) for selected cropping pattern in the North Bangladesh Tubewell Project, Thakurgaon.
Table 4. Average annual grain yield (t/ha) for selected cropping pattern in the North Bangladesh Tubewell Project, Thakurgaon.

<table>
<thead>
<tr>
<th>Year</th>
<th>DTW No.</th>
<th>Cropping pattern</th>
<th>Yield (t/ha)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>RM</td>
<td>FM</td>
<td></td>
</tr>
<tr>
<td>1984</td>
<td>63</td>
<td><strong>Sonalika-Sunhemp-BR11</strong></td>
<td>8.08 (5.28)</td>
<td>7.40 (4.70)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Sonalika-Millet-BR11</strong></td>
<td>8.08 (5.28)</td>
<td>7.40 (4.70)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Balaka-Mungbean-BR10</strong></td>
<td>8.48 (5.28)</td>
<td>7.79 (4.79)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Pavon-Dhaincha-BR4</strong></td>
<td>7.38 (5.00)</td>
<td>6.27 (3.77)</td>
<td></td>
</tr>
<tr>
<td>118</td>
<td></td>
<td><strong>Sonalika-Sunhemp-BR11</strong></td>
<td>8.30 (5.60)</td>
<td>8.33 (5.43)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Sonalika-Millet-BR11</strong></td>
<td>9.30 (5.60)</td>
<td>9.43 (5.43)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Balaka-Mungbean-BR10</strong></td>
<td>8.07 (5.80)</td>
<td>7.08 (4.12)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Pavon-Dhaincha-BR4</strong></td>
<td>7.78 (5.58)</td>
<td>6.45 (4.45)</td>
<td></td>
</tr>
<tr>
<td>126</td>
<td></td>
<td><strong>Sonalika-Sunhemp-BR11</strong></td>
<td>9.18 (5.78)</td>
<td>8.78 (5.78)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Balaka-Mungbean-BR10</strong></td>
<td>8.00 (5.00)</td>
<td>8.01 (4.81)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Pavon-Dhaincha-BR4</strong></td>
<td>8.02 (5.02)</td>
<td>7.04 (4.64)</td>
<td></td>
</tr>
<tr>
<td>1987</td>
<td>126</td>
<td><strong>Sonalika-Purbachi-BR11</strong></td>
<td>12.21 (10.33)</td>
<td>11.09 (9.21)</td>
<td></td>
</tr>
<tr>
<td>1988</td>
<td>89</td>
<td><strong>Kanchan-Millet-BR11</strong></td>
<td>8.34 (5.52)</td>
<td>7.71 (4.89)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Kanchan-Sesame-BR10</strong></td>
<td>7.33 (4.89)</td>
<td>5.30 (3.95)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Fallow-Purbachi-local rice</strong></td>
<td>7.95 (7.95)</td>
<td>7.40 (7.40)</td>
<td></td>
</tr>
<tr>
<td>120</td>
<td></td>
<td><strong>Sonalika-Sesame-BR11</strong></td>
<td>6.64 (4.59)</td>
<td>5.20 (3.15)</td>
<td></td>
</tr>
<tr>
<td>126</td>
<td></td>
<td><strong>Fallow-Purbachi-BR11</strong></td>
<td>11.44 (11.44)</td>
<td>10.89 (10.89)</td>
<td></td>
</tr>
<tr>
<td>142</td>
<td></td>
<td><strong>Kanchan-Millet-Pajam</strong></td>
<td>8.44 (3.67)</td>
<td>7.21 (3.67)</td>
<td></td>
</tr>
<tr>
<td>1989</td>
<td>89</td>
<td><strong>Kanchan-Millet-BR11</strong></td>
<td>10.02 (6.91)</td>
<td>8.46 (5.35)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Kanchan-Sesame-BR11</strong></td>
<td>6.63 (4.64)</td>
<td>6.39 (4.40)</td>
<td></td>
</tr>
<tr>
<td>118</td>
<td></td>
<td><strong>Kanchan-Sesame-BR11</strong></td>
<td>6.63 (4.64)</td>
<td>6.39 (4.40)</td>
<td></td>
</tr>
<tr>
<td>126</td>
<td></td>
<td><strong>Mustard-Fallow-BR11</strong></td>
<td>6.61 (6.04)</td>
<td>5.66 (5.09)</td>
<td></td>
</tr>
</tbody>
</table>

Notes: Sonalika, Balaka, Pavon and Kanchan are wheat varieties. BR stands for rice variety. Figures in parentheses are the rice yield for the pattern RM = Recommended management FM = Farmers' management

Source: Ghaniet al. 1990.
Information Dissemination and Exchange

One major area of weakness is the poor dissemination and exchange of information about on-station research findings. No doubt, the occasional newsletter published by the Bangladesh Agricultural Research Council and research institutes act as a medium of exchange of ideas among the researchers, but there is no information dissemination media for farmers. There are many innovative technologies evolved locally by farmers but in the absence of communication and dissemination media these remain unknown to farmers elsewhere. The Crop Diversification Program (CDP) Committee report mentions a number of examples such as year-round string bean production in Rangpur, off-set production of kachu (aroid) in Barisal, multi-harvest of potato in Bogra and mukhikachhu production with leaf mulching in Moulavibazar and Madhupur tracts. Another example of local innovativeness is the highly intensive production of vegetables under relay cropping, intercropping, mixed cropping and catch cropping under tubewell irrigation schemes in Chandina, Comilla. Farming system research also gathers many interesting local experiences and occasionally organizes field workshops with the participation of local farmers. The CDP committee report rightly suggests the need for interlocation farmer visits and orientation as a means to popularizing improved methods of nonrice crop production. The current BAU research project on crop diversification is planning to incorporate a farmer training and orientation component in the second phase in which suggested technological interventions with respect to improved irrigation management for diversified cropping will be tested in farmers’ fields.

Funding

A number of collaborative research and extension programs for crop diversification are underway at different institutes/locations mainly with assistance from various funding sources. More research and development programs towards crop diversification will require funds from national and international sources.

SUMMARY

Agroclimatic conditions in Bangladesh have favored a rice-based farming system. Rice is the staple food and farmers will continue to grow rice to meet consumption demand. But continuous monoculture of rice has already started showing symptoms of micronutrient deficiencies of soils and consequently, declines in yield levels. Irrigated rice production is also becoming less profitable to farmers. So, a more logical approach would be to concentrate on growing nonrice crops in the winter season in sequence with rice crops grown with supplemental irrigation in the wet season. In other words, providing options to farmers to grow nonrice crops such as pulses, oilseeds and vegetables with partial or full irrigation
In the dry season and to grow rice crops in the wet season should be a major strategy in increasing farmer income and improving soil fertility.

The most important factor that influences crop diversification is the economic incentives for farmers to grow nonrice crops. The production of most nonrice crops such as potato, onion, spices and leafy vegetables does involve high cash inputs and intensive agronomic practices but returns to farmers from these crops in most years are lower than returns from competing HYV boro rice production. Therefore, to promote crop diversification, institutional support in terms of credit, price support for nonrice crops, and backup services from irrigation-related agencies for storage, processing and marketing are needed. To improve performance of irrigated nonrice crop production, more research and development are needed in the field of irrigation water management and varietal development of both rice and nonrice crops.
References


Management Arrangements for Diversifying Rice Irrigation Systems in South India

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INTRODUCTION

WHEN INDIA ATTAINED independence in 1947 it was importing rice to meet its food requirements. In the early 1970s, the country became self-sufficient in rice production. This was made possible by the introduction of new high-yielding and high fertilizer-responsive rice varieties and the rapid extension of irrigation facilities where rice was grown. The heavy investment in irrigation provided the controlled flood water environment to take advantage of the full potential of the new high-yielding rice varieties. The success of this strategy, however, resulted in declining farmers’ income from rice production. Growing of nonrice crops like sugarcane, banana, turmeric and cotton increased the benefit-cost-ratio besides increasing the income of the farmers. Hence, the farmers started diversifying the cropping system to nonrice crops.

Ricegrowing areas in Tamil Nadu and Andhra Pradesh increased in the 1970s but started declining in the 1980s. Rice was replaced by nonrice crops like sugarcane, banana, turmeric and cotton. The shift to nonrice crops has taken place in large and medium-size farm holdings where enough resources were available for investment. Small and marginal farmers could not allocate the available resources for raising commercial crops which require high capital investment. Wherever sugar factories are situated, even small farmers switched to sugarcane due to the available credit and other technical services.

Private sector installations like sugar factories and government agencies like the Agriculture Department and Agricultural Universities are mainly responsible for crop diversification to nonrice crops through their consistent promotion of crops which increase farmers’ income and living standards.
IRRIGATION PLANNING AND OPERATION FOR RICE-BASED SYSTEMS

The basic principle in any case is simply to match as closely as possible the water supply available with the water demand or soil and 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. Planning can mean estimating availability of the future water supply and the water demand of the expected cropping pattern, and then matching the supply to the demand. This procedure of matching the available water supply and demand is routinely done in all irrigation systems.

In estimating the future supply, the factors considered by the irrigation staff include anticipated rainfall distribution during the different seasons by using past records; type of water capture, diversion, and storage systems used; and reliability of hydrologic and climatic data. The estimate often becomes pure guess work in which future supply is variable and unpredictable, as in some run-of-the-river schemes.

The water demand is determined 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 irrigation projects. 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 the season. 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 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 the normal irrigation; e) the end of the season; and f) distribution method. Whether continuous or intermittent, and the maintenance schedule and responsibilities.

Although new technologies and practices which can increase productivity are available, adoption of these technologies by small-scale farmers is limited owing to the small extent of available land. Lack of incentives to invest in farming, as it is a less profitable sector to invest when compared to industrial and other sectors, limits the possibilities for small-scale farmers to adopt new technologies.
CONSTRAINTS/OPPORTUNITIES IN THE MANAGEMENT CHANGES

Technical

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

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

Farmers who have grown only irrigated rice throughout are unfamiliar with agronomic and irrigation practices for nonrice crops.

There are greater economic risks associated with nonrice crops than with rice. Cash and labor inputs can be 3 or 4 times higher for nonrice crops than for rice crops. Institutional credit is scarce while noninstitutional credit carries usurious interest rates.

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

Low light intensity, cloudy weather and low night temperature during the rice growing period pose a big constraint to diversified cropping in rice fields. Inadequate drainage systems prevent the use of rice fields for diversified winter crops.

Socioeconomic Constraints

There are some economic and social constraints other than the abovementioned technical and environmental constraints which influence farmers’ decisions. One of these is the price incentives to grow nonrice crops.

The price of rice is unchanged for a long period, meaning it is relatively stable. To popularize the production of nonrice crops, price incentives should be provided. A major breakthrough in yield improvement of nonrice crops by introducing high-yielding varieties and proper cultural practices are needed to realize the full technical and physical potential for growing nonrice crops.

Institutional Aspects

The major institutional strength for pursuing a crop diversification program is the presence of agricultural universities which deal with rice and nonrice crops and a number of crop-based research and extension institutions in the country. Foremost of these are the Indian Council of Agricultural Research (ICAR) and the Tamil Nadu Rice Research Institute. Furthermore, crop specific extension activities are also provided by the Agriculture Department, the Oil Seeds Department, the Irrigation Management Training Institute.
(IMTI), Trichy and Water and Land Management Training and Research Institute (WALAMTARI), Hyderabad, the last being the most organized institution engaged in irrigation development. Any crop diversification program needs farmers' cooperation and participation.

There are, however, shortcomings of these institutions which impede the diversification of crops to a great extent.

**STRATEGIES TO ADDRESS CONSTRAINTS/OPPORTUNITIES**

**Improvement of Irrigation Facilities**

In recent years, there has been growing concern on how irrigation systems designed and operated for rice crops could be effectively utilized for production of irrigated dry crops.

Many people are of the opinion that the existing irrigation infrastructure is a major constraint to diversification from rice. Some agencies and authors have advocated improving the performance of the irrigation system by introducing the flexibility needed for large-scale crop diversification within the irrigation system.

The performance of the irrigation system can be improved by:

1. Improving the physical structures (hardware improvements).
2. Improving the operational performance of the system through improved management (software improvements).
3. Augmenting the supply of water to the system.

There are three dimensions to achieving good performance of the irrigation system. The first and foremost requisite is the need for adequate water control and flow measuring structures in the main system. The second focuses on measurement at key points in the system and feedback for good control. The third aspect deals with adequate trained manpower and their commitment and attitude towards system operation.

Realizing the importance of manpower needs, the Government of India with the assistance of the United States Agency for International Development (USAID) and the World Bank has set up Water and Land Management Institutes and Irrigation Management Training Institutes in 11 states for massive in-service training of professionals to improve irrigated agriculture. In addition, in three southern states, the World Bank has initiated a scheme titled National Water Management Project (NWMP) wherein in-service training of professionals and management staff of the system play a more dominant role than in creating physical infrastructure. These programs are in the right direction and are likely to make visible impact on irrigated agriculture.

Innovative management will be needed to find ways to overcome bureaucratic inertia and vested interests in system operation. The technical deficiencies can be corrected through the use of technologies already known, although there are opportunities for high-tech applications in telecommunication and regulating arrangements in large canals.
Innovative management approaches will also be necessary to handle manpower training. There is an urgent need to make local organizations of project beneficiaries to assume responsibility for project activities. Compatible government policies for adequate recurrent cost financing for operation and maintenance are important for sustainability of benefits and of physical infrastructure.

Component research such as case studies of improved management performance could yield tangible benefits.

**On-Farm Development Works**

On-farm development works like constructing field channels are being done through the Command Area Development (CAD) program. In rice irrigation schemes, they are not maintained by farmers since they are able to get water from their neighboring field due to field-to-field flow. But if nonrice crops are grown, farmers will have to use the field channels constructed by the CAD program, and a few more channels could be constructed by government agencies or group of farmers if properly motivated. This will develop in phases over years if rice cultivation is stopped in the dry season in any irrigation command. However, some patches affected by seepage from canals may have rice crops because of the saturated condition of the soil throughout the growing season.

**Improvement in Procedures and Practices**

*System Characterization and Mapping*

First, it is necessary to know the individual nature of the system itself. No two systems are exactly alike. They exhibit individual traits. These individualities which are unique to the particular system must be taken into account when planning.

The delivery system for rice crop or nonrice crop remains the same. But for the rice crop, water flows continuously in all sections of the distribution system. Nonrice crops need intermittent irrigation as excess water will severely damage the crops. Depending on the soil type and climatic requirements of crops, the frequency of irrigation can be decided. Minor branch canals can flow continuously, while rotational water delivery schedule must be done in minors and sub-minors. Operating the smaller canals can be practiced perfectly if the operating staff are trained in the aspects of irrigation scheduling.

Rice irrigation systems do not have appropriate in-field water application systems to favor nonrice crops. Small field-channel drains at ridges and furrows or beds are examples of requirements of in-field systems for irrigated nonrice crops. These on-farm facilities can be dismantled during land preparation for Kharif rice production.
More accurate method of prediction

Prediction of the behavior of the monsoon is difficult and beyond human control. In spite of the scientific advances made and the large efforts in the collection of weather data, weather remains as unpredictable as ever. Over a short range of 3 to 7 days perhaps, the prediction may be reliable but not beyond that. This will not be helpful for irrigation. There must be an indication whether the precipitation through the monsoon is normal, or above normal or below normal even as the cropping season starts. However, since monsoon failure is to be anticipated and droughts are felt in cycles of years, there is need to plan ahead.

In such conditions, Systems Engineering can be applied in an organized manner so that the best or optimum solution is determined. The advantages of the systems engineering approach are:

1. It is systematic and organized.
2. It is focused on the overall problem and the interactions between all parts of the system.
3. It is interdisciplinary and promotes communication among all disciplines needed for the project.
4. It promotes creativity and innovative solutions.
5. It gives the sensitivity of selected solutions to uncertainties.

Simulation modeling

The two most general types of models used in systems engineering are simulation models and optimization models. The simulation model is used to predict the outputs of various designs and operation policies. The uses of simulation models are to: a) predict; b) store data; c) identify physical and institutional relationships needed in research; d) identify system objectives; and e) help in training.

Since simulation is an extremely useful technique in systems analysis, it can be applied for prediction of water supply for different crops. The simulation technique was introduced in Periyar-Vaigai Project, Madurai, Tamil Nadu and it is functioning well without any problem.

Simulation allows the prediction of impacts of decisions. In other words, simulation provides answers to "what if" questions before a project is implemented or an operational policy is changed. By testing potential decision with simulation, one can measure the impacts both qualitatively and quantitatively. The big advantage of simulation modeling is that it allows the user to gain a lot of insight or experience with a system in a short period of time.

With the advantage of simulation modeling, rice-based systems can be successfully diversified with crops of different water requirements.

Participation of farmers

The farmers have been responsive to irrigation development and are quite conscious of the benefits from well-managed irrigation systems. However, they are poorly informed about the actual resources and the manner in which these resources have to be managed to minimize
the failure in irrigated crop production. They also seem to be afraid to accept a change unless they are assured of the benefits they will receive. A system should be evolved by which organizations are created at the field level with enough freedom to function in their best interest.

It is time that every attempt is made to increase the level of income of the farming community. Farmers can be easily benefited by crop diversification. A study on the impact of some socioeconomic factors influencing the adoption of crop diversification by farmers has shown that it is farmers with larger landholdings who were more interested in crop diversification. Small and marginal farmers grow mainly rice for family consumption while the big farmers are interested in growing nonrice crops to obtain more profits.

The caste system has had no effect on the adoption of crop diversification. Education was found to influence the adoption behavior of the farmers attracting them to crop diversification. Cosmopolitan and social participation was found to have an impact on farmers in adopting diversified cropping patterns in irrigated areas.

**Water augmentation**

In many irrigation commands where there is scarcity of surface water, conjunctive use of surface water and groundwater is taking place at a rapid pace. With the introduction of high yielding varieties, with more exacting water requirements and sensitivity to water shortages, adequate and reliable water supply has become critical. Conjunctive use of surface water and groundwater helps to meet the water requirements of crops with respect to both time and quantity.

Table 1 shows the results of an adaptive research conducted by Anna University on the comparative crop yields obtained from the fields on Padianallur tank irrigation system which were served by wells as supplementary sources of irrigation and from those fields which did not have this facility.

<table>
<thead>
<tr>
<th>Field</th>
<th>Farmers owning wells</th>
<th>Farmers purchased water</th>
<th>Farmers with no access to well water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area cultivated</td>
<td>8.27</td>
<td>4.05</td>
<td>3.09</td>
</tr>
<tr>
<td>Number of land holdings</td>
<td>7</td>
<td>21</td>
<td>12</td>
</tr>
<tr>
<td>Effective rainfall (cm)</td>
<td>1.46</td>
<td>1.46</td>
<td>1.46</td>
</tr>
<tr>
<td>Water actually released through sluices (cm)</td>
<td>42.34</td>
<td>64.46</td>
<td>65.66</td>
</tr>
<tr>
<td>Well water used (cm)</td>
<td>57.04</td>
<td>21.16</td>
<td>-</td>
</tr>
<tr>
<td>Number of irrigations from wells</td>
<td>4 to 9</td>
<td>1 to 6</td>
<td>-</td>
</tr>
<tr>
<td>Total water used (cm)</td>
<td>100.84</td>
<td>87.08</td>
<td>67.12</td>
</tr>
<tr>
<td>Crop yield (kg/ha)</td>
<td>3705 to 4817</td>
<td>962 to 3385</td>
<td>741 to 1853</td>
</tr>
</tbody>
</table>

*a One farmer who purchased water and irrigated only twice got 962 kg/ha.*
Also shown are the crop yields from the fields which utilized well water on a limited scale through purchase from neighboring well owners. The difference in the total amount of water used by owners of wells and those who purchased water was 13.76 cm. Crop yields from fields which did not use supplemental well water were very much lower than those which used well water. Farmers were quick to see the importance of having wells, and during 1983-86, 9 additional wells were constructed. Considering the potential of groundwater resources, additional wells at appropriate spacing will be helpful to address water scarcity experienced during certain periods of the year.

The conjunctive use of water in canal commands is exemplified in the Lower Bhavani Project command, where zonal irrigation with year to year rotation was followed. Under the zonal system, the command area is divided into two zones (Turn I and Turn II) and water is made available to each zone in alternate years for raising one wet crop and one dry crop. In the first year, "Turn I" areas were allowed to raise wet crops from 15th August to 15th December with continuous water supply.

From 16th December to 15th April, the same sluices were operated for only irrigated dry crops with 10 days on, and 10 days off. This is similarly done in the second year for "Turn II" areas.

The uncertain and unreliable supply of canal water, particularly in the dry season (December-April), generally compelled the farmers to supplement the canal water with well water. The present method of giving water in alternate years to farmers based on odd and even turn systems also induced the farmers to exploit groundwater to irrigate the crops mainly in the non-turn year, when the canal supply is not available at all. Instead of depending on the rainfall to take one rain-fed crop, farmers switched to dry crops irrigated with well water.

**Crop scheduling**

The soil characteristics, the traditional agronomic practices, the seasonal conditions and the price structures in the market mainly decide the cropping pattern in a command.

Farmers usually give priority to growing their own food and only thereafter think of other crops for marketing. Many cases in the South have shown that farmers resort to rice cropping whether the soil is suitable or not once they are assured of irrigation. This upsets the design parameters of many irrigation schemes where irrigated dry crops were proposed resulting in modifications in the water scheduling. The Lower Bhavani Project and the Parambikulam Aliyar Project in Tamil Nadu State are examples of these schemes.

In the Lower Bhavani Project Command area, water is released in alternate years to a rice crop and a peanut crop. When there is no water, farmers with groundwater resources opt for sugarcane, turmeric, cotton and other crops.

A study conducted at the Agricultural Research Station, Bhavanisagar on four cropping sequences in a red sandy loam soil during 1984-85, showed that a rice-based sequence with sesame, pearl millet, turmeric, and cotton gave the highest net profit (US$2,998) with a cost benefit ratio of 1:15 (Table 2). This sequence could increase productivity in the region by 174 percent. It would reduce water use for the 2-year period from 482 cm to 411 cm.
**Table 2.** Two-year rice-based cropping system yield, water consumption and net return, Bhavanisagar, India, 1984-85.

<table>
<thead>
<tr>
<th>Crop sequence and yield (t/ha)</th>
<th>Net return (US$)</th>
<th>Cost benefit ratio</th>
<th>Water consumption (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Rice (3.6)</td>
<td>Peanut (1.52)</td>
<td>Sesame (0.07)</td>
<td>Rice (3.4)</td>
</tr>
<tr>
<td>2. Rice (3.6)</td>
<td>Sugarcane (105.9)</td>
<td>Sesame (0.58)</td>
<td>Peanut (1.52)</td>
</tr>
<tr>
<td>3. Rice (3.4)</td>
<td>Sesame (0.71)</td>
<td>Pearl Millet (2.78)</td>
<td>Turmeric (16.76)</td>
</tr>
<tr>
<td>4. Rice (3.6)</td>
<td>Sesame (0.72)</td>
<td>Pearl Millet (2.86)</td>
<td>Turmeric (15.76)</td>
</tr>
</tbody>
</table>

**DIRECTION OF RESEARCH AND DEVELOPMENT ON CROP DIVERSIFICATION**

Numerous research projects related to crop diversification are already being conducted at institutions like the Indian Council for Agricultural Research (ICAR), and agricultural universities. However, there is no coordination between these institutions and the irrigation management authorities to implement the research findings. The universities and research institutes should be involved in irrigated crop diversification research which should be multidisciplinary and drawing inputs from engineers, crop scientists, soil scientists and socioeconomists.

The multidisciplinary teams that are formed at different institutes may form a national network of crop diversification research with a coordination committee composed of representatives from the individual research teams as well as from government implementing agencies. National and international agencies may fund the research.
Multidisciplinary teams in selected command areas under each agroclimatic zone should undertake a detailed diagnostic analysis to be able to define and prioritize the problems. This is possible through the coordinated effort of the staff of the agricultural universities. The Irrigation Management Training Institute could coordinate and guide the entire process. Research should include action research, adaptive trials, and systematic programs for technology transfer. The selection of crops, which could be suitable substitutes in rice-based irrigation systems, can be done on the basis of: a) agroclimatic requirements; b) higher efficiency of irrigation; c) increased returns per unit of land and water; d) marketing facilities; and e) availability and future prospects of allied agro-industries.

Action and adaptive researches may be conducted in demonstration farms and farmers’ fields. The research may be conducted for 5 years. Funding required to carry out the research has to be calculated after its scope is defined in more detail. This will depend on the location, alternate crops and cropping systems, number and size of demonstration sites, etc. To meet the recurring expenditure, agencies like USAID, World Bank, etc., may be tapped in addition to the existing funding agencies.

SUMMARY

India attained self-sufficiency in rice during the early 1970s with the introduction of high yielding varieties and extension of irrigation facilities. This success, however, resulted in declining farmers’ incomes and hence they started diversifying their cropping systems to nonrice crops, which required changes in planning, water allocation, operation and maintenance. The management changes need consideration of water control, agronomic and irrigation practices, economic risks, inputs, climatic requirements, socioeconomic constraints and institutional strengths. In order to address the above factors, strategies will have to be identified by undertaking research on policy changes, implementation and technical solutions to specific constraints by ICAR institutions, agricultural universities and water and land management institutes in the country. For carrying out the research, necessary funding may be sought from agencies like USAID, World Bank, etc.
References


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INTRODUCTION

The contribution of the irrigation sector to agricultural development in Indonesia is significant. Irrigation does not merely stabilize and increase crop yield but also induces farmers to adopt improved cultural practices. Moreover, with sufficient water, farmers are able to use more production inputs, practice double cropping and crop diversification. Final evidence of the impact of irrigation development on food production is shown in Table 1, Figure 1, and Figure 2.

With respect to the issue of crop diversification program in irrigated rice fields, technically it may not create a big problem to the existing irrigation systems. Irrigation systems in Indonesia have been planned, designed, and operated to irrigate diversified crops since the colonization of the country. Therefore, the promotion of crop diversification is just like restoring the existing systems to their intended functions and operations (van der Elst 1924; Anonymous 1986).

In diversifying crops in irrigated rice fields, three benefits are expected from the irrigation aspect. First, the pressure on operation and maintenance (O&M) of the system during the dry season when water shortages commonly occur can be eliminated. Second, the implementation of the O&M program can be carried out according to a legal basis in any particular area. The last benefit is the prolonging of the functional life of structures, decreasing the burden on the government in providing O&M cost.

From the standpoint of the agricultural development program, crop diversification (both vertically and horizontally) has been chosen by the Department of Agriculture (the Direc-
General of Food Crop Agriculture (DGFCAG) as one among four basic strategies to achieve the objectives of a) sustaining and improving food self-sufficiency; b) increasing the agricultural production in order to provide raw materials for industry and export; c) increasing farm productivity and value added of agricultural products; and d) increasing farmers' income as well as their welfare (Wardojo 1989).

Table 1. Areas harvested andields of lowland rice, maize and soybean, 1983-88.

<table>
<thead>
<tr>
<th>Year</th>
<th>IA ('000 ha)</th>
<th>RCT (%)</th>
<th>Rice</th>
<th>Maize</th>
<th>Soybean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IA (ha)</td>
<td>Yield (t/ha)</td>
<td>HA (ha)</td>
<td>Yield (t/ha)</td>
<td>HA (ha)</td>
</tr>
<tr>
<td>1983</td>
<td>4,238</td>
<td>7,987</td>
<td>4.17</td>
<td>3,002</td>
<td>1.69</td>
</tr>
<tr>
<td>1984</td>
<td>4,322</td>
<td>8,547</td>
<td>4.21</td>
<td>3,086</td>
<td>1.71</td>
</tr>
<tr>
<td>1985</td>
<td>4,329</td>
<td>8,756</td>
<td>4.23</td>
<td>2,940</td>
<td>1.77</td>
</tr>
<tr>
<td>1986</td>
<td>4,335</td>
<td>8,888</td>
<td>4.25</td>
<td>3,143</td>
<td>1.88</td>
</tr>
<tr>
<td>1987</td>
<td>4,354</td>
<td>8,796</td>
<td>4.32</td>
<td>2,626</td>
<td>1.96</td>
</tr>
<tr>
<td>1988</td>
<td>4,388</td>
<td>a</td>
<td>4.33</td>
<td>3,406</td>
<td>1.95</td>
</tr>
</tbody>
</table>

Notes: IA = Total irrigated area.
RCT = Percent of irrigated area with three rice crops/year.
HA = Harvested area.
a = No data available for harvested area of lowland rice.


Various initiatives have been made by the Department of Agriculture in an effort to promote the crop diversification program. Considering that unstable prices of food crop commodities (except that of rice) became the main constraint in the promotion, a regulation on pricing policy for maize was drawn up in 1978. In the following year (1979), another pricing policy was drawn up for soybean, groundnut, and mungbean. To make the efforts more effective, 17 provinces have been designated as centers for the upland crops intensification program. Three provinces have adequate irrigation facilities. Within the province, the intensification area is decided every year by a decree from the Minister of Agriculture (Pabinru 1990). The total areas of upland crops for 1988/1989 cropping season were: 1,833,400 ha of corn, 716,000 ha of soybean, 338,000 ha of groundnut, and 136,700 ha of mungbean. Recently, because of their high economic values, shallot and onion were also included in the intensification program.
Figure 1. Development of irrigated and harvested areas (in M ha).

<table>
<thead>
<tr>
<th>Year</th>
<th>Rice</th>
<th>Maize</th>
<th>Soybean</th>
<th>Groundnut</th>
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<tr>
<td>1969</td>
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<td>1988</td>
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</table>
Practices in Rice Irrigation Systems

Three basic principles are attached to all aspects of irrigation practices in Indonesia. These three principles are: a) the status of supplemental irrigation; b) sharing of responsibility between the government and the farmers (groups of farmers) as beneficiaries to ensure uninterrupted operation of irrigation networks, and operation and maintenance of the systems; and c) appropriateness of water utilization for the diversified crop. To ensure the application of the three principles in daily irrigation practices, a number of laws/instructions have been promulgated: a) Water Resources Development Law No. 11 of 1974; b) Government Regulation and Contribution for Operation and Maintenance Cost for Water Resource Development Infrastructure (No. 6 of 1981); c) Government Regulation on Water Management (No. 22 of 1984); d) Government Regulation on Irrigation (No. 23 of 1984); e) President Instruction on Implementation Guidance of Water Users’ Association (P3A) and Management; and f) Decree, Letter, or Regulation issued by the Local Government.

Planning for the cropping season

Planning for the cropping season is determined by Articles 7, 8, 10, 12 and 13 of Government Regulation (GR) No. 23/1984. These deal, among others, with the following:

1. Planning for cropping season and irrigation season which shall be done not later than one month before the beginning of cultivation season in every irrigation area.
2. Determining tertiary units which will receive water throughout the year (only in the rainy season), and those which will receive water only in the dry season: this includes their location, boundaries, and size specification of each village.
3. Assigning the area for a specific agricultural program, industrial crops, and 2 other specific uses corresponding to the assigned status of the area with respect to the irrigation plan.
4. Determining the time schedule of the partial irrigation for inspection and repair.
5. Establishing general rules of water allocation and distribution in case irrigation water is not sufficient to meet crop requirements.
6. Establishing water allocations for other uses, such as for sugarcane industry, domestic use, etc.

Planning for the cropping season in every region (province and district) is conducted by the corresponding Irrigation Committee, chaired by the Head of the Local Government. The representative of the Irrigation Agency in the respective areas is the treasurer of the Irrigation Committee, and all related agencies (especially Agricultural Food Crop Agency) involved in irrigation are the members. The plan is submitted by the Irrigation Committee to the Local
Government which promulgates the Local Government Regulation for cropping pattern, cropping season, and irrigation season in the respective areas.

The inputs used in the planning are: weather data (especially rainfall) and river discharge after having been evaluated for their dependability, calculated irrigation requirement based on cropping season and irrigation season in the respective areas. Other information on the government’s policy on the changes of cropping areas and crop priority, and the existing physical condition of the irrigation canal are also considered in the planning.

The plan is good for one year only. It is called the General Cropping Season Plan (GCSP). In the implementation of GCSP, various adjustments may have to be made to cope with the prevailing rainfall, the availability of water or river discharge, and the existing crop at the beginning of the cropping season. The degree of adjustment most likely depends on the accuracy of planning.

**Assessing and matching water supply and demand**

The basis for the operation of irrigation systems in Indonesia is the monthly dependable rainfall and flow (80% probable). The assessment of water supply to match the demand is influenced (to some extent) by experience and intuition of the local Irrigation Committee or irrigation personnel. There is no fixed rule and regulation dealing with this matter. However, some guidelines are available: a) A rough comparison between the requirement of rice (lowland), sugarcane, and upland crops as 4:1 and 1:2:1; b) Some basic values of water requirement of rice for 1/2 months of land preparation (1.16 l/s), 2/2 months of flowering (1.00 l/s), and 1/2 month of ripening (0.62 l/s). Water requirement for sugarcane is calculated proportionally with the value for rice; c) Tertiary losses are 20-35 percent and main canal losses range from 10-15 percent; d) Minimum areas which have to be reserved for the special program on crop intensification, or industrial crops (sugarcane and tobacco) (Sutiyadi 1986). When the irrigated area is quite large (5,000–10,000 ha), matching water supply at the beginning of the rainy season with peak demand for land preparation can be achieved by dividing the area into 3-4 blocks for irrigation. The establishment of an irrigation status in any particular area during one irrigation season, and prioritizing water utilization for the irrigating crop (Articles 10 and 11 of Government Regulation No. 23/1982) reflect the effort to match the potential supply and the demand for irrigation.

**Allocation of water and land area**

The allocation of water and land area under the current irrigation practice is rather complicated. Water allocation is updated after a certain period of time, normally 7 days (one week), or 10 days, or 15 days (two weeks). The time interval for updating water allocation is determined by the available flow discharge, the existing crops in the command area, and the adopted system in the irrigation scheme. An example of a 1s-day-basis water allocation practice is shown in Figure 3.
Figure 3. Operation of water allocation based on 15-day updating interval.

*This meeting is held on the 15th and the last day of every month and is attended by the Irrigation Supervisor/Staff, Irrigation Inspector, Weir Keeper and Head of Farmers.
Figure 3 reflects the involvement of farmers in the decision-making process, although they only provide the cropping area for the different crops. Other data which are required in updating the water allocation plan are: a) planned crop area \((F01)\) data; b) river discharge report \((F05)\) data; c) the calculated crop water requirement at tertiary offtake \((F03)\); and d) the calculated \(K\) factor. The \(K\) factor is calculated as:

\[
K = \frac{(Q_a - Q_b)}{Q_c} \quad (1)
\]

where

- \(Q_a\) is the available discharge,
- \(Q_b\) is the sum of water losses and supplemental discharge, and
- \(Q_c\) is the discharge at the tertiary offtake.

\(Q_a\) is calculated as:

\[
Q_a = \frac{(Q_5 + Q_{10} + Q_3)}{3} - (Q_{13} - Q_5) \text{ l/s} \quad (2)
\]

where

- \(Q_5\) is the average discharge from the 1st to the 5th day of operation,
- \(Q_{10}\) is the average discharge from 1st to the 10th day of operation, and
- \(Q_{13}\) is the discharge on the 13th day of operation.

In most cases, in the allocation of water and land area the following factors are also considered: a) the acceptable level of irrigation efficiency; b) the maximum capacity of conveyance and distribution canals to supply water at peak demand; c) canal safety with respect to the possibility of having high sedimentation rate and canal bank protection from damages due to overdried condition; d) opportunity to grow more rice in the whole area; and e) the existing crop at the beginning of the cropping and irrigation seasons. The areas of a special agricultural program are given priority in land and water allocation.

In some irrigated areas where sugarcane is historically planted, the allocation of water and land still follows the colonization rule. In these areas, one-third of the command area is assigned for sugarcane. The sugarcane area is rotated in the whole command. Consequently, the allocation of water and land area for sugarcane is more likely to be fixed. In an attempt to increase the cropping intensity of irrigated ricefields, the Government of Indonesia has started shifting the sugarcane cultivation to the upland (unirrigated area).

**Coping with various water availability situations**

The Government Regulation No. 23 of 1984 gives the general rules for coping with various water shortage situations. It states that:

1. The Local Government may establish the priority of irrigation water distribution in accordance with the local situation and condition (Article No. 13(2)).

2. To prevent crop failure, irrigation water shall be assured for already existing crops. When necessary, distribution of irrigation water may be reduced or rotated among tertiary units (Article No. 13(3)).

3. To meet the needs of industrial crops and food crops simultaneously, the water use may be regulated in rotation on the basis of the decision of the relevant Governor (Head of the Local Government) (Article No. 19(2)). Rotational irrigation will be carried out when the normal discharge \((Q_n)\) is less than 60 percent.
**Modified practices to accommodate nonrice crops**

In principle, it may not be necessary to make major changes in the current irrigation practices to accommodate nonrice crops. If minor modifications would be required, they must be supported by a well-coordinated development program. The program should not only be concerned with the technical aspects of irrigation and agronomic practices, but also with the influence of the socioeconomic changes as affected by adopting the new technology. These minor adjustments of the irrigation system management in Indonesia may take a long time.

The most likely modifications or improvements required to provide a better service for nonrice crop cultivation are: a) improving the drainage facilities, especially in the tertiary system; b) improving the accuracy of predicting the possible rainfall and river water discharge; and c) providing data on crop water requirements of upland crops.

**CONSTRAINTS/OPPORTUNITIES IN IMPLEMENTING MANAGEMENT CHANGES**

As mentioned earlier, the existing irrigation systems have been planned, designed, and operated to provide for diversified cropping. Accordingly, any necessary management changes in the irrigation system will require only minor adjustments. These minor management changes can be related to the following:

1. The degradation of the catchment area due to deforestation and improper land use. High fluctuation of water discharge between rainy and dry seasons causes either water excess or water shortage in the command area.
2. The adoption of high yielding varieties (HYV) with shorter growing periods. This allows farmers to harvest the second rice crop at the beginning of the dry season. As rainfall occurrence at this transition period is very uncertain, farmers tend to be more speculative as regards cultivating the third rice crop. This creates a highly diversified cropping pattern in the irrigated area and water in the field becomes very difficult to maintain at an optimum condition.
3. Rice being the staple food, it is grown by the subsistence farmers at every possible opportunity.
4. The difficulty in marketing food commodities other than rice influences the willingness of farmers to change the farming system from rice monoculture to diversified crops.

Other minor problems result from: a) insufficient facilities to carry out operation and maintenance (O&M) properly; b) insufficient irrigation personnel in terms of number and capability; and c) more time needed by farmers to adopt the new technology for profitable diversified cropping. The high economic value of nonrice crops during the last five years favored crop diversification. If this situation can be maintained, the minor changes in the irrigation management could easily be overcome.
STRATEGIES TO ADDRESS CONSTRAINTS/OPPORTUNITIES

Improvement of Irrigation Facilities

During the four consecutive Five-Year Development Programs (Pelita 1968/69-1987/88), the improvement of irrigation facilities has focused on the rehabilitation of the existing irrigation systems and the development of new irrigation schemes. Massive funds were spent for this program as shown in Table 2. At the end of the Pelita IV (1983-1988), the Government shifted focus of irrigation development from construction to O&M. By focusing the program activity on O&M, the required funds for rehabilitation were reduced without adversely affecting maintenance and the service capability of the irrigation system. This policy of irrigation development has been continued in the Pelita V (1988/89-1993-94).

As regards crop diversification, irrigation development activity will be concentrated in the selected production centers identified by the Department of Agriculture, especially in Java. The reasons for selecting Java as a priority for irrigation development are: a) crop diversification needs more fertile soil than the monoculture rice crop; b) farmers are already accustomed to crop diversification in the ricefield areas; c) presence of better marketing facilities; and d) most irrigation systems were established a long time ago.

Table 2. Irrigation development plans, 1983/84-1986/87.

<table>
<thead>
<tr>
<th>Subject</th>
<th>1983/84</th>
<th>1984/85</th>
<th>1985/86</th>
<th>1986/87</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation development</td>
<td>587.4</td>
<td>658.3</td>
<td>529.6</td>
<td>394.2</td>
</tr>
<tr>
<td>Foreign assistance</td>
<td>203.3</td>
<td>285.9</td>
<td>209.1</td>
<td>227.6</td>
</tr>
<tr>
<td>Local funds</td>
<td>(32.9)</td>
<td>(46.7)</td>
<td>(46.4)</td>
<td>(40.6)</td>
</tr>
<tr>
<td>Physical development</td>
<td>1000 ha</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New irrigation schemes</td>
<td>34.6</td>
<td>60.2</td>
<td>124</td>
<td>24.7</td>
</tr>
<tr>
<td>Groundwater development</td>
<td>43.1</td>
<td>49.1</td>
<td>41.4</td>
<td>43.7</td>
</tr>
<tr>
<td>Rehabilitation work</td>
<td>146.1</td>
<td>208.9</td>
<td>114.1</td>
<td></td>
</tr>
<tr>
<td>Tertiary development</td>
<td>157.3</td>
<td>83.0</td>
<td>26.9</td>
<td>34.1</td>
</tr>
<tr>
<td>Swampy area development</td>
<td>46.4</td>
<td>48.0</td>
<td>54.4</td>
<td>4.8</td>
</tr>
<tr>
<td>Total</td>
<td>428.1</td>
<td>449.2</td>
<td>309.8</td>
<td>107.3</td>
</tr>
</tbody>
</table>

Strengthening Institutional and Managerial Capability

Aside from the physical improvement of irrigation facilities, the government launched several measures for improving the institutional aspects of O&M (DPU 1987). These improvements include: a) strengthening the organization of Water Resources Public Work Service (WRPWS - Dinas Pekerjaan Umum Pengairan) to enable a more effective, efficient and uniform implementation of the O&M plan; b) clarifying the right, authority, and responsibility of the agencies involved in the implementation of O&M; and c) enforcing the implementation of President Instruction No. 211984 on sharing of responsibility for O&M between the government and Water Users’ Associations, and the Government Regulation No. 2311982 on strengthening the function of the Irrigation Committee. Improving personnel management, developing a management information system (MIS) and a system for monitoring and evaluation of O&M are also relevant efforts on institutional improvement.

Improvement of Procedures and Practices

Various efforts have been made to improve irrigation management procedures and practices in diversified ricefield areas. Among these are:

System characterization and mapping

To implement the improvement program on the physical facilities of the irrigation system and to strengthen irrigation management, reliable system characterization and mapping are needed. These will show the physical characteristics of a system as regards the topography, hydrology, and soils, among others. Furthermore, the structural density and variability and the network pattern could be easily identified. In Indonesia, only the physical characteristics of the tertiary system have been intensively studied so far (Pusposutardjo 1989).

The irrigation system can be characterized according to its performance in distributing and supplying water over the command area. Sukirno (1989) characterized irrigation system performance in distributing water based on the water status of the command area. The water status at any particular time was classified as: a) suitable for lowland rice only; b) suitable for upland crops (nonrice crops) but needs irrigation for rice; and c) insufficient for growing any crop. The changes of water status with respect to time and area were monitored from the depth of the table. Theoretically, the method is able to characterize system capability especially in the coastal area. However, large-scale trials are still needed.

Improvement of the accuracy of planning

Studies have been conducted to improve the accuracy of planning for the cropping season and irrigation season. The studies covered the hydrological aspect of rainfall and the estimation of crop water requirement.
Hydrological studies of rainfall include the determination of the minimum number of rain gauges per unit area, and the prediction of the start of the rainy and dry seasons. Masruki (1987) and Hadiani (1989) concluded that one rain gauge was sufficient to cover one tertiary block with an accuracy of 90-95 percent (area of a tertiary block ranges from 100 ha to 150 ha). For hilly areas or in inland areas, the accuracy would slightly decrease especially during the transition seasons.

Another study related to rainfall showed that 300-400 mm of cumulative rainfall accounted for the driest days at the beginning of the rainy season could be used as the time of the beginning of the cropping season (Anonymous 1986). Provided 15 years of serial rainfall data are available, this cumulative rainfall could be predicted by extrapolating its variogram value (Hadiani 1989).

Studies on crop water requirement have been conducted in several irrigation schemes, from areas of 700-800 m elevation down to coastal areas. In addition to estimating crop water requirements of different H-W of rice and nonrice crops, the assessment of suitable methods for estimating crop water requirement under limited available data was also done. Results from these studies were compiled by Pusposutardjo (1986) and submitted to the Directorate General for Water Resources Development (DGWRD) for use in irrigation practice. Other studies on crop water requirement were also conducted by Syamsiah and Fagi (1986) for mungbean, Sukirno et al. (1986) for rice, corn, mungbean and peanut, Hermantoro (1985) and Syamsuddin (1985) for stringbean and red pepper. Studies on crop water requirement of other crops are still continuing.

**Simulation and modeling**

Taking advantage of the availability of computers, several crop yield-water use models have been developed. Three models have been tested for their application in planning the cropping season and in predicting the effect of water shortage in the command area. These models are:

1. **CRPSM** (Crop Yield Simulation Model) developed by DAE/GMU in 1982. This model is continuously being improved and at present has the capability to handle a crop yield-water userelationship of 11 upland (nonrice) crops (Pusposutardjo 1990). RADYM (Random Simulation Model) developed from CRPSM has the capability to simulate the most possible planting date of crop, with minimum water requirement.

2. **AGWAT** (Agricultural Water Demand) developed by the Institute of Hydraulic Engineering, DGWRD (Suryadi et al. 1989). The model was developed to predict agricultural water demand in a large area of a water resources development project. By integrating AGWAT model with another model (RIBASIM) it could be used to study the impact of actual water supply on agriculture in the Cisadane-Cinamuk Integrated Water Resources Development Project (Hatmoko et al. 1990).

3. The latest model, the **Rice** Yield Model as Affected by Excessive Water developed by Arif (1989). This model is still new and intended for irrigated rice in areas with potential excess water problem. With a little modification this model might also be used for other crops.
Farmer participation

A pilot project on irrigation development using the farmer participatory approach was carried out in Madin irrigation project from 1983 to 1987. The objective of the project was to study the farmer participation process in irrigation development. Lessons from the project would be very useful in developing a strategy for involving farmers in irrigation development programs. The involvement of farmers in irrigation development enhances their sense of belonging which could result in a smooth turnover of the system to them.

DIRECTION OF IRRIGATION MANAGEMENT FOR CROP DIVERSIFICATION

Research and Development

Minor problems in irrigation management for crop diversification can be considered as associated problems in the technology transfer process of farming and irrigation practices. In this case, technology transfer means a process of translating ideas into action. The process comprises a series of activities, which are interconnected and represent the contribution of agencies involved in the process (Holt 1988).

Adopting the concept of technology transfer, the basic strategy to solve the minor problems in water management for crop diversification by a) defining the steps for achieving the objectives; b) the responsibility of each agency and its expected role in every step of the process; and c) the linkage between agencies. At present, the settlement of minor problems in irrigation management for crop diversification is far removed from the basic strategy of technology transfer. Most personnel in the agencies involved in the crop diversification programs and irrigation management do not realize that these minor problems are deeply rooted in the complicated interaction between technical, economic, and social aspects of the farming system as a whole. The diagram of technology transfer is shown in Figure 4.

Observations on research activities dealing with irrigation management improvement indicate that the linkage mechanism between researchers, researchers and the agencies as interested parties and between the involved agencies, is the weakest line in technology transfer. Because of the poor linkage, many research findings in irrigation management seemed unutilized.

Garret (1985) and Hess (1985) pointed out several benefits from good linkage with research. These are: a) avoiding the possible conflict of interest (in terms of financial, material, academic status, promotion, or prestige); b) having the same perception on the importance of the problems and their expected contribution in solving the problem; and c) effective and efficient use of the available resource. Technology transfer shows that a close linkage among agencies should not only be in the implementation of the program planned, but should start from the earliest step in the planning process.
Fig. 4. Framework of technology transfer in irrigation management.

These steps of activities are still missing.
Considering that problems in irrigation management for crop diversification cover various technical, economic, and social issues, the suggested steps to address the problems could be as follows:

1. Establishing the framework of technology transfer process in irrigation management improvement, starting from basic research until the utilization of the new technology.
2. Establishing the institutional linkages on a basis which can accommodate partnership and cooperation.
3. Establishing a definite workplan covering at least a 3-5-year program.

An initial research activity could be a one-year program on the inventory, review, and documentation of the previous research. If time allows, the activity can pursue the screening of promising research finding. In the second year, a coordinated research program on the various steps of technology transfer could be started.

**Funding**

Funds available for conducting research in irrigation management improvement are very limited. Without a well-planned program, and well-structured implementation, it may be difficult to achieve the objectives of the research. Based on similarities in irrigation management practices and problems, a regional collaboration would be helpful to address the funding problem. In conjunction with this, international sponsorship is required.

**SUMMARY**

Irrigation management problems of crop diversification in Indonesia are considered minor, because the existing irrigation systems have been developed and operated for diversified crops in ricefield areas. Although the problems are considered minor, they are very complicated in nature. These problems are deeply rooted in technical-socioeconomics interaction between irrigation management practice and the crop diversification farming system.

Great opportunities for developing crop diversification and improving irrigation management practice can be gained by having a well-planned program and well-structured implementation of research. An integrated approach in technology transfer is suggested for adoption. International sponsorship of regional collaboration in irrigation management development programs is required to address the funding problems.
References


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Management Arrangements for Diversifying Rice Irrigation Systems in Malaysia

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INTRODUCTION

The rice lands of Malaysia, totaling 0.6 M ha are broadly classified as either granary or nongranary areas. The granaries comprise 8 large and contiguous irrigation schemes, covering 210,000 ha and producing more than 65 percent of the country’s total output; and it is in these granaries that further development of rice production will be concentrated.

The nongranaries are either rain-fed or have been provided with irrigation facilities to ensure that they are cropped at least one season in a year. Following the review of the rice production policy and concurrent with agriculture diversification strategies, the non-granaries have been redesignated as diverse crop production areas in contrast to the granaries which are monocropped with rice.

In line with this decision, a feasibility study on crop diversification and rationalization was carried out under the Technical Cooperation Program between the governments of Japan and Malaysia (ANON 1990a). The study focused on the nongranary irrigated areas of Malaysia comprising 924 schemes, totaling 130,100 ha.
The purpose of this paper is to highlight results of the study and to outline current practices and issues related to rice-nonrice rotation in selected irrigation schemes originally designed and operated for rice cultivation.

SCHEME CHARACTERISTICS

The nongranary irrigated schemes are scattered all over the country (Figure 1) and their sizes vary from less than 50 ha to over 200 ha. They are located along and adjacent to the main river systems and thus share the same water resource within the catchment. The soil textures in more than 60 percent of the schemes are either heavy clay or clay. The type of schemes are either gravity, pumping, inundation, controlled drainage or a combination of these. More than 73 percent are either gravity or pumping or a combination of the two.

DESIGN CRITERIA

Depending on the scheme size, canal density varies from 20 to 60 m/ha. A farm offtake is provided for every 4 to 12 ha of farm lot. Canal capacity ranges from 0.9 to 2.4 l/s. For pumping schemes, operation time is usually over a period of 8-16 hours daily. Water distribution is rotational and on-fami from field-to-field.

The drainage system is designed to remove excess water and flood within 48 hours for total submergence and 72 hours for partial submergence. A 3-day rainfall duration for 1 in 5 years return interval is used for the design giving flows of about 91/s. Drain density ranges from 1 to 20 m/ha and one drainage offtake serves between 4 to 12 ha.

CURRENT STATUS

One of the major problems of rice areas is underutilization. Out of the 924 irrigation schemes, 305 (91,000 ha) are completely idle and in another 250 schemes (34,000 ha) more than 50 percent of their irriagable areas are not utilized during the main season. Factors leading to such situations are many and interconnected. Uneconomic farm holdings, labor shortage, aging rice farmers, difficulties in mechanization, inadequate water resources due to development, low productivity and low remuneration from rice are some examples of these factors. The incidence mechanism of idlr land is illustrated in Figure 2. In some areas, in order to overcome these problems, farmers, either on their own initiative or assisted by the government, have started to practice diverse crop production instead of the traditional rice
Figure 1. General location and distribution of irrigated rice areas in Malaysia.

Figure 2. Incidence mechanism of idle land.

monocropping. However, the extent is still small and up to 1987 only 6 percent of the total irrigated areas have been diversified. Nonetheless, indications are that farmers have adopted appropriate technology and this trend is increasing. With the current government emphasis and support, it is anticipated that diversification of other rice areas will be accelerated.

CROP DIVERSIFICATION

Crop diversification of the irrigation schemes in Malaysia takes a broad definition covering changes in seasonal and annual cropping pattern, multiple cropping, conversion to permanent tree crops, mixed farming inclusive of livestock rearing and aquaculture but not totally eliminating rice production where it can be shown that this is still the best choice.

In this context, the study has established 8 categories of diversified land-use of the existing irrigation schemes as shown in Table 1.

Table 1. Categories of diversified land use in non-granary irrigation schemes

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Converted to high value crops (e.g. vegetables, tobacco)</td>
</tr>
<tr>
<td>2</td>
<td>Converted to tree crops (e.g. oil palm, fruits)</td>
</tr>
<tr>
<td>3</td>
<td>Rice-Upland crop rotation</td>
</tr>
<tr>
<td>4</td>
<td>Grazing/Livestock rearing</td>
</tr>
<tr>
<td>5</td>
<td>Aquaculture</td>
</tr>
<tr>
<td>6</td>
<td>Positively maintained for rice</td>
</tr>
<tr>
<td>7</td>
<td>Present situation maintained for social reasons until predetermined period for review</td>
</tr>
<tr>
<td>8</td>
<td>Converted to housing</td>
</tr>
</tbody>
</table>

As can be seen, Category 3, where rice-upland crop rotation is proposed, fits the IMCD Research Network’s general definition of diversified cropping in rice-based systems.

The categorization procedure is based on 7 key factors: water resources availability, farmers’ intentions towards rice cultivation and diversification, land suitability, soil suitability, crop profitability, crop marketability and investment performance.

Using data obtained from the inventory survey and the socioeconomic survey, each scheme was evaluated on a step-wise procedure and its category identified. The procedure was repeated for various possibilities pertaining to the key factors such as profitability of crops and the best category; the one with the highest investment performance is termed the super category. The distribution of super category by number of schemes and area is shown in Table 2. None of the schemes under livestock and aquaculture categories was classified as super, primarily because of poor profitability and marketability.
A study on selected schemes to evaluate the feasibility of Categories 1, 2 and 3 was also carried out as these require some form of physical structural and non-structural adjustments to the existing system. In all cases, the feasibility was found to be positive. It is interesting to note that for Category 1 where conversion to high-value crop is proposed, the study recommended that this be introduced gradually by initially implementing Category 3. This is to allow time for the traditional rice farmers and system operators to adapt themselves as well as adopt appropriate technology for the change in cultivation system. Thus the potential of crop diversification based on Category 3 has increased to 193 schemes totaling almost 20,000 hectares.

**Table 2. Distribution of super category by number of schemes for each category of land use and total area.**

<table>
<thead>
<tr>
<th>Category of diversified land use</th>
<th>Number of schemes</th>
<th>Total area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>144</td>
<td>10,167</td>
</tr>
<tr>
<td>2</td>
<td>333</td>
<td>39,899</td>
</tr>
<tr>
<td>3</td>
<td>47</td>
<td>9,665</td>
</tr>
<tr>
<td>4</td>
<td>~</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>~</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>74</td>
<td>40,973</td>
</tr>
<tr>
<td>7</td>
<td>172</td>
<td>23,363</td>
</tr>
<tr>
<td>8</td>
<td>154</td>
<td>8,303</td>
</tr>
</tbody>
</table>

*See Table 1.

**Sources:**
*Government of Malaysia (1990).*
*Estimated from irrigation database (Department of Irrigation and Drainage, Malaysia).*

In general, Category 3 schemes are those with inadequate water resources for rice during the dry season but enough for upland crops. The farmers here are willing to diversify production, the land arid soils are suitable for nonrice crops and profitability, marketability as well as investment performance are shown to be positive.

**CASE STUDY AREAS**

Focusing on Category 3, salient features of its successful implementation and current practices with potential for adoption in future projects are summarized. These were based
mainly on case studies of three schemes, namely, the Bachaug Irrigation Scheme in Malacca State in the South-West, and Bendang Kekabu and Bendang Pauh both in the State of Kelantan in the North East of Peninsular Malaysia.

**Bachang Irrigation Scheme**

This is a pumping scheme with a single earth main canal constructed in 1950. Water source is the Malacca River. Besides the pumping station, a control drop, a check structure and several offtakes form the complete system. The system commands 140 ha of rice land. It is operated and maintained by the Department of Irrigation and Drainage (DID). Water supply is generally reliable with the occasional low flows during the dry season. Between 1985 and 1989, only 72 ha remained under rice. Of the balance, 45 ha were devoted to asparagus, tobacco, melon and vegetables. Those planting these upland crops still include rice in their rotation although not in an alternating sequence. The development of crop diversification was initiated by the farmers themselves. Most are third generation farmers and have formed a loose form of cooperative association.

**Bendang Kekabu and Bendang Pauh Irrigation Schemes**

Although the schemes are in different locations within the State of Kelantan, there are many common features. Both are groundwater pumping schemes. Bendang Kekabu was completed in 1989 and Bendang Pauh in 1986. The water yield is said to be good but supply is limited by the pump capacities running at the maximum of 70 l/s. The conveyance canal uses precast U-shaped concrete sections each ranging from 3.7 m to 4.5 m in length. The cross-sectional dimensions range from 0.3 m width by 0.3 m depth to 0.92 m width by 0.92 m depth. The minimum bed level is set so that the whole storage in the canal can be discharged by gravity into the fanns. To cater for head losses and command, the canal sections towards the pumping source have to be elevated above the ground level. Concrete boxes are provided at junctions and changes in flow directions. Both systems were designed and constructed by the DID based on supplementary rice irrigation requirements during the main season.

The rice-tobacco rotation is practiced in Bendang Kekabu scheme (ANON 1990b). The system construction was financed by the National Tobacco Board (NTB) which also organized farmers for tobacco cultivation and marketing channels. The operation and maintenance costs are borne by the farmers themselves through deductions during sale of produce.

In the Bendang Pauh Scheme, rice-tobacco-vegetable rotation is practiced. Rice is planted over 50 ha and the tobacco and vegetables, over 8 ha. Group farming is organized by the local Area Farmers’ Association. Extent of tobacco growing is controlled by the NTB by a quota system while vegetable growing is governed by prenegotiated contracts.
Other Schemes

Other schemes considered in formulating generalities and salient features of crop diversification are the Tanjung Minyak Scheme in Malacca, the Kampung Kijang Badang in Kelantan and the Pinang Tunggal in Penang.

SALIENT FEATURES OF RICE-UPLAND CROP ROTATION IN IRRIGATION SCHEMES

Towards formulating system planning and implementation criteria for crop diversification projects in other areas, the following features of current practices are summarized.

Farmer Organization Models and Institutional Support

Farming objectives are commercially oriented. Farmers either have an informal yet cohesive organization, or are organized in groups led by government agencies such as the NTB, Area Farmer’s Association and the Department of Agriculture (DOA). Existing agricultural support services provided by the Ministry of Agriculture and its agencies are still necessary. Technology development and transfer are through lead and resourceful farmers as well as through the Malaysian Agriculture Research and Development Institute (MARDI) and extension services of the DOA. The Federal Agriculture Marketing Authority (FAMA) assists whenever necessary in securing marketing outlets.

Crop Choice

Profitability and marketability are important factors for crop selection (Rabman et al., 1990). Rice is maintained in the rotation because of upland crop sensitivity to waterlogged conditions and rain drop damage during the rainy season. Another reason is that the cultural practice requiring flooded field conditions helps to control weed, remove diseases and pathogens in the soil.

Location and Extent

Diversified cropping areas are located adjacent to water sources such as canals and drains and where farms are contiguous. Soil texture ranges from sandy loam to clay loam with clay content not exceeding 40 percent and the farm elevation ranges from 0.3 m to 1 m above surrounding rice fields to reduce risk of waterlogging or flooding conditions. Water supply
reliability controls the extent of diversification within an irrigation scheme. Predetermined production targets to ensure profitability and a reasonable market is another limiting factor.

**On-Farm Adjustments**

The upland crops are planted on raised beds in order to improve drainage conditions in the root zone. To complement canal and drain storage, farm ponds have been constructed in some areas where short-term but frequent droughts occur. Where possible, shallow groundwater wells have also been developed.

Water distribution to farm plots is through farm ditches connected to farm offtakes. Being nonpermanent and crudely constructed, water loss from these ditches due to leakage, seepage and overtopping can be high. Reconstruction after the rice season and subsequent maintenance are a potential source of conflicts between farmers since the ditches need to pass through lands belonging to different owners. There is a need therefore for formal construction of these on-farm distribution systems, especially where crop type and water requirement schedules differ between farms.

In some cases, farmers have resorted to constructing their own pipe system or the use of collapsible hoses. However, portable pumps are necessary to account for the hydraulic head losses.

**On-Farm Irrigation Practices**

Furrow and basin irrigation methods are quite common. For furrows, water is diverted from the head ditch by blocking the flow with earth. Three furrows are irrigated simultaneously. Supply is cutoff when the water level at the end of the furrow is 100 mm below the top of the bed.

For the basin irrigation method, water is allowed to pond within the plot boundary to a level 100 mm below the top of the ridges. The water is then left to stagnate for about 2 hours before being released. Alternatively, it is left overnight to allow complete infiltration into the soil.

For light irrigation just after planting, a portable single nozzle sprayer attached to the end of a flexible hose is also used. With pumps becoming a standard equipment for the individual farmer, sprinkler and drip irrigation are becoming popular. Although their capital cost is higher, it provides flexibility for water management, thus stabilizing production.

Irrigation intervals vary between 4 and 6 days. The decision to irrigate is based on visual and physical inspection of the soil moisture conditions and leaf turgidity. Morning wilt in tobacco leaves is indicative of water stress situation. For some vegetable farmers, irrigation is provided daily except if it rains overnight.
Main System Adjustments

Water storage appears to be an important criterion. This allows instant water availability and lead time before the arrival from the main supply source. Some sections of the earth canals were deepened to increase storage capacity. For precast concrete canals, the construction is such that all water is available by gravity flow.

For farms situated close to canals and far away from the main drains, the canal full supply levels were purposely lowered out of command in order to facilitate drainage, although this necessitates the use of pumps for irrigation.

Operation and Maintenance

As for rice, rotational supply system is still practiced without adverse effects to the upland crop and negative reactions from farmers. Main pump operation is also maintained for periods of between 8 to 16 hours daily. However, it is reported that system operators need to operate control gates more often to regulate flows during peak demand periods.

Where farmers operate their own pumps or pay for the system maintenance, water management is improved since pumping is an added cost of production. In a way, system operators view this as an indirect cost of water to the farmers.

During drought, water supply is strictly controlled. The decision as to the time and duration of supply is made by the DID and farmers are duly forewarned. In the Bachang Scheme, the farmers then organize themselves by allocating a fixed period for pumping by each farmer. During the allocated time, usually 1 day, all pumps are loaned to that particular farmer.

General

On the whole, the present diversified schemes do not require major physical structural and nonstructural adjustments. There are 3 main reasons. First, the size and the total number of schemes involved are relatively small. Second, the area diversified within a scheme itself is small and judiciously located in relation to soil type, water availability, accessibility and topography. Third, the farmers are small in number, well-organized and continually supported by the government.

FUTURE DIRECTION AND RESEARCH NEEDS

Malaysia is fully committed to crop diversification in the nongranary areas. In the recent National Seminar on Crop Diversification (ANON 1990c), several conclusions that are reflective of future directions were made:
1. The broad policy framework now in existence for crop diversification needs to be translated into a more definitive implementation plan. The modus operandi has to be developed for specific situations.

2. Emphasis must be given to supportive activities such as planning, training, operation, farm credit, production and marketing. Marketing is particularly critical with respect to outlets and price stability.

3. The institutional framework to ensure or sustain farmers' participation needs to be carefully developed. The present inclination is towards central management systems or mini-estates. This seems to be a better approach as opposed to individual farming which is harder to organize and manage because of divergent views of individuals.

4. For long-term sustainability, continuing research and development in all areas are necessary.

The immediate plan is to implement a pilot project in Kulim Irrigation Scheme to convert 55 percent of the total irrigable area of 3,223 hectares for the cultivation of upland crops. The elements of research, monitoring and evaluation to be emphasized here include system design and management criteria, socioeconomic aspects of farmers' organizations and production technology. Meanwhile, MARDI continues to do research on component technologies related to upland crop production on rice lands. Examples of such research are water table management, suitable irrigation practices, techniques of on-farm water delivery, mechanization and agronomic practices. In research, development and implementation, there is already a close link between MARDI and DID.

CONCLUSION

The scale of current crop diversification on rice land in Malaysia is small. The impact on irrigation management is minimum. As such, for the moment, there is no monitoring and evaluation in the operation of the irrigation systems for diversified cropping. No major physical, structural and managerial adjustments have been imposed on the system but nevertheless crop diversification has been successfully practiced. Minor adjustments that were enforced and have potential application elsewhere include:

1. Reducing flow to below FSL so that a canal can function as a drain as well.
2. Deepening a canal to increase storage for pumping.
3. Acquiring portable pumps to provide flexibility in water management by farmers.
4. Having stable, reliable and predictable water supply to be augmented whenever necessary by farm ponds and tubewells at farm level.
5. Improving on-farm conveyance systems by using concrete-lined canals or pipe system and complementing with regulatory structures.
Irrigation system management will not be complex enough as to be restrictive to effective crop diversification if:

1. The scheme is small.
2. Crop diversification is on a small scale within a scheme.
3. Locational features preempt water management problems.

Malaysia is now gearing up for crop diversification on rice land. As this proceeds, complexities in irrigation management and production are expected to be encountered. The following strategies are to be adopted:

1. Identification of suitable schemes within the nongranary areas based upon water resource, physical condition, marketability, and agronomic and socioeconomic criteria.
2. Implementing pilot projects for representative schemes.
3. Coordinated multiagency implementation programs with strong participation of farmer’s associations in an integrated approach.
4. Research on, and development of system design and management, socioeconomic aspects of farmers’ organizations and production technology on rice land.
5. Collection of basic data and information to establish a comprehensive database on the nongranaries and rain-fed rice fields as the first step towards a master plan on crop diversification.
Acknowledgements

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References


66
Management Arrangements for Diversifying Rice Irrigation Systems in Nepal

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**INTRODUCTION**

Nepal is predominantly an agricultural country. Its geophysical and agroecological conditions vary considerably in many aspects which have direct and specific effects in the agricultural production systems. Approximately 18 percent of the total land area is under agricultural use while pasture lands account for about 14 percent. The agriculture sector employs more than 90 percent of the country’s economically active population. Livelihood is earned through farms and forests by almost 95 percent of the total population of 18M. Contribution to gross domestic product from the agriculture and allied sector is about 60 percent of the total national income.

The country’s 147,181 sq. km. land area is physiographically divided into three distinct agroecological zones, namely mountains and highhills, midhills (including valleys) and plains (Terai and Inner Terai). Agroclimatic and socioeconomic variations between and within the agroecological zones are considerably wide especially with respect to rainfall, temperature, soils and their fertility status, sunshine hours, topography (local terrains and terraces), agroinfrastructural facilities like irrigation, agricultural support (mainly credit), inputs (seeds, fertilizers, pesticides, agricultural tools and implements), storage facilities, markets and transportation. In order to make use of these varied situations and available facilities for the rational development of the country, it is divided into five development regions consisting of 14 administrative zones and 75 districts. As the development regions...
and physiographic and agroecological regions run perpendicular to each other, each development region consists of all three physiographic regions which provide equitable scope of all types of agro-based development. On the basis of these development regions, a specific development strategy has been adopted and the agricultural development activities are prioritized as follows:

<table>
<thead>
<tr>
<th>Region</th>
<th>Priority areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mountains/high hills</td>
<td>pastures and livestock development</td>
</tr>
<tr>
<td>2. Midhills</td>
<td>Fruits and forest development</td>
</tr>
<tr>
<td>3. Plains</td>
<td>Food grain development</td>
</tr>
</tbody>
</table>

Out of the total cultivable land area of about 2,641,000 ha almost 85 percent is used for food grain production. Rice ranks first in area (43%) and production followed by maize (22%) and wheat (15%). The remaining 20 percent of the cropped area is planted to cash crops such as oilseeds, pulses, potato, jute, sugarcane and tobacco. Yield of major food crops has not been increasing in all the agroecological zones (Fig. 1). However, some cash crops like sugarcane and potato have exhibited increased yields. These show that increasing agricultural production by improving the technology and infrastructural facilities has vast potential. However, problems do exist, which impede the realization of this potential.

**Problems in the Agriculture Sector**

Soil fertility has been deteriorating mainly due to erosion, imbalanced use of chemical fertilizer and nonreplacement of soil nutrients including organic matter. The latter problem is found to be more acute in the hills, where animal waste is also used for fuel purposes in domestic cooking.

Irrigated areas have increased steadily, but most of the irrigation is supplemented by rain during the monsoon season thereby causing acute water shortage during dry periods (winter and summer). It is estimated that only about 28 percent of the total cultivated area is at present under irrigation. Thus agriculture has remained dependent on rainfall, especially the monsoonal. In spite of these and other associated problems, the country's agricultural front appears to be marching ahead. Enhancing agricultural production through the adoption of innovative farming techniques including crop diversification.

**Rice-Based Farming Systems**

Rice is the predominant crop grown in the country but other crops are also grown during the dry season, following rice. In fact, this is not a new approach or innovation in Nepal. It has been in practice for several decades in most parts of the country. There are several reasons for diversified cropping practices. Some of the prominent ones can be enumerated as follows:
Figure 1. Average productivity of principal food crops, 1970-86, Nepal.

REFERENCE

R  Rice
M  Maize
M2  Millet
W  Wheat
B  Barley
RA  Region's Average
NA  Nepal's Average
M  Mountain
H  Hills
T  Terai
1. Almost all of the irrigation development works so far completed and/or nearing completion are rice-based and rainfall-supplemented.
2. Subsistence-level farmers cannot meet their needs from rice alone and hence adopt diversified farming practices.
3. Coarse grained rice generally yields greater output than fine grained and scented ones. But the former is not exportable and even domestic prices are low. However, the trend appears to be changing in recent years. Farmers, therefore, like to get higher yields from the coarse rice and rotate it with other crops.
4. The possibility of exporting high yielding rice being less and farmers’ option to grow high-value scented fine rice being limited. Diversification automatically follows when short-duration rice is grown.
5. Nepal’s rice lands mostly fall in the upland plateau (tars), Terai and Inner Terai plains, midhill valleys and river basins. These areas are climatically suitable for growing other crops including rice without disturbing the traditional rice fields. Hence, farmers naturally grow other crops for their needs and lands are not left fallow.
6. The returns from vegetables and other high value cash crops are more profitable than those from the traditional rice crops. The expenses incurred by the Nepalese farmers are mostly met through the earnings from their farms. Hence, the farmers’ choice to get more from their farms by diversified cropping.
7. Farmers’ movement from one place to another is difficult due to lack of means of transportation. Restricted and limited movement naturally compels farmers to grow all the food commodities required by them so that their needs are satisfied from their farm produce. This has given rise to subsistence farming practices.
8. Gradually expanding irrigated areas and innovative agricultural research and extension methodologies have also greatly helped farmers adopt diversified cropping in the rice-based irrigated as well as rain-fed areas.
9. Increased literacy among the village people and the introduction of agricultural courses in the high school curricula have helped the younger generation of farming communities to know more about cereals other than rice, and vegetables and their importance in their daily diet.

Sectors/Agencies Involved in Crop Diversification.

In general, farmers themselves are the principal agents involved in crop diversification as it has been an age-old practice in the country. However, systematic and organized government agencies involved in this program are the farming systems and research outreach divisions under the National Agricultural Research Committee (NARC) and various other crop commodity research programs including Pakhribas and Lumle Agriculture Centers. Agricultural Development Bank/Nepal (ADB/N) also participates in the program by providing loans to the farmers for diversified cropping in rice-based and other areas. Other foreign donor agencies engaged in the agricultural research and extension sector and rural and community development activities are directly or indirectly involved in helping farmers grow diversified crops with a view to modifying and improving the existing cropping practices.
<table>
<thead>
<tr>
<th>Project name</th>
<th>Present irrigated cropped area (ha)</th>
<th>Present NCA (ha)</th>
<th>Present water availability</th>
<th>Winter cropping</th>
<th>Spring cropping</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Kathmandu</td>
<td>5,000</td>
<td>3,000</td>
<td>Low</td>
<td>1,200</td>
<td>1,64</td>
</tr>
<tr>
<td>2. Mustang-Mining (EDRD)</td>
<td>64,000</td>
<td>4,000</td>
<td>Low</td>
<td>1,200</td>
<td>1,64</td>
</tr>
<tr>
<td>3. West Koski (Sepal: EDRD)</td>
<td>31,000</td>
<td>-</td>
<td>Adequate</td>
<td>1,200</td>
<td>-</td>
</tr>
<tr>
<td>4. Kumaun (Rupakot: EDRD)</td>
<td>25,000</td>
<td>-</td>
<td>Low</td>
<td>1,200</td>
<td>1,64</td>
</tr>
<tr>
<td>5. Janakpur (Katihari: EDRD)</td>
<td>5,200</td>
<td>-</td>
<td>Adequate</td>
<td>1,200</td>
<td>-</td>
</tr>
<tr>
<td>6. Narayani (Arjanpur: EDRD)</td>
<td>55,300</td>
<td>-</td>
<td>Adequate</td>
<td>1,200</td>
<td>-</td>
</tr>
<tr>
<td>7. Chitwan (Katuwewe: EDRD)</td>
<td>10,000</td>
<td>3,000</td>
<td>Low</td>
<td>1,200</td>
<td>1,64</td>
</tr>
<tr>
<td>8. West Garhwal (Nepal: WDRD)</td>
<td>15,600</td>
<td>6,000</td>
<td>Low</td>
<td>1,200</td>
<td>1,64</td>
</tr>
<tr>
<td>9. Bedma (Talhara: WDRD)</td>
<td>5,000</td>
<td>3,000</td>
<td>Adequate</td>
<td>1,200</td>
<td>1,64</td>
</tr>
<tr>
<td>10. Patrick (Kamalpur: WDRD)</td>
<td>2,13</td>
<td>3,000</td>
<td>Adequate</td>
<td>1,200</td>
<td>1,64</td>
</tr>
<tr>
<td>11. Mahendrapul (Kamalpur: WDRD)</td>
<td>5,200</td>
<td>3,000</td>
<td>Adequate</td>
<td>1,200</td>
<td>1,64</td>
</tr>
<tr>
<td>12. Rudra (Kamalpur: WDRD)</td>
<td>7,600</td>
<td>3,000</td>
<td>Adequate</td>
<td>1,200</td>
<td>1,64</td>
</tr>
</tbody>
</table>

Notes: YR = Year-round, ID = Intensive development, MS = Monsoon irrigation capacity, ED = Extensive development, CAD = Command area development, NCA = Net command area, CDR = Central development region, WDR = Western development region, FWDR = Far-Western development region, IP = Irrigation project, CI = Cropping intensity, EDR = Eastern development region.
IRRIGATION PLANNING AND OPERATION FOR RICE-BASED SYSTEM

Table 2 shows the present status, potential and possibilities of crop diversification, especially in the large irrigation project areas of the country. As explained in the table, the area under the large irrigation projects has been classified as year-round. Other classifications indicate intensive development, monsoon irrigated, extensive development, command area development, etc. All of these projects are located in the Terai plains where rice is a base crop but the growing of crops other than rice during winter and spring is possible and farmers have been growing crops on the basis of available water and their food grain requirements. However, subsistence-level farmers do grow crops other than rice even in rain-fed conditions rather than keeping land fallow.

Nepalese farmers are not free from technical, socioeconomic and institutional difficulties because agricultural production is a combined process of irrigation and crop management. These activities are handled by two different ministries. These two government agencies, the Ministry of Water Resources (MOWR) and the Ministry of Agriculture (MOA) do not have a similar organizational setup which has resulted in several coordination problems.

Hence, irrigated farming is not fully coordinated. Better results can be expected and obtained when the two most important components (agricultural research/extension and irrigation development/management) for agricultural production are interlinked and activities work in smooth coordinated fashion. In fact, Nepalese farmers are still unable to realize the genetic yield potential of the crops they have been growing. The water resources need to be harnessed and utilized for crop production in a more efficient manner.

CONSTRAINTS TO AND OPPORTUNITIES FOR CROP DIVERSIFICATION

Technical Constraints

1. Irrigation projects may not have been designed to match the farmers’ cropping practices.
2. Manpower for irrigation development is inadequate.
3. Farmers’ awareness of their need is not guided by competent technical back-stopping.
4. Training programs for the farmers as well as for the technicians of both irrigation and agriculture sectors are insufficient.
Socioeconomic Constraints

1. Landholdings are fragmented, scattered and marginal.
2. Land reform policy is not effectively implemented resulting in unequal distribution of agricultural lands.
3. The younger generation’s negative attitude to the farming profession and agriculture.
4. Returns from farm produce are low and it is difficult to maintain the minimum economic status of the farming community. Price control of various agricultural commodities has to be instituted and implemented.
5. Personnel engaged in the agricultural and irrigation project planning, development and implementation are not motivated in their respective professions.
6. The water rights need to be well-defined and equitable distribution has to be assured and implemented at different points.

Institutional/Managerial Constraints

1. Linkages and coordination among the various institutes and farmers engaged in agricultural production systems are ineffective and weak.
2. Farmers do not have a sense of ownership of the irrigation projects that benefit them.
3. Water Users’ Groups are not treated as legal entities.
4. Voluntary participation of beneficiary farmers in the management of the irrigation and agricultural system is not widely accepted.
5. Donors’ and recipients’ interests are not identical to the development of the system in totality.
6. Specialized skills and knowledge of the respective government departments are not properly delivered to the field level to ensure better production.
7. Human resources, which constitute a key element, are not given due consideration in the developmental and managerial activities.
8. The management of the scarce resources to the optimum level, to increase agricultural production as a key element is not given due emphasis.

Opportunities

With a view to solving the constraints of different magnitudes and nature, the concerned government agencies have taken various steps. Some of these are as follows:

Agriculture Sector

The Department of Agriculture (DOA) has set up regional agricultural training centers in the five development regions. These are separate for the hills and the Terai. In addition to the 5 regional agricultural directorates and 75 district agricultural offices the Farming
Systems and Outreach Research Division (FSORD) and crop commodity research programs have been separately and in collaboration helping farmers by conducting training, field days, fairs and field trials to demonstrate the improved technology on agricultural production including crop diversification in irrigated and rain-fed areas. The Agricultural Development Bank/Nepal (ADB/N) and the Agricultural Inputs Corporation (AIC) have also been paying special attention to those areas with high production potentials and crop diversification and cooperating with DOA's activities for maximizing and diversifying agricultural production. The ADB/N's Small Farmers' Development Program (SFDP) has become the most popular and beneficial institution especially in areas where subsistence-level farming has been the only profession of the people. In fact, the SFDP has been able to penetrate and extend its activities into far and remote areas of the country. Formation of cultivators' groups in different units has helped SFDP to expand its program and linked it to farmer group formation and loan distribution for production and marketing.

Irrigation Sector

In the past, the government organization for irrigation was scattered in various ministries. Different ministries were handling irrigation development programs and the end users were not deriving the full benefits of these developments due to lack of coordination. Realizing this fact, His Majesty's Government (HMG) restructured its bureaucratic organizations in 1987 and put all the units responsible for the development of irrigation facilities under the direct administrative control of the MOWR and the Department of Irrigation (DOI) is now the responsible government agency for the institutionalized irrigation development in the country. In addition to 5 regional irrigation directorates, 75 district irrigation offices (DIO) have been established for irrigation system development and management. Farmer-Managed Irrigation Systems (FMIS) also get due technical as well as financial support. At present, a bottom-up approach in the irrigation projects' planning is being followed which provides farmers' participation in selecting the irrigation projects and sharing the cost of construction through Water Users' Groups (WUG). Demand-driven irrigation projects are prioritized if these projects are technically feasible. The DOI has created a Research and Training Branch (RTB) and a System Management Branch (SMB) to provide guidance and to technically train and help the farmers financially in irrigation research, training and management activities in line with the MOA's crop research, management and farmer training. A central coordinating committee consisting of DOA, ADB/N and DOI has been formed in order to monitor and provide integrated guidelines for the irrigation and agricultural agencies in formulating and implementing action-oriented, needs-based agricultural and irrigation programs.
STRATEGIES TO ADDRESS CONSTRAINTS/OPPORTUNITIES

Issues

Most of the irrigation schemes in Nepal have been designed and constructed to supplement the rainfall for monsoon rice. In the last few decades, efforts have been made to persuade the farmers to grow wheat as a second crop in winter (dry season) and the operation of the systems has been adjusted and/or amended accordingly. Donor agencies assisting in the development of irrigation schemes during the last ten years have been insisting on the need to adopt cropping patterns for year-round irrigation except during canal closures for maintenance works. This has been planned for a few schemes where a continuous water supply is assured.

The costs of production for rice and wheat are higher than the farm gate prices of the products, and the profit margin for the farmers has declined in recent years. This has resulted in noncultivation of a second or third crop during the dry season. However, subsistence farmers are still encouraged to grow crops that suit the condition. It is necessary now to introduce profitable cash crops like sugarcane which have a ready market.

In Nepal, most of the cultivable land has already been brought under cultivation. Demographic pressure in the hills has pushed migration of people from the hills to Terai creating a problem of forest encroachment for cultivation. On the other hand, most farm lands are not utilized to the extent possible for intensified cropping. The agencies concerned need to intensify their efforts to prevent encroachment of the forest and the underutilization of the cultivated lands. There is also a greater need being felt to optimize the farm income from the existing land and available water supply. The question is how to use the land year-round. The consensus is that wherever the soil and climate are suitable, the introduction of nonrice crops must be encouraged if the farmers’ socioeconomic conditions are favorable.

The following issues need to be addressed to encourage farmers to grow nonrice crops during the dry period under existing irrigation systems:

1. Farmers should be assured of the water supply required from the canal.
2. Economic price support and markets must be available for the agricultural products.
3. Special technology and extension services should be made available.
4. In many systems, dry-season water availability is generally inadequate and so the water supply has to be augmented. Conjunctive use of groundwater and surface water is a possibility.
5. The available water supply needs to be operated and managed through the conveyance system which would need more control structures to raise full supply levels in order to divert water into the offtaking canals or tertiaries to irrigate diversified crops.
6. Most systems lack on-farm development works which have to be completed for proper water management.
7. Water User Groups have to be formed or weaker organizations strengthened to encourage adoption of diversified crops in an organized manner.
Prospects

In Nepal, out of the total cultivated land of 2,641,000 ha only 2.06 M ha is potentially irrigable (groundwater irrigation included) evidently due to mountainous terrain and difficult geography. At present about 930,000 ha is under some kind of irrigation. Traditional farmer-managed irrigation systems (FMIS) irrigate 670,000 ha whereas government-operated systems irrigate 260,000 ha. Besides, farmer-operated shallow tubewells (STWs) irrigate 64,000 ha and government-operated deep tubewells (DTWs) irrigate 16,000 ha. It is estimated that there are over 17,000 FMIS, 16,000 STWs and 220 DTWs.

The FMIS still play a very vital role in irrigated agriculture as these systems produce almost 45 percent of the grain (cereal) needs of the country. These systems operate and perform better than the government-operated systems which are generally of large and medium scale. Efforts are now being made to improve the performance of such systems through users' organizations, and involvement of beneficiaries in the management and operation of the schemes. But the country's terrain, remoteness and transport problems are constraints in attracting farmers to increase the cropping intensity. Existing marketing and prices for the products also hinder the introduction of nonrice crops.

Although the dry-season flow available in most irrigation canals can merely cover 25-35 percent of the command area, nonrice dry-season crops can easily be planned. However, this will need suitable adjustment in water management and O&M schedules. The increase in cropping intensity will create labor employment opportunities during nonrice seasons and population migration and encroachment of forest areas will be decreased.

To start pilot projects for diversified cropping, tubewell irrigated areas are best-suited because of better management and control of water. The following characteristics make them suitable for piloting:

1. The canals are small; similar to a water course or a tertiary.
2. Demand-based operation is possible.
3. Individual farms can grow designed crops. Water can be managed in each farm. The uninterested farmer will not be bothered with water deliveries as is the case with traditional flooding type of irrigation.

Action Required

Before any program is launched or attempted some questions need to be addressed: for example, "How much area in the existing scheme is suitable for low water requirement crops?" and "What additional facilities or regulating structures are needed to be installed to operate the system?" Besides agronomical aspects, like what crops are suitable for the soil and for the season and whether that would attract farmers motivated by profitability, should also be considered. Before any extensive program is launched, the introduction of diversified crops should be tested first on pilot levels like in the Farming Systems Research (FSR) sites.
Strategy

In order to introduce diversified crops in rice-based irrigation systems, action research is needed to establish appropriate irrigation methods and procedures and to bring awareness to the government officials and the farmer community of the vital need for diversified cropping in the context of Nepal’s land constraint where there is no scope for expanding croplands. The only viable option for the country is to intensify the cultivation of existing croplands, most of which are being cultivated by small and poor farmers.

The research would also provide guidance to the irrigation managers for planning the O&M and management of irrigation and drainage systems that have potential and prospects for cultivating suitable diversified crops.

DIRECTIONS OF CROP DIVERSIFICATION

The government of Nepal has been considering for a long time the diversification of cropping practices in view of the existing crop production situation in the country. Nepal has been encouraged by the research and experience gained by the national program in the country, namely, the FSORD under the NARC and the research findings of other countries that have proved that with assured irrigation water, two to four crops could be grown successfully in a unit of land in a given year. To augment the program of crop diversification, the objectives and priorities set by the government are as follows:

1. To grow different varieties and types of crops in different parts of the country on the basis of suitability based on soils, climate, available irrigation, transportation, export potential and local market.
2. To increase agricultural production by growing two or more crops, mixed, relayed or rotated.
3. To increase the land productivity by diversified cropping practices.
4. To help farmers upgrade their economic status by raising their living standards.

Priorities for Crop Diversification

In order to achieve these objectives, His Majesty’s Government (HMG) has been allocating funds and facilities to further enhance and develop research capability and generate compatible innovative technology.
Research and development

The formal government program on crop diversification was initiated by the Cropping Systems Program (CSP) of the Integrated Cereals Project (ICP) funded by the United States Agency for International Development (USAID) through the International Agricultural Development Services (IADS) in 1972. This was the first systematic government approach under the DOA to initiate and introduce cropping system studies in selected hills and Terai sites to test component technology basically for rice-based cropping systems in irrigated and rain-fed conditions. The CSP has evolved several rice-based cropping patterns for the different levels of production potential for irrigated and rain-fed Terai and hill conditions and FSORD is testing the diversification possibility for the hills. (Appendices 1 and 2).

At present, Nepal’s agricultural research activities are handled by NARC through its several crop and vegetable research programs. In addition to the FSORD and its various location-specific testing sites in the hills and in the Terai, prominent research programs operating at present are for rice, wheat, maize, potato, sugarcane, jute, oilseeds, pulses and grain legumes. The FSORD also closely collaborates with national research programs for rice, wheat, vegetables, potato, etc., to evolve newer technology for crop diversification. FSORD is the main government organization responsible for the crop diversification research activities and its principal mandate is to generate compatible technology for diversified rice-based cropping systems. The main thrust of FSORD has been to institutionalize the Farming Systems Research (FSR) approach to help develop and disseminate environment-specific technologies relevant to farmers’ socioeconomic needs and priorities.

Information dissemination and exchange

The Agricultural Communication Division (ACD) of the MOA is the principal organization responsible for information exchange and technology dissemination. The Central Agricultural Training Division and Manpower Division have a distinct role in the agriculture sector while the RTB and SMB are extension-oriented programs in the irrigation sector. Apart from this, regional agricultural directorates and district agricultural offices have very sound information dissemination systems. However, they are still to be developed and strengthened in the regional irrigation directorates and district irrigation offices as these are relatively newer ones. However, with the passage of time, RTB and SMB are expected to pick up these responsibilities at a faster pace and in more extensive areas.

Funding

Various international donor and lending agencies and domestic services like HMG, ADB/N have been allocating enough funds for research and extension of crop diversification undertaken by FSORD, RTB, SMB for technology generation and dissemination through farmer training and system management. As discussed, the crop diversification activities in Nepal in the future will be a much bigger program, possibly with IIMI’s research network assistance.
SUMMARY

The paper tried to visualize the existing situation in the country, practices being followed at present and efforts being made to improve and modify them in the changing context of agricultural crop research and irrigation development and management and extension of both the sectors.

The industrialization and urbanization processes are on the rise in the plains. The pressure on land for industries and agriculture is more in the Terai than in the hills due to population migration. On the one hand, cropping intensity is far less than the actual potential even in irrigated areas. Therefore, the government’s efforts to maximize cropping intensity and diversify cropping practices are very much a felt need today than ever before. On the other hand, it is an urgent need to protect the environment, maintain and increase the soil fertility by checking erosion and land degradation and create the necessary atmosphere so that the people could realize and feel the government’s effort for the balanced development of all the regions, especially with irrigation and crop management facilities.

In order to meet the increasing needs of the farmers in the rural areas, the government’s efforts to implement the changed irrigation development and management policy through the participatory and sectoral approach and crop research and diversification and its extension through farming systems and outreach research approach will go a long way in achieving the goals by addressing the farmers’ problems and constraints and solving them in a coordinated and integrated manner, especially in the field of irrigation management in the rice-based crop diversification activities.
References


Appendix 1

Some of the recommended cropping patterns under different levels of production potentials for irrigated and rain-fed areas, in both Terai and hill conditions.

A. Terai

1. Rain-fed lowlands with low production potential
   a) Rice-wheat-fallow
   b) Rice-lentil-fallow
   c) Rice-mustard-fallow
   d) Rice-chickpea-fallow

2. Irrigated lowlands with high production potential
   a) Rice-mustard-maize
   b) Rice-maize-maize
   c) Rice-maize-mungbean
   d) Rice-wheat-mungbean
   e) Rice-wheat-dhaincha
   f) Rice-wheat-Callow
   g) Rice-wheat-ricc

B. Hill

1. Rain-fed lowlands with low production potential
   a) Rice-broadbean-fallow
   b) Rice-oat-fallow

2. Rain-fed lowlands with medium production potential
   a) Rice-wheat-fallow
   b) Rice-fallow-maize
   c) Rice-broadbean-maize
   d) Rice-oat-maize

3. Rain-fed lowlands with high production potential
   a) Rice-wheat-makc
   b) Rice-potato-maize

4. Irrigated lowlands with high production potential
   a) Rice-wheat-rice
   b) Rice-wheat-mungbean
   c) Rice-wheat-fallow
Appendix 2

Cropping pattern trials being undertaken by FSORD at different FSR sites for the identification of component technology for crop possible diversification.

<table>
<thead>
<tr>
<th>Location</th>
<th>Cropping Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patan in Baitadi (Far-western hill)</td>
<td>Rice-wheat-fallow</td>
</tr>
<tr>
<td>Kotjali in Rukum (Midwestern hill)</td>
<td>Rice + maize-wheat + mustard</td>
</tr>
<tr>
<td>Pundibhundi in Kaski (Western hill)</td>
<td>Maize/finger millet-mustard</td>
</tr>
<tr>
<td>Nalduing in Kavrr (Central hill)</td>
<td>Rice-wheat-fallow</td>
</tr>
<tr>
<td>Khandari in Sankhuwasabha (Eastern hill)</td>
<td>Rice-wheat-seshania spp. and rice/lentil-maize</td>
</tr>
</tbody>
</table>

Note: These are the improved and modified practices introduced over the farmers’ existing patterns.
INTRODUCTION

In the Philippines, attention to crop diversification in rice-crop-based cropping systems started in the seventies when researchers began to focus on developing appropriate technology and strategies for optimizing small farm productivity. A pilot multiple cropping project by the University of the Philippines at Los Banos (UPLB) in cooperation with the International Development Research Center (IDRC) studied the adoption and impact of some intensive cropping patterns. The project succeeded in introducing production technology for some vegetables and upland crops in rice-based and cam-based systems.

The Rainfed Agricultural Development Project (RADP) in Iloilo Province and, consequently, the "KABSAKA" (literally, "bounty in the farm") program were successful in promoting the International Rice Research Institute (IRRI)-developed technology for the production of two rice crops and an upland crop in the same area within a 12-month period. The foci were on crop intensification and crop diversification in both rain-fed and irrigated areas. Nevertheless, diversification was by then only in the form of a third crop, i.e., an upland or nonrice crop, in areas where the norm was a single rice crop a year. It was strongly felt that there was still much room for increasing small-farm productivity and profitability.

In the eighties, the establishment of the Regional Integrated Agricultural Research System (RIARS) in the Department of Agriculture (DA) led to the vigorous technology verification type of research activity in all provinces of the country. Banking on the previous success of the "KABSAKA," most, if not all, of the technologies (which were verified in
on-farm trials) aimed at crop intensification and diversification not only in the rain-fed rice-based environments but also in the partially irrigated and fully irrigated environments as well. At this point, it can be stated that there are already developed technologies on the production of nonrice crops as alternatives to or supplemental to rice for most of the regions of the country. However, adoption is not as widespread in irrigated rice systems compared to that in the upland or rain-fed systems.

Ricelands, particularly the irrigated lands, are an already intensively used production resource, but in the face of the increasing population problem and the limited, if not decreasing, land and water resources, optimized and sustainable utilization of these resources becomes necessary. Crop diversification, although not a new practice to some upland as well as lowland farmers, still has vast potential, especially in lowland irrigated areas.

**Table 1. Status of irrigation development in the Philippines, 1989**

<table>
<thead>
<tr>
<th>Region</th>
<th>Potential irrigable area (ha)</th>
<th>Service (ha)</th>
<th>Pump irrigation systems</th>
<th>Total (ha)</th>
<th>Irrigation development (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>309,810</td>
<td>45,386</td>
<td>132,782</td>
<td>5,520</td>
<td>183,688</td>
</tr>
<tr>
<td>2</td>
<td>539,710</td>
<td>83,486</td>
<td>36,593</td>
<td>273,366</td>
<td>50.65</td>
</tr>
<tr>
<td>3</td>
<td>482,220</td>
<td>172,064</td>
<td>84,817</td>
<td>279,827</td>
<td>58.03</td>
</tr>
<tr>
<td>4</td>
<td>263,590</td>
<td>55,455</td>
<td>27,948</td>
<td>153,221</td>
<td>58.13</td>
</tr>
<tr>
<td>5</td>
<td>239,650</td>
<td>16,209</td>
<td>16,943</td>
<td>84,039</td>
<td>35.07</td>
</tr>
<tr>
<td>6</td>
<td>197,250</td>
<td>53,500</td>
<td>21,677</td>
<td>107,462</td>
<td>54.48</td>
</tr>
<tr>
<td>7</td>
<td>50,740</td>
<td>18,611</td>
<td>2,481</td>
<td>21,092</td>
<td>41.57</td>
</tr>
<tr>
<td>8</td>
<td>84,380</td>
<td>15,633</td>
<td>2,176</td>
<td>53,909</td>
<td>63.89</td>
</tr>
<tr>
<td>9</td>
<td>76,500</td>
<td>13,348</td>
<td>2,804</td>
<td>37,489</td>
<td>49.01</td>
</tr>
<tr>
<td>10</td>
<td>230,150</td>
<td>20,282</td>
<td>2,045</td>
<td>66,963</td>
<td>29.10</td>
</tr>
<tr>
<td>11</td>
<td>290,250</td>
<td>38,370</td>
<td>6,872</td>
<td>107,806</td>
<td>37.14</td>
</tr>
<tr>
<td>12</td>
<td>362,080</td>
<td>37,610</td>
<td>4,123</td>
<td>100,354</td>
<td>27.72</td>
</tr>
<tr>
<td>Total</td>
<td>1,126,330</td>
<td>621,144</td>
<td>695,944</td>
<td>1,469,216</td>
<td>46.99</td>
</tr>
</tbody>
</table>

**Irrigated Rice-Based Farming Systems**

In the country, 9.00 M ha are identified as arable land of which, 3.13 M ha are considered as a potential irrigable area. Of this potential irrigable area, an aggregate of 47 percent (1.47 M ha) is already provided with irrigation facilities (Table 1). Of this irrigation service area, 621,000 ha are served by the government-managed national irrigation systems (NIS), 696,000 ha are under the farmer-managed communal irrigation systems (CIS) and 152,000 ha are benefited by private pump irrigation systems (PIS). In the NIS, mean cropping
intensity is only about 134 percent per year, i.e., 74 percent during the wet season and 60 percent during the dry season (Table 2).

Table 2. Service and irrigated areas and irrigated cropping intensity in national irrigation systems in the Philippines, 1979-89.

<table>
<thead>
<tr>
<th>Year</th>
<th>Service area (ha)</th>
<th>Irrigated area (ha)</th>
<th>With 3rd crop (%)</th>
<th>Area irrigated annually (ha)</th>
<th>Irrigated cropping intensity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979</td>
<td>475,174</td>
<td>372,232</td>
<td>78.34</td>
<td>285,845</td>
<td>60.16</td>
</tr>
<tr>
<td>1980</td>
<td>472,182</td>
<td>374,349</td>
<td>79.28</td>
<td>293,472</td>
<td>62.15</td>
</tr>
<tr>
<td>1981</td>
<td>491,729</td>
<td>372,038</td>
<td>75.66</td>
<td>300,416</td>
<td>61.09</td>
</tr>
<tr>
<td>1982</td>
<td>514,334</td>
<td>390,342</td>
<td>75.89</td>
<td>320,463</td>
<td>62.31</td>
</tr>
<tr>
<td>1983</td>
<td>549,930</td>
<td>362,340</td>
<td>65.89</td>
<td>293,329</td>
<td>53.34</td>
</tr>
<tr>
<td>1984</td>
<td>548,345</td>
<td>416,824</td>
<td>76.01</td>
<td>290,851</td>
<td>53.04</td>
</tr>
<tr>
<td>1985</td>
<td>568,203</td>
<td>430,888</td>
<td>75.83</td>
<td>349,424</td>
<td>61.50</td>
</tr>
<tr>
<td>1986</td>
<td>595,902</td>
<td>438,237</td>
<td>73.54</td>
<td>381,914</td>
<td>64.09</td>
</tr>
<tr>
<td>1987</td>
<td>596,953</td>
<td>433,151</td>
<td>72.56</td>
<td>370,351</td>
<td>62.04</td>
</tr>
<tr>
<td>1988</td>
<td>614,164</td>
<td>445,287</td>
<td>72.50</td>
<td>342,786</td>
<td>55.81</td>
</tr>
<tr>
<td>1989</td>
<td>621,144</td>
<td>461,613</td>
<td>74.32</td>
<td>389,562</td>
<td>62.72</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>475,174</td>
<td>74.53</td>
<td>651,675</td>
<td>138.49</td>
</tr>
</tbody>
</table>

Many existing irrigation systems in the country are beneficiaries of improvement from irrigation operation support projects. These projects are principally aimed at increasing cropping intensity in the existing irrigation service areas. In addition to these projects, diversified cropping systems (DCS) or the planting of nonrice crops during the dry season in rice-based irrigated areas are seen as corollary measures.

Driving Factors in Crop Diversification

Acting singly or severally, the following factors are identified as significantly influencing crop diversification (planting of nonrice crops) in the country:

1. Inadequate water supply during the dry season to fully support the production of the high-water-requiring traditional crop of rice.
2. Increasing demand for vegetables and other nonrice crops as a result of increasing population and the expanding needs of the animal production sector.
3. Inherent better suitability of nonrice crops than rice on certain soil types.
4. Higher profitability per unit area of nonrice crops as against the rice crop, especially when harvest time is at a particularly advantageous period.
5. Strong desire among farmers and irrigation personnel to maximize utilization of available land and water resources.
6. Occasional occurrence of windfall prices and attractive market situations for the produce from particularly on-demand kinds of nonrice crops.
7. Adeptness of some farmers on the technique of identifying and growing promising high-market-potential and high-profit-potential nonrice crops in rice fields.
8. Generation, verification, and piloting works on cropping intensification and crop diversification technology in a number of sites in the country.

The decision of farmers to raise nonrice crops, particularly in irrigated areas, remains highly motivating as a consequence of the above factors. It is also a result of encouragement given by government technicians. This is, of course, with the exception of a few farms where a contract-growing scheme is established between a farmers' group and a sure market.

**Extent of Crop Diversification**

Actual hectarage planted to nonrice crops in irrigation service areas is not yet "closely" monitored, except in the limited areas where irrigation service fees are settled by the farmers concerned and the "commercial plantation" areas (e.g., those located at the Lasang River Irrigation System in Davao del Norte Province and in the Siluay River Irrigation System in South Cotabato Province) having irrigation service contracts with NIA. Monitoring is hampered as the individual areas actually planted to nonrice crops are small and widely scattered.

The actual extent planted to nonrice crops in the NIS service areas is, however, estimated to be about 6,000 ha. Aggregate potential area suitable for nonrice crops cultivation based on land class types within the NIS service areas is estimated at 186,000 ha. This indicates that where water is adequate, farmers tend to raise rice rather than nonrice crops. Obviously, the bulk of the volume of produce from nonrice crops comes from outside the service areas of irrigation systems.

**Agencies Involved in Crop Diversification**

The agencies which have been in the forefront of crop diversification activities in the country are the Philippine Council for Agriculture, Forestry, and Natural Resources Research and Development (PCARRD), DA, IRRI, various state colleges and universities (SCUs) like UPLB, Central Luzon State University (CLSU), Mariano Marcos State University (MMSU), Isabela State University (ISU), the Visayas State College of Agriculture (VisCA), etc., International Irrigation Management Institute (IIMI), National Economic and Development Authority (NEDA) and NIA.
The Philippine Rice Research Institute (PhilRice), created in 1985, also implements a national research and development program on improving and sustaining rice and nonrice crop production and crop diversification in the country.

In essence, line government agencies, the state colleges and universities and locally based international institutions work together for the promotion of crop diversification.

Recently, the National Committee on Crop Diversification (NCCD), composed of 14 representatives from various concerned government and private institutions, was created. The committee is mandated to:

1. Coordinate the formulation, development and implementation of a comprehensive program on crop diversification in the country to include research, development, training and extension.
2. Facilitate the provision of necessary technical, financial and other support services for the implementation of such a program.
3. Formulate and recommend policies.
4. Serve as a link between the national program and other related programs within as well as outside of the country.

**PLANNING FOR AND OPERATION OF THE SYSTEMS**

**Practices in the Rice-Based Systems**

*Planning for the cropping season*

Three main plans are usually prepared for the operation and maintenance (O&M) of NIS. They include the composite cropping plan (CCP), annual activity network (AAN) and the system management plan (SMP). These plans are also developed for the CIS and the PIS with variations. Collectively, these plans indicate, among others, the following:

1. Target schedule for the execution of the various farming activities and irrigation stages.
2. Extent and location of the irrigation-programmed areas in a particular cropping season.
3. Value of design operation water duty at any given time within the irrigation period.
4. Schedule for the carrying out of the various O&M activities for the system.

These plans serve as guides for the systems’ O&M personnel for the execution of their tasks during the irrigation season. They also guide the farmers and provide the necessary information to prepare their own farm plan and budget. Cropping calendars of most irrigation systems reflect only the rice-rice pattern. Major reasons for this may include the following:

1. Most irrigation systems in the country were designed for rice alone.
2. The fields planted to nonrice crops are usually outside the area programmed for irrigation in a particular cropping season, generally mixed with rice fields in small patches designed on farmers' initiative.

3. Production of vegetables and other nonrice crops under irrigated conditions receives low priority in most of the irrigation system due, presumably, to lack of adequate skill and knowledge to handle it.

Assessing and matching water supply and demand

The CCP enforced in a particular irrigation system is also the plan used in determining how many hectares of the system are to be programmed for irrigation service for every cropping season. This is done by dividing the projected available streamflow during the "land soaking stage," by the calculated net water duty (i.e., the estimated effective rainfall) of this stage. Well-designed cropping calendar and pattern, and a well-derived water duty value are known as important prerequisites to a water supply well-matched to demand.

Projected streamflows are taken from feasibility reports and from records of observations made during the period (5-7 years, usually) of project construction. Data collected in the course of system operation are also considered therein.

Severe irrigation water shortages occasionally occur. This is usually brought about by a combination of the following factors:

1. Lower-than-normal actual streamflow level in run-of-the-river systems, in particular, although reservoir-fed irrigation systems are equally adversely affected by it.
2. Lower-than-expected actual effective rainfall in service areas due to erratic climatic pattern.
3. Higher-than-programmed actual irrigation-served cropped area due to farmers taking the risk of planting rice even in areas which are unprogrammed for irrigation.
4. Higher-than-needed actual irrigation diversions in certain headgates partly due to farmers' desire to maintain a high water level in their fields or to irrigate upper-lying cropped areas.

Allocation of water supply and land area

The area programmed for irrigation service is only about 82 percent of the perceived service area of the irrigation system. The programmed area is usually limited by the standing agricultural and land development status of the service area. Some areas are still to be developed from second growth forests (e.g., parts of the service area of the Andanan River Irrigation Systems in Bukidnon Province). During the dry season, the area programmed for irrigation service is only about 65 percent due primarily to inadequate water supply, particularly of the direct diversion type.

The actual irrigated area for both seasons ranges from 83 to 93 percent of the programmed area and the actually benefited area (harvested with relatively good crop yields) is only 80
to 90 percent. During the wet season, there is a relatively adequate water supply from both irrigation and rainfall. At this time when the water supply is abundant, farmers usually prefer the planting of rice. They do not prefer nonrice crops because of their susceptibility to damage from likely inundation and waterlogging.

**Coping with low water availability situations**

When the water supply falls critically low and becomes inadequate to fully serve the standing rice crop, several measures are employed by irrigation officers to cushion the impact. Remedial measures employed under such an eventuality include:

1. Rotation of the irrigation water supply schedule by section of the main canals or long lateral canals, with the cooperation of the farmers.
2. Suspending or stopping irrigation water delivery to standing rice crops which are planted in areas unprogrammed for irrigation service.
3. Regulating actual water diversions at canal headgates and turnouts according to planned levels so as to avoid undue water deprivation in areas at the lower reaches of the systems.
4. Augmenting the system’s water supply with water that is pumped (usually supplied directly to farms with standing crops) from creeks, rivers and/or wells.
5. Inducing rainfall through cloud seeding (done in coordination with concerned cloud-seeding agencies and still done in a limited scale due to inadequate number of aircraft).

Encouraging farmers to shift to cultivation of nonrice crops from rice crops is not yet aggressively done by irrigation staff. Lack of adequate skill and knowledge in the cultivation and irrigation of nonrice crops is still a serious limiting factor in this regard.

**Changes in irrigation implementation strategies**

There are still no major changes in NIA’s planning, designing, and operating procedures that are focused at accommodating DCS but there are several policies and strategies directed toward this goal. The policy established five years ago to implement a reduced irrigation service fee (ISF) rate for nonrice crops, i.e., only 60 percent of the prevailing rate for rice, was envisioned to encourage farmers to diversify their farms. The response of the farmers to this incentive is, however, rather sluggish. They continue to prefer cultivating rice crops in imigated areas even at comparatively higher ISF rates.

The “1990-2000 Corporate Plan of NIA,” however, includes promoting accelerated crop diversification in irrigation service areas as one of its new thrusts. This is aimed at increasing cropping intensities through maximization of the use of the available land and water resources. The Diversified Crops Irrigation Engineering Project (DCIEP) implemented through the project-type technical assistance and grant-aid programs of the Japan International Cooperation Agency (JICA) is the first concrete move of NIA toward crop diversifica-
tion. The project is currently formulating planning and design criteria for project-type
type nonrice crop production farms. A training program to hasten the institutionalization
of crop diversification in NIA is also being prepared.

Two medium-scale conventional irrigation projects of NIA (one each in the provinces of
 Cavite and Tarlac) have vegetable production as one of their components. The nearness of
the service areas of these projects to urban centers in addition to suitable soil and climatic
types comprise the main factors considered in this arrangement. The production scheme
selected in these projects focuses on individual household farm holdings (HF) and covers
an aggregate potential area of 36,800 ha. Experiences in carrying out this project component
will provide invaluable information in future undertakings on crop diversification.

On irrigated areas where lands and climate types are suitable for DCS, the farmers
practice the following to accommodate nonrice crops:

1. They plant their wet-season rice crop early, e.g., usually within the first month of
   the irrigation season. This enables them to plant the succeeding nonrice crop also
   relatively early, to avail of the favorable soil moisture and relatively high prices for
   their produce. Early crops usually get into the "sellers' market" situation.

2. They allot the high lying rice fields of their farms for the cultivation of nonrice crops.
   These areas are difficult to irrigate due to their high elevation but are the ones least
   prone to waterlogging.

3. They supplement irrigation water through pumping from wells or creeks. This gives
   them a dependable source of irrigation water even if their farms are located in the
   lower reaches of the system.

A recent study of IRRI revealed the feasibility of growing a nonrice crop (corn) alongside
lowland irrigated rice fields during the rainy season with good crop yields. The only field
manipulation needed under this mixed cropping system is the establishment of 1-m deep
narrow trenches along the border rows of the nonrice (corn) plot to check the incidental
shallow water table. This scheme has a high potential for adoption by the farmers to
accommodate nonrice crops.

STRATEGIES TO ADDRESS CONSTRAINTS/OPPORTUNITIES

Studies conducted in the country have identified a number of strategies that can be
considered to effectively irrigate rice and nonrice crops under a mixed cropping system.
These strategies are grouped into two categories: improvement of the irrigation facilities,
and improved procedures and practices.
Improvement of Irrigation Facilities

Recommended works on this aspect are focused on effecting better water control and measurement as these are prerequisites in the implementation of an efficient water distribution plan. Construction of new irrigation systems and rehabilitation and/or improvement of existing ones are, of course, continuing to be carried out by NIA. Rehabilitation works are focused on the following:

1. Physical facilities of irrigation system: canals, structures and roads.
2. Farmer-irrigators’ associations: formation, training, mobilization and participation.
3. Irrigation staff: training and experience exchange.
4. Irrigation office facilities: communication and office equipment, parcellary maps, and O&M manuals.
5. O&M equipment.

Standing criteria for these rehabilitation works are, however, not yet directed at accommodating the requirements of DCS referred to above but just to rebuild the older systems and make them more efficient and effective in meeting desired functionality. They, nonetheless, are supportive of the thrust to promote crop diversification in irrigation service areas as both water control capability and water supply availability render the irrigation effort more efficient.

Improvement in Procedures and Practices

Under this aspect, the following are the recommendations:

1. More detailed characterization of the agro-hydrological and physiographic properties of irrigation systems for use as inputs to computer-aided mapping, determination of the suitability of DCS and improved water allocation.
2. More accurate methods of predicting streamflows and rainfall to ensure more realistic irrigation delivery schedules by using the incomplete gamma distribution function (IGDF).
3. Expanded utilization of groundwater even in service areas of run-of-the-river system through drainage reuse dams and water pumps drawing water from creeks and wells.
4. Scheduling planting earlier than normal to avert crop damage due to the usual late-dry-season scarcity of water supply and to make use of early-dry-season tail-end rains.
5. Mustering greater participation of farmers or farmers’ organizations in the development of system operation and maintenance plans to ensure their better cooperation in the execution of such plans.

Location-specific research studies are being conducted in earnest to generate more data useful in the promotion of crop diversification in rice-crop-based irrigated areas and in the improvement of the O&M of irrigation systems to accommodate nonrice crop cultivation
therein. IIMI, out of its collaborative research projects, has already evolved a recommendatory set of innovative schemes on the operation of irrigation systems.

DIRECTION OF CROP DIVERSIFICATION

Research and Development

The Medium-Term (1987-92) Philippine Development Plan (MTPDP) stipulates crop diversification as a strategy for increasing farm productivity and encourages expanded research and development (R&D) activities thereon. Efforts in crop diversification should be intended to support the objectives of attaining food security and minimizing the country’s dependence on traditional export commodities like sugar and coconut. For this reason, new and potentially viable agricultural crops based on comparative advantage should be promoted in all regions. The substitution of appropriate crops in areas where traditional crops are no longer economically viable should be initiated.

The development of production systems supportive of nontraditional crops, as well as of complementary processing activities for the conversion of primary commodities into high-value products (e.g., coffee, cacao, rubber, etc.) that are in demand both domestically and internationally or that have market development potentials, should be given priority.

A comprehensive review, in 1988, of past accomplishments on R&D showed that there was still a lack of information on crop diversification in relation to irrigation. This information deficiency rested on two issues: water management and socioeconomics for crop diversification. The following aspects were recommended for consideration under the area of water management:

1. Trials, in farmers’ fields, of new and modified water application methods;
2. Case studies of small successful irrigation units or systems to determine their merits for promotion.
3. Generation of more data needed in system design, planning and operation.
4. Verification of doubtful information or data on irrigation system design, planning and operation.

Under the area of socioeconomics, the following were recommended for consideration:

1. Characterization of the various factors affecting crop diversification in different locations and field conditions.
2. Determination of the factors that encourage farmers to engage in crop diversification.
3. Comparison of financial returns of promising nonrice crops in a single location and across locations.
4. Investigation of the competition among different crops in a certain system for farm resources.
5. Identification of the support services necessary for crop diversification.
6. Assessment of the market potential of selected crops and characterization of existing ones.

The MTFDP suggests that R&D activities in this sector should be concentrated on the development of low-cost and low-input technologies for food crops, the production of traditional and nontraditional export commodities, and the development of natural resources conservation and management systems. Current efforts in rain-fed and upland areas should be sustained and expanded.

Advanced technologies should be applied in diversifying agriculture and increasing soil-crop yield per unit of input. Biotechnology, nitrogen fixation, water conservation technologies, and multiple cropping offer distinct possibilities. Resources for R&D in these areas should be further augmented and mobilized.

Research institutions in the country are well aware of these needs and the expanded participation of the private sector in this regard, just like in the development of better varieties of diversified son-rice crops, labor-intensive-substitute farm implements, etc., should be encouraged. PCARRD should continue providing overall direction along these lines.

Information Dissemination and Exchange

The NCCD, as one of its responsibilities, is obligated to provide direction and initiate the exchange of information on crop diversification among the various institutions involved using the following fora and media: symposia, workshops, seminars, and printed material.

Individual agency-initiated efforts to effect information exchange should, of course, be encouraged and pushed through. Development, printing, and dissemination of newsletters, pamphlets and booklets on the various aspects of crop diversification should also be aggressively undertaken.

The NCCD should likewise maintain, through IIMI, close linkage and all-out participation in the activities of the Regional Research Network on Irrigation Management for Rice-Based Farming Systems. Attainment of this strategy will, of course, depend on the operationalization of corresponding thrust on the part of the Network.

Funding

Much financial resources are channeled by government agencies to research, development and promotional activities on crop diversification. Pertinent multidisciplinary programs should be formulated by the NCCD and offered for funding by the government and from traditional sponsoring agencies for implementation. Currently, foreign institutions like JICA and the United States Agency for International Development (USAID) provide some financial assistance for projects on crop diversification in the country.
SUMMARY

1. Inadequate water supply during the dry season is identified as one factor, among seven others, which tends to push diversified cropping systems (DCS) in the country.
2. In the National Irrigation Systems (NIS), only 1 percent of the irrigated area is presently devoted to diversified cropping out of an estimated potential of about 30 percent.
3. The Department of Agriculture (DA) together with at least 11 more institutions is involved in the promotion of crop diversification in the country.
4. In the irrigation systems of the country, except those with vegetable production components, nonrice crops are still not considered in the planning of operations.
5. Programmed area for irrigation during the dry season is traditionally based on predicted streamflows as against calculated net operation water duty.
6. Irrigation water shortages are believed to be rooted in erratic predictions of streamflows and rainfall, and caused by unscrupulous farming practices like planting in unprogrammed areas and excessive water diversions.
7. Programmed area for irrigation in NIS is only 82 and 65 percent during the wet and dry season, respectively, due to inadequate water supply, development status of the area and other factors.
8. Encouraging farmers to shift from rice to irrigated nonrice crop cultivation to help alleviate recurring water shortages is not yet extensively done due to know-how deficiency.
9. Formulation of technical criteria for project-type nonrice crop production farms in irrigation service areas is one of NIA’s roles in the promotion of crop diversification in the country.
10. Suggested research studies on water management for crop diversification deal with the generation and verification of more data on the planning, design and operation of irrigation systems.
11. On the aspect of socioeconomics, recommended research direction addresses the characterization of the various factors that tend to hinder or promote crop diversification.
12. Crop diversification is recognized by the national government as a strategy in enhancing farm productivity, and research and development (R&D) works thereon are promoted.
13. In addition to pursuing current thrusts and schemes, expanded participation of the private sector in R&D on crop diversification should also be explored and tapped.
14. Exchange of information on crop diversification should be, as usual, vigorously pursued and related multidisciplinary projects should be evolved and undertaken.
References


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Management Arrangements for Diversifying Rice Irrigation Systems in Sri Lanka

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INTRODUCTION

Sri Lanka is a 65,600-square-kilometer island with a population of just over 16 million. Seventy-five percent of the people are engaged directly in agriculture or related activity. Tea, rubber, and coconut are the main foreign exchange earners. Until the full impact of Sri Lanka’s recent development effort was felt, considerable sums of money were spent to import rice and other subsidiary food crops.

Sri Lanka is divided into three main agroclimatic zones, based on the annual rainfall and its distribution (Figure 1): the dry zone with an annual rainfall of less than 1,905 mm, the intermediate zone with 1,905 mm to 2,540 mm, and the wet zone with over 2,540 mm.

Sri Lanka’s irrigation systems fall into two categories, which are basically differentiated by their command areas: major irrigation systems with a command area of 80 ha or more, and minor irrigation systems with command areas below 80 ha.

Most of the irrigation schemes, including the Mahaweli areas, are concentrated within the dry zone owing to the abundance of land, sparse population and the shortage of water. Solar radiation is the most favorable factor for crop production in the dry season, whereas other climatic factors have a mixed effect.

The precipitation having a bimodal pattern influences crop production mostly in the dry zone. The major rainy season (rainfall around 950 mm), maha, occurs between mid-October and mid-January, and the minor rainy season (rainfall around 360 mm), yala, occurs between late March and mid-May. Although the total rainfall in yala is sufficient for short rain-fed crops, the main problem lies in the spatial and temporal distribution of the rains. Long, dry
Figure 1. Climate zones of Sri Lanka
spells are common within the season and the high wind velocities towards the latter part of the season make crop husbandry virtually impossible. Therefore, any type of cultivation during the yala season in the dry zone needs irrigation whether within rice lands or on highlands.

Diversification during the maha season is somewhat difficult owing to the conditions that prevail in the area during this period. The cloudy skies, high rainfall and very wet soils create unfavorable conditions for other field crops unless they are established before the high rainfall period and after adequate drainage facilities are provided. Since rice can survive such conditions, it thrives during the maha season.

The yala season is relatively more favorable for Other Field Crops (OFCs) or nonrice crops, which can withstand soil moisture stress for short periods better than rice. The evapotranspiration increases to about 6.0 mm per day in yala compared to 3.5 mm per day in maha. Thus crop water requirements also increase during yala. Under such conditions rice needs more frequent irrigation, and in a water scarce situation, yields of rice become very low and uneconomical. If irrigation water is not guaranteed, the farmers, due to the high risk involved, use only a low level of inputs as a measure of economy, thereby not expecting high yields and high profits.

Under yala conditions therefore, the cultivation of OFCs becomes more profitable. Furthermore, it allows a greater area of land to be cultivated with the same amount of water than when rice is cultivated. However, the major soil group in the dry zone, Reddish Brown Earths (RBEs) or Rhodustolls and their associates, play a key role in growing OFCs. Sudden high intensity rains, which are very common during the yala season, lead to slaking, surface sealing, erosion and temporary waterlogged conditions. On the other hand, a few days without water will make the soil very hard and unworkable. Both these extremes adversely affect OFC cultivation. On-farm drainage as well as system drainage facilities are important when growing crops other than rice on irrigated rice lands.

Continuous desiccating winds during the latter part of the yala season, increases the crop evapotranspiration to a peak between 6 and 7 mm per day. This makes it necessary for the crops to have deeper root systems for better absorption of water. Thus, even though the plant may have suitable characteristics for crop diversification in rice fields, physical impediments also play a major inhibitive role.

Conditions during the yala season are very favorable for biomass production if provided with adequate amounts of nutrients and water. Yet, the major constraints to be considered are the extensive and proliferating weed growth which smothers the crop if uncontrolled, and the associated pests and diseases. The soils of the dry zone carry a high population of disease organisms and soil-borne pests. Yet, equally prevalent are the symbiotic organisms which increase the yield, such as in leguminous crops.

The traditional cultivation pattern in the old villages in the dry zone, prior to the development of settlement schemes, was to store water from the monsoonal rains in the village tanks and use it for rice cultivation. There was also a unique cultivation arrangement known as bethma practices in these old villages. In a bethma system, the volume of water available in a village tank dictates the land area that could be cultivated. This land area is then divided among those in the village, based on the amount of land that each one has. The old (purana) villages were entirely dependent on the rains for their cultivation.
However, the assurance of water availability for a successful season is higher in the major irrigation schemes compared to the minor irrigation schemes. Every year, the land area left fallow is higher and the harvested area is lower in minor irrigation schemes, the problem being aggravated in the dry yala season. Table 1 gives details of the cultivable and harvested areas under major and minor irrigation schemes.

**Table 1. Area under rice in major and minor irrigation systems (in '000 ha).**

<table>
<thead>
<tr>
<th>Season</th>
<th>Major irrigation systems</th>
<th>Minor irrigation systems</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cultivable area</td>
<td>Net harvested area</td>
</tr>
<tr>
<td><strong>Maha</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>84/85</td>
<td>264.1</td>
<td>225.9</td>
</tr>
<tr>
<td>85/86</td>
<td>267.9</td>
<td>225.3</td>
</tr>
<tr>
<td>86/87</td>
<td>278.3</td>
<td>236.4</td>
</tr>
<tr>
<td>87/88</td>
<td>292.3</td>
<td>248.3</td>
</tr>
<tr>
<td>88/89</td>
<td>281.1</td>
<td>238.2</td>
</tr>
<tr>
<td>89/90</td>
<td>295.2</td>
<td>250.3</td>
</tr>
<tr>
<td><strong>Yala</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>85</td>
<td>152.5</td>
<td>132.1</td>
</tr>
<tr>
<td>86</td>
<td>167.8</td>
<td>145.8</td>
</tr>
<tr>
<td>87</td>
<td>194.2</td>
<td>168.9</td>
</tr>
<tr>
<td>88</td>
<td>204.1</td>
<td>178.1</td>
</tr>
<tr>
<td>89</td>
<td>184.9</td>
<td>160.9</td>
</tr>
<tr>
<td>YO</td>
<td>191.4</td>
<td>166.1</td>
</tr>
</tbody>
</table>

In the late 1960s, the Extension Division of the Department of Agriculture (DA), recognizing the need for crop diversification in rice fields in yala, to enable the farmers avoid the risk of rice crop losses and obtain higher incomes, embarked on the initial testing of OFCs in major irrigation schemes. After these pioneering efforts, the rice-based farming systems in major irrigation schemes took on a new dimension under the Accelerated Mahaweli Development Project (AMDP) when System H of AMDP successfully carried out a program for the cultivation of OFCs in rice fields during yala. The Annex is a note on the progress of crop diversification in the Mahaweli projects.

At present, farmers in System H grow a full rice crop during the maha season followed by OFC cultivation in well-drained soils and rice in poorly drained soils during the dry yala season. This rice-based cropping system is being gradually introduced to other areas where water scarcities occur, to enable the farmers get better incomes. Table 2 gives the details of rice and OFC cultivation since 1984 in Mahaweli System H and in the major/minor irrigation schemes outside Mahaweli. The security situation in the country in 1988 and 1989 had an adverse effect on OFC cultivation in certain areas.
The details of areas under crop diversification in some of the major irrigation schemes during yala 1990 are given in Table 3 together with the extent under rice in these schemes.

Table 2. Comparison of extents (ha) of rice and OFCs in Mahaweli System H and in other major and minor irrigation systems during yala.

<table>
<thead>
<tr>
<th>Year</th>
<th>Mahaweli System H</th>
<th>Major/minor irrigation systems</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rice area</td>
<td>OFC area</td>
</tr>
<tr>
<td>1984</td>
<td>16805</td>
<td>5640</td>
</tr>
<tr>
<td>1985</td>
<td>10220</td>
<td>8570</td>
</tr>
<tr>
<td>1986</td>
<td>8570</td>
<td>12815</td>
</tr>
<tr>
<td>1987</td>
<td>3990</td>
<td>12680</td>
</tr>
<tr>
<td>1988</td>
<td>1460</td>
<td>8860</td>
</tr>
<tr>
<td>1989</td>
<td>1455</td>
<td>2290</td>
</tr>
</tbody>
</table>

Information from some districts not available.

Source: Extension Division, Department of Agriculture.

Table 3. Proportion of crop diversification in some major irrigation systems during yala, 1990.

<table>
<thead>
<tr>
<th>Irrigation scheme</th>
<th>Area (ha) under</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rice</td>
</tr>
<tr>
<td>Kantale</td>
<td>5838</td>
</tr>
<tr>
<td>Giritale</td>
<td>2935</td>
</tr>
<tr>
<td>Minneriya</td>
<td>8943</td>
</tr>
<tr>
<td>Kaudulla</td>
<td>4312</td>
</tr>
<tr>
<td>Rajangana</td>
<td>5000</td>
</tr>
<tr>
<td>Huruluwena</td>
<td>2900</td>
</tr>
<tr>
<td>Mahavilachchiya</td>
<td>975</td>
</tr>
<tr>
<td>Nachchaduwa</td>
<td>2987</td>
</tr>
<tr>
<td>Inginimitiya</td>
<td>1200</td>
</tr>
<tr>
<td>Dewahuwa</td>
<td>498</td>
</tr>
<tr>
<td>Minipe</td>
<td>4808</td>
</tr>
<tr>
<td>Muthukandiya</td>
<td>720</td>
</tr>
</tbody>
</table>
Progress of Crop Diversification

Crop diversification in rice fields in Sri Lanka has developed to its present position due to a number of reasons such as:

1. The gradual banning of imports of subsidiary food crops starting in the early 1970s.
2. Higher economic benefits for farmers through higher net returns and cost benefit ratios with better product prices on some OFCs, compared to rice.
3. Frequent water scarcities in the low rainfall season yala, in most of the major irrigation schemes.
4. Better extension services and improved communication between farmers and agency officials.
5. Institutional support for crop diversification mainly through greater interest generated for irrigated crop diversification among policymakers.

Agencies Involved in Crop Diversification

The following sectors are involved in crop diversification in Sri Lanka:

Irrigation. Basically, the control of regulatory and conveyance structures as well as their maintenance in the major irrigation schemes outside Mahaweli is handled by the Irrigation Department (ID) while the Mahaweli areas come under the Mahaweli Economic Agency (MEA). The activities of the ID are expanded through the Irrigation Management Division (IMD) which is responsible for looking after the interests of farmers mainly through farmers’ organizations. Within the minor irrigation schemes, maintenance of the reservoir and other structures and the control of water are basically the responsibility of the Department of Agrarian Services (DAS).

Agriculture. The MEA has its own agricultural staff for extension and farmer training and an efficient agricultural input system for the Mahaweli areas. The basic agricultural policy adopted by the Mahaweli is the national agricultural policy.

The DA carries out the extension work in the rest of the country through an intensive network of trained extension workers. It is also responsible for all agricultural research. Agrochemicals, fertilizer, machinery, and implements are sold through the retail outlets of the Department of Agrarian Services (DAS) located in the Agrarian Service Centers set up in strategic places throughout the country.

Credit and insurance. Several public and private banking institutions extend credit facilities to farmers. viz., Bank of Ceylon, People’s Bank, Rural Banks, Hatton National Bank, Commercial Bank. Crop insurance is effected through the Agricultural Insurance Board (AIB), a state organization. Due to their bureaucratic approach and lack of finances, the AIB crop insurance schemes have become failures.
Marketing and pricing. A number of state sector institutions such as the Cooperative Wholesale Establishment (CWE), Department of Marketing Development (DMD), Paddy Marketing Board (PMB) and Multi-Purpose Cooperative Societies (MPCS) are instrumental in the marketing and pricing of produce. In addition, the private sector plays a key role in marketing and pricing, a role which the state sector has failed to play. Floor prices are fixed by the government for some farm products, to encourage farmers to get a better income and to encourage the cultivation of these crops.

**Mahaweli (a special case).** Within the Mahaweli areas, irrigation, agriculture and other support services are all provided by the MEA. This enables a better coordination of all activities in relation to the services and inputs necessary for agricultural production. Although marketing and pricing are not handled by the MEA, it provides infrastructural support services such as storage space, transport to better markets, and arranging of forward contracts with interested buyers, etc., for the benefit of the farmers.

**IRRIGATION PLANNING AND OPERATION FOR RICE-BASED SYSTEMS**

**Practices in Rice Irrigation Systems**

Planning for the cropping season within Mahaweli areas. Planning for rice irrigation in the Mahaweli projects is started 60 days before the season using the rainfall and inflow probability values based on data of the past 30 years. Closer to the season, necessary adjustments are made to allocations to each area and within the area, from the main system. This is possible due to the reliable information and communication system that is in place, as well as the continuous monitoring and evaluation at each level of management within the Mahaweli on irrigation, agriculture and lands. The weekly progress is monitored specifically for agriculture and irrigation to enable necessary adjustments to be made at the system level. Usually, the mahaseason does not pose many problems of irrigation for rice cultivation since the demand for water is met by rainfall and supplementary rotational irrigation towards the end of the season.

In the Mahaweli areas, the opportunities for and the constraints to cultivation are discussed in a series of preseasonal meetings of smaller farmer groups, organized by the MEA staff, where consensus is reached through effective communication and dialogue.

The Water Panel (WP), which consists of all senior officers of the departments and sections involved in irrigated agriculture in the Mahaweli downstream areas and those which benefit from Mahaweli water, meet once in the preseason and confirm the Seasonal Operational Plan (SOP) which has been formulated at all levels, starting with the farmers in the field. The WP has jurisdiction over all areas that receive Mahaweli water at some stage. The logistical backup and database for the WP is provided by the Water Management Secretariat (WMS), which operates at a higher intersystem level and plans and monitors very closely all activities in the cultivation areas covered by the WP.
**Planning for the cropping season outside Mahaweli areas.** Outside the Mahaweli areas, the situation is entirely different, where individual reservoirs or run-of-the-river systems (diversion schemes) have to manage their own systems and resources. They may have to depend entirely on the rainfall in their own catchment and its runoff. Planning officials have to wait until the reservoir is filled to a certain level so that at least selected areas could be irrigated. Farmers would like to cultivate with the minimum risk and therefore, even though the officials propose to start cultivation early with the first rains, they will not initiate any activity under water scarce situations. The allocations of water are made only after ascertaining the availability of water in the reservoir.

Under the Irrigation Ordinance, each irrigation scheme should hold a *kanna* (seasonal cultivation) meeting, immediately before the start of the season, to decide on the dates to begin and terminate the water issues for cultivations, which *crop/crops* are to be cultivated and other calendar deadlines for various activities related to cultivation. Farmers are informed of the available resources (mainly water), opportunities, options and expected problems at these meetings, and they are allowed to take decisions on the above aspects. Once the farmers agree on the dates and other matters, the decisions taken are confirmed.

The basic organizational structure for planning a cropping season in the major irrigation schemes is the Project Committee, which comes under the program for Integrated Management of Major Irrigation Schemes (INMAS). A Project Manager coordinates the functions of the line departments if that irrigation scheme comes under the management of the Irrigation Management Division (IMD) of the Irrigation Department. Otherwise the Government Agent (GA) of the district is entrusted with these functions.

At the district level, program planning, implementation and monitoring are supported by the District Agricultural Committee (DAC), chaired by the GA and consisting of the district heads of all the line departments. They meet once a month. The progress of cultivation, supply of *inputs*, marketing of produce and other field problems are discussed at these meetings.

Policy guidelines, decisions, and directions for the program are sent by the Central Coordinating Committee at national level comprised of the secretaries of the Ministry of Land, Irrigation and Mahaweli Development and the Ministry of Agricultural Development and Research as well as the Heads of the Departments of Agriculture, Irrigation, Land Commission, and Agrarian Services and the state banks.

The main functions of the Project Committee are to formulate and implement a cultivation program taking into account availability of water for the *maha* and *yala* seasons, to ensure the proper distribution of water, arrange timely provision of inputs and marketing *facilities*, arrange operations and maintenance programs for the irrigation system and organize farmer participation.

**Assessing and matching water supply and demand.** The Mahaweli areas have the necessary infrastructure for assessing and matching water supply and demand. In areas outside Mahaweli, *facilities* and staff are seldom available for the measurement and control of water, monitoring of activities, etc., to carry out these programs. The absence of sufficient hydrological data and its unreliability when available, are common to most major irrigation schemes.

In the case of rice irrigation, management arrangements are not as effective yet to supply the optimum on-farm water requirement with respect to space and time although the total
quantity may have been supplied. On-farm supply may be either continuous or rotational or both. It is very seldom based on the agronomic requirements of the plants. This apparently is due to the incapability or shortcomings of the delivery system and/or the reluctance of the management to take on extra responsibilities.

Allocation of water and land areo. Allocation of the land during yala is usually for rice cultivation in poorly drained soils which occupy the bottom of the valley or the catena. Although there is no legal requirement to do so, rice farmers are compelled to adhere to this drainage class due to the restricted issue of rotational water during yala. In Mahaweli, every effort is made to get as many farmers as possible to grow OFCs in well-drained soils in order to be able to cultivate as large an area as possible. The bethma system, referred to earlier, has also been tried out successfully in System H. Under this system, water is issued for cultivation only under selected distributary channels which are close to the source of water. Even in these distributary channels, the poorly drained soils at the tail end are not taken up for cultivation.

Modified practices to accommodate nonrice crops. In changing to OFCs from rice during the yala season, the Mahaweli system can generally cope with the planning needs since they have a good base of past hydrological data and performances. In the areas outside Mahaweli, such support information is not fully available for accurate planning. allocation of water and operation of their irrigation systems. Due to this shortcoming, the farmers have little faith in the system, or in the management, as a result, the allocation of land and water by the management has to wait until the season has almost begun, by which time the farmers have very limited options.

Some irrigation systems do not have the necessary infrastructure and adequate canal delivery capacity to supply intermittent flows for irrigating OFCs, although in some of the major irrigation schemes, the delivery system has been subsequently modified to cater to such requirements.

A major setback in accommodating OFCs in almost all the major irrigation schemes is that adequate drainage facilities to convey excess water from a heavy downpour have not been provided. Even if the on-farm drainage facilities are provided, OFCs may suffer substantially due to lack of surface drainage facilities. However, the undulating landscape provides for natural drainage in the dry zone where most irrigation schemes are situated.

Adequate on-farm drainage facilities are also necessary for OFC cultivation. On-farm land preparation has to be carried out within a shorter period for OFCs compared to rice, as relative dryness of soil is necessary. Consequently, the water requirement for land preparation is less for OFCs where only soaking to an optimum water content is necessary before working the soil. Unlike flat bed cultivation of rice, the method of seed bed preparation recommended and adopted for OFCs is the raised bed system. Farmers may adopt the recommended method or deviations from it such as flush basin flooding and broad bed and furrow systems, depending on their ability to bear the costs, and socioeconomic expectations.

The difficulty in demarcating the land precisely between the different drainage classes poses problems for officers as well as farmers. In addition, no precision leveling is done before farmers are given land. Seepage is very high along unlined canals resulting in an elevated groundwater table. The narrow moisture range of workability of reddish brown earths, which is the dominant soil group in the dry zone, is a constraint to promoting OFCs.
Only a few OFCs are tolerant to high soil moisture levels. No short duration varieties of OFCs with high productivity have been identified. Although some farmers have mastered the cultivation of OFCs in rice fields, the majority have yet to improve their field agronomic practices.

The requirement of cash and labor inputs is higher for OFCs compared to rice and the majority of farmers are not financially capable of investing or undergoing the risk of such investment. Institutional credit is not available to most farmers who have been rendered uncreditworthy due to weak monitoring by the banking agencies. Noninstitutional credit is available at any time, but at very high interest.

Farmer participation in management is an important aspect when scarce water has to be shared rationally under rotational issues of irrigation. Some major setbacks for such collective action are land tenurial problems such as leasing, subletting and other related land transfers, where the temporary occupant is not interested in participating in making improvements to or maintaining the system.

Low and unstable market prices as well as a lack of organized marketing structures and storage facilities are hindrances to the development of OFC cultivation. The unpredicted and unplanned importation of locally produced crops leads to low market prices. It is also important that farmers are made aware that uniformity and high quality of their produce are important aspects of marketability.

As empirically observed, it should be noted that social norms and rituals also have a bearing on most of the decisions taken by the farmers. Auspicious dates and times, festivals and religious observance days, become a constraint to effective implementation of a cultivation program.

STRATEGIES TO ADDRESS CONSTRAINTS AND OPPORTUNITIES

Improvement of Irrigation Facilities

A more accurate database for all the major irrigation schemes based on rainfall probabilities, mean rainfall and inflow values should be developed so that effective planning could be done. This will help the management to take into account the different scenarios of water availability and plan accordingly for water and land allocation. As a result, there will be better integration of management and farmers.

Canal capacities have to be improved to deliver water up to the tail end in equal quantities. This would entail better regulation and control measures and better maintained structures.

Improvements in Procedures and Practices

System characterization and mapping. Identification and mapping of different drainage classes of the soil in the command area under the field channel, with fair accuracy, may help the
fanners as well as the management to decide, ahead of the season, what crops to be grown, what cultural practices to adopt, etc. Improvement of the monitoring capacities is important for the effective control of water at every stage of delivery to the on-farm turnout.

**Simulation modeling.** The rainfall-intlow-capacity modeling based on past available data will be of significant benefit for predicting water availability and cultivable areas.

Simulation modeling to find out the various input requirements, including water for OFCs based on the varieties and age classes of the different crops together with the ratio of OFC to rice on turnout and distributary-channel bases would help the management to make effective decisions. In addition, they will help project the effective cultivation of marketable produce and provide other information which will help farmers obtain better incomes.

**Participation of farmers.** One way of improving system management is to improve communications between themanagement and farmers as well as allowing fanners to share the responsibilities of management at least at secondary and tertiary levels. This will make fanners aware of the conditions which lead to management decisions and help create a better understanding.

Where leasing and other land tenurial problems occur, the temporary occupant should be invited to farmer group meetings and the importance of sharing water resources in an equitable manner explained to him. Regularizing such practices may be of advantage when attempting to solve farmer-participation problems. However, research has to be carried out to ascertain the best approach to such regularization.

A successful start has been made, in an informal manner, in the Kimbulwana Oya Irrigation Scheme where farmers have effectively participated in the management of the system.

**Wateraugmentation.** Most irrigation systems cannot cope with long-duration OFCs during the yala season, due to water scarcity. Most short-duration crops available are not high productivity crops and do not have high market prices. On the contrary, high productivity crops such as chili (long duration) and onion (requires frequent irrigations) need extra water. Farmers who grow high productivity crops should obtain additional requirements of water from a shallow well, which should be dug in their field and which will get water from canal seepage and groundwater.

**Cropscheduling.** The main objective of crop scheduling should be to match the duration of the different crops to the period of water availability and to take advantage of limited water resources. In addition, crop scheduling to obtain stable market prices is of paramount importance when farmers are encouraged to go for commercial agriculture. Any management changes should be for the sustainability of the system. An additional income could be obtained from a crop of short duration, established immediately after the maha season (as has been successful in Mahaweli SystemH early this year), taking advantage of the residual moisture (Annex). Sandwich cropping, as it is called since it is between two cropping seasons, will help to stabilize the market and increase the cropping intensity as well.
On-farm irrigation practices. Although technology is available for on-farm irrigation and drainage for OFCs, most farmers deviate from the recommended practice of seed bed preparation due to the need for higher investment. Land prepared for this purpose can be used only for a single season. It also requires a considerable amount of labor during a period of peak labor demand. Therefore, it is necessary to consider an OFC/OFC cropping system in well-drained soils instead of a rice/OFC system, at least for a few years, until the soils require a different cropping system. This will allow farmers to make a one-time investment in seed bed preparation for OFCs and save such expenditure each succeeding season.

Farmer training. The training of farmers is an essential component of any crop diversification program. Such training must be supported by experienced and effective trainers, good training material and other infrastructure requirements. The achievements in the Mahaweli project and a few other irrigation projects in crop diversification during the last few years is mainly due to the active involvement of the extension workers (field assistants/krushi viyapthi niladhari), who were well trained and dedicated to extension.

Cropping for future local and foreign markets. The expansibility of OFCs is limited due to the national requirement of rice as the staple diet and the limited domestic demand for OFCs. Overproduction may result in the collapse of the domestic market with irreversible repercussions unless export markets could be found early.

Other field crops grown locally do not have a large export market unless they are processed into the products the export markets demand. Farmers should be made aware of the quality and type of products that the export markets take in, and their profitability if a diversification program is to be successful and sustained.

Alternatively, new crops for international markets should be tested in the dry zone for suitability and higher incomes. The Mahaweli Authority has been successful to some extent in this respect, where private entrepreneurs are actively cultivating exportable crops like gherkins, asparagus, and strawberries. Sri Lanka’s continued presence in the export market for a long period depends on its ability to compete with other countries. On the other hand, there is another school of thought which says that eventually it will be best to introduce crops which could feed the local market at a price lower than that for rice or wheat. This can help to replace a considerable quantity of the staple diet with a lower cost food. Cassava, sweet potatoes, and other yams which come under this class of crop, are already being grown in smaller areas under irrigation in rice fields. Import substitution will save foreign exchange.

Instead of short-duration OFCs, another alternative cropping system would be to introduce semi-perennial crops that do not require as much water as rice and thus, can survive no-water-issue periods. Banana, which is grown successfully under irrigation in Uda Walawe, and some other fruit bearing trees come under this category. After a few years of semi-perennial crops, rice can be cultivated for a short duration. This system does not, however, earn much foreign exchange for the country as export crops would.

Extension services. Extension services should be able to cater to the growing need for technical and financial information for farmers who will be turning more and more towards commercial farming.
DIRECTION OF CROP DIVERSIFICATION

Research and Development

Stretching the limited water available during the dry yala season over a larger extent has to be the key issue in crop diversification. At present, land utilization, using the available water resources, is not at an optimum. It is either underutilization of land or overuse of water where available. The records of water use in most irrigation schemes show high usage both at ex-sluice and on-farm. On the other hand, the annual cropping intensities for two consecutive seasons are as low as 150 percent.

Crop diversification in Sri Lanka is supported by a number of agencies for various reasons, but mainly to contribute to the GDP and for import substitution. There is a growing awareness among the planning agencies on the need for crop diversification. For further acceleration of crop diversification the following aspects are important.

Agronomic aspects. The technology available for irrigated OFCs in rice fields is fairly adequate at present. The trend during the last few years on net returns of some OFCs is of a diminishing pattern due to diseases, pests and the high unit cost of labor and other inputs. Research should be directed towards developing comparatively high yielding varieties of crops to overcome the increased cost of production. In addition, these varieties should be of short duration to minimize any risk of water stress.

Pure seed material of the varieties suitable for the situation should be available to enhance the income of every farmer. Hybrid varieties, which will give a uniform crop and thereby a higher marketability, are of paramount importance in this respect.

Research on different cropping systems involving various OFCs which may complement each other on resources requirements will be advantageous to farmers. Finding a wide range of crop combinations suitable for irrigated rice lands will give the farmers better options.

Research should be conducted on reducing costs of cultivation of OFCs, through optimum use of resources and minimum use of costly inputs and even mechanization wherever possible.

New crops and new avenues should be explored for the local as well as export markers. Development of value-added products of processed food made from traditional and non-traditional OFCs should also be explored.

Irrigation aspects. Simple methods should be developed to assess the field irrigation requirements for different cropping systems and crop combinations. Suitable water application methods should also be explored.

The water requirements for land preparation under different systems of seed bed preparation have to be reassessed.

Macro-drainage systems have to be designed for all the irrigation systems, the majority of which do not have proper drainage systems.

Methods to distribute water equitably among farmers as well as within a farm (on-farm) have to be evolved. The present distribution pattern necessitates high irrigation which has attendant social problems.
Farmer participation in irrigation management has to be looked at closely. This is now the government policy in Sri Lanka. Where and how best farmers can participate in the management of their delivery system have to be analyzed. At present, farmer participation is effected through farmers’ organizations at various levels, perceived as needed by farmers and donor agencies. It is opportune to study whether another concept is needed under Sri Lankan conditions, at what levels and in what form.

**Marketing aspects.** Stable prices and marketing support services have to be analyzed to ascertain the factors which will give the optimum rate of growth without a crash in the market. In the meantime, cropping during the off-season to “catch” high prices should also be explored.

**Credit and financial aspects.** Credit facilities should be available to all farmers irrespective of their creditworthiness. How these farmers could be made creditworthy should be analyzed. Monitoring of disbursements and repayment of credit are key issues neglected by most of the credit giving agencies. This is something which policy planners should focus on. A crop insurance scheme for other field crops is necessary.

**Dissemination and Exchange of Information**

Dissemination and exchange of information should be more effective in respect of the various subjects related to crop diversification such as irrigation, irrigation management, agronomy, marketing and finance. This process should not only be vertical but horizontal as well and both aspects should be of a reciprocal nature.

**Funding**

There is a growing awareness among the planning agencies, of the seed for crop diversification. The institutions already active in this respect will continue to carry on with their projected programs with a gradual and careful increase in activities. These institutions will continue to accommodate and expand the support for research and development, extension, marketing, etc.

It is unlikely that at present the country can afford to disburse funds for various studies required for crop diversification, except for obtaining the services of professionals. Funds are required for research on various aspects including irrigation, agronomy, socioeconomic, marketing, extension and training of officers and farmers, where special studies and projects have to be undertaken and information has to be collected and documented. Research and extension are of importance towards the integrated farming systems approach, where rice/OFIC cultivations in irrigable lowlands and the farming activities on highlands will complement each other for stabilized incomes, in the context of the small farmer.

Finally, the importance of coordination at national level cannot be overemphasized if the above requirements are to be fulfilled.
We wish to record our gratitude to Dr. C.R. Panabokke, who has long years of experience in irrigated agriculture in Sri Lanka and who assisted us greatly with his suggestions, etc., in the preparation of this paper. His efforts contributed much to its improvement. We are also grateful to Dr. Senen Miranda for his help and encouragement in our efforts.
References


Annex

Progress of Crop Diversification in the Mahaweli Projects

Jayantha Jayewardene

The Accelerated Mahaweli Development Programme (AMDP) has made every effort to diversify its cropping programs from rice to Other Field Crops (OFCs) in all its project areas. (See map which shows the AMDP Projects [p. 124].) This effort, from modest beginnings a decade ago, achieved its best results in yala 1990 when diversified cropping in all Mahaweli projects produced crops valued at Rs. 1,797,026,500 or US$44,935,662. Diversification to OFCs in the Mahaweli projects which have rice-based irrigation systems, was undertaken to increase settler incomes and to make better use of the land and water during the dry period.

Detailed below are some of the areas in which significant diversification progress has been made.

Intermediate Season

With the objective of giving the fanners in System H an additional income, the Mahaweli Economic Agency (MEA) organized a short-duration cultivation in the fallow period between the maha 1989/90 and the yala 1990 seasons. Pulses were encouraged as their water requirement was less and the growth duration and cultivation costs low.

Soon after the maha 1989/90 rice harvest in System H, an extent of over 100 ha was sown with soybean, cowpea, and green yam. With no tillage the seed was just dibbled into the soil in an effort to use the residual moisture in the field. This meda or middle cultivation, also called sandwich cropping, proved a success in terms of farmer enthusiasm, farmer incomes and agricultural production potential capability. It is hoped to increase the area under this type of cultivation after the maha 1990/91 harvest as well using the experiences that have been gathered in the past effort. Most farmers made over US$370 per hectare (Rs 6,000 per acre) from this cultivation. These successful cultivations gave farmers the incentive and confidence to cultivate more OFCs in the yala season that followed.
Figure 2. The Accelerated Mahaweli Development Programme, Sri Lanka.
Big onion. Though the Mahaweli planned a large scale cultivation of big onion in Systems B, C, G, and H, a shortage of reliable seed caused a setback to the planned program. The MEA, however, made special arrangements to make seed available to the farmers from other sources. With difficulty, especially in terms of the credit facilities necessary for seed purchases, adequate quantities of seed were purchased from the private sector, their viability tested and cultivated by the Mahaweli farmers.

A total of 4,210 metric tons of big onion from 566 hectares, valued at Rs35,785,000 or US$894,626 were to be harvested from the Mahaweli areas this yala season. Special training sessions on the storage of big onion were organized for the farmers, as such large quantities coming in once would cause a glut in the market, resulting in low prices and waste through spoilage.

Chili. System H has established itself as the largest chili producing area in Sri Lanka. Chili was one of the first crops encouraged under the Mahaweli Diversification program that started in System H in 1980. Now, System H produces nearly 50 percent of the country’s chili. In yala 1990 season, 9,330 ha of chili valued at Rs. 612,990,000 or US$15,324,750 were cultivated in the Mahaweli projects. The total production was 13,622 metric tons. A variety of diseases, including leaf curl, affected production but the yields harvested were satisfactory.

Gherkin. In the last four years, the export of gherkin from the Mahaweli projects, mainly to Australia and some European countries, has grown very fast. The 1990 yala season saw export orders for gherkin valued at Rs 22 M. The Mahaweli farmers are now quite experienced in the cultivation of gherkin having grown it over the last four years. Since this is a fast-growing crop and the project has to be harvested at the correct time, it is a very labor-intensive crop. Family labor is utilized intensively. In spite of Sri Lanka’s growing export trade in gherkin no research has been carried out yet by the Department of Agriculture on this crop.

Banana. The cultivation of banana under irrigated conditions has become popular in some of the Mahaweli areas, especially the Uda Walawe Project in south Sri Lanka. The reddish brown earths which are well-drained have promoted the change, together with the high profits that can be achieved by this crop.

Earlier, banana was planted with the onset of the maha monsoon rains and the plant went through some stress in the following dry yala period, to bear fruit during the next maha season. Small bunches were produced due to the stress experienced during the intervening yala season.

The Mahaweli Economic Agency introduced banana cultivation under irrigation with a view to increasing the incomes of the fanners and also to counter a water shortage in the tail-end sections of the Uda Walawe Project. The area under banana has increased from 205 ha in 1985 to 801 ha in 1989. High profitability, low labor input, a low water requirement and tolerance to drought make banana a popular crop. It also has the potential for intercropping with cowpea, chili, green gram, and onion in the initial stages and later with ginger, turmeric and yams.
Banana requires a considerable amount of moisture which has to be met by supplementary irrigation. Farmers in Uda Walawe use mainly furrow irrigation though some farmers have used flood irrigation which has caused water waste and lodging. Proper rotational water issues, 5-7 days initially and 7-10 day issues after 6 months are resorted to. Proper drainage is an important factor in the cultivation of banana under irrigation.

**Irrigation**

The Mahaweli irrigation systems have been designed for a rice-OFC cropping system. One of the main yala season cultivation problems in the Mahaweli, as elsewhere in the country, is the lack of adequate water. With diversification to OFCs, it is possible to cultivate a larger extent of land with the same quantity of water. The water requirements of each of the other crops are different and, therefore, rotational issues of water have to be extended accordingly. In poorly drained soils in the bottom of the valleys, only rice can be grown due to stagnation of water.

Effective rotational water issue systems have been worked out and are being implemented. These have worked fairly well as close monitoring of water issues is being carried out within the Mahaweli projects and at the macro Mahaweli system level as well.
Management Arrangements for Diversifying Rice Irrigation Systems in Thailand

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Lersak Rewtarkulpaiboon  
*Irrigation Engineer, Royal Irrigation Department Ministry of Agriculture and Cooperatives, Bangkok, Thailand*

**INTRODUCTION**

RICE IS THE most important crop in Thailand. It is the main staple food of the population, and is ranked first in terms of land utilization, planted area, number of farmers and export earning income.

Presently, out of the 23.65 M ha of agricultural land, 11.87 M or 50.19 percent is rice land (Table 1). Of the total 4.97 M farmers, 3.85 M (77 percent) are rice farmers. Out of the total area of rice land, 9.5 M ha were planted as the main crop in 1985/86 and 0.853 M ha as the second crop in 1989.
The rough rice output has varied from 16 to 18 M tons a year for the main crop and around 2-3 M tons for the second crop, making a total output of 20-21 M tons a year (Table 2). Normally, 13 M tons of rough rice are consumed domestically and 7-8 M tons rough rice or about 4.45 M tons rice are exported yearly. 1989 was an exception, when rice exports reached a record high of 6.04 M tons, accounting for 40 percent of the world market, and earning an income of 44,802.5 M bahts.

Thailand has been recognized as the world’s largest rice exporting country, leading the U.S.A. Vietnam and Pakistan. During the last five years, the average yield of rice was 1,843.52 kg/ha for the main crop and 3,692.85 kg/ha for the second crop. In terms of total rice land, the main crop, rice, accounts for 93 percent while the second crop accounts for only 7 percent.

In Thailand, rice could be grown in any part of the country. but 50 percent of the total area planted to rice is in the northeast, 22 percent in the north, 21 percent in the central region and 7 percent in the south (Table 3). However, most of the rice planted land in the northeast is in the plateau, saline and sandy areas, and relatively unsuitable for rice. In addition, the northeast region is dry with rain occurring in 80 days or less of a year. Here, only 0.62 M ha or 6.41 percent of the agricultural area is irrigated. Agricultural practices heavily depend on the weather and face high risks. As a result, the productivity of rice sown in this area has been lower than that in other parts of the country.

Only 4.12 M ha or 17.42 percent of the total agricultural land is irrigated. (Table 4). Irrigation is concentrated mostly in the central region with 2 M ha or 48.62 percent of the total irrigated area.

In 1957, the Chao Phraya Dam was completed and equipped with its main water distribution system. The system, at the tertiary level, was started in 1963 with ditches and dikes designed for wet-season rice cultivation. The land consolidation program was initiated as a pilot project in 2,000 ha with support from the Government of the Netherlands. The master on-farm development program was launched in 1974 and expanded in 1982 to cover 0.63 M ha.

In 1969, high-yielding varieties of rice, which are non-photo sensitive, fertilizer responsive, and short-maturing were sown in the irrigated areas, as the second crop during the dry season.
Table 2. Rice planted area yield and production

<table>
<thead>
<tr>
<th>Crop year</th>
<th>Planted area (M ha)</th>
<th>Yield (kg/ha)</th>
<th>Production (M ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Uain Crop</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1984/1985</td>
<td>9.266</td>
<td>1,864.34</td>
<td>17.275</td>
</tr>
<tr>
<td>1985/1986</td>
<td>9.510</td>
<td>1,864.34</td>
<td>17.930</td>
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<tr>
<td>1986/1987</td>
<td>9.271</td>
<td>1,864.34</td>
<td>16.826</td>
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<tr>
<td>1987/1988</td>
<td>8.626</td>
<td>1,864.34</td>
<td>15.272</td>
</tr>
<tr>
<td>1988/1989</td>
<td>9.499</td>
<td>1,864.34</td>
<td>17.882</td>
</tr>
<tr>
<td>Average</td>
<td>9.234</td>
<td>1,864.34</td>
<td>17.037</td>
</tr>
<tr>
<td><strong>Second Crop</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1984/1985</td>
<td>0.706</td>
<td>3,725.21</td>
<td>2.630</td>
</tr>
<tr>
<td>1985/1986</td>
<td>0.638</td>
<td>3,658.31</td>
<td>2.344</td>
</tr>
<tr>
<td>1986/1987</td>
<td>0.580</td>
<td>3,520.69</td>
<td>2.042</td>
</tr>
<tr>
<td>1987/1988</td>
<td>0.730</td>
<td>3,794.52</td>
<td>2.770</td>
</tr>
<tr>
<td>1988/1989</td>
<td>0.849</td>
<td>3,982.33</td>
<td>3.381</td>
</tr>
<tr>
<td>Average</td>
<td>0.701</td>
<td>3,736.21</td>
<td>2.631</td>
</tr>
</tbody>
</table>

Such developments have made the central region the major rice bowl of the country producing large surpluses for export. New technologies for higher yields and lower production costs make Thai rice competitive in the world market. Since one-third of the rice output is exported, world market prices have strongly influenced domestic prices. Overprotectionism and high export subsidies implemented in many countries have caused a decline in the world market price of rice.

Crop diversification programs have been launched in the central irrigated rice-based areas in Thailand in 1968 when a severe drought occurred. In some areas, the second-crop rice was grown while in others, low-water-requiring cash crops were introduced. Since then, the second-crop rice production has been regulated and limited to one crop every two years. Irrigation is alternately provided to each side of a canal.

The Ministry of Agriculture and Cooperatives (MOAC) heads the Committee for Dry Season Crop Production Acceleration. Before the beginning of the dry season, the committee plans the production targets for rice and other cash crops, the amount of water supply and the markets for those crops. In the past, diversification was not quite successful, owing to the unfamiliarity of rice farmers to prices and market demands for other crops.
Table 3. *Main-crop rice production by region.*

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>2.129</td>
<td>2.135</td>
<td>2.140</td>
<td>2.041</td>
<td>2.260</td>
</tr>
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<td>Central</td>
<td>1.964</td>
<td>2.009</td>
<td>1.954</td>
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<td>2.004</td>
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<tr>
<td>South</td>
<td>0.602</td>
<td>0.593</td>
<td>0.576</td>
<td>0.513</td>
<td>0.565</td>
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</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>2,393.14</td>
<td>2,389.23</td>
<td>2,357.48</td>
<td>2,215.49</td>
<td>2,507.96</td>
</tr>
<tr>
<td>Central</td>
<td>2,175.15</td>
<td>2,241.91</td>
<td>2,231.18</td>
<td>2,317.92</td>
<td>2,365.27</td>
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<tr>
<td>Northeast</td>
<td>1,524.61</td>
<td>1,548.71</td>
<td>1,387.52</td>
<td>1,362.72</td>
<td>1,423.28</td>
</tr>
<tr>
<td>South</td>
<td>1,559.80</td>
<td>1,573.36</td>
<td>1,526.04</td>
<td>1,245.61</td>
<td>1,546.90</td>
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<td>Whole kingdom</td>
<td>1,864.34</td>
<td>1,885.38</td>
<td>1,814.91</td>
<td>1,770.46</td>
<td>1,882.51</td>
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</table>

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<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>5.095</td>
<td>5.101</td>
<td>5.045</td>
<td>4.462</td>
<td>5.668</td>
</tr>
<tr>
<td>Central</td>
<td>4.272</td>
<td>4.504</td>
<td>4.518</td>
<td>4.513</td>
<td>4.740</td>
</tr>
<tr>
<td>Northeast</td>
<td>6.969</td>
<td>7.392</td>
<td>6.384</td>
<td>5.658</td>
<td>6.600</td>
</tr>
<tr>
<td>South</td>
<td>0.939</td>
<td>0.933</td>
<td>0.879</td>
<td>0.639</td>
<td>0.874</td>
</tr>
<tr>
<td>Whole kingdom</td>
<td>17.275</td>
<td>17.930</td>
<td>16.826</td>
<td>15.272</td>
<td>17.882</td>
</tr>
</tbody>
</table>

Table 4. *Irrigated area in 1988.*

<table>
<thead>
<tr>
<th>Region</th>
<th>Agricultural land area (ha)</th>
<th>Irrigated area (ha)</th>
<th>% of agricultural land area</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>5,433,323.6</td>
<td>1,088,037.2</td>
<td>20.02</td>
</tr>
<tr>
<td>Central</td>
<td>5,434,061.6</td>
<td>2,003,553.9</td>
<td>36.87</td>
</tr>
<tr>
<td>Northeast</td>
<td>9,732,399.2</td>
<td>623,501.0</td>
<td>6.41</td>
</tr>
<tr>
<td>South</td>
<td>3,038,319.6</td>
<td>405,792.8</td>
<td>13.38</td>
</tr>
<tr>
<td>Whole kingdom</td>
<td>23,648,012.0</td>
<td>4,120,884.9</td>
<td>17.42</td>
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</table>
IRRIGATION PLANNING AND COOPERATION FOR RICE-BASED SYSTEMS

The Chao Phraya and Maeklong Irrigation projects are the two largest irrigation projects in Thailand. This report is mainly about the Chao Phraya Irrigation Project, the larger of the two which covers approximately 25 percent of the whole irrigated area in Thailand.

Water Management System in the Chao Phraya River Basin

Large-scale development of irrigated agriculture in the Chao Phraya Delta, the largest granary of Thailand, started at the beginning of the 20th century and has continued to function under the Royal Irrigation Department (RID) for almost a century. Thus, the irrigation and drainage systems in the delta vary: some being fairly recently constructed have been operational since the last three decades while others are about 90 years old. Some of these structures were constructed at the lower left bank in the 1930s, at the lower right bank in the 1950s, and at the upper delta in the 1960s. The Chao Phraya Dam (diversion dam), Bhumibol Dam (storage dam) and Sirikit Dam (storage dam) were completed in 1957, 1964 and 1972, respectively (Figure 1).

Bhumibol Dam and Sirikit Dam were constructed to secure supplementary irrigation water in both wet and dry seasons and to support the Chao Phraya Project for flood control, navigation, hydropower generation, and salt water intrusion control as well as for domestic water requirements. The key diversion structure in Chao Phraya Basin is shown in Figure 2.

Today, the water supply from both dams cannot meet the increasing demands for dry-season rice cropping, industrial development, and urbanization.

Water Allocation System in the Chao Phraya River Basin

The water allocation system in the Chao Phraya River Basin follows a nearly pyramidal organization with the O&M Head Office in the RID Headquarters at the top, followed by field offices, regional offices, project management offices and respective terminal organization. The basic concept of a water management system is depicted in Figure 3.

The RID O&M Head Office, after receiving data/information from the field office via radio, makes analyses and judgements. Instructions on water distribution at the irrigation canals and operation of the facilities are sent back to each field office.

The project engineers assigned to each project office are responsible for the control of several branch offices. In each branch, a water master is responsible for an area of about 16,000 ha. Several zone men assist the water master. One zone man covers an area of 160 to 240 ha.

The present water allocation system was developed by the Canadian consultants, Messrs. Acres & Co., Ltd. on the basis of the aforesaid field-level system, and has been operational since 1982. This system has enabled the collection of data/information available at the
zoneman level to the Water Management Center of the RID Headquarters. Information flow in the Water Operation Center (WOC) is schematically shown in Figure 4.

Figure I. Chao Phraya Basin
Figure 2. Key diversion structures in Chao Phraya Basin.
Figure 4. Information flow in the Water Operation Center.

<table>
<thead>
<tr>
<th>DATA REPORTING</th>
<th>DAILY AINFALL DATA</th>
<th>WEEKLY CROP DATA</th>
<th>WEEKLY FIELD CONDITION DATA</th>
<th>FIXED SYSTEM DATA</th>
<th>DAILY FLOW DATA</th>
<th>DAILY WATER LEVEL DATA</th>
</tr>
</thead>
</table>

COMPUTER SYSTEM

INTERPRET OUTPUT

WATER ALLOCATION

REVIEW PROCESS

FEEDBACK

DATA

RATIONING

REVIEW OF OPERATIONS POLICY

YEARLY REVIEW OF OPERATING SYSTEM
Assessing and Matching Water Supply and Demand

The total irrigation demand for the Chao Phraya River Basin is computed on a weekly basis. The computed total demand is combined with the releases required for the Bangkok Water Supply and the needs to maintain river navigation and salinity control. An estimate is made of the quantity of uncontrolled inflow expected to enter the system over the coming week and the net demand on the reservoir is computed by subtracting the estimated quantity of uncontrolled inflow from the gross demand.

The net demand value is conveyed to the Electricity Generating Authority of Thailand (EGAT) and it becomes the target reservoir release for the coming week. EGAT is free to release water during each day in a pattern suited to electrical demand requirement, with the understanding that the mean release over the week will be in accordance with the RID's request. In deciding the amount for the dry season the reservoir capacity at the end of November should be considered (Figure 5).

Irrigation Water Use for Chao Phraya Delta

The water resources of the Chao Phraya Delta are the water releases from the Bhumibol and Sirikit reservoirs, uncontrolled side flows, and direct rainfall in the Delta. Kiulom Reservoir in Wang River and other reservoirs in the basin only function to supply water to their own irrigation areas.

The amount of water received from resources of the Chao Phraya Delta from 1977 to 1986 is shown in Table 5.

| Table 5. Amount of water received from resources of the Delta |
|-----------------|-----------------|-----------------|-----------------|
| Season          | Release from reservoir (MCM) | Side flow\(^a\) (MCM) | Available water (MCM) |
| Wet\(^b\)       | 3,800            | 14,700           | 18,500          |
| Dry\(^c\)       | 6,200            | 1,200            | 7,400           |
| Total           | 10,000           | 15,900           | 25,900          |

\(^a\) Side flow at Nakhon Sawan and Rama VI Barrage. 
\(^b\) From July to December. 
\(^c\) From January to June.

Water released from reservoirs amounts to 3,800 to 6,200 MCM or 25 percent to 90 percent of available water, during the wet and dry season, respectively. Side flows are not expected during the dry season especially from January to April, and most of the irrigation during this period depends on water released from the reservoirs.
Figure 5. Combined storage of Bhumibol and Sirikit reservoirs.
Water Balance in the Chao Phraya Delta

The relationship between available water and water consumption in the Delta is shown in Table 6. The consumptive use and the effective rainfall for crops are estimated in a simulation model. It can be seen that available water is fully consumed in the dry-season. Storage of river flow and rainfall in the wet season is effective for extending dry-season crops. River flow in 1979 was less than in other years even in the wet season.

Table 6. Result of water balance study in Chao Phraya Delta.

<table>
<thead>
<tr>
<th>Year</th>
<th>Season</th>
<th>Irrigation area (ha)</th>
<th>Actual</th>
<th>Calculated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Intake (MCM)</td>
<td>Release (MCM)</td>
</tr>
<tr>
<td>1977</td>
<td>Wet</td>
<td>992,000</td>
<td>7,790</td>
<td>6,299</td>
</tr>
<tr>
<td>1978</td>
<td>Dry</td>
<td>336,000</td>
<td>2,772</td>
<td>2,217</td>
</tr>
<tr>
<td></td>
<td>Wet</td>
<td>960,000</td>
<td>6,010</td>
<td>24,771</td>
</tr>
<tr>
<td>1979</td>
<td>Dry</td>
<td>512,000</td>
<td>5,343</td>
<td>3,268</td>
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<tr>
<td></td>
<td>Wet</td>
<td>976,000</td>
<td>7,118</td>
<td>3,890</td>
</tr>
<tr>
<td>1980</td>
<td>Dry</td>
<td>208,000</td>
<td>1,967</td>
<td>3,370</td>
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<td></td>
<td>Wet</td>
<td>976,000</td>
<td>6,819</td>
<td>22,507</td>
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<tr>
<td>1981</td>
<td>Dry</td>
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Water Shortage in Dry Season Cultivation for Chao Phraya Delta

At present, water in Chao Phraya River Basin is completely utilized to cultivate the rice fields (320,000-480,000 ha) in the dry season. In collaboration with the IUD and Acres Company, the rice cultivation area in the dry season is determined considering the storage of Bhumibol and Sirikit reservoirs at the end of November and the necessity to maintain the water levels of both reservoirs at allowable levels (Figure 6). In the release of water from the reservoirs the maximum benefits have to be considered.

Due to water shortage for rice cultivation in the dry season, increasing irrigation efficiency will increase the cultivated area. Increase in irrigation efficiency requires better water management and related factors such as technology.

Possibility of Nonrice Crop Farming in the Greater Chao Phraya Project

The major crop grown in the Greater Chao Phraya Project is rice because farmers still consume rice as their staple food while selling surpluses to generate income. If the farmers will grow nonrice crops instead of rice, the irrigation system will be affected, especially the capacity of the canal, water control and irrigation structures. Moreover, water control operations for nonrice crops will need more manpower. As such, the government has to consider:

1. Improving the main canal delivery of irrigation projects, including irrigation networks and on-farm facilities for nonrice crop farming.
2. Organizing water user groups for operations which should be implemented by the IUD in theimgable area.
3. Strengthening cooperation among the Department of Agriculture, Department of Agriculture Extension, Central Land Consolidation Office, Bank for Agriculture and Agricultural Cooperatives.

Planning for the Cropping Season

Background. After the construction of the Chao Phraya Dam in 1957, the water stored has been used to support rice cultivation in the irrigation project area of 1.2 M ha. However, because of the limited storage, the total irrigated area in the rainy season was only 0.88 M ha. This was increased to 0.98 M ha with the completion of the Bhumibol Reservoir in 1964 and Sirikit Reservoir in 1971. In 1970, farmers started dry-season rice cultivation of 48,000 ha in Tung Chao Phraya and this increased to 0.48 M ha during 1981-1984. The increase in irrigation area causes water shortage as the storage is limited. Therefore, the water is distributed alternately each year so that all farmers at the upper part of the project who receive water under gravity are able to farm equally. In 1987, the irrigation area of Tung Chao Phraya was decreased from 0.48 M ha to 0.4 M ha. However, during 1988-1989 the price of rice went up and this stimulated farmers to grow dry-season rice in an area exceeding the target.
area. This caused severe water shortages and improper water management. Consequently, the following criteria were set to alleviate the constraints:

Figure 6. Typical dry-season cultivation area reduction in relation to storage level.
1. The area which was not cultivated for rainy season rice is given first priority for dry season irrigated rice.
2. The area which suffered natural disaster with damage of more than 50 percent is given second priority.
3. The area which is the next in turn for irrigation is given third priority.
4. If more water can be used for dry season rice cultivation, the area could be increased accordingly.

With these criteria, target areas and reasonable rotational water distribution are determined. However, the problem of water shortage cannot be eliminated. This was compounded by the fact that Thailand experienced drought for four consecutive years resulting in diminished water reserves. The problem of water distribution often arises with stronger competition for water among farmers. A possible solution is to alter the practice of rice production to cultivate other cash crops that require less water and give higher returns. Therefore, a proper cropping system must be planned for both rainy and dry seasons. This includes the identification of crop boundaries.

The land use record of Chao Phraya Project indicates a small area, estimated at 6 percent of the rice area, that has been used for upland cropping. Upland crops are mostly cultivated on the upper part of the project along the naturally raised bank of the Chao Phraya River where irrigation is done by gravity and the soil is well-drained. The major upland crops grown are mungbean, soybean, peanut, sugarcane and watermelon. Soybean is grown and consumed fresh or sold to the local market or to the central market in Bangkok. It is observed that upland cropping is practiced in some areas. In relation to rotational water distribution, farmers grow rice on the land to be irrigated and upland crops on the lands not scheduled to be irrigated.

The situation gives some idea of the changing pattern from rice cultivation to the cultivation of other cash crops. Alternative crops were selected according to their physical suitability and marketing potential. At the beginning, farmers were supported with production technology, inputs and price information. They were also informed of the limitation of reserved water and cautioned of possible critical shortages. Crop diversification was promoted by:

1. Introducing cash crops such as soybean, maize, etc., to replace dry-season rice.
2. Maintaining upland crop area, and preventing it from being used for dry-season rice by providing farmers with good varieties of peanut and mungbean seed which give higher yields and income.

Procedure. The yearly workplan includes the following:

1. The irrigation area is determined in proportion to the amount of water reserved for both rainy-and dry-season cropping.
2. The cultivation period is set by adjusting the growing period of the rainy-season crop to that of the dry-season crop. The irrigation period is also adjusted to match the cropping schedule.
3. The cropping plan for the whole year is formulated to meet the requirements of topography, soil, water, and seasons.
4. Farmers are organized to ensure the start of planting operators at the same time, regulate irrigation timing and reduce conflicts among farmers.

As upland crops such as soybean, peanut, muligbean, maize, sesame, and vegetables were introduced, many problems surfaced as farmers were not familiar with these crops. Technical assistance and other support services were therefore provided. These were:

1. Instruction to farmers on land leveling and proper land preparation, particularly, ridging.
2. Introduction of drainage canals around and inside plots.
3. Introduction of herbicides.
4. Introduction of postharvest technologies.
5. Coordination with the private sector for marketing.

The cropping schedule of each crop was adjusted to start the growing season not later than December, especially for soybean, maize and peanut, with a view to harvesting in April. This would obviate harvesting during the rainy season and the attendant problem of aflatoxin in peanut and maize.

CONCLUSION

The diversification of crops in Chao Phraya Project can be practiced in a small portion of the project area during the dry season as farmers in the project area prefer rice to other crops. The farmers do not want to reduce their rice area. Besides, the project area is mostly lowland with clayey soil and poor drainage capacity. An attempt at crop diversification is, therefore, made by:

1. Specifying the upland crop area for diversification by creating production zones.
2. Adjusting the water allocation system in a manner consistent with the production zones.
3. Introducing crop production technology.
4. Coordinating with the private sector for marketiiig and ensuring reasonable prices.
Summary/Highlights of Papers/Discussions: Country Reports

The eight participating countries presented their experiences on irrigation management for rice-based cropping as these relate to planning, implementation, monitoring and evaluation both at the system and farm levels. Constraints and opportunities for crop diversification and activities related to research and development (R & D), information exchange and dissemination, and funding and organization were discussed. The direction in which these activities were headed was highlighted.

Bangladesh

In Bangladesh, the agroclimatic conditions favor a rice-based farming system. Rice is the staple food and farmers will continue to grow rice to meet consumption demand. However, irrigated rice production is becoming less profitable and growing nonrice crops such as pulses, oilseeds and vegetables with partial or full irrigation in the dry season becomes a major strategy to increase farmers’ income and improve soil fertility.

The most important factor that influences crop diversification is the economic incentive to farmers in growing nonrice crops. To promote crop diversification, institutional support is needed in terms of credit and price incentives for nonrice crops, back-up services from irrigation-related agencies, and storage, processing and marketing of nonrice crops. More research and development are needed in the field of irrigation water management and varietal development of both rice and nonrice crops.

Government subsidies on farm chemicals and cost of power have been a major issue. Officially, there is a minimal subsidy on fuel and pumps and a subsidy of about 40 percent on chemical items, but none on fertilizers.

Strategies by which the government convinces the farmers to plant nonrice crops considering that returns on rice are higher, are: a) agricultural extension; b) distribution of seedlings/seeds; c) distribution of small-scale facilities; and d) providing access roads. However, the effectiveness of extension services still remains very low.

India

India attained self-sufficiency in rice production during the early 1970s with the introduction of high yielding varieties and extension of irrigation facilities. This has resulted in declining farmers’ income and a need to diversify the cropping system to nonrice crops. This requires changes in planning, water allocation, and operation and maintenance of irrigation systems which consequently need consideration of water control, agronomic and irrigation practices, economic risks, inputs, climatic requirements, socioeconomic constraints and institutional
strengths. To address the above factors, strategies have to be identified by undertaking research in terms of policy, and implementation of technical solutions to specific constraints. This could be carried out by ICAR institutions, agricultural universities and water and land management institutes in the country.

**Indonesia**

From a purely technical standpoint, crop diversification in Indonesia is not **perceived** as a major problem because the existing irrigation systems have been developed and **operated** for diversified crops in rice-field areas. The problem becomes complicated considering the technical-socioeconomic interactions between irrigation management practices and the crop diversification farming systems.

The government explicitly recognizes crop **diversification** as a major policy to improve, among others, productivity and income. Developing crop diversification and improving irrigation management practices can be addressed by conducting a well-planned program and well-structured implementation of research. To speed up development, a program approach in technology transfer is suggested.

Indonesia reached self-sufficiency in **rice** during **1984-1985**. With the Special Intensification Program on non-rice crops of the Ministry of Agriculture and the marketing assistance provided, farmers were persuaded to shift to non-rice crops.

**Malaysia**

The scale of current crop diversification on rice land in Malaysia is small. For the moment, there is **no** monitoring and evaluation in the operation of the irrigation system for diversified cropping. No major structural and managerial adjustments have been imposed on the system. Nevertheless, crop diversification has been successfully practiced. Minor adjustments that were enforced and have potential application elsewhere include: a) reducing flow to below **FSL** so that the canal can function as a drain as well; b) deepening canals to increase storage for pumping; c) acquiring portable pumps to provide flexibility in water management by farmers; d) having **stable**, reliable and predictable water supply to be augmented whenever necessary by **farm** ponds and tubewells at **farm** level; and e) improving the on-farm conveyance system by using concrete-lined canals or pipe system complemented with regulatory structures.

Malaysia is now gearing up for crop diversification in rice land. As this proceeds, complexities in irrigation management and production are expected to be encountered. The following strategies are adopted: a) identification of suitable schemes within the nongranary areas based on water resources, physical condition, marketability, and agronomic and socioeconomic criteria; b) implementing pilot projects for representative schemes; c) a coordinated **multiagency** implementation program with strong participation of farmers’ associations in an integrated approach; d) research and development on system design and management, socioeconomic aspects of farmers’ organization and production technology on rice land; and e) collection of basic data and **information** to establish a comprehensive database on the nongranaries and rain-fed rice fields.
Agricultural lands are classified as granary and nongranary areas, depending on the stability of water supply. The granary areas have met 70-75 percent of the production target. The nongranary areas with no stable water supply are the target for crop diversification. At the moment, small-scale crop diversification is already taking place in these areas. However, some farmers do not diversify because of low yields and the problem of pests and diseases.

Diversified land uses in the existing irrigation schemes under Category 3 are the areas relevant to crop diversification. This is where the rice-upland crop rotation is practiced. The possibility of expanding the areas for crop diversification is seen in Category 7 which is subject to land-use changes. Conversion of these areas to Category 3 is hindered by tenancy. However, if the farmers have no successors, then conversion is possible.

Diversified cropping areas are located near water sources. This provides the farmers easy access to water. Farmers want to be independent and they can achieve this by having their farm near a water source.

In terms of design, canals are deepened to facilitate control of water and provide for temporary storage from where water could be pumped. There is, therefore, no need to maintain a head.

**Nepal**

Diversified cropping in the rice-based cropping systems in Nepal is not new. It is probably more than a century old and practiced partly due to farmers' diversified needs for food grains and other essential farm commodities and partly due to the small and scattered landholdings. The government's efforts to maximize cropping intensity and diversify cropping practices are very much a felt need. It is urgently needed to protect the environment and maintain and increase the soil fertility by checking erosion and land degradation.

Vegetables, root crops and fruits, peas and fruit vegetables are given priority in crop diversification. In some areas, there is a surplus of rice, while there are shortages in some others. Transportation, being costly, is the major problem in the distribution of the rice surplus.

As proposed, crop diversification will be concentrated in areas where groundwater pumping will be done. The experience in Bangladesh has shown that farmers have grown diversified crops in similar areas and have realized its practicality. There is a need though to have joint pump ownership, particularly if the landholdings are small.

**Philippines**

In the Philippines, one identified factor which tends to push the diversified cropping system is the inadequate water supply during the dry season. In the national irrigation systems, only 1 percent is presently devoted to diversified cropping out of an estimated potential of about 30 percent. Except for those irrigation systems with vegetable production components, non-rice crops are still not considered in the planning of irrigation operations. The programmed area for irrigation during the dry season has been based on predicted streamflows as against calculated net operation water duty.
Encouraging farmers to shift from rice to irrigated nonrice crop cultivation to help alleviate recurring water shortages is not yet extensively done due to know-how deficiency. Suggested research studies on water management for crop diversification deal with the generation and verification of more data on the planning, design and operation of irrigation systems. The characterization of the various factors that tend to hinder or promote crop diversification needs to be addressed.

Previous efforts at crop diversification have concentrated on the rain-fed areas. The National Committee on Crop Diversification (NCCD) considers crop diversification in a general perspective to include lowland irrigated areas and upland rain-fed areas.

Identification of priority areas for crop diversification should be done nationwide. This will help in identifying the need for research activities on water management, socioeconomic aspects and site specific factors affecting crop diversification.

Information now available shows areas presently under crop diversification and at the same time identifies potential areas for crop diversification: the entire area of the country is considered in each of the pedoecological zones.

**Sri Lanka**

Crop diversification in rice fields in Sri Lanka, especially in the Mahaweli Project areas, has developed because of the following reasons: a) gradual banning of imports of subsidiary food crops; b) higher economic benefits for farmers through higher net returns and cost-benefit ratios with better product prices of some nonrice crops; c) water scarcities during the low rainfall season; d) better extension services and improved communication between farmers and agency officials; e) shortfall in nonrice crops to meet the growing needs of the population and the resultant price increases due to higher demand; and f) institutional support for crop diversification and increased interest among policymakers.

**Thailand**

The diversification of crops in Chao Phraya Project in Thailand during the dry season can be practiced in only a small portion of the project area as farmers are accustomed to growing only rice. Besides, most of the area is low-lying and has poor drainage. Even if the price of rice decreases, the farmers do not want to reduce the area devoted to rice. In attempting to diversify the area, the following should be considered: a) production zoning to identify the area for diversification; b) adjustment of the water allocation system to consider irrigation timing and drainage; c) transfer of crop production and irrigation management technologies; and d) coordination with other sectors to provide the production inputs and markets for the products.

Thailand farmers continue to plant rice in spite of low yields. Rice is considered a secure crop and the government finds it hard to convince farmers to shift from rice to other crops. Although the yields are low, the farmers still make profits as the cost of production is also low and labor is cheap.

Thailand is able to export rice despite low yields. The reason must be big landholdings which average 4 ha.
Special Papers
Irrigation Management for Rice-Based Farming Systems in Indonesia, Bangladesh, and the Philippines: A Synthesis of Findings under the IIMI-IRRI Collaborative Project

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INTRODUCTION

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

Theoretically, there are, at least, three ways in which this problem could be addressed: a) by increasing the economic yield of rice; b) by increasing the area served by scarce water resources through more effective and efficient irrigation system management; and c) by introducing crops of higher value than rice into the irrigated rice farming systems. In July 1987, the Rockefeller Foundation provided a grant to the International Irrigation Management Institute (IIMI) and the International Rice Research Institute (IRRI), for the two organizations, with their complementary strengths, to conduct a joint study of the three options. IRRI clearly has interest in the first option. The second is part of IIMI’s mandate to improve irrigation system management. Both institutes are concerned with the third option of getting higher economic and more equitable social returns from the water and its associated land. In addressing the three options, the project attempted to look at the problem...
from a comprehensive point of view to include agronomic, socioeconomic and institutional issues related to rice and nonrice crops in irrigated rice-based farming systems. This paper presents a synthesis of the findings of the studies conducted under the project.

The IIMI-IRRI Collaborative Project covers three countries, namely, Bangladesh, Indonesia, and the Philippines, which are all in the humid tropics of Asia. Sixteen separate studies were conducted in Bangladesh, and eleven each in Indonesia and the Philippines. The six broad objectives of the project are:

1. To characterize the factors influencing the options for changes in rice-based farming systems, and to identify the more important options in selected geographic locations.
2. To determine the degree to which different levels of irrigation system performance influence the ability to incorporate changes in the farming systems effectively.
3. To develop efficient and economical methods for managing irrigation water delivery and use of post-rice residual water for rice-based systems in which nonrice crops are grown, with special reference to implications for agronomic practice and for institutional performance and change.
4. To transmit and interpret the research findings to agricultural and irrigation system managers, planners and policymakers to encourage informed and better decision making.
5. To enhance the development of trained professionals in the area of irrigation problems through provision of graduate research opportunities.
6. To provide an opportunity for IRRI and IIMI staff to interact in a variety of collaborative activities which would permit the development of an effective and mutually supportive long-term relationship.

PROJECT IMPLEMENTATION PROCESS

While the broad project objectives were defined early on, the different implementing activities covering problem area identification, research sites selection and various modes of interaction between the two institutes and national agencies were done on a country-to-country basis.

Setting Country Specific Objectives

Bangladesh

In Bangladesh, limited consultations were held in Dhaka with senior staff of the Bangladesh Water Development Board (BWDB), Bangladesh Rice Research Institute (BRRI), the Bangladesh Agricultural Research Council (BARC), the Bangladesh Agricultural Development Corporation (BADC), the Bangladesh Agricultural University (BAU), etc. As sug-
gested in the grant document, the work in Bangladesh had to take into account the following: a) the need for rice production in the country to continue at a level sufficient to maintain the basic economic value of rice production in irrigation systems -- thus, the objective was to increase the efficiency and equity of rice production; b) the agricultural and irrigation techniques already proven successful in increasing rice productivity could be extended more widely in the government irrigation systems, with adaptation to site-specific conditions; and c) organizational and institutional modifications might be needed for the implementation and maintenance of revised irrigation procedures. It was recommended that the Project build on the results obtained so far in the ongoing BRRI/BWDB/IRRI collaboration with IIMI’s interest on main system management complementing the on-farm mandate of IRRI.

**Indonesia**

In Indonesia, planning meetings were held in June and October, 1987 and March, 1988 with the Directorate General for Water Resources Development (DGWRD), the Agency for Agricultural Research and Development (AARD) and the University of Gadjah Mada (UGM).

The primary objective of the project in Indonesia is to develop and test irrigation system management strategies that take into account variations in the physical environment, crop management, water availability, and farmers’ crop decision making. Current irrigation system management practices, largely based on the pasten system (an index to relate the quantity of available water to the irrigated area) or derivatives thereof, already respond to certain aspects of demand and supply but are relatively insensitive to variations in physical conditions. Through the Irrigation Committee, seasonal cropping plans are drawn up based on previous experience but it is clear that there are significant deviations from this plan during each season. Biweekly estimates of planted area and average water demand are obtained and compared with estimates of water availability during the same time period. As long as supply exceeds demand, the systems operate largely on a continuous flow basis to all parts of the irrigated area, leaving farmers to make local adjustments where needed. When supplies are inadequate, rotational irrigation is implemented between tertiary blocks along a secondary canal and, under more severe conditions, between secondary canals.

For the irrigation management system to be effective, two different time frames should be taken into account: within season system operation and seasonal planning.

**Within Season System Operation.** Initially, research was concentrated on responses to existing irrigation management practices before moving on to innovations later in the project. The following specific objectives were identified:

1. To determine optimal rotational irrigation schedules to be adopted when water supplies are inadequate to meet demand through continuous and simultaneous deliveries to all tertiary blocks. The institutional arrangements and supporting information flows required to implement alternative water delivery practices including modifications to rotational irrigation need to be evaluated.
2. To evaluate the relationships between irrigation system operation and groundwater fluctuations that may be detrimental or beneficial to nonrice crops and to develop methods for the productive use of residual soil moisture and the prevention of overirrigation during periods of abundant water supply that may lead to untoward buildup of groundwater that inhibits cultivation of nonrice crops in subsequent seasons.

**Annual Planning of Irrigation Schedules.** Since the Annual Crop Plan involves several components relating to the assessment of water supplies based on ten-year moving records, soil and crop water demand, allocation of cropping patterns within the system, and development of a set of operational plans to accommodate variations in both supply and demand, the following objectives were pursued:

1. To develop methods of assessing water availability better, from both rainfall and rivers throughout the year, with particular emphasis on simple methods of predicting periodicity and intensity of water deficit during the dry season.
2. To obtain better estimations of probable cropping decisions to be made annually by farmers which can be integrated into seasonal cropping plans, to evaluate cropping choices by farmers and assessment of the constraints to cropping practices or crop establishment and to develop alternative cropping patterns that better suit variations in physical conditions.
3. To improve procedures for dry-season allocation of area to be irrigated and the crops to be grown, based on predictions of water availability at the system level and assessment of field-level demand.
4. To develop plans for operationalizing system management from the Annual Crop Plan to accommodate anticipated demand and probable water supplies to the system, and assess the capability of the system to accommodate alternative rotational irrigation practices.
5. To propose modification of the annual and seasonal planning process that incorporates more site-specific information and which includes feedback from performance in previous seasons.

**Philippines**

In the Philippines, consultation meetings were held in October, 1987 with the National Irrigation Administration (NIA), the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD), the University of the Philippines at Los Banos (UPLB), the Central Luzon State University (CLSU), the Bureau of Soils and Water Management (BSWM), the Bureau of Agricultural Research (BAR) and the Philippine Rice Research Institute (PhilRice). It was decided that IIMI and IRRI, either separately or together, take major responsibility for developing and facilitating research with collaborating national agencies in the following areas:

1. Documentation and analysis of the management procedures of irrigation systems with rice-based cropping (IIMI). The analysis should include an assessment of
factors that influence the management and decision-making process of systems manages, central office staff, and fanners as well as policymakers. The analysis should also focus on the changes that may have to be introduced in the systems designed for monocropping of rice.

2. Assessment of the physical characteristics and design of the irrigation system for suitability for rice-based farming systems, with the possibility of introducing modifications in the present design to support mixed cropping (IIMI/IRRI).

3. Exploration of strategies and recommendations for irrigation managers, fanners, and policymakers on how to manage irrigation systems for crop diversification efficiently and effectively (IIMI/IRRI). These include water resource augmentation to extend the dry-season irrigated area in different types of systems and opportunities for alternative water allocation to establish higher efficiency of water use and greater equity among farmers (rice and nonrice). The results will help formulate policy recommendations that will support the government’s effort in both maintaining self-sufficiency in rice and enhancing farmers’ income from the use of rice lands through crop diversification.

4. Identification of the physical infrastructural requirements for effective water control at the farm level to support mixed cropping after wet-season rice, and the methods for their optimal use (IRRI).

5. Determination and analysis of the factors influencing farmers’ decision making in crop selection and management during the dry season within the context of the household socioeconomic situation (IRRI). Factors such as water supply, soil type, farm location, profitability of various crops, availability of off-farm employment, input supply, credit availability, markets, and irrigation service fees for different crops will be investigated.

6. Assessment of the status and behavior of dry-season groundwater regimes in nonirrigated areas, particularly in areas adjacent to irrigated rice (IRRI/IIMI). The problems and opportunities that these regimes present for production of nonrice crops should be evaluated. Soil and crop management and irrigation inputs that can maximize the benefits of both metric and groundwater reserves for nonrice crops should be identified.

7. Assessment of drainage options for rice and upland crops under different hydropedological, topographical, and local cropping environments and their implications for system design and management (IRRI/IIMI). Benefits and costs of investments in drainage facilities should also be addressed.

Research Site Selection

The research site selection was greatly influenced by ongoing research conducted by either or both IIMI and IRRI in each of the three countries.

In Bangladesh, the research sites chosen initially were the Ganges-Kobadak lift-cum gravity irrigation system and the North Bangladesh deep Nbewells where IRRI has been conducting collaborative research for a number of years with BWDB and BRRI. Later, BADC deep tubewells in Rajshahi (with the participation of the Rajshahi Krishi Unnayan Bank and Grameen Bank) were added. While IRRI research has resulted in some significant
improvements in the management of irrigation water in the two earlier systems as well as in the crop production practices of farmers, the present IIMI-IRRI Collaborative Project is conceived to enhance the process of internalizing the available results and to generate relevant new information in support of the project objectives.

In Indonesia, two sites were chosen in Cirebon, West Java where IIMI has been conducting research and which were in proximity to the Sukamandi Research Institute for Food Crops of the AARD. The bulk of the fieldwork is done in the Maneungteung Irrigation System which is a run-of-the river diversion. The second diversion system is at Ciwaringin. Because of research done in the past there, IIMI has established a good data base in irrigation management activities at these two sites.

In the Philippines, the research sites chosen, all in Luzon, are the same systems where IIMI conducted studies on irrigation management for crop diversification with funding from the Asian Development Bank. These are the Upper Talavera River Irrigation System (UTRIS), the Laoag-Vintar River Irrigation System (LVRIS), and the San Fabian River Irrigation System (SFRIS), which are all run-of-the river diversion types. Three other sites are used by IRRI to conduct parallel component studies. Most of the work by both IIMI and IRRI is done in UTRIS.

**FINDINGS AND RECOMMENDATIONS: A SYNTHESES**

With the Project due for completion by end-1990, final national workshops were held during 13-14, June in Yogyakarta, Java, Indonesia, and during 10-12, September in Los Banos, Laguna, the Philippines to disseminate and receive feedback on the research findings. In Bangladesh, a workshop scheduled for 23-24, September, 1990 could not take place because the needed government permit was not obtained.

A culminating activity was an intercountry workshop held during 12-14, November in Colombo to review and integrate the research findings in each country and across the three countries, and to deliberate on the recommended course(s) of future action. The workshop was able to produce a consensus on the findings and recommendations which were categorized into: a) Main irrigation system management for rice-based farming systems; b) Farm-level water management for rice-based farming systems, c) Economics and institutional issues in irrigated rice-based farming systems, and, d) Critical issues discussed. The following questions were used as the guide in sorting out the findings and recommendations of the project:

1. What are the factors that influence the options for changes in rice-based farming systems?
2. What are these options and how do the different factors affect them?
3. What are the implications of these changes on irrigation management both at the system and farm levels?
4. How could these implications be addressed? What are the recommendations already utilizable? Is there a need for further research? What should be done next?
Main irrigation system management for rice-based farming systems

Some background issues were considered such as the differences in the types of irrigation systems used as research sites (large gravity direct diversions in the Philippines and Indonesia, and lift and deep tubewell systems in Bangladesh). It was recognized that there were lessons that could be learned from drier environments (Egypt, Morocco, Pakistan, etc.) where diversification is widespread and management issues may be simpler or better understood. The main issue is how the irrigation agency is able to respond to diversification once the external environment is encouraging farmers to do so in terms of water allocation and delivery in the main system. It was agreed that changes be introduced in the planning, implementation, monitoring and evaluation procedures being followed by the irrigation agency.

On water distribution, reliability of timing may be more important than trying to meet adequacy. Rotational irrigation of some form is almost inevitable because of the risk of overirrigation and the need to maintain the hydraulic head, and because rationing by time is easier than rationing by discharge.

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

It is important that rotation plans be known by all concerned. Irrigation system managers should have different plans for different levels of water deficit. The level of rotation which can be below or at the tertiary, secondary, or along sections of the primary canal, depending upon the nature and severity of the water shortage, needs further rationalizing to improve reliability and equity. The not-quite-satisfactory weekly rotation being implemented in Indonesia and the Philippines and the 9-10 day rotation in the G-K Project in Bangladesh are indications in this regard. It was understood that developing new rotational plans is a gradual process involving negotiation and testing. The selection of alternative rotation plans is a contract between the irrigation agency and the farmers. The activities should be based on suitability for farmers (time of delivery/non-delivery), manageability by agency (staff, number of gates, etc.), and technical feasibility (conveyance capacity, cross-regulation provision).

There should be an early warning in case of a change in the rotational plan, and this should be done with concerted communication effort between and among the agency staff and farmers.

The information management required should include the monitoring of the dynamic situation at the intake (available river flow and diverted flow to the
system), and the overall implementation of the plan. Regular meetings between the irrigation staff and farmers or their representatives during the implementation of the plan such as after water rotational delivery, should be held to serve as a means for monitoring the operations of the system. The meetings could provide the needed feedback mechanism to make the schedule more realistic and to settle conflicts in water distribution.

* The involvement of farmers and farmer participation as early as during the planning stage (annual seasonal planning) is implied and should be institutionalized to minimize problems during implementation. Active participation of farmers in decision making and in managing the system increases their awareness of the system’s capabilities by helping them understand the plan better and the reasons for actions taken.

* The objectives of the plan (whether they are productivity, equity, sustainability, etc.) should be clear to all concerned and translated into clear operating rules.

* Water availability prediction must be good. If water available is less than the demand, rotation between years (i.e., 2-3 years planning cycle, not 1 year) may be more appropriate.

h) Farm-level water management for rice-based farming systems

* Although there are several factors influencing the options for changes in rice-based farming systems such as availability of adequate water, land suitability, climatic condition, availability of management technology, time constraint caused by the presence of rice crop, farmers’ preference, resource base, influence of neighboring farmers or extension agents and land tenure status, income stability was identified as the major consideration that influences the farmers to diversify or not.

* In responding to the changes, it is implied that farmers must assume greater responsibility in water sharing to effect the desired changes in water management. Some checking facilities may have to be added to provide the hydraulic head required at certain points to implement the flush basin flooding method for irrigating a number of crops such as onion, tobacco, etc. Additional facilities during the dry season in the form of extra field channels (some already temporarily built by farmers) to facilitate the distribution, application and removal of excess water for nonrice crops are needed. The resulting density of the field channels can be more than three times those being retained for rice cultivation during the wet season.
The use of groundwater to supplement canal supplies in the dry season was significant and economically attractive in both the Indonesian and Philippine sites. The same result is expected in similar groundwater use for Rabi (dry) season cropping in the Ganges-Kobadak Irrigation System (GKIS) area in Bangladesh.

The use of residual soil water is significant in Bangladesh for growing wheat, onion, garlic and legumes after the Aman (wet) season in the GKIS area. While the potential is present in Indonesia and the Philippines, the use of residual soil moisture, especially for mungbean, has not been systematically documented.

The challenge of managing a high water table resulting from seepage from adjacent unlined canals and surrounding fields was addressed in the Upper Talavera Irrigation System (UTRIS) site in the Philippines by establishing a properly designed interception-cum-drainage channel around and across the average size fields to convert an unsuitable area to effectively produce maize of 7.3 ton/ha, compared with 3.3 ton/ha in the control area.

It was found that a cropping pattern of rice-mungbean-maize replacing rice-rice-nonrice has higher productivity than rice-maize-mungbean for systems without adequate irrigation. In Bangladesh, green manure-rice-legume is recommended to replace rice-rice.

Optimal yields for nonrice crops are obtained if soil moisture depletion is not allowed to go beyond 40 percent available soil moisture.

c) Economics and institutional issues in irrigated rice-based farming systems

Different cropping options were identified which the farmers may consider during the dry season. These include leaving the land fallow, planting nonrice crops alone, growing combinations of nonrice crops or rice and nonrice crops, and planting dry-season rice crops. These options are influenced by a variety of factors such as crop scheduling/timing, tenurial status, prices of inputs, product (market) prices, land suitability, drainage constraints, farmer experiences/attitudes, agency staff skills, labor/farm power, farmer’s ability to control water, availability and access to technology, government policies and existence of residual soil moisture.

The implications of changes on irrigation management, as earlier indicated, include the need for better coordination among farmers, between farmers and agency staff, and among agency staff, to increase the reliability of irrigation delivery. Conjunctive use of surface water and groundwater need to be enhanced and drainage information should be considered.
These implications could be addressed through a pilot-testing of management changes and an assessment of successful cases. These would involve the agency, farmers and researchers interacting with each other for fine-tuning of management procedures in the internalization process while the participation of the researchers is gradually phased out. The budget implications of the new management changes need to be assessed.

d) Critical issues discussed

**Irrigation service fees.** Policies on irrigation service fees should be reviewed in relation to the differences in managing the system for rice as against nonrice. Consideration should be given to farmers who are using water more efficiently, or who practice water conservation measures such as mulching and water augmentation. It was suggested, however, that the review may also look at strategies to encourage the farmers to pay irrigation fees.

**Tenurial status.** The status of land tenure has some implications on farmers’ attitudes to improving land productivity. Not owning the land somehow deters farmers from using the recommended technologies to improve land productivity. Landlord-tenant arrangements also do not provide clear indications as regards membership in irrigators’ associations, and the payment of irrigation service fees. Who is responsible? The tenant or landowner? The present situation does not provide any mechanism to address the problem, more so to improving land productivity through crop diversification.

**Farmers’ decision to diversify.** As the report indicates, a number of factors influence the decision of the farmers to plant rice or nonrice, and they should be given some degree of flexibility. However, this flexibility should consider not solely the farmer’s own advantage but its influence on other farmers and the flexibility of the irrigation system itself. What may be done is for the irrigation agency and other support services to be ready with options to match the requirement of not one farmer but the larger group of farmers. Likewise, the agency should also have some kind of mechanism to influence the farmers.

**Farmer’s organizations.** Organizing farmers is not an absolute necessity for effective irrigation management. In Pakistan, the farmers use the water as they see fit. This cannot happen in the Philippines, Indonesia and Bangladesh where farmers have no fixed water rights. Somehow there is a need for sharing of responsibility between the farmers and the agency. It thus depends on the sociopolitical situation existing in the area where the system is located.
PLANS FOR THE IMMEDIATE FUTURE

A modest proposal has been submitted to the current donor to wind up the work in Bangladesh. The work will consist mostly of pilot-testing promising irrigation management innovations over one cropping season with the active participation of concerned irrigation agency staff and farmers. The period from November, 1990 to June, 1991, which covers the drier part of the year (from the beginning of the dry-season until the start of the wet season) when water becomes scarce is the most critical in fine-tuning the pilot-testing process and in determining the actual operational requirements for the methodical transfer and institutionalization of management innovations.

RECOMMENDATIONS FOR FUTURE ACTION/RESEARCH

The project may be completed but a lot of things remain to be done. Useful information and technologies which are expected to enhance irrigation management have emerged from the findings but these need to be further evaluated through some kind of piloting. It is anticipated that a gradual internalization process is required for the impact of the recommended innovations to be really felt.

There should be action plans to put into reality and operation the findings made so far. Stronger and more active participation of the irrigation agency and the farmers are envisioned. Other agencies involved in agriculture (from production to marketing) should likewise be included.

The outstanding or unresolved issues like the following may be addressed in future research:

* Is the design of the irrigation system flexible for crop diversification or is it complex?

* How can assessment and matching of both available water supply and water demand be improved to match the under-diversified cropping conditions?

* Should the government get involved directly through such mechanisms as crop plans?

* How should the agency and farmers cope with different soil/drainage environments, considering zoning and water requirements?

* For both rice and nonrice production, how should better techniques for improving water use efficiency and productivity be developed?
In addition, studies on drainage seem to be underplayed. Basic drainage facilities are necessary, particularly for upland crops. An in-depth study of the motivation of farmers to participate in irrigation management is more important than their need to form associations. Agency-farmer relationship is an integral component of diversification. This still has a long way to go. This has to be related to reliability of water delivery and variability, which cannot be controlled. A measure of reliability is still to be developed. Market forces and postharvest facilities should also be given due consideration.

Three years of activities under the IIIMI-IRRI Collaborative Project have addressed important and comprehensive issues of irrigation management for nonrice crops in rice-based systems. The next step is to evolve strategies to operationalize the recommendations that have come out of the present findings, and to disseminate the information as widely as possible to irrigation and agricultural agency officials. The Research Network on Irrigation Management for Crop Diversification (IMCD) will be very useful for this purpose.
References


INTRODUCTION

Irrigation management for diversified cropping, or crop diversification of rice-based agriculture in general, is an important research and policy issue which has been attracting a lot of attention in Sri Lanka as well as elsewhere in tropical Asia. The rapidly growing body of literature in the field best testifies to this increasing attention in recent years (IIMI 1987; Schuh and Barghouti 1987; World Bank 1988; Bhuiyan 1989; Miranda 1989; Valera 1989; IIMI 1990a). A basic factor, among others, behind such a rather abrupt proliferation of research in this field is the fact that the rice sector of many countries in this part of the world has come to a turning point; the introduction and diffusion of new rice seed-fertilizer technology coupled with the expansion of irrigated rice land in the last two decades or so has helped a number of countries in the region to either approach or attain self-sufficiency in rice, with a consequence of a long-term declining trend in the world rice price. The farmers in rice-based irrigation systems need to diversify their income sources, while the demand for agricultural products diversifies from the major staple to various non-staple items as the economy grows. A logical deduction is that diversification of rice-based agriculture in general and crop diversification of rice-based irrigation systems in particular, and research thereof, are a necessity.

It is well-recognized that the nature of this issue of irrigation management for crop diversification in rice-based systems is so multifaceted that multidisciplinary approaches, embracing engineering, agronomy, soil science, economics, management, and other social as well as natural sciences, are necessary in its research. In fact, research in this field, as any other farming-system research, has usually been carried out in this multidisciplinary mode. Generally speaking, however, this multifaceted nature of the issue, coupled with its very location specific nature, often leaves research in this field at loose ends, e.g., partiality in analyses with certain ad hoc assumptions in facets that are not in main focus, difficulty in
deriving general conclusions/principles that could be applicable under different settings, research-based recommendations that are rarely followed by farmers in actual farming, and the like. In other words, the multifaceted nature inherently makes the issue/subject of crop diversification elusive, which means that, whenever certain research in this field is undertaken, it is always important to keep in mind the entire structure of the issue in its full spectrum while identifying clearly the specific problems to be addressed in the research.

The purpose of this paper is to reexamine briefly, mainly based on recent literature in the field in general, and experiences in Sri Lanka in particular, the structure of crop diversification of rice-based irrigation systems as an object of research and policy in order to facilitate understanding of the configuration and weak (often missing) links in this multifaceted research/policy topic. The primary intention of doing such a "thought exercise" is to help refine research subjects to be studied under this research network. It is further hoped that the exercise would be useful in promoting successful crop diversification in the irrigation systems in Asia where few countries, including the fast-developing East Asian countries, have been fully successful so far in attaining it on a sustainable basis.

**BACKGROUND AND DIMENSIONS OF THE ISSUE**

If crop diversification, or, more generally, agricultural diversification is defined as the process of broadening and maintaining the sources of incomes of rural households, as defined in a World Bank report (World Bank 1988; Shuh and Barghouti 1987), it is not a new issue. The origin of the issue could be traced back at least to the eighteenth-century Agricultural Revolution in England, if not to the early civilizations in Mesopotamia and the Nile Delta.

**Structural Transformation and Agricultural Diversification**

As an economy starts growing from a static, traditional agriculture-based society to a dynamic, industrial one, the traditional agriculture, which is characterized by producing a limited list of traditional staple food crops, is bound to be diversified, in order to meet the increasing demand for lion-traditional food commodities. This process begins with increases in the productivity of traditional agriculture due to technological advances. Accompanying this is a relative decline in the importance of the agricultural sector as a whole in the total economy, which process is called "structural transformation." In this broadest framework or dimension, agricultural diversification and structural transformation are two sides of a coin; as an economy develops, rural households are forced to maintain and increase their incomes through diversifying their farming while transferring some of their resources, especially labor, to other income generating activities in the nonfarm sectors.

At the dawn of the industrial revolution, British crop agriculture experienced a major transformation in which the old cropping pattern was replaced by the Norfolk crop rotation with such new strategic fodder crops as clover and turnip. In nineteenth-century Denmark,
Danish agriculture successfully transformed itself through diversification from the old grain-based pattern to the one based on a new crop-livestock combination. In the early twentieth century, Japanese rice farmers succeeded in introducing sericulture production into the rice production cycle with a result of significantly diversifying their income sources. All these early examples of agricultural diversification occurred in response to changes in product and factor markets within a broader framework of structural transformation (Hayami 1989).

Of course, we do not always have to go so far in dealing with the contemporary issue of crop diversification in Asia, which emerged in sharp profile in the 1980s because of the historic low level of world rice (and wheat, to a lesser extent) prices in the early 1980s, which in turn was partly a result of the successes in "Green Revolution" technology in Asian developing countries. In pursuing crop diversification, governments in these countries (which have promoted self-sufficiency programs in staple foods), donor agencies (such as the World Bank and ADB, which have invested in crop specific agricultural projects), and practitioners of international agricultural research institutes (who have been mostly crop specific), are concerned mainly about low levels of world prices and the surplus situation in production of staple food crops, resulting in low incomes for the farmers producing these crops, and low rates of returns on the investments that have been made thus far in agriculture, particularly in irrigation infrastructure.

In such a context, agricultural crop diversification tends to be considered as a problem within the agricultural sector, or even within the smaller sector of "irrigated agriculture." In the case of this research network on crop diversification, the focus is naturally confined to the "irrigated agriculture" sector. The issue can be dealt with at each level, from the farmers' field level to the macro-economic level. However, it should always be recognized that, since crop diversification in Asia is inevitably a part of the structural transformation process of the economies, policies for diversification at each level must be consistent with each other and with the broadest framework of structural transformation.

The process of structural transformation is nothing but the process of economic development that requires efficient resource allocation. One immediate implication of this understanding is, therefore, that policies for agricultural diversification at the macro-economic level and at any lower level should be such that efficient resource allocations among the sectors of the economy as well as within the agricultural sector and between its subsectors are facilitated.

Rural Poverty and Diversification

On the other hand, the process of structural transformation is nothing but the process of adjustment in which the agricultural sector adjusts itself to new economic conditions that are created by economic development. This adjustment is not cost free, but rather entails painful costs to the agriculture sector. Most distinct among them would be increases in income inequity in the society, which is an inevitable consequence of the development, the intrinsic nature of which is unbalanced growth among the sectors. There has been a growing concern among governments and donor agencies about this problem, and, as a consequence, existing policies for agricultural diversification at any level very often aim at alleviating poverty or improving the income distribution in rural areas.
Difficulties arise if the relationship between these two basic problems, efficiency and equity, is not one-to-one, and unfortunately this is often indeed the case. At least in the short run, the potential solutions to these problem do not necessarily correspond. The best example to illustrate this difficulty can he found in pricing policy, which is always central to any policy framework for agricultural diversification at any level. Price support for a certain crop is obviously the easiest and most effective way to maintain or improve the income level of the farmers who grow the crop, and therefore it is always a strong temptation for policymakers to resort to this measure. It is also obvious, however, that, by keeping the price of a crop higher than the equilibrium level in the market, the resources that otherwise leave for other sectors remain in the crop sector, thus impinging against the efficient resource allocation and thereby structural transformation. Although huge budgetary costs that are to be borne by the governments if price support is extended beyond a staple crop to other subsidiary crops virtually negate this option in diversification policy, economists usually not in favor of price support mainly on account of efficiency consideration in the long run (Timmer 1986).

Conventional wisdom among economists as to this trade-off between efficiency and equity is that economic development based on efficient resource allocation in the long run solves the income distribution problem; this is the U-Curve Hypothesis found by Kuznets (Kuznets 1955) and further evidenced empirically by others (e.g., Ahluwalia 1976). Taking this wisdom as granted, a practical solution to this trade-off is to introduce explicit time dimensions into the argument; when changes are so abrupt and adjustment costs are so high that the welfare of the losing party is intolerably endangered, adopt some kind of price-stabilizing measures in the short run, while not losing the sight for efficiency in the long run. This argument directly implies that the issue of agricultural diversification involves different time dimensions; diversification policies intended to mitigate adjustment difficulties in the short run must not override the efficiency perspective in structural adjustments in the long run.

Diversification and Changing Role of Irrigated Agriculture

The recognition that the problem of rural poverty could be solved only through the development of the entire economy reminds us of the role of the agriculture sector in economic development. As explained in development economics textbooks, an important role of agriculture at an early stage of economic development is to supply resources, financial as well as human, to the rest of the economy. In developing countries in Asia, except in traditional rice exporting countries, this role has been mainly played by the plantation sector (Thorbecke and Svejnar 1987, for the Sri Lankan case), and the irrigation sector has been absorbing from the other sectors resources mainly in the form of irrigation investments. This direction has been right; it was imperative for the development of a country to establish a productive domestic food production sector. Many countries which neglected their food sector in the past paid a high price in terms of lost development.

However, now that the irrigated land base has been well-established in many of these countries with near or full rice self-sufficiency, the role of the irrigation sector should have changed from a resource taker to a resource contributor to the rest of the economy. The shift
from the traditional "construction" phase to the "management" phase, which has been going on in the irrigation sector in Asia (Aluwihare and Kikuchi 1990), releases a bulk of resources from the sector. **Crop diversification** in the sector with import-substituting and/or export promoting nonrice crops will further strengthen this role of the irrigation sector to the **economic development** of the economy as a whole.

Crop diversification in the irrigation sector thus considered, therefore, precludes any policy which envisages a continuous net inflow of resources to the irrigation sector on a secular basis. The introduction of price support measures at a significant scale for nonrice crops is one such policy which naturally ends up absorbing, not supplying, resources from the rest of the economy in an unproductive manner. It should always be clear that, when considered in the broader **context**, crop diversification is more a **means** or process to attain economic development, rather than an **objective** by itself.

**Diversification as an Endless Process**

A more crucial implication of the whole argument above is that agricultural/crop diversification is a **process of dynamic adjustment** rather than a static target of establishing certain cropping patterns. The **elusiveness as a policy issue** largely **stems** from this characteristic of crop diversification. How it **makes diversification policy** difficult to deal with is **apparent if compared to the policy for rice self-sufficiency** which offers a very clear-cut stationary target. In diversification policy, there **cannot** be such a target, or, if any, it is **at best a "moving" target**. Since each country has heterogeneous agricultural regions, it is not possible, nor feasible, to set up a certain cropping pattern for the **country as a whole**. **Certain cropping patterns** may be established specific to a certain region or area of a country, but they **keep changing** according to changes in the outside world. In certain agricultural regions/areas, the best opportunity for diversification may exist in switching a part of the rural labor force from the nonfarm sectors while an increase in the size of operation is being required in the farm sector.

Given such a **distinct nature** of the issue, the only definite policy target that can be established, cutting across the full range of the issue, would be to build **flexibility** into agriculture in general, and the traditional **staple** crop production system in particular, by which the never-ending adjustment process is made smoother. This should be the strategic target for whatever policy related to agricultural/crop diversification: price and income policy, investment policy, land and labor policy, market and credit policy, research and extension policy, and so on. A good example of the need to build in the flexibility is found in the irrigation systems in Asia which are constructed and operated solely for **growing rice**. An attempt to make such rigid systems amenable to diversified crop production, which is the major research theme of this research network, is nothing but an effort to bring about **flexibility in irrigated agriculture**.
Horizontal and Vertical Diversification

Finally, in this section, a short remark should be made on geometric dimensions of the issue; horizontal and vertical diversification. Agricultural/crop diversification intended in the present Asian context is primarily horizontal diversification; diversification through the introduction of nonrice crops in replacement of, or in addition to, rice.

It should be noted that at the national level, horizontal diversification can be attained through regional "specialization." Because of possible regional comparative advantages resulting from soil-climatic conditions and other location-specific factors, and of the economies of scale, this could be an efficient route to national level diversification. In fact, this method has been the major one adopted by developed countries, such as the U.S.A. and Japan, in their diversification processes. Among the developing countries in Asia, Thailand is the country that is most often mentioned as successful in diversifying agriculture. Although crop diversification in the rice-based farming system has been in progress in some regions of Thailand (Plusquellec and Wickham 1985), the major stream of agricultural diversification has been through "specialization" away from rice (World Bank 1988). There is a serious implication for attempts to diversify crops in rice-based farming systems while keeping rice as a major crop: such attempts are handicapped in terms of exploiting efficiency to the extent that comparative advantage and scale economies of such a system diverge from those in "specialized" systems.

Vertical diversification refers to a process in which value-added of certain crops is increased through processing the crops into other commodities, e.g., rice to rice cake, soybean to soybean curd, mango to mango juice, etc. Since the potential of diversification in this direction in increasing the income-earning opportunities of rural population is no doubt large, any policy towards agricultural diversification should take this potential into account. Here too, however, the economy of scale through specialization would work critically in many fronts: marketing, processing plants, quality control of raw materials, etc. We have to recognize that diversification in rice-based farming system may have disadvantages in this respect too.

RESEARCH FACETS AND THEIR LINKS: DIVERSIFICATION IN RICE-BASED SYSTEMS

The issue of crop diversification is multifaceted, and so, any general discussion on this issue includes some kind of enumeration of the facets involved. For instance, the World Bank report referred to in the previous section, categorizes the facets into agronomic, technical, and economic factors (World Bank 1988), while Moya and Miranda (1989), dealing specifically with crop diversification in rice-based irrigation systems, organize their discussions into technical, economic, and social and institutional issues.

A similar attempt to show research facets involved in the issue of crop diversification in rice-based irrigation systems and links between them, is presented in Figure 1. Here, the issue is divided into four groups of sub-issues: a) engineering; b) agronomic; c) institutional;
Figure 1. Engineering agronomic, institutional and economic issues related to crop diversification.
and d) economic. The engineering components are shown in the southwest corner of Figure 1 in several boxes. Similarly, the economic components are shown from the northeast corner (output and input markets) to the center (farmers' crop choice).

Facets

Engineering facets. The engineering issues can be classified into a few components of different dimensions: structural capacity of irrigation schemes at different levels from the main system down to the farmers' field, and water management at respective levels.

Since nonrice crops generally require water in ways that are different from rice, the structural capacity of irrigation systems which were designed and constructed solely for growing rice may not be adequate for irrigating nonrice crops. Continuous delivery of water at low flow rates in the main part of the systems is typical for rice irrigation, whereas many nonrice crops require intermittent water supply with high flow rates. The capacity of a conveyance system for rice may not be adequate. The intermittent water supply may require more controlled water release, which may, in turn, necessitate better measurement devices at various levels of the systems. Some argue that substantial costs will be entailed in converting rice-based system into multiple-cropping systems (World Bank 1986, 1988 Bhuiyai 1989). The issue of how to make rice-based irrigation system flexible to accommodate nonrice crops in relation to their physical capacity comes under the heading of "physical infrastructure" in Figure 1.

Recent research carried out by [IM] and others suggests that rice-based irrigation systems indeed have the flexibility to make it reasonably possible to grow nonrice crops in the dry season (Miranda 1989; Bhuiyai 1989). If this is taken for granted, then comes the question of how to manage the systems towards nonrice crop cultivation which generally requires furrow irrigation as opposed to basin irrigation for rice cultivation. The management issues associated with the shift from rice to nonrice crops may be dealt with according to different levels in the systems, from the main system down to the farmers' fields.

At the main system level, water availability in a system for a certain season is determined by the physical structure of the system, and by rainfall and other associated factors; given the water availability, water release and distribution plans at the main, secondary, and tertiary levels are made, and, at the on-farm level, proper methods of irrigation and drainage for nonrice crops are determined. The issues at each level, needless to say, are closely related to each other. For instance, the availability of water and the type of rotation needed for intermittent irrigation depend on the type of crop to be grown.

Considered along this line, oil-farin water management seems to be an issue which has been relatively better researched as compared to main system management for diversified cropping. It is often said, for instance, that diversified cropping could save the water in the system which can be utilized to expand the planted area in the same season or in the following seasons. If this were the case, crop diversification would be instrumental in enhancing the efficient use of scarce water (Moya and Miraiaida 1989). Little evidence, however, has been accumulated to demonstrate this impact.

Agronomic facets. Issues such as crop water requirements and soil-water-plant relations come under this facet. Rice is the plant that is best grown with wet puddled soil and/or with
ponded water, while nonrice crops fit lighter soil textures, and can withstand neither waterlogging nor prolonged water stress. Cultivation of nonrice crops on lowland soils has inherent disadvantages relative to lowland rice. On the research side, agronomy of lowland rice cultivation has been one of the best-researched fields, and that of nonrice crops under upland conditions also has a long research history. Reflecting the disadvantages, agronomy of upland crops to be grown in lowland paddies has been a relatively neglected field of research, though efforts have been made in recent years in this field (FAO 1984, 1986).

Institutional facets. Nonrice crops, if grown in rice-based irrigation systems, generally require more deliberate delivery, distribution, and management of water than rice does. Diversified cropping is more demanding in terms of system operation and management. The management practices adopted in rice cultivation, typically top-down planning and implementation, are in most cases not congruent with diversified cropping (Stone 1987). The deep-rooted rice monoculture pattern in these systems has brought about among the managers of the systems an ingrained mentality of low-intensity, safety-first type of management (Moya and Miranda 1989). All issues related to making irrigation system management flexible and accountable to farmers' needs fall under this facet.

Examples of the issues in this facet, among others, are: the role of farmers' organizations and their participation in system management; farmer-agency interaction and interface; information channels and control; agency motivation; and so on. It should be noted that many issues in this facet are not specific to crop diversification. Most of them are issues that are applicable to the systems where rice is the sole crop to be grown. Diversified crops only make the issues more acute than otherwise.

Economic facets. The issues in this facet revolve around the profitability of nonrice crops which are supposed to replace, or be added to, rice in rice-based systems. When reviewing the literature on crop diversification in general, not necessarily limited to that of rice-based systems and even excluding that written by economists, it is rather difficult to find a paper which has no mention of market and marketing problems, profitability of nonrice crops relative to rice, the needs of credit provisions, and other related economic issues.

These economic issues can be arranged according to the flow of the issues as shown in Figure 1. First, the markets, both for outputs and inputs, determine the prices. Second, these prices together with production technology available to the farmers determine the profitability of crops. And, third, the farmers choose crops to be grown depending on the profitability.

Some qualifications are necessary along this line. First, the issue of "marketing" is an important part of "market issues." The market is the mechanism through which price signals are transmitted. There are cases where the market is either not working well or even nonexistent. For instance, it is an often heard problem in the crop diversification business that crops grown by farmers cannot find buyers, or that some inputs for nonrice crops, such as seeds and fertilizers, are not available to farmers in time. These are typical marketing problems in which high "transaction costs" due to imperfect markets are involved; the "real" prices to the farmers are lower for outputs and higher for the inputs than the "nominal" prices by the transaction costs.
The second qualification is that the term "profitability" here is a loosely defined one; it does not necessarily imply that the farmer is a "profit" maximizer. He may be so, or he may he an "income" maximizer. What he maximizes may depend on the basis on which he operates his farm. This leads to the third qualification that farmers' decision on crop choice may be restricted not only by economic consideration of their own but also by other factors such as their status in the farming community. The fourth qualification, also related to this, is on distributive impacts of diversified cropping, which are determined by crops to be grown, prices in output and input markets, production technology, and the ownership of the inputs used in the production process. Crop selections made by individual farmers imply certain income distribution consequences to the farming community. Their selections could diverge from the ones which give the highest income increase to, and the best income distribution in, the community.

Links

Apparent and obvious links exist among the facets. It could be said that crop diversification in rice-based irrigation systems is a research issue which should be studied in its entirety to observe how these facets are closely related to each other, rather than study each facet independently.

For example, the issues of "on-farm water management," classified as a part of the "engineering" facet in Figure 1, largely overlap those of the "agronomic" facet. Without knowledge of soil-water-plant relations for a certain nonrice crop or a sequence of crops, irrigation and drainage methods to be adopted on farmers' fields cannot be determined. Similarly, given specific characteristics of an irrigation system, such as soil, water availability, and possible water delivery plan, the best cultivation methods for nonrice crops must be sought. Water management at the farm level and agronomic potentials together determine the level of "crop production technology," or production functions in economic terms, available to the farmers. Water availability at the farm level may affect even more directly "farmers' crop choice," as pointed out by some observers (Miranda 1989, Bhuiyan 1989).

The issues in the "institutional" facet are also associated intimately with other facets. Planning and implementation of water delivery and distribution in a system for diversified crops are issues more of management (therefore institutional) than of engineering, in which agency's motivation and accountability to farmers' needs, farmer-agency interaction, and information control are all more demanding than in the rice monoculture system. Needs exist not only on the side of the managing agency but also on the side of farmers to be better organized for ensuring more precise water management at tertiary as well as on-farm levels. More often than not, diversified cropping in an irrigation system requires collective actions of certain degrees among the farmers in the system, even for the choice of crops to be grown. If so, the choice of crops becomes an institutional issue rather than a narrow economic issue of an individual farmer's decision making.

In addition to the facets explained thus far, two more facets are shown in Figure 1: extension service and socioeconomic factors. The importance of the former is obvious. The farmers in rice-based irrigation systems are used to growing rice, and nonrice crops to be grown may be exotic for them. In such cases, production technology for nonrice crops,
without effective extension services, remains as potential, not available to the farmers. It may play a critical role, if the choice of crops is to be made collectively.

In Figure 1, socioeconomic factors are distinguished from "economic" factors in order to make the flow of issues in the latter clearer. If the related markets and production technology are given, and if farmers are profit maximizers, the issue of economic profitability and crop choice is fairly straightforward, even though risk and uncertainty inherent in nonrice crop cultivation, as compared to rice, complicate the issue. However, farmers operate in a certain cultural domain wherein class structure and other social traits restrict the process of agricultural production and the distribution of generated incomes in the community. To the extent that the markets, particularly labor and land markets, diverge from the typical impersonal market, and are endowed with cultural and institutional traits, the socioeconomic factors as defined here give more decisive impacts and effects to the "economic" factors. The socioeconomic factors as such are also closely related to the "institutional" issues. Without due understanding of the basic cultural characteristics of the community, it is rather difficult to think of sustainable solutions to the institutional issues.

WEAK AND MISSING LINKS THE MARKET

Central to the interlocking issue of crop diversification in rice-based systems in Figure 1 is "crops to be grown," which replace rice. Unless a list of substitute crops is specified, neither agronomic nor engineering research on farm water management can be designed. Even if some crops are recommended by authorities, farmers may not adopt them for economic or other reasons. Without viable nonrice crops, the whole business of crop diversification does not go ahead at all, which would be the worst nightmare crop diversification advocates can ever have. All this means that a series of issues in the "economic" facet of Figure 1 are vital to the whole issue.

Output Markets

First of all, it should be pointed out that the issue network in Figure 1 is open-ended toward the northeast corner of the figure. That is, the output markets in general lie out of the control of the system management and of the farmers in the systems, and in most cases, even of the government policymakers. All changes, which occur in the markets outside the systems, depending on changes in demand and supply, domestic as well as international, are brought into the system and affect directly the profitability of crops, and hence the list of crops to be grown. The input markets have similar characteristics, but to a much lesser extent. For instance, a change in fertilizer price affects the agricultural income, through the production process, of certain crops grown. However, the cost of fertilizer is only a part of the total production cost, and the price change affects, more or less alike, all crops that need the fertilizer.
This open-ended nature makes the issue of crop diversification elusive and keeps its target moving. There exists some uncertainty in other facets of the issue too. For instance, water availability in a system depends on rainfall which is beyond the control of managing agency and farmers. However, this problem of stochastic nature can, or should, be dealt with at the system level, and does not break the completeness of issue structure in that end. With less available water, for instance, crops which require less water can be selected, provided that such crops are economically viable, which depends eventually on the output markets.

The fact that crop selection at the system level is subject to market conditions outside the system means that crop diversification in rice-based systems as a research and policy issue comprises at least two different levels: the national and the system levels. Since any attempt at the system level to establish the list of crops is constrained by the conditions at the national level, and not vice versa, it is critical to have a clear understanding on the markets and a clear policy at the national level as to crop diversification. Although policies at the national level affect not only rice-based irrigation systems but also other subsectors of agriculture, such as rain-fed agriculture, firm policies at the system level cannot be spelled out without them. In most of the countries where efforts have been made to diversify crops in rice-based systems, the most serious gap seems to exist in this macro-level policy/understanding, in general, and interaction between the macro-national level and the micro-system level, in particular.

The literature in the field, available at hand, gives a mixed picture about the nonrice crops that perform better than rice in terms of economic returns and which can, thereby, replace it in rice-based systems. Some of the literature show that there are nonrice crops which are more profitable than rice (e.g., Adriano and Cabezón 1987, for the Philippines; Miranda 1989, for Indonesia; the Philippines and Sri Lanka). Some others fail to identify such crops (e.g., World Bank 1986 for Thailand). Our study in Sri Lanka reveals that possible nonrice crops for rice-based systems can be grouped into two broad categories: low-value crops which generate value-added at best as high as, or generally lower than rice, and high-value crops of which value-added is far better than rice (IIMI 1990b). Most traditional food crops such as corn and various legumes fall in the first category. The second group consists of traditional high-value crops, such as chili and onion, and exotic exportable crops, such as gherkin and asparagus. If nonrice crops were to be substituted for instead of adding to, rice in crop diversification, only those in the second group could be candidate crops (Table 1). It should be noted that these high-value crops are characterized by very high labor and capital intensity as compared to rice production.

It should be noted further that these results are obtained using micro-level data. It is suggested therefore that, given the present price structure and technology, there are some nonrice crops that can be substituted for rice, though the list of such crops is rather short. What is not known is the list of nonrice crops in the medium- to long-run where both price and technology are variable.

Chili, in Sri Lanka, would be a good case to illustrate the nature of the problem, particularly of traditional high-value crops which are produced mainly for domestic consumption. This is the crop which has traditionally been planted, mostly in the Northern Province of the country, but, because of its high substitutability for rice, it has become an important nonrice crop in recent years in rice-based irrigation systems in Sri Lanka, particularly in the North-Central Province. The statistics in Table 2 are from the Agricultural Research and Training Institute (ARTI) of Sri Lanka (1989).
### Table 2: Domestic Production and Imports of Chillies 1987-88, Sri Lanka

<table>
<thead>
<tr>
<th>Year</th>
<th>Domestic Production</th>
<th>Imports</th>
</tr>
</thead>
<tbody>
<tr>
<td>1987</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1988</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1989</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Marketing Costs
- The sum total of cost of harvest, transport, fixed capital services, and hired labor.
- Average of typical labor requirements.
- Average of typical hired labor, and average income earned for the crop.
- Average of typical prices prevailing in the 1987-88 Yela (dry) season.
- Average of typical yields under irrigated conditions.
- Average for six months.

For data sources see NIMI (1990b, 20(c)).

### Table 1: Comparison of Profitability and Requirements for Irrigation Labor and Capital Between Rice and Selected Nonrice Crops: the Case for Sri Lanka

<table>
<thead>
<tr>
<th>Crop</th>
<th>Green Soybean</th>
<th>Green Oat</th>
<th>Yellow Soybean</th>
<th>Yellow Oat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (ha)</td>
<td>62.0 100</td>
<td>15.0 100</td>
<td>40.0 120</td>
<td>10.0 100</td>
</tr>
<tr>
<td>Labour (days)</td>
<td>125</td>
<td>110</td>
<td>150</td>
<td>115</td>
</tr>
<tr>
<td>Water (m³)</td>
<td>50000</td>
<td>70000</td>
<td>70000</td>
<td>70000</td>
</tr>
<tr>
<td>Irrigation Requirement (days)</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>Seed (kg/ha)</td>
<td>3.5</td>
<td>3.5</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Number of Irrigations</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Crop Duration (days)</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>120</td>
</tr>
</tbody>
</table>
The domestic production of chili has been increasing quite rapidly due mainly to the increase in its cultivation in rice-based systems. As a result, it is estimated that the domestic production exceeds the domestic requirement of the crop by 10-40 percent. A puzzling picture however emerges, if we look at the import statistics of chili which shows that the imports have also been increasing, making the total supply-demand ratio around or more than 1.5. Had these statistics been reliable, and should the demand elasticity of chili been rather low as slated in ARTI (1989), the domestic price of chili would have declined drastically. However, such a drastic decline in the price due to this oversupply has, fortunately to the farmers, not been reported yet, though the real price to the farmers has declined slightly from the end of 1987 to 1989.

The puzzle is why the oversupply has not resulted in a sharp price fall. There are three possible explanations: first, the data on production are not reliable; second, the data on consumption are not reliable or the domestic demand for chili is more elastic than expected; and third, a part of domestic production was exported (this means that the demand curve is highly elastic). Unless the right answer to this question is given through further research, it is too dangerous to promote chili cultivation beyond the present level. If the first explanation is right and if the demand curve for chili is indeed inelastic, the result of overproduction could be disastrous to the farmers.

What this "chili problem" suggests is the need to have good knowledge on output markets, international as well as domestic. Without it, no firm national policy for crop diversification can be established. In this sense, it was a quite legitimate approach that was taken for crop diversification research in the Philippines, in which IIMI-ADB irrigation management research was preceded by IFPRI-ADB food crop sector research (Rosegrant et al. 1987). The type of analysis made in this study using the domestic resource cost approach (e.g., comparative advantage, import substitution, and export promotion), are quite useful and essential for realizing the configuration of nonrice crops to be adopted for crop diversification, although this approach itself is static in nature so that it has certain limitations. Going into crop diversification without this kind of information is just like sailing in an ocean without a compass. Not only in Sri Lanka but also in other countries, this kind of research should be done periodically.

It may be interesting to note that this Philippine study by IFPRI shows that rice still has a comparative advantage and is one of the most efficient crops to be grown in irrigation systems (Rosegrant et al. 1987: Gonzales 1989). This could be the case for other countries too, implying that, if crop diversification is to be promoted, more research to improve the productivity of candidate nonrice crops relative to rice would be a prerequisite. A basic contention of promoting crop diversification in rice-based systems is that many developing countries in Asia have attained or are approaching self-sufficiency in rice. This study and some others (Bhuiyan 1989) suggest a need to reexamine this contention periodically in the light of rapid changes in demand due to population increase and general economic development, and in agricultural technology. The national policy on crop diversification in rice-based systems cannot be independent of the national policy on rice.

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1 International Food Policy Research Institute
Marketing

Marketing is the most often mentioned weak or missing link in crop diversification. This pertains to the issue of the "market" as explained earlier. The existence of a "marketing" problem could be an obvious sign of insufficient demand in the market. More often than not, however, the problem could be due to the underdevelopment of market channels through which price signals are transmitted from the markets to the fields and through which crop products are marketed the other way around. The agricultural/rural marketing systems in developing countries are complex, comprising numerous actors, such as middlemen, local traders, transport agents, processors, export agents, and governmental or semi-governmental marketing agencies. In spite of the fact that an efficient marketing system is critical not only for crop diversification but also for agricultural development in general, little attention, beyond the mere mentioning of its importance (Schuh and Barghouti 1987, World Bank 1988), has been paid to this sector.

This negligence of rural marketing systems can be explained partly by the traditional, stereotype image of middlemen and merchants: the ones who exploit peasants through the practice of monopolistic pricing and usury. The fact that most of rural marketing systems in developing countries belong to the informal sector has also made it difficult to study this sector. However, recent studies have been accumulating evidence that indicate that indigenous rural marketing systems are quite competitive and thereby efficient in transmitting price incentives (Siamwalla 1978, Unnevehr 1984, Hayami et al. 1987). It should be remarked that these studies were done in the areas where crop diversification has been most progressive, such as Thailand and Java, Indonesia. This evidence, coupled with the evidence that governmental organizations are typically less efficient in the field of marketing, imply that the role of the government with respect to rural marketing lies not in direct intervention in the markets through controls on prices and profits but in providing conditions under which the markets are well-developed and functioning.

It seems that Sri Lanka is a country where the traditional negative image of middlemen and traders has rather been prevalent and government intervention into the rural markets has been pervasive. If so, the first policy step necessary for a long-term success in crop diversification would be to foster efficient rural marketing systems, no matter how long it takes. Without it, any effort at crop diversification is bound to face failure in the long run. Crop diversification is synonymous with building flexibility into traditional agriculture, and it hinges on the flexible, efficient marketing sector. The so-called "dependency syndrome" in agriculture and other sectors of the economy is the antonym of flexibility as such.

Credit

Credit is another problem quite often mentioned in the crop diversification business. Although credit is not an input in an ordinary sense, this is a part of the market problem. It is said that while market-oriented nonrice crops require high cash inputs, credit is not available to farmers, or if available, it is at too high rates of interest. Provided that there is a well-functioning marketing sector, nonavailability of credit could be an obvious sign that the crops are not economically viable and/or too risky to grow. High interest rates in informal
lending are nothing but a sign that opportunity costs of money, loan-default risk, and costs involved in financial transactions are all high.

Negative image of, or prejudice against, informal money lenders has been even more serious than that of middlemen and traders, and this has given way to cheap credit policies in the primary sector adopted in almost all developing countries. Confusion among policymakers on the role and function of rural financial markets has been widespread. Just as in the case of middlemen and traders, however, the empirical evidences from recent studies indicate that the informal financial market in rural areas in developing countries are much more efficient than ever thought, and, more importantly, that the cheap credit policies adopted in these countries have contributed negatively to rural development, in spite of all good intentions envisaged in these policies (Howell 1980; Adams et al. 1984).

This does not necessarily mean that a government must not intervene in the financial markets. Under the condition of underdeveloped financial markers, a government would do so in such a way to help the markets develop. The introduction of a formal credit system may be one of them, but it should be implemented so as to be effective in mobilizing rural financial markets. The traditional cheap credit policy has little economic ground to be justified even as a means of infant industry protection.

If there exist good economic opportunities for rice crops, credit would become available to farmers in one way or another. As a matter of fact, it is a widespread practice in rural Asia that middlemen and traders advance credit to farmers to purchase cash inputs in exchange for the exclusive right to purchase crops to be marketed from the farmers (Siamwalla 1978; Hayami et al. 1987; Pingali et al. 1989). This kind of credit is usually interest-free. It should also be noted that, contrary to the popular view, this kind of credit arrangements emerge when the market is fairly competitive; it is neither exploitative nor of the feudal bondage type. A typical case is reported by Pingali et al. (1989) for an irrigation system in Central Luzon, the Philippines, in that middlemen and traders advance interest-free loans to the rice farmers who grow onion in the dry season. If crops are "economically viable," then, credit follows.

It may seem that the situation in Sri Lanka in this respect too is not so encouraging. However, there are signs indicating that the rural financial market is working. For example, IIMI (1990b) reports that fairly large amounts of informal loans are available to farmers in an irrigation system in the southern part of the country. Bouman (1984) reports that informal financial arrangements in Sri Lanka provide very valuable services to many rural people. Although much research needs to be done in this field, it is certain that there is a potential. What is important for policymakers is not to demolish such a potential but to set up policies that will help develop efficient and flexible rural financial markets.

As pointed out by Schuh and Barghouti (1987) and World Bank (1988), an important and effective policy towards this end would be credit programs for middlemen and traders. Since the primary bottleneck for crop diversification could be in marketing the output, not in getting farmers to grow the crop when profitable, such programs could be instrumental in building flexibility in the marketing system in general and for speeding up the crop diversification process in particular. In this sense, the two-step loan now envisioned in Sri Lanka, if implemented properly, could be an effective means to mobilize rural markets.
Input Markets

The need to make rural markets flexible applies to the input markets as well. As complaints in Sri Lanka are often heard that seeds, fertilizers, and agrochemicals are not supplied to farmers in time, rigidity in these markets is presumably relatively well-recognized. Policies should be taken to ease such rigidity through the development of efficient markets for these inputs. What is not so well-recognized are the workings of other input markets such as labor, land, and draft power.

Farmers in developing countries in Asia, unlike the typical peasant described by Chayanov, are integrated with the market economy not only in the output side but also in the input side. They purchase inputs in the market. Labor and land are not the exception. Particularly in well-irrigated rice growing areas, the existence of landless laborers, whose income depends on hired labor in rice farming, is substantial. It is not uncommon in many Asian countries to find rice villages where the population of the landless laborers is much more than that of "farmers" who cultivate land as owners or as tenants of some sort. A significant portion of the income generated in rice farming is earned by these landless laborers. Sri Lanka is not an exception in this respect. The percentage of rice income earned by hired laborers is as high as 20-30 percent of the total rice income generated in many irrigation systems. In some areas, more than 90 percent of the total labor requirements in rice production is met by hired laborers.

Crop diversification under such conditions would have profound implications in the local labor markets. One implication is its impact on income distribution among rural people. It is often said that crop diversification is necessary in order to increase "farmers' income." In many rice growing areas, this should always be restated as including landless laborers' income. Should the income of rural households be of concern, more emphasis should be put on landless laborers who are the poorest of the poor in rural communities. This point of view seems to be usually lacking in policy consideration for crop diversification.

Another implication is changes in labor requirements due to crop diversification. In Asia, rice is a labor-intensive crop. Some nonrice crops are, however, more labor-intensive than rice. Although the labor is generally a relatively abundant resource in these countries, there could be a case in which seasonal bottlenecks in labor supply emerge with new cropping patterns. The solution to this depends critically on how flexibly and efficiently the labor market works.

As to the income distribution implication, the land market is even more important than labor because land is the resource that is most scarce in Asian countries, and because tenancy arrangements are pervasive in many rice growing regions there. It is also important in terms of efficient resource allocation. Even if legal restrictions to tenancy arrangements exist, tenancy transactions are popularly practiced by farmers. There is a tendency for the incidence of tenancy in rice growing regions to be more in the dry season than in the wet season, and that diversified cropping in these regions increases it even further (Kasryno et al. 1982; Pingali et al. 1989). For example, Pingali et al. (1989), studying an irrigation system in the Philippines where crop diversification is in progress in the dry season, reports that farmers adopt seasonal tenancy arrangements to cope with labor constraints and inherent risks in the nonrice crops grown. This suggests that the flexible land market helps crop diversification, and that rigidity in it, if any, should be minimized. It is counterproductive to treat the land
market as if no tenancy problem exists. In order to maximize the efficient use of the land resource, crop diversification should be promoted on the basis of a flexible land market.

Mechanization in peasant agriculture in Asia has been progressing. It is nowadays popular to see tractors and threshing machines in rice growing areas in this region. A distinct characteristic of this kind of input, as compared to inputs like fertilizer, is its indivisibility which could bring a scale economy into peasant production. Once this comes in, farm size becomes an important issue not only in terms of income distribution but in terms of efficiency. However, it is fairly common throughout the rice growing areas in the Asian tropics to see well-developed custom service markets for these agricultural machines (Siregar and Kikuchi 1988). Therefore, if there is a bottleneck in these services, as in Sri Lanka where such bottlenecks reportedly exist in many irrigation systems, in relation to the time allowable for land preparation, the reasons why the markets are not working properly should be looked into.

In essence, how these input markets work is crucial to a successful promotion of crop diversification. It determines not only the supply of inputs necessary for diversified cropping, but also how the income generated is distributed among the agents involved in the production process. The flexibility of these markets is an integral part of the flexibility that is needed for crop diversification. Understanding of the role to be played by the markets is grossly insufficient both in research and in policy arenas related to crop diversification.

**Market and Collective Action**

Mention should be made of the link between the markets and the nonmarket elements inherent in the management of irrigation systems. Irrigation water could be "marketed" under certain technological conditions, which the irrigation system in Asia generally lack. This entails the free supply and utilization of water in an irrigation system in this part of the world which makes the market mechanism inoperative and which necessitates collective action among the agents involved in the system. For instance, such matters as the ensuring of adequate water distribution, regulation of timing of water supply, and prevention of excess water use can only be dealt with by coordination among the agents through collective action, not through the market in a narrowly defined sense (Pingali 1990). A shift from a rice monoculture pattern to diversified cropping makes this need for collective action more imperative.

In almost all the countries under consideration, a major means of attaining this collective action is through the formation of strong water users' associations or farmers' organizations. As shown in Figure 1, the facets of "Institutional issues" and "Socioeconomic factors" are all related to the issues of farmers' organizations and their linkages with the managing agencies, if any. These are the facets that constitute the links where the markets outside as well as inside irrigation systems meet with the nonmarket elements of system management. Although it is well-recognized that the institutional aspects of irrigation management are of critical importance for better system performance, particularly when diversified cropping is envisaged, what is not clearly understood is how they are related to the markets.

These market and nonmarket linkages in system management range over a wide spectrum; some need collective action more than others. Moreover, even for a certain aspect,
the degree of need could differ from one system to the other, depending on the prevailing socioeconomic and sociocultural environments. For instance, solutions to conflicts in water distribution between the head-end and tail-end sections of a system may require collective action, in the absence of any market solution under usual circumstances. But some market, may exist under other circumstances where water rights are clearly specified and some compensation payments to losers can be enforced.

There seems to be a tendency among those involved in irrigation management in Sri Lanka, as well as elsewhere, to consider that market mechanism and system management are two independent things which never go together. Needless to say, the market is not always a substitute for collective action. It is equally counterproductive to assume that institutions such as farmers’ organizations can always be a better substitute for the market. The need is for certain amicable combinations of these two extremes, which is perhaps the most serious challenge that research has to confront in paving the way for successful crop diversification in rice-based systems in the long run.

CONCLUDING REMARKS

Crop diversification in rice-based irrigation systems is often treated as if problems in it can be solved by government or system management directives; if there is a need to diversify crops, the need should be there; if certain crops are to be substituted for rice, farmers should plant the crops; if certain inputs are needed to these crops, they should be there; and so forth. Crop diversification is an inevitable process that the agriculture sector has to adopt as the economy grows; it is a part of the structural transformation process of the economy. This process is designed to build flexibility into agriculture. A command type mode of operation is furthermore to this approach. Instead, the success of crop diversification critically hinges on the markets. Only with well-functioning markets could its objectives be attained, while being consistent with the long-run need of structural transformation and efficient resource allocation.

Crop diversification in rice-based systems is not easy to attain. Timmer (1987), which is an earlier version of the World Bank (1988) report, mentions Thailand and Japan as the countries where agricultural diversification has been successful; Thailand without government intervention, and Japan with heavy intervention. It should be noted that the major type of diversification that has progressed in both countries is not the one in rice-based systems but that through regional specialization away from rice. In the case of postwar Japan, agriculture as a whole has been diversified adding livestock and horticulture production to staple food production, but the rice sector itself has failed to diversify. The failure is twofold: rice farming has remained largely as monoculture despite all policy efforts made by the government to promote diversification, and it has totally lost its economic viability because of too heavy protection through rice price-support. This experience in Japan clearly suggests that crop diversification policy is not independent of rice policy. Both should be consistent with each other and with long-run needs of the economy.
Unlike policies to attain rice self-sufficiency, policy targets for crop diversification keep moving, and the issue of crop diversification is open-ended towards the output markets. Research, that makes clear the conditions of the crop markets, both domestic and foreign, for both rice and nonrice, needs to be carried out periodically. The comparative advantage of producing certain crops domestically relative to imports should be examined carefully according to changes in the markets and in the economy, in order to keep renewing the list of crops to be grown in rice-based systems.

It is worth remembering that major success cases of agricultural diversification in the past accompanied technological as well as institutional innovations consistent with the conditions of product and factor markers. In the case of the eighteenth-century English Agricultural Revolution, new technology in the form of new crop rotation systems was the technological basis with the enclosure as the institutional basis; the consolidation of communal pasture and farmland into single private units facilitated the introduction of an integrated system of crop-livestock production. At the turn of the century in Denmark, small grain farmers succeeded in introducing efficient dairy farming; accompanied were the technological innovation in the form of the centrifugal cream separator and the institutional innovation in the form of the cooperative creamery. Similarly, in Meiji, Japan, the introduction of sericulture alongside rice farming was made possible by the invention of the summer-fall cocoon rearing technology supported by a series of institutional innovations such as the establishment of silk inspection stations, national and prefectural silkworm egg multiplication stations, sericulture colleges, and sericulture cooperatives. As stated by Hayami (1989), "the scope of success for agricultural diversification strategy is but limited if it simply attempts to divert resources from the production of basic cereals to other crops and livestock products with no major technological innovation in either farm production or processing and marketing. If this resource reallocation would be enforced by government programs such as price supports and input/credit subsidies, it would prove to be counterproductive for the purpose that agricultural diversification tries to achieve.

In spite of all difficulties, crop diversification will be the direction that many rice-based irrigation systems have to take in the long run as well as in the short run, if they are to be a part of the agricultural sector which is bound to diversify as the economy develops. Research efforts in irrigation management for crop diversification should all be aimed at the ultimate objective of making rice-based systems as flexible as possible. To build flexibility into the systems is nothing but to provide necessary conditions for diversification. A part of sufficient conditions for diversification is coming from outside the systems, but necessary conditions can be prepared within the systems as well.
References


IIMI. 1990a. Research network on irrigation management for diversified cropping in rice-based systems. Colombo: IIMI.


IN ADDITION TO the country papers, two other papers were presented. The synthesis of findings under the IIMI-IRRI Collaborative Project in Bangladesh, Indonesia and the Philippines was discussed. The project implementation process which includes the setting of the country-specific objectives, the research site selection and implementation procedure were described. In the analysis, four critical issues were highlighted. They are: a) irrigation service fees; b) tenurial status; c) farmers’ decision to diversify; and d) farmers’ organizations.

Policies on irrigation service fees should be reviewed in relation to the differences in managing the system for rice versus nonrice. There should be a provision for a mechanism to address the problem of landlord-tenant arrangements, especially in improving land productivity through crop diversification. Although the farmers should be given some degree of flexibility in their decision to diversify, this flexibility should consider not solely his own advantage but also its influence on other farmers and the flexibility of the irrigation system itself. Organizing farmers is not an absolute necessity to have an effective irrigation management but depends on the sociopolitical situation existing in the area where the system is located.

There were still unresolved issues which may be addressed in future research. These could be related to: a) the design of the irrigation system with flexibility for crop diversification; b) improved assessment of both available water supply and water demand to match the requirement of diversified cropping conditions; c) direct government involvement through such mechanisms as crop plans; d) coping, by the agency and farmers, with different soil and drainage environments, considering zoning and water requirements; and e) better techniques for improving water use efficiency and productivity for both rice and nonrice crops.

Some clarifications were made regarding farm ditches in the Upper Pampanga River Project. It was mentioned that originally, the project had an elaborate system of farm ditches consisting of main farm ditches, and supplementary and internal farm ditches to facilitate rotational irrigation. Later on, all internal farm ditches and some supplementary farm ditches occupying unproductive areas were removed. Only the main farm ditch and some necessary supplementary farm ditches were retained. This was done through trial and error.

To demonstrate the IIMI-IRRI research results or technology to the farmers, seminars/workshops to which farmers are invited could be conducted. During these seminars, data/research results could be presented and explained and problems and possible solutions and necessary improvements determined.

To determine whether the technology is feasible and applicable or not, pilot-testing could also be done.
Irrigation management at the systems level is also affected by the choice of nonrice crops. As the root environment for nonrice is aerated, water should be delivered in an intermittent way. To remove drainage water and prevent overirrigation, intercepting ditches could be put up in areas with high water tables.

The second paper emphasized that crop diversification is an inevitable process that the agricultural sector has to undergo as the economy grows. It is a part of structural transformation of the economy to build flexibility into agriculture. The success of crop diversification critically hinges on the markets. Only with well-functioning markets could its objectives be attained, while being consistent with the long-run need of structural transformation and efficient resource allocation.

In spite of all difficulties, crop diversification will be the direction that many rice-based irrigation systems have to take in the long run as well as in the short run, if they are to be a part of the agriculture sector which is bound to diversify as the economy develops. Research efforts in irrigation management for crop diversification should all be aimed at the ultimate objective of making rice-based systems, as flexible as possible. To build flexibility into the systems, the necessary conditions for diversification should be provided.

The output market influences the farmers’ decision on whether to diversify or not. The input market is also important. Water was not included in the input market but was considered a nonmarket input. If included as an input market, then, water becomes almost as important as an output market affecting farmers’ decision on whether or not to produce irrigated crops. If they go for producing irrigated crops, the amount of water will determine whether to plant an irrigated rice crop or irrigated nonrice crops.

Water was treated as a nonmarketed commodity. As such, there is need for a corrective factor for regulating markets outside of this nonmarketed element. This corrective factor can be dealt with through farmers’ organizations where water is a constituent or institutional component of its irrigation management.

Equities and subsidies are important means to augment or create income. It was a common observation that a profitable market is an important factor for successful crop diversification.
Workshop Group Sessions
Workshop Group Sessions

The Small Workshop group discussion was an opportunity for the participants to share their ideas and expertise to address the objectives of the workshop. It provided a venue for deliberation of the issues that were raised and those that were not raised in the earlier sessions. It was also a chance to look more closely at cross-country comparisons to find out commonalities, similarities and differences in rice-based systems, in essence, addressing the sharing and complementation objective of the networking.

The participants were divided into three groups corresponding to the major activities of the network a) research and development, b) information exchange and dissemination, and c) funding and organization. Each group was also requested to give suggestions on the possible theme or focus of the next progress review and coordination workshop.

GROUP A: RESEARCH AND DEVELOPMENT

The group identified five research and development areas in the context of market demand, transport/storage costs, postharvest processing, subsidies/taxes/tariffs, and marketing association. It also considered water sources, water demand, structures, and institutional issues.

<table>
<thead>
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<th>Structures</th>
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<td>Existing soil moisture</td>
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<td>Agency and outlet</td>
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<td>Soil-water characteristics</td>
<td>Pumps</td>
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<td>Irrigation efficiency</td>
<td>Tubewells</td>
<td>Turned-over systems</td>
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<td>Private ownership</td>
</tr>
<tr>
<td>Water quality</td>
<td></td>
<td></td>
<td>Scale of system</td>
</tr>
</tbody>
</table>

179
Research and Development Areas

1. Drainage requirement for rice and nonrice mops in rice-based systems.
2. Techniques of quantifying water demand.
3. On-farm water distribution facilities.
5. Farmers’ support services for diversified cropping in turned-over systems

Suggested Theme for Next Workshop

Two possible themes for the next workshop were suggested:

1. Drainage requirement for nonrice crops in rice-based systems.
2. On-farm water distribution facilities.

GROUP B: INFORMATION DISSEMINATION AND EXCHANGE

Forms of Dissemination and Exchange

The conduct of annual workshops, publication of the workshop proceedings and the IMCD Newsletter should continue. As regards the newsletter, there is a need to establish a more responsive mechanism for soliciting contribution materials. A suggestion was for each member of the Steering Committee of the IMCD Network to spearhead, in their respective country, the collection of materials and dissemination of information to their counterparts. Identified members were:

- Dr. Manuel M. Lantin – Philippines
- Dr. Suprodjo – Indonesia
- Dr. Wong Koh Fiu – Malaysia
- Dr. Prakriti S. Rana – Nepal
- Dr. M. A. S. Mandal – Bangladesh
- Mr. Jayantha Jayewardene – Sri Lanka
- Dr. Kulaadaivelu – India
- Dr. Skulwattana Chanthrobol – Thailand

Each of the identified members was requested to initiate the formation of a suitable form of national information network.

The newsletter should be published at least twice a year. It could include information on activities being planned, carried out, views, and news of workshops, seminars, etc. Special publications on specific reports, reviews, technical papers, case studies, etc. could be done. There is a need for information feedback, to identify major issues and encourage interaction among members.
Special leaflets can be prepared for policy/decision makers in order to create awareness of the IMCD issues.

Training

The group encourages the development of training curricula on IMCD topics. These could be incorporated into existing training programs such as the irrigation and water management program of IRRI. It is suggested that IIMI develop curricula on IMCD issues for national and international training programs. Training programs should be conducted for farmers, junior technicians and officers.

Theme for Next Workshop

The theme "Promoting Implementation of Crop Diversification in Rice-Based Irrigation Systems" was suggested for the next workshop. This could further focus on: a) impact of research on crop diversification in rice-based systems; b) application of research findings and technology; c) training needs; and d) implementation issues.

Other Suggestions

Some members of the group strongly felt that there should be an evaluation of the IMCD Research Network Program. The evaluation would help the Network to be more effective in the future. A mechanism to get feedback from concerned sectors should be formulated. Funds should be made available for the operation of the network.

GROUP C FUNDING AND ORGANIZATION

Sources of Funding for Research

It was evident that all countries have existing projects on crop diversification with the corresponding funding. For future activities, each country may formulate its own research program and IIMI and the Network could help obtain the necessary support. Joint programs between and/or among countries are suggested.

The existing programs on crop diversification and funding sources in the different countries are:
Nepal

1. Farming Systems Research Program - USAID
2. Agriculture Extension Research Program - WB
3. Small Farmer Development Program - ADB
4. National Wheat Development Project - USAID
5. National Rice Improvement Project - USAID
6. National Maize Improvement Project - Government of Japan
7. National Vegetable Development Program - Agriculture Department, FAO, UNDP, Swiss Government
8. National Potato Development Project - Agriculture Department, FAO, Swiss Government
9. Grain Legume Improvement Program - WB/USAID

Thailand

1. Cropping Systems Research Program - Department of Agriculture
2. Rain-fed Agricultural Systems Research - USAID
3. Diversifying Cassava to Other Products - EEC

Malaysia

1. Government Budget through MARDI
2. Support from the Private Sector
3. Crop Diversification in Nongranary Areas - JICA

Bangladesh

1. Crop Diversification Program - CIDA
2. Crop Diversification Program - Rockefeller Foundation through IIMI/IRRI
3. Programs of the NGOs
4. Bangladesh Water Development Board Programs with BRRI
5. Crop Diversification for Improving Irrigation Water and Farming Systems Researches Incorporating Rice and Nonrice Crops Funded by the Ford Foundation
6. Improved Vegetable Cultivation - Mennonite Central Committee

Sri Lanka

1. Diversified Agricultural Research Project - USAID
2. Mahaweli Agricultural and Rural Development Project - USAID
3. Irrigation Management and Crop Diversification Project (Phase II) - ADB
**Philippines**

1. Farming Systems Research Project—Coordinated by PCARRD
2. Diversified Crops Irrigation Engineering Project - JICA

**India**

1. All India Coordinated Research on Water Management and Cropping Systems - Funded by Indian Council of Agricultural Research/Government of India
2. Crop Pattern Scheme - Tamil Nadu Agricultural University

**Indonesia**

1. Irrigation Management Improvement for Crop Diversification in Rice-Based Systems - IIMI/IRRJ

**National Committee for Crop Diversification**

It was felt that each country should have a national committee or some umbrella organization to oversee the activities on crop diversification. No standard objectives or rules were recommended but the NCCD in the Philippines could be taken as a model and modified as necessary. The Farming Systems Institute in Thailand could also be looked at. This committee should have independent and effective funding from appropriate agencies.

**Annual Workshop**

The group feels that the present workshop format could be maintained but paper presentation and discussion could be lengthened. It was suggested that the National Committee or similar body should nominate the representatives of the country. It may even nominate somebody outside of the Committee. **Two** or three representatives from each country should be enough.

**Theme for Next Workshop**

The group suggested the theme "Improvement of Reliability of Water Supply for Crop Diversification."
Summary/Highlights of Group Sessions
and General Discussion

Small Group Sessions

IN THE CONTEXT of market demand, transport, storage costs, postharvest processing, subsidies/taxes/tariffs, marketing association and considering water sources, water demand, structures, and institutional issues, five research and development areas were identified. They were: a) drainage requirement for rice and nonrice crops in rice-based systems, b) techniques of quantifying water demand; c) on-farm water distribution facilities; d) development of flexible supplemental water sources; and e) farmers’ support services for diversified cropping in turned-over systems.

Support services to be given to farmers for diversified cropping in turned-over systems should depend on the demand or need. Research related to this will determine the type and scale of support needed to promote and implement crop diversification.

As regards research on drainage, it was pointed out that it should be done for both rice and nonrice crops.

On information dissemination and exchange, the group recommended that the conduct of annual workshops, the publication and distribution of the workshop proceedings and the IMCD Newsletter should continue. There is a need to establish a more responsive mechanism for soliciting contribution materials for the newsletter. In this regard, each member of the Steering Committee shall initiate in their respective country, the collection of materials and dissemination of the information to their counterparts. Each member was also requested to initiate the formation of a suitable form of national information network. Special leaflets may be prepared with policymakers as the target.

Training curricula on IMCD topics should be developed and incorporated into existing training programs such as that conducted by IRRI. IIMI should develop curricula for national and international training programs. Training should be directed at farmers, junior technicians and officers, particularly.

Some kind of evaluation of the activities of the Network should be done. Feedback from concerned sectors should be helpful.

It appears that all countries have existing projects on crop diversification with the corresponding funding. For future activities, each country may formulate its own research program and IIMI and the Network could help obtain the necessary support. Joint programs between two or more countries are also suggested.

It was felt that each country should have a national committee or some kind of an umbrella organization to oversee the activities on crop diversification. No standard objectives or rules were recommended, but the NCCD in the Philippines could be taken as a model and modified as necessary.
The creation of institutes like the Fanning Systems Institute (FSI) of the Department of Agriculture in Thailand could be another strategy. The national committees should have funding support from appropriate agencies. It should be instrumental in determining research priorities and translating research findings into action.

It was suggested that in order to get funding for a national committee, a proposal indicating the objectives of the committee should be prepared and submitted. This could be built into research and extension proposals.

**General Discussion**

Water supply during the dry period becomes a necessary factor to encourage farmers to engage in crop diversification. There is a need to augment water, especially in run-of-the-river type systems, or gravity irrigation systems, as water supply decreases during the dry period. How to augment water for crop diversification is a major area of concern that needs to be tackled. Using the shallow groundwater pump system was mentioned as one way of augmenting water supply. However, this technology may be constrained by the fuel crisis. If this technology is to be used, there is a need to devise a system where economic and efficient use of water coming from the said system could be effected.

Since IMCD is very much tied up with crop diversification, it was clarified that it is not a "Crop Diversification Network" but rather an "Irrigation Management for Crop Diversification Network." If the network is on crop diversification per se, it will just be duplicating a number of existing farming systems networks.

The IMCD Network has been created to facilitate research implementation and information exchange related to irrigation management for crop diversification with reference to problems/issues common to all member countries. On the other hand, the national committee or its equivalent could take charge of country-specific type of research.

Considering the various comments related to the formation of the national committee, it was suggested that each country may develop its own mechanism or means (such as committee, institution, or network) to effectively provide the direction of crop diversification programs.

Besides being constrained with problems on irrigation, rice farmers are getting low incomes due to the declining price of rice. Addressing these problems, crop diversification aims to enhance profitability of irrigated agriculture. In relation to this, the network should be able to investigate the factors constraining the implementation/promotions of crop diversification.

Regarding sustainability of irrigation systems or agricultural systems, the major requirement mentioned was the development of a flexible or adaptable system. A dynamic system is likely to improve its long-term sustainability. Adaptability is an important key in maintaining a sustainable system.

The importance of water reliability was underscored, especially when investing on high-value corps.

JICA expressed its willingness to collaborate with the IMCD network's member agencies.
Summary/Highlights of the Second Steering Committee Meeting

13 December 1990
La Parilla Inn, Cabanatuan City, the Philippines

I. Attendance

1. Dr. Jose A. Galvez, Philippines
2. Ir. Soenarno, Indonesia
3. Dr. M. A. S. Mandal, Bangladesh
4. Dr. R. Kulandaivelu, India
5. Dr. Prakriti S. Rana, Nepal
6. Mr. Wong Kok Fiu, Malaysia
7. Mr. Jayantha Jayewardene, Sri Lanka
8. Ms. Anchalee Ouraikul, Thailand
9. Dr. Senen M. Miranda, IIMI
10. Mr. Charles Aberiethy, IIMI
11. Dr. Amado R. Maglinao, IIMI

II. Call to Order

The Steering Committee Chairman, Dr. Jose A. Galvez, called the meeting to order at 8:05 p.m.

111. Review of the Highlights of the First Steering Committee (SC) Meeting

The committee reviewed the highlights of the first SC meeting held in Kuala Lumpur, Malaysia on December 1-2, 1989. The highlights were approved with no modifications.

IV. Business Arising from the Highlights

Dr. Kulandaivelu clarified that the paper presented by Mr. Gopalakrishnan is a case study which is not yet complete. By changing the system operational plan, rice will be replaced
by groundnut. He mentioned other projects which are being implemented in India but which
do not address any objectives related to crop diversification. He proposed that a project with
specific objectives on crop diversification be conducted in India in collaboration with IIMI.
In this regard, Dr. Galvez suggested that India prepare a proposal which could be submitted
to IIMI for consideration. Dr. Miranda said that this could be facilitated with the assistance
of Dr. Saktivadivel of IIMI.

Another suggestion is to expand the ongoing projects to include crop diversification. In
this regard, the relationship with the coordinator of the All India research projects should be
strengthened. The coordinator may not be aware that IIMI is doing research on crop
diversification. Dr. Miranda said that this could be related to the type of networking in the
country. India should strengthen the national network and may evolve its own model similar
to the NCCD in the Philippines and the FSI in Thailand.

Dr. Mandal said that in relation to the format for the papers for the first workshop, he did
not receive comments from all the members and therefore did not know what to do. He only
received comments from Mr. Jayewardene. He further mentioned that the plan to come up
with proposals related to research methodologies and pilot-testing of management innova-
tions for possible discussion during the workshop of the network did not push through. Dr.
Miranda referred to some researches that should be done. In this regard, Dr. Mandal
discussed a two-phase project he was involved in Bangladesh. Phase I was a survey-type
study to learn the practices of the farmers related to economics, engineering, etc. They were
able to identify 15 patterns which they analyzed and compared. Based on these, intervention
was introduced although the farmers were allowed to do it their way (Phase II). Other related
research which may be considered are a sensitivity analysis on macro variation relating to
different price levels, marketing of rice versus nonrice crops and their influence on water
management, and crop diversification as an alternative to increasing water markets.

Dr. Maglinao mentioned the pilot-testing proposal which was also discussed in Malaysia.
He said that it could also be looked at as a research on methodology of transferring
information and technologies on water management for crop diversification. He said that it
was started in the IIMI-IRRI project in the Philippines but had to be cut short because of
lack of funding. The Philippines is still optimistic that this proposal could be funded and
implemented sometime in the near future. Mr. Wong voiced his concern with the problems
related to the implementation of suggested recommendations. For example, he mentioned
the need to have an area of about 1,700 ha to implement some identified recommendations
in Malaysia.

Mr. Abernethy made a distinction between generic and national projects. Generic projects
could be done at the regional level, while at the national level, more specific studies may be
conducted. Both of these require resources and IIMI is willing to help, particularly in
approaching some donors. What can be done is for the different country proposals to be
consolidated and then for IIMI to submit a packaged proposal to donors. The country
proposals could be sent to Dr. Miranda for consolidation.

Ir. Soenarno inquired whether IIMI has a framework upon which the research could be
based. He said that the framework will help the proponents in identifying what research
should be done. In this regard, Ms. Ouraikul suggested that a state-of-the-art should be evolved
to determine what research should be done. This could also be useful in the preparation of
the implementation plan. She referred to the need to do research to address the problem of
marketing of diversified crops.
Mr. Abernethy reiterated the action to be taken, that is, to pool information, concretize ideas for research, whether generic or national. Dr. Miranda will consolidate all the ideas for the funding strategy. Examples are the earlier suggestion to have a study on research methodology and pilot-testing of management innovations. The committee agreed to focus on the more specific issues on irrigation management.

On information dissemination, Mr. Abernethy said that the papers of the just concluded workshop could now be produced as a publication. He also mentioned the first newsletter of the network, copies of which have been distributed to relevant persons and agencies. Not all members received their copy though. Dr. Miranda will check on this problem at IIMI headquarters.

In terms of funding, Mr. Abernethy mentioned that Japan gave about US$50,000 this year primarily for the holding of the first workshop. At present, IIMI is no longer earmarking any funds specifically for crop diversification. This means that activities on crop diversification have to compete for funding with other activities. The committee therefore agreed to pass and submit a resolution to IIMI for it to consider crop diversification as a priority. As a protocol, a formal letter signed by Dr. Galvez should be sent with the resolution.

Mr. Abernethy also referred to the plans he presented in the closing session of the Kuala Lumpur meeting. Although nothing much has been done about this, he assured the group that it still remains the objective of IIMI as regards the network. The intention is still there and with the hiring of the Project Development Officer by IIMI, fund sourcing could be facilitated.

V. Election of Officers

As the Vice-Chairman automatically becomes the next Chairman of the Steering Committee, Ir. Soenarno of Indonesia, the present Vice-chairman, took over the chairmanship of the meeting.

Before proceeding to the selection of the next Vice-Chairman, Dr. Miranda aired the observation that the first two chairmen of the committee represent countries in the Southeast Asia (SEA) region and it may be worthwhile to consider other areas. Concurring with the observation of Dr. Miranda, the committee unanimously voted in Dr. Mandal as Vice-Chairman. Thus, in 1992, the workshop will be in Bangladesh, probably in February or March.

VI. Plan for the Second Progress Review and Coordination Workshop

With the arrangement that the workshop of the network is to be hosted by the country which the Chairman represents, the next workshop will be in Indonesia. Ir. Soenarno suggested that it should be held about the second week of September 1991, in Yogyakarta.

Of the four themes suggested by the workshop participants, the committee selected "Promoting Implementation of Crop Diversification in Rice-Based Irrigation Systems." Some specific issues which could be presented and discussed in relation to the theme are:
a) impact of research; b) application of research results; c) training; and d) identification and alleviation of constraints.

To firm up the outline and contents of the country reports, ideas from the members are expected to be sent to and received by Dr. Miranda before the end of February 1991.

VII. Other Matters

The issue on accepting new member-countries was taken up. Vietnam has indicated interest in becoming a member of the network. The group did not object to considering the membership of Vietnam. In this regard, IIIMI will contact and identify the relevant agencies which could represent Vietnam in the workshop next year. Vietnam will attend as an observer at this time.

Another issue that was mentioned was that on training, and the following points were mentioned:

1. Training should be conducted at different levels, generic (regional) or specific (national). At present IIIMI is conducting training activities through the national agencies.

2. JICA is willing to support international training programs and a proposal has been suggested. This could be done at the Diversified Crops Irrigation Engineering Center, the Philippines.

3. India has training on crop diversification in irrigation commands.

4. Information on related training workshops conducted by other agencies/institutions will be useful. It was suggested that information on the outputs of the recent farming systems seminar in Bangkok should be obtained.

5. The Central Luzon State University of the Philippines had a proposal for a training program on irrigation management for rice-based farming systems, but it was not pushed through because IIIMI was not able to provide the funds.

VIII. Wrap-up

Before adjournment, the chairman in his wrap-up comments said that it was a fruitful meeting. In conclusion, he mentioned that the proceedings of the workshop will be published, and a resolution will be duly prepared to be submitted to IIIMI to stress the importance of crop diversification and the activities of the network. A new set of officers has been selected, and the venue, date and theme of the next workshop have been agreed upon.

XI. Adjournment

The meeting was adjourned at 10:30 p.m.
Appendix A

Workshop Program

10 December (Monday)
Arrival of participants and hotel check-in

11 December (Tuesday)
0800  Registration
0900  Opening ceremony

Welcome Address: Admin. Jose B. del Rosario
National Irrigation Administration

Statement of Objectives and Expectations: Dr. Senen M. Miranda
International Irrigation Management Institute

Introduction of Participants: Asst. Admin. Jose A. Galvez
National Irrigation Administration

Introduction of Keynote Speaker: Ms. Jovita Corpuz
Department of Agriculture

Keynote Address: Asst. Sec. Manuel M. Lantin
Department of Agriculture

Master of Ceremonies: Dr. Rodolfo C. Undan
Central Luzon State University

1000  COFFEE/TEA BREAK
**Session I: Country Reports**

Chairman: **Mr. N. Ansari**, Nepal  
Rapporteur: Dr. C. M. Wijayaratna, IIMI

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<tr>
<td>1120</td>
<td>India</td>
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<tr>
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<td>LUNCH BREAK</td>
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Chairman: **Mr. Virgilio Cabezon**, Philippines  
Rapporteur: Dr. C. M. Wijayaratna, IIMI

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<td>Nepal</td>
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Chairman: **Mr. Shahrin B. Yob**, Malaysia  
Rapporteur: Dr. **Shaul** Manor, IIMI

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<td>Philippines</td>
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**12 December (Wednesday)**

**Session II: Special Papers and General Discussion**

Chairman: Dr. **Manuel M. Lantin**, Philippines  
Rapporteur: Dr. **Donald Parker**, IIMI

0800  Irrigation Management for Rice-Based Farming Systems in Indonesia, Bangladesh and the Philippines  
Dr. **Senen M. Miranda**

0900  Research and Policy Issues on Irrigation Management for Crop Diversification  
Dr. **Masao Kikuchi**
1000 General Discussion
1030 COFFEE BREAK

Session III: Small Workshop Group Sessions
  Group A Research and Development
  Group B Information Dissemination and Exchange
  Group C Funding and Organization
  1100 Small workshop group briefing
  1200 LUNCH
  1330 Small workshop group sessions
  1530 COFFEE/TEA BREAK
  1600 Resumption of small workshop group sessions
  1700 City tour/shopping
  2000 DINNER

13 December (Thursday)
Session IV: Small Workshop Group Reports and Closing
Chairman: Mr. Charles Abemethy, IIMI
Rapporteur: Dr. Amado R. Maglinao, IIMI
  0800 Presentation of group output and discussion
  1000 COFFEE/TEA BREAK
  1030 Workshop wrap-up
  1100 Closing
  1200 LUNCH
  1330 Visit to JICA DCIEP Farm in Bulacan
  1600 Leave for Cabanatuan City
  1700 Arrive Cabanatuan, Check-in at La Parilla Inn and Village Inn
  1900 DINNER and Second Steering Committee Meeting

14 December (Friday)
  0700 BREAKFAST and Check-out
  0800 Travel to District I, UPRIIS, CLSU
  0915 Briefing at District I Office
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<td>1145</td>
<td>LUNCH at Cafe Capritz, CLSU</td>
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<td>Travel to NIA Region I</td>
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<td>1600</td>
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<tr>
<td>1815</td>
<td>Travel to Quezon City</td>
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15 December (Saturday)

Departure of foreign participants
Appendix B

Workshop Groupings

Group A. Research and Development

Venue: Class Room A
Chairman: Dr. M.A.S. Mandal
Facilitator: Dr. Donald Parker

Members:
  K.N. Raja Rao
  Suprodjo Pusposutardjo
  Ram Prasad Satyal
  Wong Kok Fiu
  Shahrin B. Yob
  Lersak Rewtarkulpaiboon
  Amado R. Maglinao
  Rodolfo C. Undan
  Edilberto D. Reyes
  Hideyuki Kanamori
  Evangeline Sibayan
  Romeo Labios
  Aurora Pecson

Group B Information Dissemination and Exchange

Venue: Class Room B
Chairman: Dr. Prakriti S. Rana
Facilitator: Dr. Shaul Manor

Members:
  Abdul Ghani
  R. Kulandai Velu
  Soenarno
  Adnan Mohd Nor
  Jose A. Galvez
  Ananda Jayasinghe
Anan Lila
C.M. Wijayaratna
Sumio Oishi
Virgilio Cabezon
Maria Teresa Agarrado
Franklin Ramones

Group C: Funding and Organization

Venue: 4th Floor Conference Room
Chairman: Mr. Jayantha Jayewardene
Facilitator: Dr. Senen M. Miranda

Members:
Muzibul Haq
N. Ansari
Aminah Mohained Nawi
Marietta S. Adriano
Anchalee Ouraikul
Masao Kikuchi
Charles Abernethy
Manuel M. Lantin
Bonifacio Labiano
Manoru Fukuda
Gina Nilo
P. Dionisio E. Reyes
Appendix C

List of Participants

Bangladesh

1. Dr. M. A. S. Mandal
   Associate Professor and Head,
   Department of Agricultural Economics
   Bangladesh Agricultural University
   Mymensingh

2. Dr. Abdul Ghani
   Principal Agricultural Engineer and Head,
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