Research Network on Irrigation Management for Diversified Cropping in 'Rice-Based ,Systems

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Proceedings of the Organizational and Planning Workshop
held at the Asian Institute of Technology
Bangkok, Thailand
from 30 November to 3 December 1988

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Summary: This book constitutes the proceedings of an organizational and planning workshop for a research network on irrigation management for diversified cropping in rice-based systems held in late 1988 in Bangkok. The workshop 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.

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Foreword

THE INTRODUCTION OF new rice seed and fertilizer technology and the expansion of irrigated rice areas have helped a number of countries in the humid tropical regions of Asia to either approach or attain self-sufficiency in rice. This situation has led to a decline in economic returns from rice production. With encouragement from national governments and support from international agencies, farmers now seek to diversify their production and income sources. The farmers, however, face many obstacles in growing non-rice crops on land prepared mainly for rice production. The need for appropriate management practices has become apparent for these irrigation systems to be of effective and productive use for non-rice crops, especially during the past of the year when the water supply is limited. The need is obviously not to displace rice, but to find better ways to grow other crops in association with rice, particularly in parts of irrigation commands suited to diversified (upland) crops during the dry season.

The problem of effective irrigation management for crop diversification in rice-based systems has been addressed by field research conducted by the International Irrigation Management Institute (IIMI) in collaboration with irrigation agencies and other national institutions in several countries in South and Southeast Asia. Such research, however, has principally been oriented toward country-specific needs. As there are similar conditions and problems in all the countries studied, intercountry comparison of research results may prove beneficial in terms of optimizing the utilization of scarce research resources. In a regional workshop on irrigation management for crop diversification organized by IIMI and held in November 1986 in Sri Lanka, the 31 participants from 12 countries concluded that it would be highly beneficial to conduct the research in a network mode. The network would permit various levels of participation of interested countries, ranging from active research to exchange of information.

As a continuing effort to address the key issues on irrigation management for crop diversification in rice-based systems and as a follow-up to the 1986 workshop, IIMI sponsored the ***"Organizational and Planning Workshop for a Research Network on Irrigation Management for Diversified Cropping in Rice-Based Systems"*** which was held from 30 November to 3 December 1988 at the Asian Institute of Technology (AIT) Center in Bangkok, Thailand. Specifically, the workshop aimed to:

1. exchange information *on* government policies regarding irrigated rice production and the role and importance of irrigated crop diversification in rice-based farming systems; the potential of, and constraints to, producing selected diversified crops under irrigated conditions; and promising

irrigation management practices for relaxing constraints in diversified cropping;
2. determine outstanding researchable issues and appopriate research methodologies and strategies to address such issues;
3. discuss and agree on a methodology for information exchange, publication, and dissemination of research results among members of the network; and
4. formally organize the proposed research network on irrigation management for crop diversification in rice-based systems in Asia, and discuss funding strategies to support network activities.

The workshop participants from the different countries agreed on the establishment of a research network on irrigation management for crop diversification. Likewise, the objectives of the network, the research issues that should be addressed, the methodology for and the expected results from the research, and the mechanisms for information exchange and dissemination of the results were discussed and finalized. Most importantly, a steering committee which will coordinate all related activities and link with the national groups working on irrigated crop diversification was formally organized. Depending on the support that will be generated, the next major activity of the network will be a workshop in January or February 1991 in the Philippines.

IIMI wishes to thank the Asian Development Bank (ADB) for all its effort and generous support. Through the Bank's financial assistance, the initial activities and the organization of the research network on irrigation management for crop diversification as an output of this workshop have been realized.

IIMI also extends its gratitude to **AIT** and the Royal Irrigation Department (RID), Kingdom of Thailand, for co-sponsoring this workshop and for making the necessary arrangements during the workshop and field trip. The assistance of Dr. V.V.N. Murty and his staff at AIT and Mr. Nukool Thongthawee and his staff at RID is particularly acknowledged.

Thanks are also due to several IIMI colleagues at the Institute's Headquarters in Sri Lanka and to the Heads of IIMI's country field operations in Bangladesh, Indonesia, Nepal, and the Philippines for facilitating the preparations and arrangements for the workshop.

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

ROBERTO LENTON
Director General
IIMI

Highlights of the Opening Session

THE OPENING SESSION of the ***"Organizational and Planning Workshop for a Research Network on Irrigation Management for Diversified Cropping in Rice-Based Systems"*** included messages from Charles Aberoethy, Director, Programs, International Irrigation Management Institute (IIMI); Chamroon Chindasanguan, Senior Expert in Operation and Maintenance, Royal Imgation Department (RID); and **H.** Eggers, Professor and Vice-President for Academic Affairs, Asian Institute of Technology (AIT).

C. Abernethy discussed the purpose of the workshcp which was to form a research network in irrigation management for diversified cropping in rice-based irrigation systems. Most of the countries represented in the workshop have rice monoculture as the dominant practice in irrigated areas. This system is not as problematic as a new scheme where non-rice crops would be introduced in rice-based systems.

In addressing this concern, it is necessary to have a demand-responsive system. For instance, there is a need to look at the institutional changes that would be required to enhance the introduction and acceptance of crop diversification.

In irrigated crop diversification, there is a need to consider a number of factors, such as soil type, existing irrigation system, fisheries, drainage of polluted water into irrigation canals, and farmers' conflicts over the use of water.

The presence of the heads of IIMI's country field operations made it apparent that irrigated crop diversification is a regional concem. With the establishment of the research network as an expected output, interaction should be a continuing process. Perhaps eight years from now the effort will bear fruit and irrigated crop diversification can take off.

The support the Asian Development Bank (ADB) has provided as well as the participation of the different agencies like the RID and the AIT were acknowledged.

C. Chindasanguan welcomed the group on behalf of RID, Kingdom of Thailand. He mentioned the necessity to set up a diversified cropping plan to offset the problem of rice surplus and its low world market price. In Thailand, the Sixth Five-Year Plan (1987-1991) has drawn up a reduction of dry-season rice in irrigated area to approximately 160,000 hectares and finds other crops suitable for the area not used for rice production.

H. Eggers welcomed the participants on behalf of the AIT. As the participants represented a cross-section of the research and development sectors, complementation among university professors, irrigation practitioners, researchers, and others can be hastened.

If the network is formed, it would serve as the center for exchange of information and experiences on irrigation management for crop diversification.

It was hoped that with the seemingly ambitious expected outputs of the workshop, recommendations of value to farmers can be formed

Section I: Special Papers on Irrigation Diversification

CHAPTER 1

Some Highlights of IIMI's Research on Irrigation Management for Crop Diversification in Indonesia, the Philippines, and Sri Lanka

Senen M. Miranda

This paper presented at the Bangkok conference has since been published by IIMI as a separate document under the title "Irrigation management for crop diversification in Indonesia, the Philippines, and Sri Lanka: A synthesis of IIMI's research" by Senen M. Miranda.

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

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

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

It became apparent early in the conduct of the research that rainfall distribution - and not so much the annual total - significantly influences the cropping pattern. The rainfall pattern itself **is** determined by the prevailing monsoon and the presence of mountain harriers. During the first wet-season cropping, the primary crop grown **is** rice, as to tie expected, in all three countries. During the second or third cropping season, the irrigation and cultivation practices observed vary across countries and situations. In the Philippines and in Sri Lanka which basically have two cropping seasons, the service area is reduced to a fraction of the area served during the wet season. The reduced irrigated area is rotated every year in the Philippines while institutional sharing of reduced area is practiced in Sri Lanka. In Indonesia where the cropping intensity is highest, the third cropping has been decreed by the government to he devoted only for cultivation of non-rice crops. Rice, however, is still being grown in the poorly drained low-lying areas. Except for the residual soils in the Sri Lanka sites, the soils in Indonesia, and in the Philippines are all alluvial. The soils range from sand to clay texture, from poorly drained to well-drained, and from good riceland to diversified land class. The Philippines is currently pushing the cultivation of non-rice crops in the diversified and dual land class soils while Sri Lanka is now promoting the same in the well-drained soils.

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

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

* There are non-rice crops grown in each country showing higher and consistent profitability than rice.
* There are well-drained and coarse-textured **soils** in parts of the commands of the irrigation systems which are well-suited to diversified crops.
* **A** limited water supply not adequate to meet the requirements of riceduring the dry season is observed in many schemes with favorable soils. Related to this is the distinct unimodal rainfall pattern which makes it possible to have the desired well-aerated soil condition during the dry season.
* No major land movement or landshaping is needed to irrigate non-rice crops, although farmers have to introduce a rudimentary system of on-farm supply and drainage ditches in these plots to facilitate the timely application of water to their fields, and removal of water. Rice basin huuds are retained where the appropriate seedbeds are prepared according to the water-application requirements of specific non-rice crops.
* Imgation systems properly designed and constructed for supplementary irrigation for wet-season rice, which can meet the land soaking and land-preparation requirements, have enough

canal capacity for the intermittent flow of water for irrigating non-rice crops, although the need for greater canal water regulation is apparent.

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

There are, however, the following constraints:

* Water control is more demanding in terms of supply and removal for non-rice crops due to their far stricter requirements of soil moisture. The intermittent delivery of limited and uncertain water supply during the dry season requires greater joint management effort and, in turn, needs effective communication between irrigation staff and farmers.
* To provide the necessary functional water control, regulation, and measuring facilities have to be present to enable effective monitoring and feedback of the water supply.
* Farmers who have grown only irrigated rice before are unfamiliar with the agronomic and irrigation practices for non-rice crops.
* There are greater economic risks associated with non-rice crops than with rice. Cash and labor inputs can be three or four times higher for non-rice crops than for rice crops. Institutional credit is scarce while noninstitutional credit carries usurious interest rates.
* Unlike in the case of rice, unstable prices and lack of organized marketing for non-rice crops increase the risks for fanners involved in their procuction.

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

* For diversified cropping those irrigation systems with a limited water supply condition not adequate to meet the requirements of rice for the whole command during the dry season, and which have substantial areas of well-drained, coarser-textured or diversified land class of soils should be selected first.
* The irrigation system should be at least in a physical condition that would enable a satisfactory level of water delivery and control at various levels of the system.
* There is an urgent need to improve the interaction between irrigation staff and fanners in irrigation system management, from planning and implementation to monitoring of irrigation deliveries. Some form of joint management by encouraging increased organized farmers' participation in the irrigation management process is needed to meet the more demanding requirements of non-rice crops in a situation of limited and uncertain water supply.
* A more vigorous extension program to disseminate the irrigation as well as agronomic practices for non-rice crops showing potential profitability is suggested to help farmers consider options on what non-rice crops to grow.

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

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

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

* Research needs to focus on the assessment of suitable methodologies for the introduction of an effective process for bringing about the desired improvement in communication between agency staff and farmers in the management of the more demanding intermittent water delivery.
* There is a need to come up with improved methodology for assessing and matching water supply and demand, including water supply augmentation possibilities under diversified cropping conditions.
* To reduce, if not eliminate, the undesirable excess soil moisture condition, there is a need to work out appropriate alternative designs of irrigation and drainage systems which enable the timely application and removal of water by evaluating a spectrum of available technology from the ingenious rudimentary ways of the farmers to the capital intensive practices already being applied in Japan and Taiwan.

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

CHAPTER 2

Diversified Cropping in Rice Fields in South Korea: The Present Situation

Young Kun Shim

INTRODUCTION

SOUTH KOREA IS a peninsula in northeastern Asia. It has an area of 9.9 million hectares (ha), of which 63.5 percent is classified as mountain or forest land and 21.6 percent as cultivated. About 63.1 percent of the arable land is classified as rice fields and 36.9 percent as dryland. Because of the variation in topography, temperature, soil, irrigation, and drainage facilities, different cropping systems exist in the two types of arable land.

With 1,871 million farms and 2,143 million ha of cultivated area, the average farm size is only 1.1 *ha*. As *a* result *of* the land reform law of 1950, all farmers were able to own land. Ownership of more than three hectares for cropping by any farm household, however, was not allowed.

In 1967, the total farm population was about 16.1 million, accounting for 53.4 percent of the total population. This decreased to 7.8 million (18.5 percent cf the total) in 1987, representing a decrease of 8.3 million people or 51.6 percent. The total farm households, however, decreased by only 27.7 percent from 2,587 million to 1,871 million resulting in a decrease in average family size from 6.3 to 4.2 members during the same period (Table I.2.1).

Table I.2.1. Farm population and family size by year, 1965-1987.

Year	Total population ('000)	Farm population: Total ('000)	Farm population: % of total	Family size (number/farm)
1965	28,705	15,812	55.1	6.31
1967	30,131	16,078	53.4	6.22
1970	32,241	14,422	44.1	5.81
1975	35,281	13,244	37.5	5.57
1980	38,124	10,827	28.4	5.02
1985	41,055	8,521	20.8	4.42
1987	42,082	7,771	18.5	4.15

Source: Ministry of Agriculture, Forestry and Fisheries (1988).

Farming operation is still dependent on human and animal power. Recently, farm machinery such as tillers, sprayers, and threshers have been introduced by the farmers to meet labor demands during some periods of the farming reason. 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 size of arable land. Lack of incentive 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.

All of the grains produced are used for human ccnsumption. Farmers are motivated to produce more food grains fur family consumption and for szle. The domestic production, however, cannot cope with the increasing population's demand for food grains. The percentage of the self-sufficiency ratio for domestic food grain production was 93.9 percent for all grains in 196.5 but decreased to 41.3 percent in 1987. The percentages of the self-sufficiency ratios for rice and barley, the most important food crops, however, remained relatively high at 99.8 percent for rice and 97 percentforbarley, but was only 0.2 percent for wheat and 2.4 percent for corn in 1987 (Table I.2.2).

Table I.2.2. Self-sufficiency ratio offoodgrains, 1965-1987.

Year	Self-sufficiency ratio (%)					
	All	Rice	Barley	Wheat	Corn	Soybeans
1965	93.9	100.7	106.0	27.0	36.1	100.0
1970	80.5	93.1	106.3	15.4	18.9	86.1
1975	73.0	94.6	92.0	5.7	8.3	85.8
1977	65.1	103.4	53.4	2.3	6.2	67.5
1980	56.0	95.1	57.6	4.8	5.9	35.1
1983	50.2	97.6	129.0	6.0	2.8	25.7
1985	48.4	103.4	82.4	0.4	4.1	22.5
1987	41.3	99.8	97.2	0.2	2.4	16.2

Source: Ministry of **Agriculture,** Forestry and Fisheries **(1988)**

LAND USE FOR DIVERSIFIED CROPPING

Because total agricultural production falls short of national demand and most farmers have low income levels and limited opportunities for off-farm employment, the governmenthas implemented a variety of programs for the development of traditional agriculture. Efforts to develop the agricultural sector have initiated major action programs such as, the improvement of irrigation systems, intensive use of arable land, development of higher-yielding varieties of rice, supply of agricultural inputs at low price levels, provision of ural guidance services and institutional loans for farm operations, training of farmers, and price support for increasing production. As a result, agricultural productivity has increased considerably The rate of growth, however, was slower than that of other economic sectors. Taking into account the continuous shortage of domestic production in staple food except rice, increased productivity is critical to achieve the target of food self-sufficiency. Thus, it is necessary to use the idle resources.

Available land is limited and, therefore, South Ksrean agriculture is characterized by its heavy emphasis on crop production to meet the food requirement. As shown in Table 1.2.3, *food* crops including rice, barley, wheat, pulses, potatoes, and other crops accounted for 68.3 percent of the total area planted in 1987.

Table I.2.3. Land use for various crops, 1965-1987

Item	1965	1975	1985	1987
Total area planted ('000 ha)	3,560.0	3, L44.0	2,592.0	2,598.0
Food crops (%)	90.5	80.2	68.7	68.3
Rice	33.5	38.8	47.7	48.6
Barley + wheat	33.7	24.2	9.3	8.0
Pulses	10.3	10.3	7.6	8.2
Potatoes	6.0	4.6	2.5	1.8
Miscellaneous	6.0	2.3	I.6	1.7
Special (%)	I.7	3.8	5.1	6.8
Vegetables (%)	4.2	7.8	13.0	11.9
Fruits (%)	1.2	2.4	4.2	4.4
Mulberry fields (%)	1.4	1.4	0.5	0.3
Others (%)	1.0	4.5	8.5	8.3

Source: Ministry of Agriculture, **Forestry and Fisheries (1988).**

The total area devoted to the main food crops has decreased by 44.9 percent in the last 22 years, while the total production of food grains has increased by 2.4 percent during the same period mainly owing to increased yield per hectare. Rice accounted for ***5.5*** million of the 6.1 million tons of food grains produced in 1987. Although the area planted with rice was only 71.1 percent of total area for food crops, rice production accounted for 82.1 percent of the total food grain production. This means that rice yields were higher than those of other food crops. Because of its relatively high government support price, rice has become a favorite crop to cultivate.

The government has promoted the intensive use of arable land as the solution to meet the food shortage. The cropping intensity, however, has decreased continuously since 1970 (Table I.2.4).

Table I.2.4. Change in cropping intensity (%) by year. 1970-1987.

Type of arable land	1970	1975	1980	1985	1987
Rice field	148.0	130.0	119.1	114.9	112.9
Dryland	160.7	152.9	135.9	129.2	131.4
All	151.3	140.4	125.3	120.4	120.0

Source: *Ministry of* **Agriculture,** *Forestry and* **Fisheries** *(1988)*

Rice fields produce only rice during summer, with 12.9 percent planted with second crops such as winterbarley, wheat, springvegetables, and forage. Drylands are usedforavarietyofcoarse grains, vegetables, fruits, and oil crops during summer, and about 31.4 percent of this land is used for diversified cropping with winter barley, wheal, vegetables, fruits, etc. This resulted in a national cropping intensity of 120.0 percent for all arable land in 1987. This means that only 20.0 percent of the total arable land had two crops planted in the same field during the year.

Cropping systems in the rice fields are quite simple. Rice is grown in summer and a few second crops are grown in a limited area (Table I.2.5). Most of the rice fields are left uncultivated during winter.

Table I.2.5. Cropping systems in rice fields

Crop production	Spring			Summer			Autumn			Winter			% of area planted
	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feh	
Crops													57.1
Rice + barley			O	X			O						
Rice + wheat			O	X			O						
Rice + rye - green forage			O	X				O					
Rice +potatoes				O	X			O					
Rice + rape				O	X			O					
Vegetables													8.2
Rice + tomato				O	X				O				
Ricc +cucumber				O	X				O				
Rice + red pepper				O	X				O				
Rice + onion				O	X				O				
Rice + garlic													
Ricc + spinach			O	X					O				
Rice + strawberry			O	X					O				
Forage crop													32.4
Rice + Italian rye grass				O	X				O				
Others													
Rice + rape seed				O	X				O				1.2
Rice +potatoes					O	X			O				1.1

Note: : seeding, X: transplanting, O: harvesting
:Rice, .: second crop

Among thewinter crops grown in rice fields are cereal grains, commonbarley, nakedbarley, wheat, and rye. Barleycanbeapotential secondcropafterric:. In 1965, 933,000 ha wereplantedtobarley which increased to 208,000 ha in 1987. Barley, rye, wheat, and garlic are sown in the fall, soonafter the rice harvest. Forage, spinach, and other vegetable!, are sown either in autumn or in early spring. The area planted withvegetablesisrapidly increasing due tobetterpricerelativeto thatofotherfood crops. The demand for vegetables has expanded with the increases in incomes of farmers and the urban population. In addition, vinyl mulching technology made possible the production of vegetables, even under cold temperature.

It is possible to expand the area of rice fields for growing food and forage crops during the winter. Various technical and environmental constraints, as well as economic and social constraints which affect diversified cropping in rice fields, however, have to be considered.

FACTORS IMPEDING DIVERSIFIED CROPPING IN RICE FIELDS

Technical and Environmental Constraints

South Korea has four seasons. The temperature ranges From 10 to 24 degrees centigrade from April to October in the northern area (Seoul). Winter is quite cold and temperature often goes down to 7°C and even to -10°C from November to March. A frost-free period of seven months is adequate for the cultivation of rice and a variety of dryland crops. Barley and wheat are sown in late October.

Many Korean fanners believe that diversified cropping in rice fields is not appropriate. The annual precipitation averages about 1,300 millimeters (mm) although it has reached as high as 1,500 mm in some years. The monsoon brings heavy rain with about 60-70 percent of the annual precipitation falling from June to August. Rice is therefore planted during summer.

Considering that rainfall is not much of a problem for the winter crops which do not require additional water supply through irrigation, the low temperature during winter poses a big constraint to diversified cropping in rice fields. Further, inadequate drainage systems prevent the use of rice fields for diversified winter crops. Unless the soil is thoroughly dried after the rice harvest, seeds sown on the rice fields may freeze. Moreover, spring sowing may be affected as the soil thaws late in spring.

Fear that a delay in the harvest of barley will prevent timely transplanting of rice which would result in a decreased rice yield causes farmers not to practice double cropping. Farmers would give priority to increase rice production. Less attention is given to cultivating a second crop. If in the early summer a sufficient amount of water is not available in the rice fields, rice planting is delayed; this causes a decrease in yield. Therefore, fanners allow water to collect in the fields after the rice harvest to have an adequate water supply at transplanting time. This is not necessary if irrigation water can he made available when needed and, there would he no fear that diversified cropping will delay the transplanting of rice. In this respect, farmers without irrigation believe that they could better utilize their rice fields during the winter season if only the irrigation system could be improved.

Economic and Social Constraints

There are some economic and social constraints other than the abovementioned technical and environmental constraints which influence farmers' decisions to plant a second crop in rice fields during winter. Most farmers believe that the low price of barley hinders diversified cropping. The price of barley is relatively low to cover its production cost. To provide a better price and give farmers an incentive to increase production of barley through the expansion of the cultivated area, the government has maintained the same price of barley relative to the price for rice (Table **1.2.6).** In addition, the government announces in advance the buying price as guaranteed for the produce of the following year. The area planted to barley, however, has been decreasing.

Table 1.2.6. ***Relative price levels between*** *rice and barley, purchased by government, 1970-1987.*

Year	Purchasing prices of rice	Purchasing price of barley	Barley/rice (%)
1970	5,150	3,348	60.0
1975	15,760	9,901	62.8
1980	36,600	22,000	60.1
1985	57,650	34,460	59.8
1987	64,160	39,070	60.9

Note: **Unit: Won/80 kilograms.**
Source: Ministry of **Agriculture,** Forestry and Fisheries (1988).

Farmers who believe that the price of barley is too low are hesitant to use their fields for the production of second crops. Recently, however, the production of vegetables in rice fields was made possible owing to the use of vinyl-covered houses. Vegetable production is common near large cities, and growing of vegetables as winter crops becomes more profitable under the present unfavorable price condition of barley.

Cultivation of barley also requires additional labor which could not he provided by the family members. The decrease in the number of farmers not adopting farm mechanization has led to an increase in the wage rate in rural areas. Therefore, if farmers were to hire wage labor, they could hardly expect any returns.

POSSIBILITY OF EXPANDING DOUBLE CROPPING IN RICE FIELDS

The technical, environmental, economic, and social constraints are not the only concerns of the farmers. The inadequate understanding of the prospects of using the rice fields for diversified cropping is another of their concerns. Nevertheless, several possibilities can be looked into as there' is a high potential for expanding diversified cropping.

* ***Provision of a more favorable price for barley.*** Considering that there are suitable rice fields, particularly in the southern parts, that can be used for diversified cropping, provision of favorable price conditions for the purchase of agricultural inputs and the sale of barley may promote diversified cropping.

* *Cultivation of green manure crops.* The use of organic compost is necessary to prevent acidification of old and acidic soils in rice fields. If farmers are unable to make compost using rice straw, wild grass, and other wastes, green manure is the most logical choice. Winter crops such as vetch and Italian grass will not suffer from a cold winter. Therefore, the government should give strong support to the growing of green manure as a winter crop by providing appropriate seeds and technical assistance to farmers.

* *Production of green forage crops.* The second crop of a rice field should not hinder the cultivation and harvest of rice. Forage crops such as rye, oats, and barley can be harvested in spring before rice is transplanted. Therefore, the production of forage crops as the second crop in rice fields has become desirable. Further, in early spring, as wild grass to feed livestock **is** rarely available, the use of rice fields for cultivating green forage for livestock can he profitable. Recently, the increase in the income of consumers has increased the demand for beef and milk, necessitating **an** increase in the number of cattle and dairy cows. The problem, however, is the lack of incentive for the fanners to produce the feeds. South Korea imports several million tons of relatively cheap feed grains, and it may he cheaper to import forage or hay than to produce it domestically.

* *introduction of crops other than barley.* The use of ricz fields for feed crops, green manure crops, and barley shows some promise. Other crops, including early potatoes and vegetables, which have a short growth duration can he grown in rice fields, if appropriate irrigation and drainage facilities are provided.

Presently, most farmers are not interested in growing other crops during the winter owing to low economic returns and technical constraints associated with the production of such crops. Expansion of diversified cropping areas and full utilization of the available rice fields can be achieved only when the price of barley, the most important crop among possible diversified crops, is increased when stable and favorable price levels for livestock products are established; and when costs of agricultural inputs to reduce production cost of crops are lowered.

The potential for using rice fields in winter for feed production is most feasible under the condition of limited land resources in South Korea. Increased use of land, and improved irrigation and drainage facilities will certainly contribute to the promotion of diversified cropping.

CONCLUSION

South Korea has a population of about **43** million, hut has only ***2*** million hectares of arable land, most of which are mountainous. **At** present, domestic production of food covers only **45** percent of the total consumption. Therefore, the urgent task is to produce more food to fulfill the domestic needs.

There are roughly two ways to increase agricultural production using available technologies. One is the expansion of the cultivated area and the other **is** the intensification of use of the present cultivated areas. In South Korea, it is reasonable to resort to intensifying the use of present cultivated areas because most of the available land is already being reclaimed for cultivation. Land development, including reclamation of hillsides, is too costly for farming.

Increased agricultural productivity can he achieved either in rice fields or in the drylands. Increasing the productivity of rice fields, however, provides greater potential. Rice fields account for 63.1 percent of the total cultivated area, hut only 12.9percent is used for growing 2 crops a year.

Another reason why South Korean farmers do not plant other crops in rice fields after rice is the need to store water in the field as there is a lack of irrigation facilities. This, however, is a problem that can he solved by investing capital on irrigation facilities.

Many rice fields remain unused during the winter owing more to economic constraints than to environmental or technical ones. Even if environmental and technical conditions were favorable to grow a second crop in winter, unfavorable prices may become a constraint.

In recent years, crops such as barley, vegetables, potatoes, and green manure and green forage crops have been introduced for cultivation as second crops, but the total area planted has been decreasing. Favorable prices for these crops would surely promote diversified cropping in rice fields even under the present conditions of irrigation and drainage. The most important issue, therefore, is how to assure reasonable price levels or benefits that would encourage farmers to increase and intensify the use of land.

A further means to encourage increased production of winter crops would be the introduction of fann machinery to supplement labor supply during the fall planting season. Fall planting competes for labor with the harvesting of rice. Many farmers who want to plant winter crops cannot do so owing to labor shortage. Efficient agricultural machinery for fall plowing would alleviate this shortage and reduce the high cost of hired labor.

There are other second crops that may he planted besides barley and wheat. In recent years, some farmers, especially those living in suburban areas of large cities, have been growing cash crops, including vegetables. Prices for these crops hold the key to their production on the existing cultivated rice fields. The possible crops are not limited to those produced for sale in markets. Other crops may he grown, including green manure crops, to maintain the fertility of the soil. Intensive use of labor for the growing of such crops, however, is not justified owing to the high cost of labor. Measures such as government assistance and subsidies are required to alleviate this problem.

The most suitable crops for diversified cropping are forage crops. The forage produced would be most profitably used as livestock feeds and in turn would contribute to the development of the livestock industry in South Korea.

The most important long-range measure to he undertaken by the government to promote diversified cropping is greater investment for irrigation and drainage facilities. Many fanners have to store water in the rice fields during winter to he used the following year because of inadequate irrigation facilities, making it impossible to plant winter crops.

Finally, if the earlier mentioned technical, environmental, economic, and social constraints which prevent farmers from cultivating other crops in rice fields can be overcome, larger portions of the rice fields will be used for growing food or forage crops during winter.

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Summary/Highlights of Discussion: Special Papers

Two SPECIAL PAPERS were presented and discussed to give insights into the issue of crop diversification in rice-based systems and the possibility of networking as a strategy for conducting research.

The first paper highlighted IIMI's research on irrigation management for crop diversification in Indonesia, the Philippines, and Sri Lanka through a comparative synthesis of the results obtained since 1985. Some of the potentials and incentives found for more diversified cropping during the drier part of the year in irrigation systems that had been developed for rice production were presented. It was found that no major land movement or landshaping is needed to irrigate non-rice crops, although farmers have to introduce an additional rudimentary system of on-farm supply and drainage ditches in their plots to facilitate the timely application of water to their fields and removal of excess water. Further, the fanners' presence in the fields is essential to receive and supply water as well as to remove the excess water because of the stricter soil-moisture requirements of non-rice crops. There are non-rice crops grown in each of the three countries showing higher and consistent profitability than rice. Though economic returns from non-rice crops are much higher than from rice, inputs (cash and labor) are **also** higher. This raises the need for credit which is not readily available. Unlike in the case of rice, however, unstatle prices and lack of organized marketing for non-rice crops increases the risks for fanners involved in their production.

The second paper reported the experience of irrigated crop diversification of a developed country, South Korea. South Korea's experience showed that there are regional differences in the pattern of double cropping in the country. Vegetable cultivation after rice is more popular near big cities. To address the problem related to temperature, greenhouses are used to grow vegetables and flowers. These crops are more profitable to grow than barley. Price subsidies are given to rice and barley, and also to other crops like red pepper, onion, and peanut. Farmers' income of US$9,000/farm/year on the average is 10 to 15 percent lower than that of non-fanners.

The use of simulation models to enhance the utilization of research results taking into consideration the technical as well as the socioeconomic and institutional factors (i.e., incentives for farmers to practice crop diversification) was suggested. In the long run, there may **also** he a need to consider the flexibility that crop diversification requires in irrigation system designs.

Dissemination of research results is to be done through publications, seminars, and workshops. It is worth noting that the ultimate objective of the research is to provide technical as well as socioeconomic conditions for diversifying irrigation systems designed for rice to increase farmers' income.

Section 11: Country Activity Papers

CHAPTER 1

Irrigation Management for Diversified Cropping in Rice-Based Systems of Bangladesh

M.A.S. Mandal

BACKGROUND

IN BANGLADESH, THE need for maintaining the population-food-nutrition balance can hardly he overemphasized. The country, which has only 8.9 million hectares (ha) of arable land, has to feed about 110 million people. The population has doubled in the last 26 years, and despite a decline in the population growth rate to ***2.6*** percent per annum in recent years, the population density is 7 13 persons per square kilometer. Two important implications of the rapidly expanding population are that per capita land availability has declined from 0.19 ha in 1961 to 0.14 ha in 1987, which puts heavy pressure on land for human habitation and crop production; and that per capita foodgrain production also has declined from 173 kilograms (kg) in 1961 to 158 kg in 1987, indicating lesser availability of foodgrains on a per capita basis.

Bangladesh **is** composed of flood plains covering around 88 percent of its total area. The remaining area is composed of terraces and hills. The flood plains are categorized into five land types according to the depth of flooding as high land, medium high land, medium low land, low land, and very low land. The plains cover an area of 14.3 million hectares 67 percent of which accounts for net cultivable area. The high land and medium high land jointly cover 71 percent of net cultivable area, while 28 percent is covered by medium low land and low land with the remaining 1 percent as very low land. Table II.1.1 shows the depth and incidence of flood, and suitability of land for crop production.

Table 11.1.1. Land types, flood depth, and major crops grown in Bangladesh.

Land type	Flood depth	% of cultivable area	Remarks
High land	0-30 cm	37	Intermittent flooding, suitable for rice, wheat, jute, sugarcane, vegetables, banana, fruits, potato, pulses, oilseeds, etc.
Medium high	30-90 cm	34	Seasonal flooding, suitable for boro rice, transplanted aman rice, aus rice, jute, wheat, potato, sugarcane, vegetables, fruits, banana, pulses, oilseeds, etc.
Medium low	90-180 cm	16	Suitable for boro rice, aus rice, broadcast aman rice, jute, oilseeds, pulses, tobacco, sugarcane, banana, fruits, etc.
Low land	>180 cm	12	Seasonal flooding, suitable for broadcast aman rice. oilseeds, pulses, etc.
Very low	>180 cm	01	Seasonal or perennial flooding.

Source: Modified from Islam (1988).

The cropping seasons are divided into ***kharif-I*** (April-June), ***kharif-II*** (July-November). and ***rabi*** season (November-March). Kharif-I which covers about 74 percent of the cropped area is characterized by monsoon rain and high temperature. The major crops grown in this season are *aus* rice (i.e., rice grown from March to June) summer vegetables, summer pulses and oilseeds, and spices. Broadcast *aman* and jute are also sown in this season. The kharif-II season is characterized by heavy rains, low solar radiation, an overcast sky. high humidity, floods, and on some occasions, drought. Transplanted aman rice is the major crop grown in this season. Jute is harvested in the kharif-II season. The rabi season is characterized by low rainfall, high evapotranspiration rate, low temperature, and a bright sky. These characteristics of the rabi season favor cultivation of ***boro*** rice, wheat, potato, vegetables, pulses, oilseeds, and totacco. Crop growth in this season is limited by inadequate soil moisture. Both acreage and yields of these crops can be significantly increased if irrigation is applied using appropriate methods.

Foodgrain Production Programs

The emphasis of the Government in the Third Five-Year Plan (1985-1990) has been to attain self-sufficiency in foodgrain production. The plan targeted foodgrain production to grow at an annual growth rate of 5.2 percent from the estimated benchmark production of 16.1 million tons in 1984/1985 to reach the target of 20.7 million tons in 1989/1990 (Table II.1.2).

Table II.1.2. Foodgrain production target in Bangladesh, 1985-1990.

Cereal food	Bench mark (1984/1985)		Target for (1989/1990)	
	Area[a]	Output[b]	Area[a]	Output[b]
Rice				
Aus	2.96	2.78	2.91	3.42
Aman	5.71	7.93	5.83	9.18
Boro	1.54	3.91	1.94	5.40
All rice	10.21	14.62	10.69	18.00
Wheat	0.69	1.46	0.97	2.60
Coarse grains	0.04	0.03	0.02	0.10
Foodgrains	10.94	16.11	11.68	20.70

[a] In million hectares.
[b] In million tans.
Source: Planning Commission (1985)

Efforts were directed towards increasing acreage and output of aus rice (kharif-I), aman rice (kharif-II), boro rice (rabi), and wheat through the introduction of high-yielding varieties with the provision of complementary inputs. Aman rice covers more than half of the total acreage and total rice production, and the plan intends to replace existing low-yielding varieties with the high-yielding ones. Boro rice, which is grown during the dry winter months, received primary importance in terms of the provision of irrigation equipment, fertilizers, pesticides, repair and maintenance of equipment, and credit distribution.

The growth rates of crop production in the first half of 1985-1990 (i.e., the first half of the Third Five-Year Plan period) was less than expected. Recent studies show that the growth rates of all cereal foodgrains (wheat and rice) achieved in the first half of the plan period (1985-1987) was only 2.59 percent against the expected growth rate of 5.2 percent for the entire plan period (Table II.1.3).

Table 11.1.3. Trends in cereal production in Bangladesh

Crops	Third Five-Year Plan 1984/1985 - 1989/1990	Period (1984-1987)		
	Output[a]	Output[a]	Area[b]	Yields[c]
Aus rice	3.42 (4.23)[d]	2.91 (-2.43)	2.90 (-0.43)	1.01 (0.31)
Aman rice	9.18 (2.97)	8.20 (3.21)	5.93 (-0.43)	1.38 (3.65)
Boro rice	5.40 (6.69)	3.84 (5.25)	1.59 (4.79)	2.42 (0.45)
All rice	18.00 (4.29)	14.95 (2.54)	10.41 (-0.38)	1.41 (2.94)
Wheat	2.60 (12.23)	1.19 (3.54)	0.60 (4.46)	1.98 (-0.88)
All foodgrains	20.70[e] (5.20)	16.15 (2.59)	11.02 (-0.14)	1.45 (2.72)

[a]In million tons.
[b]In million hectares.
[c]In million tons/ha.
[d]Figures in the parentheses indicate annual growth rates.
[e]Includes 0.10 million tons coarse grains.
Sources: Planning Commission (1985) and Parthasarathy and Chowdhury (1988).

Parthasarathy and Chowdhury (1988) in a recent study, showed that the growth rate of foodgrain production as a whole (rice and wheat) was only 2.22 percent in the 1980s as against the trend rate of 2.86 percent for the period 1976-1987, which implied a decline. They further showed that aus rice, boro rice, and wheat recorded a steep decline in growth rates of yields in the 1980s with an absolute decline in aus rice acreage and a sharp fall in the growth rate of wheat acreage. The growth rate of boro rice acreage showed a mild rise in recent years. While there has been a decline in the overall growth rates of foodgrain production in the 1980s, an improved growth rate of aman rice, the major rice crop, was obtained mainly because of a higher growth rate of yield resulting from varietal improvement. The higher growth rate of aman rice, however, was not sufficient to compensate for the decline in the growth of production of other crops.

With the decrease in the foodgrain production in recent years, the Government decided to reset the target of producing 20 million tons of foodgrains to attain self-sufficiency in food by the year 1990 through a massive technological intervention (Rahman. 1988). The production of foodgrains (rice and wheat) in 1987/1988 has been estimated at 16.40 million tons. This means that to attain self-sufficiency, an additional 3.6 million tons of foodgrains will have to be produced in only 2 years, which necessitates an annual growth rate of over 10 percent. The two-year action plan towards foodgrain self-sufficiency is no doubt ambitious, but it reflects Government concern and priorities towards achieving food security. The important elements in this redirected, strategic plan as illustrated in Rahman, 1988, show that the incremental production of 3.67 million tons of foodgrains will come from three major sources: 1) increased coverage of high-yielding varieties for aus, transplanted aman, and boro rice (2.10 million tons); *2)* improved fertilizer management with emphasis on increased usage of sulfur and zinc (1.01 million tons); and 3) supplemental irrigation to transplanted aman rice production (0.56 million tons).

One striking feature of the two-year action plan is that rice has been targeted **as** the only crop to attain self-sufficiency in food. Wheat, an impon-substitution crop covering about four percent of total foodgrain production in 1987/1988, was not included in the two-year action plan. Similarly, other minor cereals such as maize, millet, barley, and sorghum, which cover about 28,935 ha of land were also excluded from the action plan because "significant improvement in production" of these minor crops is not anticipated in two years.

Importance of Irrigated Crop Diversification

In Bangladesh, crop production has been diversified so as to include more than a hundred crops grown in different seasons of the year. Given the chronic food shortages and the agro-ecological suitability, however, more than 80 percent of total cropped area **is** devoted to the production of rice, and about **4** percent to wheat. The dietary bias towards rice is **so** prominent that other food crops such as potato, maize, millet, and some coarse grains have been insignificant in terms of acreage and production. Another bias **is** that among rice crops, boro rice production gets almost the entire government support with regard to mechanized irrigation, input supplies, credit distribution, and electricity. Owing to the declining cereal prices in the international market, however, the value of the scarce land and water resources used in the production of rice and wheat is remarkably low. Even domestically, producers' net returns from the production of high-yielding varieties of boro rice and wheat have significantly declined in recent years because of declining yields and increasing input costs (Mandal, 1988).

Given the rapidly expanding population, scarcity of land, highly expensive and import-dependent capital, energy-intensive irrigation for rice, and the recurring incidence of floods damaging the major rice crops, emphasis should be giver to the production of higher-value non-rice crops. Undoubtedly, rice will continue to dominate farmers' decisions in almost **all** areas in the wet season during which mainly aman rice **is** grown. There **is** an increasing need, however, to identify other more profitable options for the dry season, when water supply is scarce and agronomic conditions are favorable for growing other crops. For example, some cash crops such **as** tobacco have export potential, while sugarcane has the potential for import substitution. Other crops such as potato, pulses, oilseeds, vegetables, and coarse grains have important dietary implications and potential for import substitution. The Third Five-Yea. Plan emphasized crop diversification to broaden the growth base of agricultural production. The Directorate of Agricultural Extension in collaboration with the Bangladesh Agricultural Development Corporation, and the Directorate of Marketing has officially launched a Canadian Intematicnal Development Agency-sponsored crop diversification program initially concentrating on pulses, oilseeds. and potatoes. The program, however, is not yet been in full operation.

Crop diversification **is** stressed because it will imprcve the nutritional intake of the people and also improve **soil** fertility and productivity. However, two major dimensions should be considered 1) administrative efforts and investment should be gradually shifted from the currently irrigated boro rice production to irrigated production of other crops such as wheat, vegetables, pulses, and oilseeds in the rabi season; and 2) emphasis should be shifted from the dry-season irrigation to year-round irrigation *so* that the use of irrigation facilities can he diversified to provide supplemental irrigation to *aus* and *aman* ricecrops. In recent years, there was a tendency for providing one or two supplemental irrigation applications to transplanted aman rice production in many areas. This is one of the reasons for the slight increase in overall aman rice yields for the period 1984-1987.

POTENTIAL OF AND CONSTRAINT TO IRRIGATED DIVERSIFIED CROPPING

Technical Aspects

Crop production in Bangladesh is already diversified. The question, nevertheless, is how to raise the productivity of land, labor, and water resources devoted to rice and non-rice crops using available technologies and improved imgation management practices. Table II.1.4 shows that very little irrigation is given to other crops, except for boro rice and wheat with only one-half of the area irrigated.

Table II.1.4. Total ***area*** *and irrigated* ***area*** *under different* ***crops*** *in* ***Bangladesh,*** *1985/1986*

Crops	Total area ('000 ha)	Irrigated area ('000 ha)	% irrigated
Rice	10,403	1,614	15.5
Aus rice	2,846	165	5.8
Aman rice	6,023	190	3.2
Boro rice	1,534	1,260	82.1
Wheat	540	267	49.4
Other cereals	9	3	33.3
Pulses	257	4	1.7
Oilseeds	290	12	4.2
Potato[a]	164	68	4.1
Vegetables		53	.
Sugarcane	160	11	6.6
Cotton	17	3	1.9

[a] Includes sweet **potato.**
Source: Bangladesh **Bureau of** Statistics **(1988)**

Three factors, then, need to be looked into:

1) Non-rice crops are customarily grown with natural soil moisture available after the main aman rice crop is harvested in winter, implying that yield of these crops can be improved by providing irrigation (see Bangladesh Agricultural Research Council, 1986):
2) Land utilization for rice crop has reached its maximum extensive limits, and rice production has serious physical and biological problems such as formation of plowpan in wetland cultivation, declining bearing power of soils, increasing incidence of pests and diseases, and declining soil fertility resulting from sulfur and zinc deficiency (Rahman, 1988). Appropriate input uses and agronomic practices have the potential to significantly improve yields of rice crops, and thus release a considerable amount of current rice acreages for growing non-rice crops: and
3) The flood control of irrigation and drainage projects falling under large-scale irrigation have created some potential for crop diversification during the dry season. But, there has not yet been any significant breakthrough as the flood control structure has not always proved successful.

There are important physical and technological constraints, some of which were pointed out by Biswas and Sarker (1987).

1) Huge land areas that used to be suitable for cultivation of rabi crops such as pulses, oilseeds, potatoes, are not available for these crops because the soils are not properly drained and dried. The situation has been aggravated in recent years because of late floods or serious drainage congestions or both, resulting from the construction of flood control embankments, roads, and highways. For example, large areas of Sirajgonj and Pahna districts on the western side of the Jamuna River such as the Chalan Beel areas generally remain submerged even in November.
2) As more and more mechanized irrigation facilities are being installed, more land is being put underbororiceproduction: consequently, crops such as pulses and oilseeds are being pushed into the low-quality marginal land giving lower yields and net returns.
3) The existing irrigation facilities and water conveyance systems, mainly *kutca* canals, are designed for rice production requiring flood irrigation. These structures and imgation methods are inappropriate for irrigating non-rice crops. To quote Biswas and Sarker (1987):

> ...border irrigation is more suitable for wheat; maize is grown in rows and water is applied in between; and furrow irrigation is essential for potato (sic), tobacco, and vegetables. These methods are not applicable for oilseeds including groundnuts which require soft irrigation, mist of sprinkler type, with controlled and high-level technology.

4) Flood water damages the kutca canals in most areas so that these are inappropriate for providing supplemental irrigation to transplanted aman rice and the subsequent non-rice crops because canals take time to dry for repair. The problem with repairs gets further complicated as canals are dug across highly fragmented lands belonging to different owners.
5) Shortage of draft power and mechanized tillage is reported to be a problem because most non-rice crops grown using residual soil moisture during the dry season need timely tillage and planting for optimum yields.
6) The growth in wheat production declined. Factors affecting wheat production are sterility problems resulting from micronutrient deficiency in the soils: late- planting due to high water table and late rains in November resulting in soil saturation, rise in temperature and dry weather

at grain-formation stage; and damage caused by rains and hailstorms.

Institutional Aspects

The major institutional strength for pursuing a crop diversification program is the presence of the Bangladesh Agricultural Research Institute which deals with rice and non-rice crops and a number of crop-based research and extension institutions in the country. Foremost of these are the Bangladesh Rice Research Institute, the Bangladesh Jute Research Institute, and Bangladesh Sugarcane Research and Training Institute. Furthermore, crop-specific extension services are **also** provided by the Agricultural Extension Department, the Intensive Jute Cultivation Scheme, the Bangladesh Cotton Development Board, the Bangladesh Tobacco Development Board, and the Bangladesh Tobacco Company. The Bangladesh Agricultural Development Corporation is the most organized institution engaged in imgation development. The Corporation also distributes irrigation equipment and oilfuel and provides repair and maintenance services exclusively for boro rice. Any cropdiversification program needs farmers' cooperation and participation, and Bangladesh Rural Development Board has sponsored farmers' cooperatives to disseminate new knowledge on and inputs for diversified cropping. The Irrigation Management Program of the Bangladesh Rural Development Board has the objective of supporting crop diversification in the deep tube well schemes. Little progress is achieved, however, for some initial successes in a few schemes intensively supervised by the BRDB-GTZ- (Bangladesh Rural Development Agency-Getman Agency for Technical Cooperation) supported Targail Agricultural Development Project in the upland areas of Madhnpur Tract.

There are, however, shortcomings of these institutions which impede the diversification of crops to a great extent. For example, the Bangladesh Agricultural Development Corporation rents out pumps (deep tube wells and low-lift pumps) and provides oil fuel and repair services for only dry-season boro rice cultivation. This scheme implies that there is no institutional support for irrigated crop cultivation in other seasons. Similarly, irrigation equipment is disconnected from the electricity supply once the boro rice and wheat have been harvested. Moreover, cooperative credit is advanced only for the boro rice production. The Government has, however, intensified the credit operation this year for transplanted aman and rabi crops on easy terms following the major crop damages by floods.

Economic Aspects

The economic opportunities for diversified cropping vary between crops, between years, and between farmers' groups. For example, compared to aus and aman rice, crops such as maize, mustard, potatoes, tobacco, and some spices have shown higher-profit advantages, but jute and sugarcane have shown variable profitability depending on the highly uncertain and variable year-to-year prices. Likewise, even in years of good prices for these crops, small-scale farmers are bypassed because they prefer growing rice to non-rite crops on whatever small amount of land they have (the average farmsize is less than a hectare).

The economic constraints to cultivation of irrigated non-rice crops are as follows:

1) Most irrigatednon-ricecrops grownduring the dry seasonhave very low returns when compared

to irrigated boro rice and wheat crops at the prevailing market prices;

2) Exorbitant price support is needed for the non-rice crops to compete with irrigated boro rice. A recent estimate shows that to do this, price of mustard has to he raised by 60 percent at the present yield level, lentil and blackgram by about 100 percent, and *khesari* by about 300 percent (Chowdhury, 1988). Such price increases may be too high to achieve without increasing the demand for these crops. The production of these crops. however, will increase soil fertility so that extra value will be created in terms of increased yields from subsequent rice crops;
3) Prices of wheat remained unchanged in recent years, and the lower prices of wheat relative to rice caused a decline in the growth of wheat acreages;
4) Potatoes still seem to be a promising irrigated crop with an average of net returns over cash cost of *Tuka* 15,000 (US$484)/ha. Its production, however, is affected by the lack of storage and marketing facilities;
5) Production of maize is constrained by the lack of adequate demand. For example, in Sirajgonj District this year, there was enough supply of seeds for maize, hut, there was no demand because farmers are not used to eating maize; and
6) the policy of subsidizing the import of oilseeds, through lower tariffs has affected production of oilseeds.

To popularize the production of non-rice crops, measures to provide price incentives are needed. Major breakthroughs in yield improvement by introducing high-yielding varieties and proper cultural practices are needed to realize the full technical and physical potentials for growing irrigated non-rice crops.

IRRIGATION MANAGEMENT PRACTICES FOR CROP DIVERSIFICATION

As rice dominates cropping patterns, irrigation management practices have focused on the production of boro rice. There have been few attempts in research and extension services to devise effective practices to facilitate irrigation for non-rice crops by using existing irrigation equipment. Some of the notable innovations which have shown promising results are as follows:

1) Problems of water distribution and water loss with kutca canals have been minimized by improving the water conveyance system of deep tube wells and shallow tube wells through buried concrete pipes in both upland and lowland areas of the central district of Tangail. The practice is still at the experimental stage, with the water conveyance system of only a few tube wells improved by the Tangail Agricultural Development Project, sponsored by the Bangladesh Rural Development Board and the German Agency for Technical Cooperation. Preliminary reports indicate that buried-pipe irrigation showed high-benefit cost ratios (3.63-4.94) and high internal rates of return (60-65 percent) (Ahmed and Gisselquist, 1988). Major advantages of buried pipe irrigation are water saving by reducing water loss, reduction in pumping costs, saving on land, and ease of crop diversification by facilitating water distribution to any plot, at any interval. in any quantity. This practice is particularly useful in the upland areas with broken undulating topography as in Madhupur Tract where this improved water-distribution system has been associated with the production of irrigated crops such as horo rice, potatoes, wheat, banana, and

vegetables.

2. There are also some research findings which suggest promising irrigation practices for different non-rice crops based on field experiments in selected locations of the country, hut these practices need more experiments under varying physical, agro-economic, and social environments. Some examples are given below:

   * Research findings suggest that four irrigations — at planting, floral initiation, anthesis, and grain-filling stage — substantially increase yield of wheat as against intensive irrigation required for rice.
   * In the case of potatoes, irrigation at land preparation, a few days after gemination, and at vegetative phase so as to maintain high-moisture content throughout the growth period increases tuber yield (Islam, 1988); this reduces irrigation input requirement substantially in producing food crops.
   * Cultivation of high-yielding varieties of watermelon is widespread in the northern district of Natore by using "plant-to-plant" irrigation from water pumped and collected from shallow tube wells and hand tube wells, indicating a new dimension of irrigation for high-'yielding varieties of summer fruits.
   * One or two flood irrigations for banana diring the hottest months of March and April increases the yield substantially. Irrigated banana cultivation is becoming popular in the upland areas of Tangail and also in the floodplains of Tangail, Narshingdi. Dhaka, Magura, Jhenaidaha, and Bogra.

RESEARCHABLE ISSUES

There are numerous researchable issues related to diversified cropping in Bangladesh. The important issues are as follows:

* response of non-rice crops to irrigation and water-management practices at different periods of the year;
* location-specific on-fam trials of the experiment station results;
* location of and farmers' practices with diversified cropping, and explanation of the variations in these practices;
* technical intervention for adopting existing rice-based irrigation and water-management systems for providing irrigation to non-rice crops:
* prices and marketing of non-rice crops in comparison to those of rice;
* profitability of non-rice crops in relation to conipeting crops;
* irrigation water market with diversified crop production (system of payment for water and contractual arrangement for land, labor, and otter inputs):
* changes required in the organization of water users and institutional support services to cater to the need of crop diversification;
* impact of diversified cropping on employment, nutritional status, and income distribution; and
* nature of agricultural extension services required to disseminate existing knowledge about non-rice crop production.

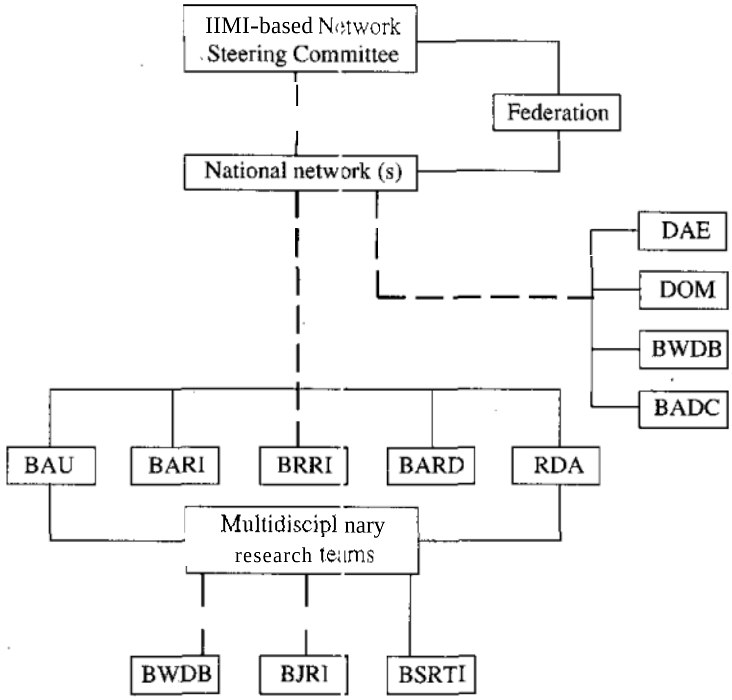
STRATEGY FOR CONDUCTING RESEARCH

Numerous research projects on some of the above issues are already being conducted at different institutions of the country. The most actively involved institutions are the Bangladesh Agricultural Research Institute, the Bangladesh Rice Research Institute, the Bangladesh Jute Research Institute, Bangladesh Sugarcane Research and Training Institute, the Bangladesh Water Development Board, and the Bangladesh Agricultural University. The role of the Bangladesh Agricultural Research Council (BARC) is to coordinate and/or sponsor research endeavors of the different institutes. The faculty members of the universities and scientists of the research institutes should be involved in irrigated crop diversification research which will be multidisciplinary in nature, drawing inputs from engineers, crop scientists, soil scientists, and socioeconomists. It is noteworthy that the Bangladesh Agricultural University, the Bangladesh Agricultural Research Institute, and the Bangladesh Rice Research Institute can organize multidisciplinary research teams with personnel from various departments.

The multidisciplinary teams that are formed at different institutes may form a national network of crop diversification research with a coordination committee comprising representatives from the individual research teams as well as from government implementing agencies. National and international agencies may fund the research.

The national research network may then relate to the international network based at the International Irrigation Management Institute (IIMI). The proposed Steering Committee of the IIMI-based network can be more useful if it works as a federation of national networks (Figure II.1.1). The network members can benefit immensely from mutual exchange of ideas, research methodologies and findings, study visits, and perhaps research advisory services.

Figure II.1.1. Proposed national research nerwork on irrigation management for diversified cropping in Bangladesh.



Legend:

IIMI	International Irrigation Management Institute
BAU	Bangladesh Agricultural University, Mymensingh
BARI	Bangladesh Agricultural Research Institute
BRRI	Bangladesh Rice Research Institute
BARD	Bangladesh Academy far Rural Development
RDA	Rural Development Academy, Bogra
DAE	Directorate of Agricultural Extension
DOM	Directorate of Marketing
BWDB	Bangladesh Water Development Board
BADC	Bangladesh Agricultural Development Corporation
BJRI	Bangladesh Jute Research Institute
BSRTI	Bangladesh Sugarcane Research and Training Institute

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CHAPTER 2

Crop Diversification in the Irrigated Area in Malaysia

Sardar Ali

BACKGROUND

THE AGRICULTURAL SECTOR plays a dominant role in he Malaysian economy though its relative importance is declining as the country proceeds towards industrialization. In the 1960s and early 1970s agriculture grew at **7** percent per annum but slowed to an average of 5.5 percent per annum during 1976-80 and to **3.7** percent during 1981-84. In 1985, agriculture contributed about **23** percent of gross domestic product, 40 percent of the total merchandise exports and 36 of the percent of the total employment. Production has been primarily export-oriented with Malaysia being not only the world's largest producer of rubber and palm oil but one of the leading producers of cocoa and hard-wood timber.

Up to the early 1960s Malaysia's agriculture and its economy, were largely hased on rubber, rice and coconut, with the **3** crops accounting for 91 percent of cropped area. Concern was expressed **by** the govemment on the need to widen the **base of agrjcolture for income and employment stability.** At other times attention has been drawn to the need for higher food production for security reasons. **As** a result, agricultural diversification has been a national policy for the past three decades. These efforts on crop diversification brought about significant changes in the Malaysian agriculture.

Malaysia's agriculture is more diversified now as illustrated in Table II.2.1. In 1960, cocoa and oil palm were virtually unknown in Malaysia (only 200 hectares [ha] of cocoa, mostly in Sabah and 48,000 ha of oil palm were planted). Now there are 258,000 ha planted to cocoa and 1.5 million ha planted to oil palm. Initiatives by the public sector have also resulted in the doubling of rice production in less than a decade as large irrigation schemes were completed.

Table II.2.1. Agricultural land use by crop.

	1960 Area ('000 ha)	%	1985 Area ('000 ha)	%
Rubber	1,584	66	1,927	41
Rice	384	16	658	14
Coconut	216	9	235	5
Oil palm	421	2	1,457	31
Cocoa		0	258	5
Other crops	168	7	188	4
	2,400	100	4,700	100

Hitherto, major efforts have been mainly confined to the diversification/development of tree crops such as oil palm and cocoa. Only in recent years have strategies and programs been developed for diversification of food crops, particularly in idle rice areas.

There is presently about 658,000 ha of rice fields of which 331,850 ha or 50 percent are irrigated, 261,650 ha or 40 percent are rain-fed or non-irrigated and 64,500 ha or 10 percent are hill or dry rice areas. The irrigated areas are divided further into two categories i.e., granary areas which are large irrigation schemes each exceeding 5,000 ha and non-granary areas which are small irrigation schemes. About 211,850 ha are granary areas made up of eight large contiguous irrigation schemes. On the other hand, 120,000 ha are non-granary areas comprising over 800 schemes distributed throughout the country.

Rice production in Malaysia comes mainly from the granary areas. In 1985, the total rice production was about 1.27 million tons, of which two-thirds was supplied by the granary areas occupying about 33 percent of the total rice area.

The National Agriculture Policy, formulated in 1984, emphasized the modernization and revitalization of the agricultural sector. Development efforts were directed towards increasing productivity, efficiency and competitiveness. In line with this policy the development of granary areas was encouraged. Non-granary areas, however, will be gradually phased out.

THE NEED FOR CROP DIVERSIFICATION

Malaysia does not have a comparative advantage in rice production and policies on self-sufficiency in rice production have been maintained mainly because of strategic reasons. In 1985, while the economic cost of producing rice was M$1,120/ton (the financial cost was M$1,374/ton), the landed cost insurance freight (CIF) price of rice at Kuala Lumpur was only M$651/ton. (From 1975-1985, the landed CIF price of rice at Kuala Lumpur ranged from a high of M$1,111 in 1975 to a low of M$ 651/ton in 1985 indicating a falling trend). In contrast, the local cost of production shows an uptrend.

With increasing industrialization and higher incomes, rural youths are migrating to urban areas thus reducing the agricultural labor force (about 100,000 ha of rice land out of a total of 500,00 ha in Peninsular Malaysia were left idle). About 300,000 foreign laborers were needed for jobs in tree plantations. Even **so,** much rubber remained untapped and harvest losses were incurred in oil palm due to labor shortage.

In low-productivity rain-fed areas, rice lands are increasingly being left idle as the opportunity cost of labor rises above the expected returns. This could not be mitigated by mechanization due to the small farm sizes; hence, the absence of large-scale economies. The schemes are not large enough nor readily accessible for large machinery services. Income of rice farmers in these areas (average farm holding is 0.73 ha) is very low, at M$245/family/year with subsidies. In comparison, fanners in the Muda Irrigation Project (the largest granary area where the average farmholding is 1.6 ha) have an average income of M$4670/family/year with subsidies.

Production in the non-granary areas has also been declining over the last several years due to shortage of labor, predominance of old fanners, shortage of water and attacks by pests and spread of diseases. With these prevailing conditions, the present strategy is to diversify production to more lucrative crops to increase incomes. For rice, the present policy is to encourage planting in regions with comparative advantage. The strategy is via production cooperatives using mechanization and professional management in the large-scheme areas.

At present, Malaysia produces about 64 percent of its rice requirement. Taking the above factors into consideration, the target of the rice self-sufficiency policy was lowered from 80-85 percent to 60-65 percent. It is estimated that with minimum upgrading in support facilities within the granary areas, this target could be achieved, releasing all other non-granary areas gradually (approximately 120,000 ha) to other more viable crops, namely, oil palm, vegetable, fruits and other economic crops.

POTENTIAL AND CONSTRAINTS

The most obvious goal for diversification is the substitution of food and animal feed imports. Malaysia imports some MIF2.8 billion of food products annually, and some 40 percent of these are grains and pulses.

Development of upland irrigation in Malaysia has been slow and existing irrigation systems in these areas have been mostly undertaken by private concerns.

Some of the problems facing upland crop cultivation are the high incidence of pests and diseases which lower yield and quality, and hence, the farmers' income. Marketing is another area of concern as crops like vegetables are highly perishable and any marketing problem such as the lack of transport or ready buyers can result in substantial losses. Extension services to the vegetable farmers are inadequate. An average of 24.8 percent of the vegetable farmers in Peninsular Malaysia received extension services from government agencies.

A likely constraint to the rapid spread of upland crop cultivation in rice-based systems is the present restrictions regarding land use. In all gazetted rice irrigation schemes, land titles have stipulations which prohibit the cultivation of crops other than rice. This ensures that the investments made on the construction of irrigation facilities for rice, are put to effective use through the cultivation of rice only. In the event that crops other than rice are to be planted on these lands, prior approval has to be obtained from the relevant Land Offices. While this restriction has been beneficial in the past, it may now hinder efforts towards diversification of irrigated rice-based systems. This has made it necessary to review and modify such restrictions in line with changing situations.

Rainfall in peninsular Malaysia is high and unpredictable. Although the average annual rainfall is sufficient to meet the water requirements of most crops, short periods of drought and water excess are common throughout the country. Supplementary irrigation is needed during periods of drought while during the wet season problems of flooding and poor drainage exist. Yields of rain-fed crops are therefore highly variable.

In existing irrigation schemes, while adequate irrigation water for upland crops can he supplied by the canal systems, on-farm water application methods need to he refined to suit a particular crop or group of crops in rotation with rice.

The existing drainage systems, on the other hand, are designed mainly for excess storm water removal for rice cultivation. For the precise control of water table for successful cultivation of upland crops a greater drainage network is required.

INSTITUTIONAL SET-UP

Successful crop diversification is dependent on various agricultural agencies. The Malaysian Agricultural Research and Development Institute for instance, carries out research in the field of agriculture; the Department of Agriculture provide:; extension services, the Federal Agricultural Marketing Authority assists in marketing, the Farmers' Organization Authority assists in providing institutional support for farmers' development, the Agriculture Bank of Malaysia provides credit facilities and the Drainage and Irrigation Department provides technical inputs relating to water resources, irrigation engineering and infrastructure development.

While the above institutions were established with specific functions and responsibilities, their activities were concentrated in upland crop development in non-rice crop growing areas. However, efforts need to he further strengthened and extended to cover diversification programs in rice-based irrigation systems.

UPLAND CROP DEVELOPMENT IN EXISTING IRRIGATED AREAS

Because of the shift in government policy with respect to domestic rice production, alternative sources of employment and livelihood have to he fcund for the existing rice farmers. Cultivation of upland crops is lucrative and favorable returns can he obtained as compared to rice cultivation. Table II.2.2 shows the expected returns from the cultivation of some selected crops.

Figure II.2.1. A typical cropping pattern for mixed crop cultivation.

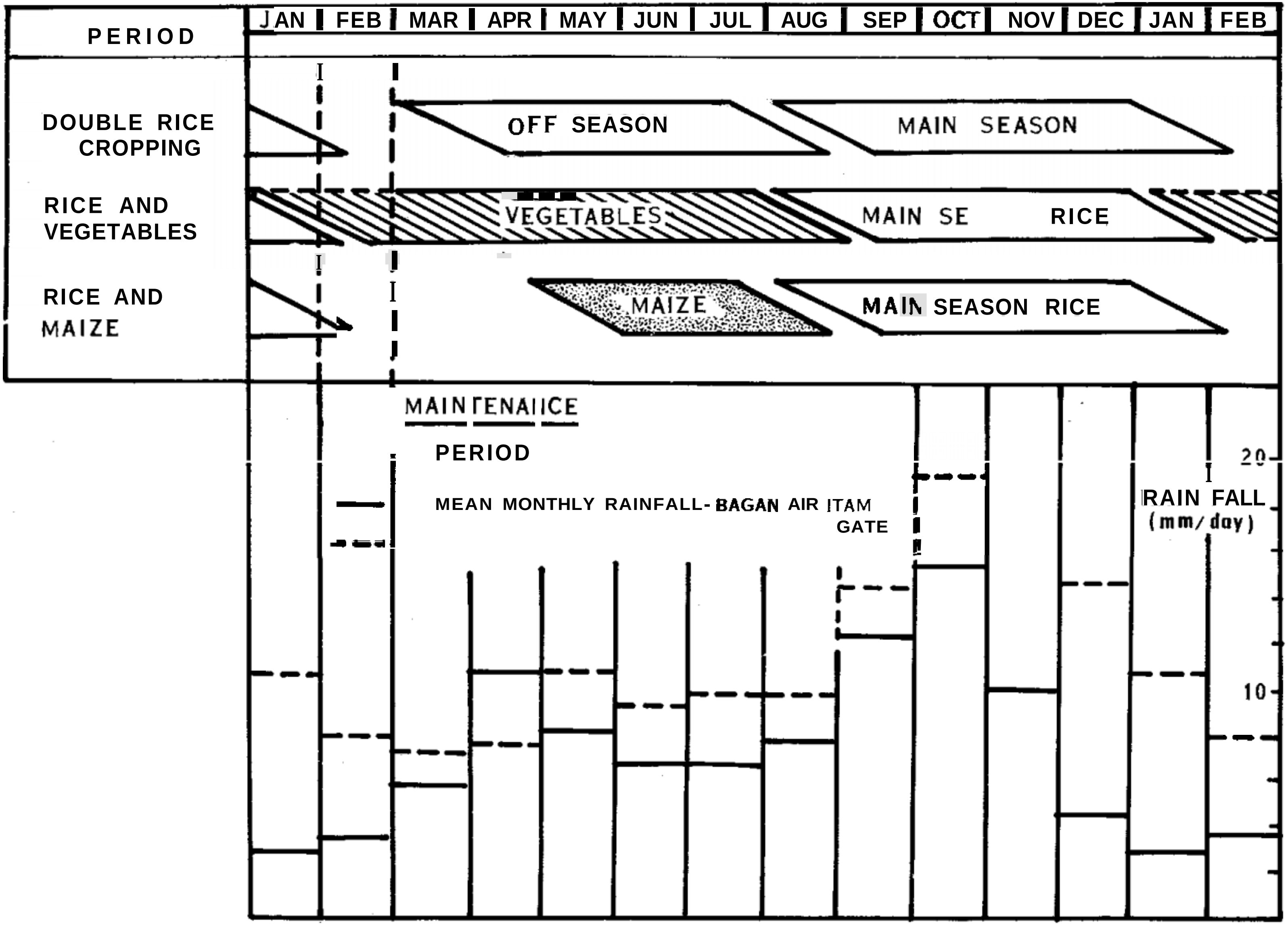

Table II.2.2. Returns to production of rice and some selected crops.

Crops	(Per ha/year) Net returns M$	Family labor returns M$
Rice	780	1,120
Vegetables	1,250	3,000
Groundnuts	2,450	4,000
Tobacco	4,400	9,000
Bananas	4,000	4,700

In recent years, small-scale cultivation of upland crops has been successfully undertaken. Since water requirements for upland crops is lower, areas that could not he cultivated with rice are now cultivated with selected upland crops such as vegetatdes and maize. At present, of the 120,000ha of non-granary rice areas, less than 1,000ha are cultivated with upland crops in rotation with rice.

Cropping patterns follow two seasons, i.e., wet and dry seasons. The wet season which occurs from August to December is termed the main season when rice is cultivated. The off-season, occurs between January and June and the intensity of rice cultivation varies depending on the availability of water. In areas that could not sustain off-season rice cultivation, selected upland crops are grown.

There are three general cropping patterns during the off-season. These are:

1) Rice cultivation,
2) Mixed cultivation, i.e., rice cultivation in conjunction with selected upland crops, and
3) Upland crop cultivation.

A typical cropping pattern for mixed crop cultivation is shown in Figure II. 2. 1.

Factors such as water application, soil suitability, and marketing are considered prerequisites for the successful development of upland crops.

Water Application

The major source of water for upland crops is irrigation water from irrigation systems.

The general patterns of water requirement with growth stage are similar for most crops, with a mid-season peak evapotranspiration at about 10 percent higher than the reference values of short, green grass.

Due to the absence of appropriate systems for water application, cultivation of upland crops during the off-season is largely concentrated alongside canals and drains.

Most water application is by furrow irrigation. However, during drought farmers pump water from canals and drains, and use sprinkler systems to supplement irrigation needs.

Soils

The main factors influencing the choice of crops and cropping patterns, are the quality of the soil and availability of imgation water. The majority of soils are deep, poorly drained, heavy clays of marine origin. While the fine texture and slow drainage characteristics are ideal for rice cultivation, they are unsuitable for the upland crops. With drainage, however. it is possible to cultivate a range of annuals and perennial fruit crops, such as maize, sorghum, leafy and fruit-bearing vegetables.

Markets for Upland Crops

The availability of markets for agricultural produce *is* likely to restrict the type and quantities of crops grown. Some of the potential crops are maize, fruit trees, groundnuts and tobacco. Vegetable cultivation has been largely undertaken by small-holder fanners and private concerns, mainly for the domestic market. The market potential for annual crops and vegetables **is** good. The National Agriculture Policy indicated that consumption of vegetables is steadily increasing and that by the year 2000 the annual demand will be 922,000 tons. A total of 20,000 ha of land will have to be cultivated to produce this quantity. There is thus, a potential for the development of an additional 8,000 ha for the cultivation of vegetables within the next 10 years.

Engineering Facilities

There are over 800 non-granary irrigation schemes, ringing in size from 50-2000 ha. **A** typical irrigation system consists of river intakes either pumped or gravity-fed, and a distribution system of canals to convey the water to the fields. For control and management of distribution, the irrigated area is divided into 10-15 ha units, each receiving water from a gated offtake. Water management for monoculture rice cultivation during the off-season is easier than mixed cultivation of rice and upland crops.

Canal capacities are sized on the basis of peak presaturation requirement for the off-season rice crop which is 2.4 liters per second per ha (lps/ha). **A** typical canal density for a non-granary scheme **is** about 60 meters per hectare.

Complementing the irrigation system is the drainage system to remove excess water from the fields and to enable adequate control of water levels in the rice fields. Drains are sized for runoff value of 9.3 lps/ha based on a 3-day duration rainfall with a 5-year return period. **A** typical drain density for rice cultivation is about 10-20 meters per hectare.

In upland crop cultivation, the drainage requirement is more acute as flooding is impracticable. Drains are designed for a typical runoff value of 14.1 lps/ha corresponding to 1 in 5-year, 24-hour storm rainfall.

Current Actions Regarding Crop Diversification

The non-granary irrigated areas are characterized **by** simple irrigation and drainage facilities, consisting of run-of-the-river type intake and gravity drainage, and low density of on-farm facilities. There is scarcity of data on the present conditions of these irrigation schemes. Non-granary irrigated areas are faced with the following basic problems:

1) drastic decrease in cropping intensity and rapid increase of abandoned land:
2) conversion of rice cultivation to other crops and other non-agricultural purposes; and
3) deterioration of facilities due to suspension of operation and maintenance.

To understand the prevailing conditions of these schemes and to formulate appropriate strategies for rehabilitation, the government has embarked on an inventory survey of all the schemes. This survey along with the feasibility study of selected schemes will take two years to complete.

The objectives of the survey are to:

1) determine the prevailing conditions and to identify constraints and problems;
2) classify the schemes according to constraints and problems and prepare action programs for representative cases showing basic strategy for revitalization including selection of suitable crops and cropping patterns; and
3) carry out a feasibility study on selected schemes to examine their technical feasibility, economic viability and social acceptability.

CONCLUSION

Crop diversification in rice-based irrigation systems has yet to take hold in Malaysia. Thus, major constraints to diversify **as** well as appropriate irrigation management techniques remain largely unidentified. **A** start has been made, however, with the undertaking of an inventory survey of all the non-granary irrigation areas. The findings of this inventory survey shall form the basis for future strategies and programs for implementation including appropriate research programs. In the meantime, Malaysia, through the Drainage and Irrigation Department will participate in the research network through the exchange of technical nformation. In the long term, the Department may consider participating in active research on selected issues.

CHAPTER *3*

Irrigation Management for Diversified Cropping in Rice-Biased Systems in Andhra Pradesh, India

T. Hanumantha Rao

BACKGROUND

In India, there was a decrease in yield of foodgrains on three occasions from 1983-88 due to unfavorable weather conditions. This has upset earlier calculations on the food front. Buffer stocks of over 30 million tons in 1985 had to be drawn upon liberally towards relief operations in the drought-affected areas. During 1983/84 there was difficulty in absorbing fully the record output of 152.37 million tons. The buffer stocks of rice and wheat swelled to over 30 million tons by the middle of 1985, from 18 million tons in July 1982. It was then hoped that the uptrend in food production would be sustained. It was even suggested that vigorous efforts should be made to export foodgrains to neighboring countries even on a subsidized basis after meeting the requirements of the public distribution system and other welfare schemes. However, the shortfall in annual production for 4 seasons after the record output of 1983/84 has resulted in a depletion of buffer stocks from 30 to 10 million tons.

During 1987/88 with buffer stocks of wheat at 11 million tons in April 1987 and rice with at only 4.5 million tons, the Union Ministry of Agriculture thought it necessary to import one million tons of wheat from the United States on a subsidized basis. It has become clear from the trends in output and consumption of food grains during 1983-88 that continuing self-sufficiency can be assured only if there is a rise in annual output to over 160 million tons. The output during the year 1988/89 is estimated to reach 170 million tons.

Irrigation in Agricultural Production

Over the past few decades, more and more emphasis has been placed on constructing community-operated irrigation systems to increase agricultural production to meet the demand of increasing population. Massive investments have been made on new irrigation projects in the different parts of the country. However, experience has shown that performance of these large community-operated irrigation systems has been disappointing. The creation of the Command Area Development Authorities (CADAs) which are given the responsibility of making the best use of land and water resources, has made a better evaluation of existing systems possible. Many systems were found to be either incomplete or inadequate to irrigate the entire command area despite the efforts of the CADAs. It **was** necessary to have better project planning towards more effective irrigation utilization.

The Government of Andhra Pradesh established the Commission for Irrigation Utilization in early 1981 to look into various problems related to irrigation utilization. The Commission spent nearly two years recording evidence, visiting projects in several states, and studying previous reports and records.

Policy is aprerequisite of any planning. Planning aims to formulate guidelines or principles for effective and balanced utilization of the resources within manageable limits of state machinery. In constructing irrigation systems, specific policies must be laid down. The National Commission on Irrigation (1972) has broadly stated the irrigation policies **as** maximization of production per unit of land and water. This was also supported by the National Commission on Agriculture (1976).

The Department of Agriculture in the State Covernment, Andhra Pradesh, examined the recommendationsoftheAgriculture Commission in 1982 but withouttheactivecoordinationofand discussions with the Director of Agriculture and Ch ef Engineers. No decisions were taken by the government on this report at that time.

Crop Diversification in Irrigated Areas

With the release of high-yielding, fertilizer-responsive varieties of wheat in the late sixties and of rice in the early seventies, the cropping pattern in India shifted to a rice and wheat system. This was observed in areas with assured irrigation, because the two crops had greater and assured returns compared with other crops. In a 16-year period ending in 1981-82, the area under wheat and rice in India increased by 74 and 14 percent, respectively.

The need for diversification from the predominant rice-wheat system was strongly felt for the first time during the 1985 *kharif* (wet season) when Punjab farmers had difficulty in selling their produce, Besides this marketing problem, other factcrs which favored crop diversification were: a) deterioration of soil fertility; b) multiplication of pests, diseases, and weeds; c) low water use efficiency: d) intensive use of energy: e) reduced availability of protective food such **as** pulses and oil seeds: and f) deterioration of wheat-rice and rice-rice systems.

Crop diversification should consider technologically feasible and economically viable changes in theexisting cropping systems towards more balanced farming systems to meet the need for food. fiber, fodder, and fuel. These changes should consider improving soil fertility, productivity, and the agro-ecosystem. In addition tohigherprodnctivity, the cropdiversification program shouldalso aim at betterprices andensuredmarketsfornew and surplus products likely to heproducedindiversified cropping systems.

POTENTIALS OF AND CONSTRAINTS TO DIVERSIFIED CROPPING

Technical Aspects (Physical and Biological)

Intensive cropping systems involving rice or wheat have been reported to remove nitrogen (N), phosphorous pentoxide (P_2O_5), and potash (K_2O) to the extent of 500-700 kilograms/hectare/year. Nutrient removal by these crops exceeds the recommended or applied doses of these numents. Rice cultivation has lately been extended to coarse textured soils which easily lose the applied nitrogen through leaching. Application of phosphorus only to *rabi* (dry season) crops is also being questioned as rice has shown responses to phosphorus in most places in India. Likewise, rice responses to potassium were moderate in red and yellow soils and high in red and in alluvial soils. Apart from zinc, deficiencies of iron, manganese, and copper are not uncommon. Copper deficiency causes male sterility in wheat. Sulfur deficiency is also reported in sandy soils, particularly in winter. It is more acute when phosphorus is supplied as diammonium phosphate.

In north India, both rice and wheat are mostly grown under irrigation with intensive use of energy in the form of electricity and chemical inputs. It is estimated that an irrigated wheat crop yielding 3 tons/hectare (t/ha) requires an energy input of nearly two million kilocalories (kcal), more than 60 percent of which is accounted to chemical fertilizers alone. Puddling in rice and seedbed preparation for the succeeding wheat crop require a lot of energy. In fine-textured soils, the number of cultivations required for seedbed preparation after rice is twice that after maize, particularly if the succeeding crop is potato. The energy requirement for harvesting wheat and rice is also relatively higher. Electricity used in rice can have a better pay-off in industry and other activities because the energy used in agriculture has a very high opportunity cost.

With the dominance of cereal-based cropping systeins, the production of pulses and oilseeds is declining. The per capita availability of pulses in the country, for example, has been reduced to half in the last 35 years. Pulses and oil seeds are cheaper sources of protein and fat than animal products. Increasing the area planted to vegetables and fruits would help in improving human nutrition. Intensive cultivation of rice and wheat has aggravated the problem of malnutrition due to lack of protein in the diet.

Institutional Aspects (Strengths and Weaknesses)

There is no reason why the schedule of water release and cut-off in the irrigation systems cannot be permanently fixed for the kharif and rabi seasons in major commands like the Godavari Delta System. This will facilitate the planning by the Department of Agriculture for the kharif and rabi seasons. If, however, there is a water shortage, the areas to be irrigated could be reduced or different cropping patterns could be suggested.

The Department of Agriculture conducts workshops during April for the kharif season and in September for the rabi season, The irrigation officials who usually participate in these workshops, however, are not in a position to comment on several important issues such as the time of release of water in the various projects, the pattern of irrigation, and the areas to which water will be made available. This is because there is no carryover storage in the systems and there is uncertainty in the occurrence of rains and extent of inflow into the reservoir. Because of this, not much can be done in planning for crop production to suit irrigation supplies. The irrigation authorities should have the choice and freedom to tailor their irrigation policies to the production planning activities proposed by the agricultural scientists.

It is the policy of the Department of Agriculture to encourage the growing of irrigated non-rice crops during the rabi season under major, medium, and minor irrigation sources. This policy is based on many factors such as the economic use of water, less incidence of pests and diseases, and higher yields of more remunerative crops. But in the small or medium irrigation projects under the old tanks, the command (*ayacut*) is usually situated in low-lying areas which have problems of salinity or alkalinity (due to poor drainage). In such areas, the practice is to raise wet rice crops (*Taibandi*) even though in some pockets it is possible to grow irrigated dry crops.

It is apparent that there should he a coordinated policy for the development of irrigated agriculture. The departments involved should not work in isolation. Modernizing agriculture and maximizing agricultural production according to th: needs of the country have to be taken as the primary goal.

PROMISING IRRIGATION MANAGEMENT PRACTICES FOR DIVERSIFIED CROPPING

Crops and Cropping Systems

Fruits and vegetables are rich sources of vitamins and minerals. They are also highly palatable in fresh and processed form and thus constitute an indispensable part of the human diet. The soil and climatic conditions in India are favorable for growing a variety of fruits. An economic analysis showed that the returns from fruit cultivation exceeded that of the rice-wheat system, except the cultivation of ber trees, which are grown mostly on marginal soils with limited availability of water where cultivation of rice is not possible. High initial establishment and subsequent costs in orchards may, however, be beyond the resources of a poor farmer. Farmers have to pay 12.5 percent interest on the borrowed capital from the cooperatives. Taking this into account, discounted future returns from the orchards (except in a few cases), are not attractive when compared to the most common cropping systems. If, however, the rising fruit prices are taken into account, cultivation of fruit is expected to be more profitable than field crops. Farmers in Punjab have begun to realize the economic benefits from orchards, and the area planted to fruit has increased considerably from 28,850 hectares (ha) in 1985. Thus, there is promise of increasing the area under fruit in Punjab.

Productivity of rice lands may also be increased through diversification with a suitable combination of potato, wheat, greengram, and groundnut. Several trials conducted in Punjab, Uttar Pradesh, and Tamil Nadu in India showed promising results (Table II.3.1).

Table II.3.1. Quality and quantity (quintals/ha) of the food produced by ***intensive cropping systems involving rice and wheat.***

Cropping system	Location	Total production /ha	Net returns (Rs'000 /ha)	Digestible Carbo-hydrate (q/ha)	Digestible Pro-tein (q/ha)	Energy kcal/ha
Rice-potato-wheat-greengram	Masodha (Punjabj	84.3	21.0	87.4	11.0	48.0
Rice-wheat-greengram	Varanasi (U.P.)	92.4	10.6	62.4	10.0	37.2
Rice-rice-groundnut	Tanjavur (T.N.)	95.1	15.5	80.1	12.6	**47.1**

Monocropping with rice, sugarcane, and cotton has le3 to soil deterioration and the emergence of new pests and diseases. Salinity and soil-fertility problems arising out of monocropping have depressed the yields of sugarcane and rice. It is, therefore, necessary to work out rice-based, cotton-based and sugarcane-based cropping systems. Maize, blackgram, and groundnut could be alternate crops to rabi rice in Godavari Delta. Similarly, maize, soybean, chili, pulses, and groundnut could replace a sizeable area under cotton in Guntur and Prakasam districts. Recently, there has been a diversion of about 1.1 million hectares of millet area to other crops such as cotton, pulses, maize, and groundnut.

Fanners at the tailendofthecommand areasusually have problems of water availability for rice. **In** such areas, light irrigated crops such as maize (15-25 q/ha), groundnut (light soils), soybean (15-25 q/ha), redgram (10-15 q/ha), greengram and blackgram (15-20 q/ha), proved profitable. It has beenestablished that it is possible to raise two or three light irrigated crops in place of rice in the Nagarjunasagar Project **left** command area with the same quantity of water (Table II.3.2). The system of growing greengram, blackgram, or groundnut after rice is establishing well in the light soils in the area.

Table II.3.2. New cropping systems in the Nagarjunasagar Project left command area.

Cropping sequence	Duration (days)	Yields (kg/ha)			Net return per rupee invested
		1st crop	2nd crop	3rd crop	
Greengram-based systems					
Grecngram-groundnut-groundnut	290	1.935	1,203	1,101	1.33
Grecngram-groundnut-greengram	248	1,844	1,144	931	1.66
Greengram-greengram-groundnut	251	1,964	1,166	1,958	2.44
Groundnut-based system					
Groundnut-groundnut-(greengram)*	229	1,141	1,947	*	1.15
Groundnut-greengram-(groundnut)*	187	1,122	1,166	*	1.07
Groundnut-groundnut-(blackgram)*	229	1,155	1,979	*	1.18
Groundnut-blackgram-(groundnut)*	194	1,210	1,106	*	1.10
Rice-hased system					
Rice-rice	231	4,218	5,139		0.78
Rice-greengram	193	4,211	1,006		1.16
Rice-blackgram	197	4,234	802		0.99

* 3rd crop in groundnut-based crop sequence could not be harvested for want of irrigation at Garikapadu farm. Hence, data is available for only two crops.

The introduction of new crops and crop substitution has been possible. Soybean and mustard are being introduced in the black soils under the Nagarjunasagar right command. Mustard gave 2-6 q/ha under rain-fed conditions, and 4-12 q/ha when irrigated, in black soils in Guntur district. Soybean yielded 10-15 q/ha in years of low rainfall and 15-23 q/ha in years with adequate rains.

Another way of increasing production is through increasing the cropping intensity. This is more relevant in rain-fed areas. A two- or three-tier system of cropping with horticultural crops is being attempted apart from intercropping with bananas, coconut, cashew, and other widely spaced crops. Cocoa, banana, yam, colocasia, pineapple, direct-seeded vegetables such as bittergourd, clusterbean, and bottlegourd have performed well in coconut plantations. Intercropping of banana with yam, turmeric, *bhendi* and colocasia has been tried with success.

Varietal diversification considering the date of transplanting, cropping system to be followed, and other conditions may also be tried. High-yielding, scented basmati rice varieties which have increasing demand in India and in the Middle East may be grown instead of the common varieties of rice. Basmati rice can be transplanted as late as July or August and commands a higher price.

Irrigation Planning and Management Procedures

Localization, which is a concept and process by which the boundaries of command areas and the cropping patterns followed are surveyed, has helped in planning. For the K. C. canal, it was ordered in 1956 that:

a) All lands contiguous to wet areas should be converted to wet cropping areas to the extent possible considering the suitability of soil;
b) Separate blocks should be defined for wet and irrigated dry cropping considering the suitability of soils, drainage, etc.

Where rainfall is inadequate, the area could be utilized for irrigated dry crops during the kharif season with facilities for protective irrigation when needed. Where rainfall is substantial, the area could be planted to wet crops during the kharif season, regardless of the soil. Water stored in the reservoir could be used for rabi season irrigation.

The present practice is to fix a 1:2 ratio of wet to irrigated dry areas at the formulation stage of the irrigation project to extend its command area. Acccrding to the Director of Agriculture, the Soil Correlator evaluates the feasibility of irrigating an area based on soil type and the water requirements of crops. The Department of Irrigation consults the Department of Agriculture only at the formulation stage of a project. Thereafter, there is hardly any communication between the two Departments. It is only recently, with the creation of CADAs, that a dialogue between the two is conducted up to the operation stage of the project.

Currently, about 5,660 million cubic meters of water is being used in Nagarjunasagar Right Canal. This can be distributed equitably throughou: the cultivable command area, the actual allocation at the pipe outlets being the quantity arrivedst after deducting the conveyance losses from the head regulator down to the pipe outlets from the total amount used. This water could be allocated during both kharif and rabi seasons, giving farmers the option to grow whatever crops they choose, keeping within the water allocated to them. Presumably all the farmers would plant rice during the kharif season when they will have the benefit of substantial rainfall, and grow irrigated dry crops during the rabi season. There should be no technical difficulty in regulating the water supply. What is necessary is to ensure that whether it is the kharif or rabi season, every landholder is allocated water proportional to the area of his land after allowing for conveyance losses. Each farmer would then be able to grow any crop of his choice in a part or all of his land. This will induce him to use water economically and achieve higher efficiency of irrigation. It would also encourage him to exploit groundwater to supplement irrigation.

The present system of localization in some cases has neither succeeded in improving productivity per unit of land and water nor secured social and economic justice to all the farmers. In addition, it has resulted in giving undue advantage to some farriers resulting in the concentration of wealth and means of production among only a few people.

For equitable distribution of water on a unit of land basis, the majority of O&M engineers favor allocating a fixed quantity of water per unit of cultivable area to all the landholders under the command of a canal. This amounts to introducing a system of rotational water distribution *(warabandi)* and permitting the farmers to grow crops of their choice using their water allocation, encouraging them to use water efficiently and securing equity among the farmers. Some farmers, however, had some reservations that: a) it would be desirable if discipline can be enforced, b) it may not give fruitful results and would create difficulties in implementation. and c) fixed quantity allocation has to be tested on a pilot project.

PROBLEMS AND RESEARCHABLE ISSUES ON DIVERSIFIED CROPPING

With the growing demand for food and fiber, the depleting water resources, and the high cost of harnessing river and rain water, the need for efficient use of irrigation water has become extremely important in the overall planning for improved agricultural production. This could be addressed by implementing an integrated approach to water management. Integrated water management for agricultural production needs skills in coordinating various water sources - tapping, storage, conveyance, diversion, delivery, distribution and application - consistent with soil suitability and crop requirements for maximizing irrigation efficiency and economic returns.

The CADAs have so farlimited theiractivities to distribution of water below the pipe outlet only. For scientific water management, there is a need for adopting an integrated approach from the reservoir down to the irrigation network. All steps should be taken to avoid wastage of water and achieve optimum use of water for maximizing agricultural production. Such scientific water management needs integration and coordination of all field agencies. It should include systematic canal operation and rotational water supply, etc. Another important research activity is the introduction of the systems approach to the operation of the main canal, branch canals, and minor canals. This is very much needed for improved water management.

Besides the minimum improvement of the physical infrastructure in the irrigation network, the integrated water management strategy envisages systematic canal operation by properly scheduling deliveries of water *so* that all lands including the tail-end areas get adequate water. Rotational water distribution or warabandi should ensure that all farmers get water on time and as per plan.

Selection and propagation of short- and medium-duration varieties of crops are equally important to maximize production. No less important is the need for adopting a package of agricultural practices to include high-yielding varieties, balanced fertilizer application, and plant protection measures, in addition to water management practices. There is a need for better Coordination among the departments concerned to ensure sufficient credit, marketing of products, and other support services. Effective monitoring at (differentlevels and motivating the farmers in the field to participate in the integrated water management plan should also be studied.

Other problematic areas where research is needed include the following:

a) Monocropping resulting in deterioration of soil productivity,
b) Deep-percolation losses leading to waterlogging and salinity,
c) Decreasing rate of returns from imgatcd rice-based cropping systems,
d) Market fluctuations due to high production and glut in the market,
e) Motivating farmers to grow more irrigated dry crops instead of wet crops like rice, and
f) In rice-based irrigation systems such alternative crops as:

- groundnut,
- cotton,
- pulses as catch crops in between two rice crops,
- fruit and vegetables,
- fodder cultivation (for white revolution), and
- agroforestry.

STRATEGY FOR CONDUCTING 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 proposed subcenters under the World Bank aided Andhra Pradesh Composite II and National Water Management Project and the field engineers **of** the command areas. The Water and Land Management Training and Research Institute (WALAMTARI) could coordinate and guide the entire process.

Research should include action research, adoptive trials, and systematic programs for technology transfer. The selection of crops which could he suitable substitutes in rice-based irrigation systems can he 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 industries (food processing units, cold storage facilities, canning industries, etc.).

Being of an action and adoptive type, the research will he conducted in demonstration farms and farmers' fields. Existing project development and demonstration farms under the two major command areas - Sriramsagar Project and Thungabhadra Project (Anantapur) may he availed of.

The research may he conducted for five years — two years for action research and three years for a continuing program of adoptive trials and technology transfer.

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 recurring costs, agencies like the USAID, World Bank, International Irrigation Management Institute (IIMI), etc. may he tapped in addition to the existing funding agencies of WALAMTARI.

CHAPTER 4

Irrigation Management to Support Crop Diversification in Indonesia

Effendi Pasandaran, Budiman Hutabarat and Soekarso Djunaedi

BACKGROUND

DIVERSIFIED CROPPING IN Indonesian irrigation systems has been practiced since the early 20th century when the Dutch colonists introduced modem irrigation systems to increase the welfare of the population and promote the cultivation of sugarcane, one of the important export commodities. Pressure to continuously supply water to irrigated lard, even though it only occupied a small but productive area, affected the present degree of crop diversification in irrigated areas.

In 1928, the Dutch established strict regulations with respect to the area under sugarcane, introduced production area quotas involving rotations between rice, sugarcane and secondary crops, and established procedures for determining water distribution schedules. The criteria for water allocation had probably been developed and revised before 1936 when a general water law was introduced. Water allocation was based on the relative water requirement of the three important crops. The concept of water allocation, based on this relative requirement, is called *pasten* which is expressed as an index to relate the quantity of available water to the irrigated area.

Many irrigation systems deteriorated after independence, and this was one reason for the subsequent difficulties in implementing *pasten*.

During the first and second five-year development plans (1969-1979), attention was focused on rehabilitation of irrigation systems. This was one of the strategies employed to support the program to attain self-sufficiency in rice. Other policy instruments were subsidy on inputs (fertilizers and pesticides) and expansion of irrigated area through the construction of new irrigation systems, particularly outside Java.

Although the pressure to maintain rice self-sufficiency is still great, there is an increasing awareness of the importance of resource base diversification. It is one of the important policy measures which will be adopted during the fifth five-year development plan (1989 to 1994).

Diversification is a complex process with several dimensions to be considered, including technologies, price of commodities, and marketing arrangements.

The rapid technological progress in rice has led to the dominance of this crop, particularly in irrigated areas. This is one of the important constraints in the expansion of diversified crops in irrigated areas.

The rapid development of technology for rice production has also caused research on other food crops to lag behind. Productivity of soybean, for example, is still below the level of Asia. Sugarcane production in irrigated areas is no longer promising. The relatively low world price of sugar and low technological development of sugarcane production have increased pressure for sugarcane to be moved to non-irrigated areas. This was aggravated by the pressure to maintain rice self-sufficiency which relies heavily on the production in irrigated areas.

PRINCIPLES OF IRRIGATION MANAGEMENT

There are two imporlant principles underlying irrigation water allocation in Indonesia.

The first is based on equal opportunity to receive irrigation. The right to receive water is proportional to the size of land to be irrigated in all sections of an irrigation system. This principle is exercised by Subak Systems in Bali and Java.

The second is based on the needs of the predetermined cropping systems in irrigation systems managed by the irrigation agency. Although this principle is considered efficient to accommodate the need for diversified crops, it does not necessaril) imply that it is better than the first principle.

Each principle has been developed in its own manner in three stages of development as follows.

a) Irrigation systems which are still in the early stage of development. They are usually planted to rice with low water use efficiency.
b) Irrigation systems which are already developed but are predominantly planted to rice with a relatively high water use efficiency and with higher social benefits to the farmers.
c) Irrigation systems which are responsive to external changes and demands. An irrigation system is considered responsive if it is able to overcome immediately any problem that may occur. For example, if some component of the irrigation system is suddenly destroyed, then the system may immediately find out the way to repair damage to maintain productivity. Such systems tend to show a higher degree of crop diversification.

An irrigation system is not necessarily successful in achieving a higher stage of developmentjust because it has existed Cor a long time. A system has to achieve the third stage of development mentioned above in order to support diversified crop,;. Such a system has lo be quite responsive not only to the maintenance of irrigation performance but also to the changes in technology, market price of commodities, etc.

There are three important constraints to support diversified crops in irrigation systems: system design, technical information, and production technologies.

System Design

Constraint in system design is cdused hy inflexibility of existing on-farm canals to serve the seasonal changes in irrigated non-rice crops in systems designed to irrigate rice.

Typically, rice-based irrigation systems have to be able to deliver at least 1.5 liters per second per hectare (lps/ha) at tertiary level to meet land preparation requirements. This means that actual design capacity of canals is normally close to 2.0 lps/ha, and structures are generally designed to function effectively only when discharges are within 70 percent of design capacity.

For diversified cropping, however, the demand should be much less, and may be as little as 0.2-0.3 lps/ha. To deliver such amounts in a system capable of handling much larger flows and to maintain effective flows require a higher density of control structures and frequent operation of gates.

In some irrigation systems in Java, the on-farm canal system is constructed permanently with concrete lining. Therefore, it is difficult to change the canal layout to respond to the changing pattern of the cropping system.

Technical Information

Constraints in technical information are caused primarily by inadequate information available to operate irrigation systems efficiently. This also includes information required to implement the concept of pasten and its variants such as faktor K (see Appendix 1). This is particularly true of irrigation systems that have facilities to control and measure discharges such as those of technical systems. In irrigation systems operated by farmer communities which are not usually equipped with inflow control facilities, fanners control the excess flow in some parts of the system by a rearrangement of water allocation. This *social* outflow control is an important feedback to improve operational performance.

Under diversified cropping conditions, the pattern of water demand is more complex than that of rice monoculture. Demand varies ***spatially,*** depending on the location of rice and non-rice crops in the system, and in ***rime.*** depending on the duration of each crop. The fluctuation in demand means that system managers have to work harder to balance supply and demand, a task made even more difficult when discharge into the system varies, as is thr: case in most run-of-the-river type systems.

Soil information, which is lacking, though of relatively little importance to the rice crop under flooded conditions, has great importance to the effective cultivation of non-rice crops under non-flooded conditions.

Production Technologies

Production technologies for non-rice crops suitable for irrigated area are also limited. Better water management for noo-rice crops might improve productivity, but other components of technology such as pesticides, crop varieties and fertilizers have to be handled properly.

There is still little information on the physical constraints to non-rice crop production caused by physical changes in soil that occur in the process of land preparation for rice, particularly in older systems. This affects rooting depths and densities of non-rice crops, making them more vulnerable to water stress. However, there are also problems associated with excess moisture in the soil in the period following the rice crop that may inhibit quick and effective plant establishment.

MANAGEMENT TOOLS TO IMPLEMENT W ALLOCATION AND DISTRIBUTION FOR DIVERSIFIED CR

In irrigation systems operated by the irrigation agency, the annual cropping plan is made on the basis of several factors, including government policies, farmers' preferences and expected water availability. During the planning stage, the potential availability of water is estimated and appropriate cropping systems are then determined to optimize the use of the anticipated water. In daily operations, the challenge is to allocate and distribute water efficiently to meet the demand of the crops. Elaboration of operational procedures is described in training guidelines of the irrigation agency (see Appendix 1).

These operational procedures require continuous monitoring on both the demand and the supply side of irrigation. On the demand side, area under land preparation, and area planted in each stage of growth are monitored. On the supply side, flow discharges are measured in each level, depending on the control facilities available.

The diversity in sources of water, pattern of canal development, and variations in the time of planting of crops complicate the control of supply and estimates of demand for irrigation.

Village level decision making has a strong influence in managing water at the tertiary level of many irrigation systems in Java. In many cases a block of rice field is served by more than one source of water. This diversity in water reuse and delivery alternatives, while increasing the stability of the block as a basic social entity for water management, makes the task of delivering the correct amount of water to each block by the irrigation agency more complicated.

Although during the planning stage the irrigation agency uses design water allocation based on the anticipated cropping pattern, farmers' decisions on which crop to grow are strongly influenced by the performance of canals in delivering water (Pasandaran, 1982a and 1982b). This leads to significant differences in the planned and actual conditions.

There are two general patterns in which water availability in canals affects the cropping system: (1) where rice is the only crop planted even though water availability is quite limited; and (2) where within a certain range of supply, there is a tendency for fanners to plant more diversified crops as their irrigation supply is reduced.

Figure II.4.1 shows the relationship between seasonal water availability (indicated by seasonal TWRS[1]) and area planted to rice (percentage of irrigated area) in areas where there is no crop diversification. There is a minimum amount of water (M) which is acceptable to the community for the whole area that can he planted to rice. This minimum amount of water varies depending on the stage of development of the irrigation system.

The minimum amount needed (Me) is relatively large in the early stage when the system has just begun to learn the feedback from environment, and here is relatively little managerial input into the system.

In a more resilient system, the minimum amount (MR) may fall below theoretical equilibrium point (TWRS = 1) because there is greater management capability, and water supplies can be more closely matched to variations in demand. Although overall, the system is marginally in deficit, the management inputs will minimize the potential impact on production.

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1. The theoretical relative water supply (TRWS) is defined as the ratio of actual water supply to calculated demand for water, assuming all the land area of irrigation unit is planted to rice under unstressed condition. This concept is different from that of pasten in that the latter is based on the actual crops with normative demand for water.

Figure II 4.1. The relationship between seasonal TRWS and crop area (the first pattern).

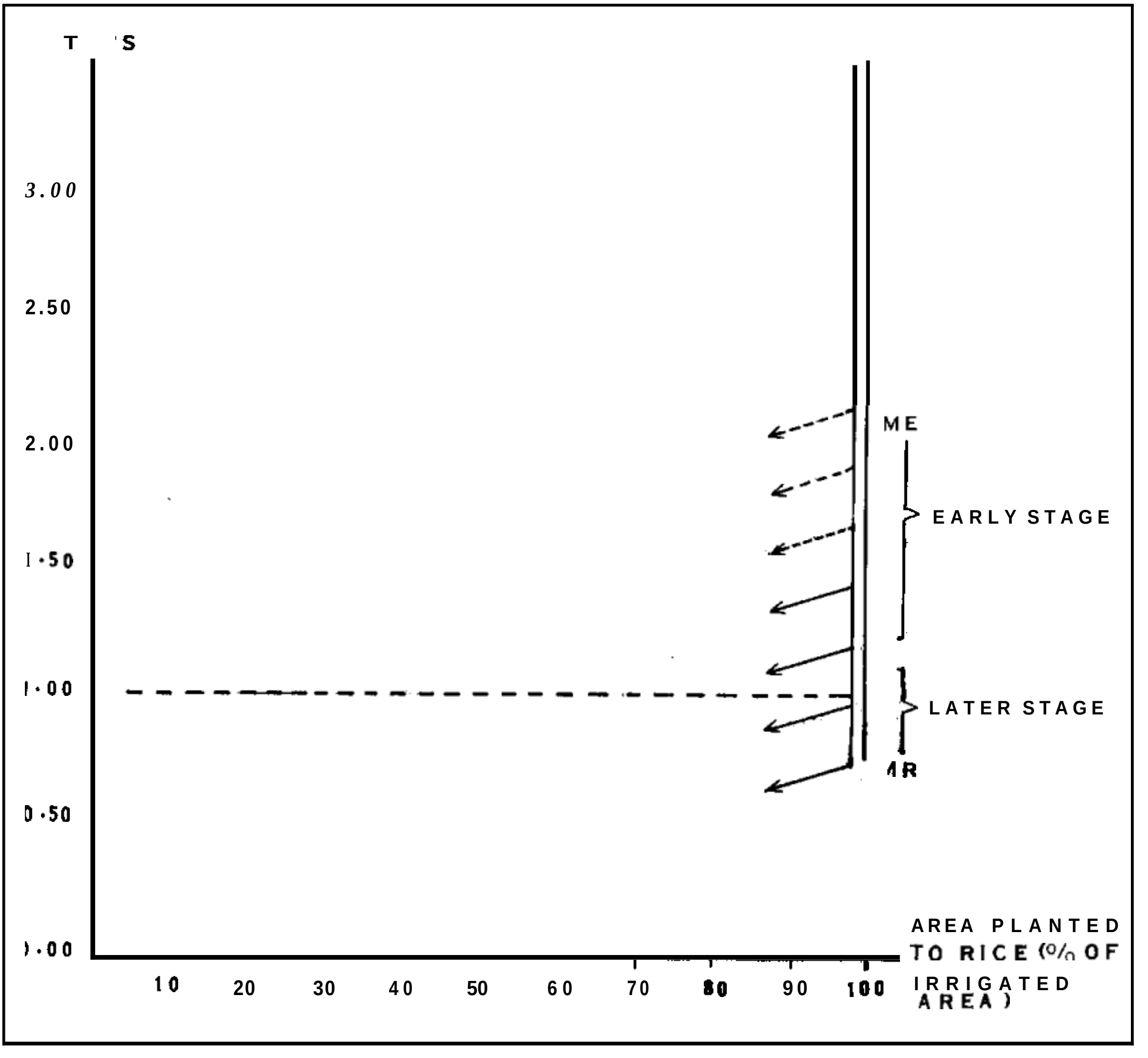


Figure II. 4. 2 shows the relationship of the seccnd pattern, between area planted to crops and water availability where there is widespread crop diversification.

The decision to diversify is not necessarily taken only when the minimum amount of water (Md) is not sufficient for rice.

In some irrigation systems where water is not limited and the existing canals permit internal water control, farmers may decide to plant a range **of** different crops even though irrigation water is adequate for rice throughout the season. Once th: basic decision to diversify has been made, a large number of production alternatives are feasible, depending on the market demand, and the skills and the experience of each farmer.

There is also a minimum amount of water which is acceptable to the communities for the whole area that can be planted to diversified crops (Mc). This amount again varies, depending on the stage of development of the irrigation system and the area of each crop type.

RESEARCH ISSUES

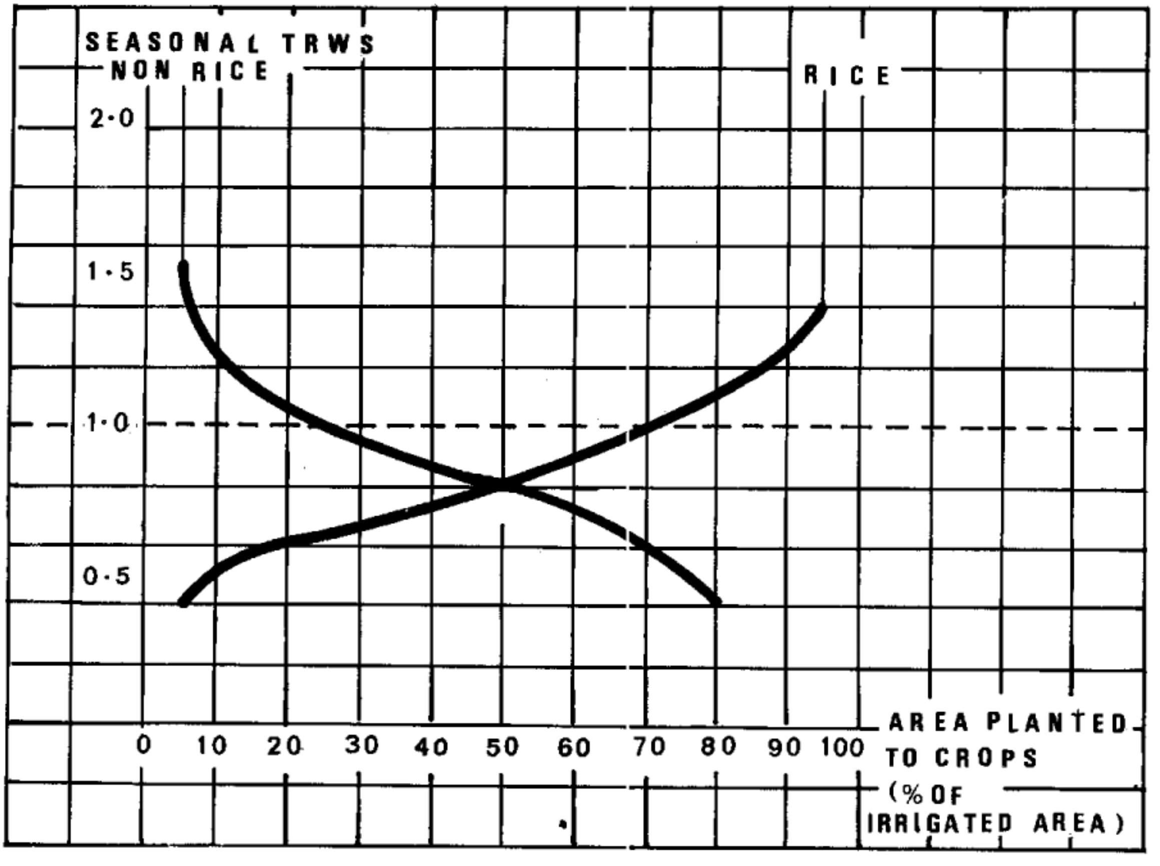
The challenge of the Indonesian irrigation management is to bridge the gap between the first and the second pattern, which is essentially the shift from the second to the third stage of development. **So** far, research on irrigation management for civersified crops has put more emphasis on technological change and identification of constrai its.

This paper has identified three technological constraints to the adoption of diversified crops in irrigation systems: canal design, technical information, and production technologies. Although research undertaken by IIMI has, to a certain extent, addressed these issues (Appendix 2), they need further and more detailed investigation so that they can be more widely addressed by irrigation and agricultural agencies.

A list of research issues has also been proposed by Hutabarat and Pasandaran (1987) on the complexity of irrigation management. None of these issues have been addressed properly during the last two years.

There is a need to develop a framework for a more holistic approach to implement diversified crops in irrigation systems. The induced innovation model (Ruttan, 1987) which describes the relations between changes in resource endowments, cultural endowment, technology and institution is suggested to be undertaken to help identify the areas of ignorance and to put the proposed research issues in a proper framework.

Figure II.4.2. The relationship between seasonal relative water supply and relative area planted to rice and to diversified crops.



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APPENDIX I

Water Distribution According to the K-Faktor Method

INTRODUCTION

THE YEARLY CROPPING pattern and cropping plan describes the kind of crops and planned area with each crop during the year. It includes the delineation of the *golongan,* the crops to be cultivated in the golongans and the starting dates of planting in each golongan. The golongan system permits the staggering of land preparation and planting dates within and between irrigation systems so **as** to spread peak water demand, in order not to exceed water availabilities and canal capacities.

The annual cropping plan is made on the basis **of:**

- expected water availability;
- farmers' preferences:
- government policies: and
- water requirements of the crops to be grown:

The plan is made in such a way that the water requirements in the system throughout the season are expected to match the water availability.

After approval of this plan by the Irrigation Committee, the farmers are so informed, and then the implementation of the plan follows. If everything goes **as** planned, the implementation would be easy when it is a matter of merely following the distribution plan of irrigation water as scheduled in the annual plan.

However, the implementation of the distribution plan is not easy. There are various reasons why the annual plan should not be followed blindly. The main reasons are:

1. The water availability in the river may be lower than foreseen. In the annual plan, the water availability is calculated on the basis of the dependable flow. Variations during the season will always occur.
2. Not all farmers in a golongan will start planting at the same date. It is difficult to predict how many farmers will start at a particular time.
3. Some farmers may not start planting at all for some reasons.
4. Other farmers grow **a** different crop from that originally planned.

From the above it can be seen that deviations from the annual plan will occur during the irrigation season both in the water demand (the crops in the field) and in the water supply (the flow in the river).

Good irrigation management aims to allocate and distribute the water in a fair and efficient way to ensure that all crops receive the required amount **of** water and that if shortages occur these too are shared by all farmers.

For this reason it is necessary to make regular adjustments to the water allocation, so that the allocation of water is in line with the crops actually grown in the field.

The following information is needed to decide on the adjustments to the water allocations.

- water availability;
- water demand of the cultivated crops; and
- water losses.

Water availability and water demands change constantly during the irrigation season. It is not necessary to determine these changer every day. Normally, a period of 10 days or 15 days is taken for such determinations. The gate setting will remain constant during this period.

During this continuous process of water allocation when the irrigation season is on, the following questions have to be answered:

1. How much water do the plants in the tertiary units need ?
2. How much water is lost before the water reaches the plants ?
3. Do water requirements meet water availability ? If not, how will the distribution be done ?

In Indonesia, the K-faktor method is being used to given an answer to these three questions.

THE K-FAKTOR METHOD

The K-faktor method is schematically shown in Figure II.4.3. The water demands of the crops which are cultivated in the tertiary unit are expressed in liters per second.

The water losses in the tertiary units and in the main system are taken into account by multiplying the water demands of the crops with a conveyance loss factor. This leads to the gross water demand of the system being expressed in liters per second.

The total water availability in liters per second is divided by the water demand in liters per second. The result of this division is called the K-faktor. The water allocation to secondary canals and tertiary units is calculated by multiplying the gross water demands of the units with the K-faktor.

Figure II.4.3. K-FAKTOR METHOD

1) Crops cultivated in each TU x Water req of crops in lisec (WR crops)

2) Net WR each TU in lisec x Factor water losses TU (LT)

3) Gross WR each TU in l/sec

Gross WR TU1 + gross WR TU2 +.. each secondary unit X Factor water losses SU (LS)

4) Gross WR each SU in lisec

Gross WR SU1 + gross WR SU2 X Factor water losses main (LM)

6) Water Availability in l/sec ÷ 5) Gross WR at intake in l/sec = 7) K=Faktor

8)	K-Faktor	x	gross WR TU	=	Water allocation to TU
	K-faktor	x	gross WR SU	=	Water allocation to SU

TU = Tertiary unit
SU = Secondary unit
WR = Water requirement
L = Losses

Explanation of The K-faktor Method

The K-faktor method will be explained step by step in this paragraph. For easier understanding the explanation will be illustrated with an example. See figure II.4.4.

Let us consider the irrigation system which is shown here. A main canal branches into secondary canal SSI at B and into secondary canals SSII and SSIII at C.

The secondary canals supply 3, 3 and 2 tertiary units, respectively

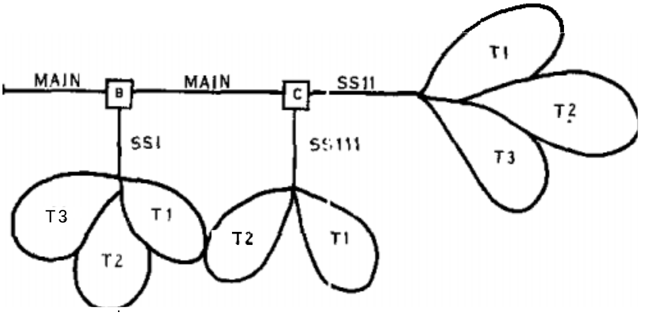

Figure II.4.4. Scheme of the system in our example

1. The water requirement of the crops is calculated as follows: In each tertiary unit a list **is** made of the crops which are actually grown in the field. The growth stage of the crops is determined as well. In addition, the area *is* determined on which land preparation and seedbed preparation are going to start during the next period.
2. The number of hectares with the various crops **is** then multiplied with the water requirements for each crop and growth stage. The water requirements are expressed in liters per second per hectare. The following water requirements are normally used:

Kind of crops	Water requirement in liters/sec/ha
1. Rice	
a) Land preparation + seed bed	1.125
b) Growing stage	1.000
c) Ripening stage	0.625
2. Sugarcane	
a) Land preparation	0.750
b) Young crops	0.500
c) Old crops	0.125
3. Upland crops	
a) Much water required	0.250
b) Less water required	0.125

The validity of these data must be checked in the fie d. Deviations may occur due to differences in soil types, topography etc. If no validity check bas been done as yet the figure in the table can be used as an approximation of the water requirements.

The number of hectares with each crop is multiplied by its water requirement which results in the water requirement of that crop in the tertiary unit. This calculation is done for every crop in the tertiary unit. The results of these multiplications ar: then added which lead to the net water requirement of the tertiary unit (net WR TU).

The figures in column 2 show the area of the crops which ar: planned in tertiary unit 1 of secondary unit no. 2.

	Planned cultivation (ha)	Water requirement (liters/sec/ha)	Water requirement (liters/sec)
1. Rice			
a) Land preparation	2	1.125	2.25
b) Growing stage	1	1.000	1.00
c) Ripening stage	0	0.625	0.00
2. Sugarcane			
a) Land preparation	20	0.750	15.00
b) Young crops	0	0.500	0.00
c) Old crops	0	0.125	0.00
3. Upland crops			
a) Much water required	50	0.250	12.50
b) Less water required	10	0.125	1.25
Total water requirement in tertiary unit			32.00 liters/sec

3. Water losses occur in the tertiary units, in the secondary canals and in the main canals. The losses are taken into account by multiplying the water requirements with a losses factor.

Experience has shown that, usually, losses of water in the tertiary unit amount to 20-30 percent. The efficiency of the water is thus **70-80** percent. The net water requirements in the tertiary unit are therefore multiplied with a factor ranging from:

$$\frac{100}{80} = 1.25 \quad \text{to} \quad \frac{100}{70} = 1.43$$

This factor is called the losses factor for the tertiary unit (LT). The result of the multiplication gives the gross water requirement of the tertiary unit (WR gross TU).

WR net	x	LT	=	WR gross T
32 liters/sec		1.43		**46** liters/sec

For each tertiary unit the gross water requirements can now be calculated

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Water losses in the secondary canals are estimaied by assuming an efficiency of 80-90 percent. This means that the multiplication factor is between 100/80 = 1.25 and 100/90 = 1.11. The gross water requirement of all tertiary units is multiplied by 1.11 or 1.25. The result is the gross water requirement of the secondary unit.

We will calculate the gross water requirement of secondary **unit** no. 2. We have already calculated the gross water requirement of tertiary imit no. 1 **(46** liters/sec).

Let us assume that we have calculated the gross water requirement of tertiary units T2 and T3 as well, and that we have determined a requirement of *56* liters/sec for T2 and **64** liters/sec for T3.

The gross water requirement for secondary unit S2 assuming an efficiency of 80 percent in the secondary canal is calculated as follows:

$$
\begin{aligned}
(\text{gross TU1} + \text{gross TU2} + \text{gross TU3}) \times 1.25 &= (46 + 56 + 64) \times 1.25 \\
&= 166 \times 1.25 \\
&= 208 \text{ liters/sec.}
\end{aligned}
$$

The gross water requirement for each secondary unit can now be calculated.

Water losses in the main canal are estimated by assuming an efficiency of 90-95 percent. Again, we see that the losses in the main canal are lower ihan in the tertiary canal. **This** means that the multiplication factor is 100/90 = 1.11 or 100/95 = 1.05.

We will calculate the gross WR at the intake. The gross WR of secondary unit S2 amounted to 208 liters/sec. Let us assume that we know the gross WR of secondary unit S1 and S as well and that we have calculated a requirement of 150 liters/sec for S1 and 220 liters/sec for **S3.**

The total water requirement at the intake assuming an efficiency of 90 percent **is** :

$$
\begin{aligned}
(\text{gross WR S1} + \text{gross WR S2} + \text{gross WR S3}) \times 1.05 &= \\
(150 + 208 + 220) \times 1.05 &= \\
578 \times 1.05 &= 607 \text{ liters/sec}
\end{aligned}
$$

At this stage we have obtained the gross water demand of the system in liters per second.

The water allocation is determined by comparing the water availability with the water demand. The comparison is done by dividing the water availability by the water demand. The result is the K-faktor.

$$
\text{Faktor K} = \frac{\text{available water in liters/sec}}{\text{gross water demand in liters/sec}}
$$

If the K-faktor is greater than 1, the water availability is higher than the water demand and all units can be supplied according to the calculated demand. **A** K-faktor smaller than 1.0 means that a shortage occurs.

The value of the K-taktor expresses the extent of the shortage. The lower the value, the higher the shortage.

Let **us** assume that the water availability is 500 liters/sec

$$\text{Faktor K} = \frac{\text{available water in liters/sec}}{\text{gross water demand in liters/sec}} = \frac{500}{607} = 0.824$$

The water allocation to the secondary units is calculated by multiplying the gross water requirements for each unit by the K-faktor. We have now allocated the available water in a fair way. Each unit receives an amount of water based on the needs of the plants cultivated in the area, the water losses and the water available in the system.

The water allocation to the secondary units:

Allocation	S	=	gross WR S x K-factor.			
	S1	=	150 x 0.824	=	124 liters/sec.	
	S2	=	208 x 0.824	=	171 liters/sec.	
	S3	=	220 x 0.824	=	181 liters/sec.	

The water allocation to the tertiary units in S2:

Allocation	T	=	gross WR T x K-faktor		
	TI	=	46 x 0.824	=	38 liters/sec.
	T2	=	56 x 0.824	=	46 liters/sec.
	T3	=	64 x 0.824	=	53 liters/sec.

The values of the K-faktor

In the previous paragraphs we have learned how we can allocate the available water in a fair way. We have seen that if K = 1.0 no shortage occurs and all plans receive the amount of water needed.

If K < I, a shortage has occured. Based on many years of experience it **is** generally accepted that a K-1 faktor greater than 0.75 is adequate for plant growth. When the value is between 0.5 and 0.75, the amount is not sufficient, but there is no danger to plants. Plants will experience water stress if the value is lower than 0.5 during a period of more thaii one week.

When severe water shortages occur the K-faktor falls below 0.5. The amount of water in the system is then so low that rotation in the tertiary canals has to be applied.

Procedures for 10-15 days Management Cycle

During the process of water allocation and water distribution the procedures followed are as follows:

- The planned cropping schedule in a tertiary unit is prepared by the Management of Water Users Association (WUA) in the WUA's meeting.
- The Tertiary Water Distributor gives this information to the Juru Pengairan (Sub Water Master) who writes these data on the Operation Board near the tertiary offtake. The Juru **fills** the data in a form for each tertiary unit.

- The Juru Pengairan submits this information to the Water Master. If the jurisdiction of the Juru covers an entire secondary unit, the Juru Pengairan fills the form for the secondary unit as well.
- The Water Master completes the forms **for** the secondary units in his area and submits these data to the Section Irrigation Office. If the jurisdiction of the Water Master covers an entire system, the Water Master will calculate the K-faktor himself. He receives the data on water availability from the weir gatekeeper.
- The Section Irrigation Office completes the forms for the entire systems and calculates the K-faktor.
- The calculated K-faktor is given to the Water blaster whoinforms the Juru Pengairan. The Jurus will then write the water allocation on the Operation Board at each secondary and tertiary offtake and will then adjust the gates and weirs at each offtake.

APPENDIX 2

Constraints to Irrigation Management for Diversified Cropping

IRRIGATION MANAGEMENT FOR diversified cropping requires much greater information than that for rice monoculture because of greater variety in water demand according to both locality and duration of each crop. The extent to which successful irrigation management for diversified cropping can he introduced depends heavily on the accuracy of this information base, and in the development of effective system operational plans.

In Indonesia the pasten system provides a sound and proper starting point for this process as it attempts to determine both supply and demand, and to mike operational adjustments depending on the relative supply and demand conditions. However, the extent to which it can be actually implemented has to be considered in the context of the managerial resources available to the irrigation agency responsible for system operation.

The extent to which planned activities and actual activities coincide relies to a large extent on the validity of the assumptions used in the calculations, and on the degree to which assumptions are replaced with actual data from the system question.

Research undertaken in several irrigation systems under the collaborative program between the Directorate General of Water Resources Development and IIMI in Indonesia over the past three years has addressed both the overall question of the validity of assumptions used in diversified systems, and the extent to which there is mangerial capacity to actually implement planned operations.

In assessing the managerial performance and managerial potential for an irrigation system it may be useful to distinguish between what is an assumption and what is actually known. This assessment is divided into two basic parts:

- within-season operation of the irrigation system, based on the pasten system that is essentially a response to actual demand and supply conditions every 10 or 15 days;
- seasonal planning activities, with a focus on how seasonal plans are made and disseminated, and the interrelationships between seasonal planning and shorter term operations.

The list below identifies those items where it is more common to find assumptions than actual data.

1. Within-Season Irrigation System Operation (every 10 or 15 days)

a) Calculation of Demand at Tertiary Block Level.

- actual irrigated area.
- area of each crop type.
- crop water requirement for each crop type known in relation to the climatic and soil conditions encountered.
- conveyance losses within the tertiary block

b) Calculation of System Level Water Availability

- likely discharge at head of system for next lime period.
- other sources of irrigation water, including groundwater, village weirs, suppletions, etc.
- conveyance losses within the main and secondary system.

c) System Operation Requirements

- discharges are known at head of system, head of each secondary and into each tertiary block.
- actual, not planned, discharges are reported.
- gates can he adjusted and settings maintained.
- staff can make adjustments in response to discharge fluctuations.
- rotations can be introduced when the demand-supply ratio so dictates.
- rotations can he implemented and maintained.
- staff can cope with this process within each reporting period.

2. Annual and Seasonal Planning

a) Plan Development

- village level compilation of likely cropping choices.
- system level water availability.
- district level quotas for different crops.

b) Plan Dissemination

- system level allocation of gross area under each crop
- block level allocation of crops
- determination of golongan (staggering of land preparation between groups of tertiary blocks to minimize peak water demand at system level)

c) Matching of Plans to System Operations

- farmer constraints to implementation of planned cropping patterns due to water conditions, soils, financial condition, domestic needs, etc.
- availability of system level resources: manpower budget for O&M, transportation for field staff, workloads, etc.
- feedback of seasonal performance into subsequent annual plans.

CHAPTER 5

Diversified Cropping Practices and Irrigation Management in Nepal

Prakriti Shumsher Rana and Ram Prasad Satyal

NEPAL IS A small Himalayan kingdom surrounded on three sides by India and in the north by the autonomous region of Tibet. It has a population of 15,022,839 according to the 1981 census. The cultivated area is 2,653,300 hectares (ha). Agriculture's contribution to the gross domestic product is Rs 14,646 million or 60 percent of the national income. Nepal is predominantly an agricultural country. More than 90 percent of the economically active are employed in this sector.

The majority of Nepalese, particularly in the mid- and high-hill areas, *are* subsistence farmers with small landholdings (82 percent of the farms are less than 0.67 ha). Their agriculture practice is intensive cropping patterns that involve sequence crcpping, mixed cropping, and relay cropping with a wide array of crops.

Nepal is also characterized by widely varying agroclimatic and socioeconomic conditions. The country can be broadly divided into *Tarai* (plains of Nepal), inner Tarai, mid-hills and high hills. Within each of these categories are extensive variations in rainfall, temperature, soils, topography, and irrigation facilities. The availability of agricultural inputs, farmer credit, trained extension personnel, and relevant technology for extension and road access is also variable. More infrastructure has been developed in the Tarai and inner Tarai, diminishing in availability as one moves to the mid-hills and into the remote high hills.

Some **of** the major cropping patterns under the given irrigation system or rain-fed area in the *Tarai* region of Nepal are as follows:

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

2) *Irrigated lowland with high production potential*
   a) Rice-mustard-maize
   b) Rice-maize-maize
   c) Rice-maize-mungkan
   d) Rice-wheat-mungbean
   e) Rice-wheat-dhaincha

f) Rice-wheat-fallow
g) Rice-wheat-rice

Some of the major cropping patterns under the given irrigation system or rain-fed area in the hill region of Nepal are **as** follows:

1) *Rain-fed lowland* with *low production potential*
   a) Rice-broadbean-fallow
   b) Rice-oats-fallow

2) *Rain-fed lowlands with medium production potential*
   a) Rice-wheat-fallow
   b) Rice-fallow-maize
   c) Rice-broadbedn-maize
   d) Rice-oats-maize

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

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

In 1984/1985, Nepalproduced4.31 million metric tons of foodgrains. By the turn of the century, Nepal will have to produce 8.65 million metric tons of food grains as per the Basic Needs Program of the Government of Nepal. Irrigation is one of the major means of increasing food production. This applies more particularly to Nepal as its staple food crop is rice, which is an aquatic plant, and therefore needs an ample amount of moisture for growth. In 198511986, the total area under irrigation has been estimated at 0.434 million hectares. The Basic Needs Program requires 1.25 million hectares of land to he brought under irrigation by the year 2000. This is certainly a very challenging task. **To** meet this need, the program of he Government for irrigation development has set 0.589 million hectares for the Irrigation Department and 0.227 million hectares for the Agricultural Development Bank. Furthermore, the target of the Irrigation Department is broken down to 0.233 million hectares for small-scale irriagtion, 0.260 million hectares for medium- and large-scale irrigation, and 0.085 million hectares for groundwater irrigation, taking into'account the different categories of surface as well as groundwater sources.

A summary of the irrigated areas of the five regions of Nepal is shown in Table II.5.1.

Table II.5.1. ***Irrigated areas in the different development regions in Nepal, in hectares.***

Develop-rnent region	Canals	Tube wells, bore holes and pumping	Tanks and natural flows	ACB' construction ses	Farm irrigations	Others	Total
Eastern	75,386	34,351.0	119,990	18,923	1,555		250,205.0
Central	11,083	49,147.0	114,702	-			174,932.0
Western	19,837	17,620.0	68,232.	-	2,022	814	108,525.0
Mid-western	691	16,274.0	49,924	-			66,889.0
Far-western	4,048	33,233.9	13,702	-	40		71,023.9
Total	111,045	150,625.9	386,550	18,923	3,617	814	671,574.9

'Agricultural Development **Bank.**
Source: DFAMS

Similar to the targeting of irrigation development for the Basic Needs Program, the breakdown of the targets for food requirements to meet the demand of basic needs is given in Table II.5.2.

Table II.5.2. Targets for food requirements of the Basic Needs Program for 1988/1989 and 1999/2000.

Type of food	Target for 1988/1989 Area ('000 ha)	Target for 1988/1989 Production ('000 ton)	Target for 1999/2000 Production ('000 ton)
Foodgrain			
Rice	1,368	3/88	5,096
Wheat	550	859	1,625
Maize	566	905	1,750
Fruits	619	433	702
Vegetables	140	922	1,515
Pulses	229	110	247
Potato	66	524	869

Nepal's irrigation development and food production policy will be governed and directed by the Basic Needs Program for the rest of the century. In light of this, Nepal's position in crop diversification and irrigation management, especially for non-rice crops, is briefly reviewed in the following paragraphs.

Most of the rice fields in Nepal are suitable for other crops considering that the various rivers flow from the Himalayas in the north to the southern plain. More than 80 percent of rice land lie in the southern plain which are well drained. Waterlogged areas that are unsuitable for growing non-rice crops account for 10-28 percent of the total rice lands. Rice is followed by wheat in winter in about 70-80 percent of cropped plain and hill areas whereas the rest are planted to either winter maize, pulses, or other legumes. Thus, rice need not be replaced to accommodate non-rice crops; rather rice can be substituted by spring and summer maize crops, sngarcane, tobacco, and other suitable crops.

Monsoon rain is the major source of moisture for crop production in Nepal. The permanent and perennial sources of irrigation do not cover more than 671,536 ha **of** cropped areas, whereas the seasonal source has been estimated to cover over 614,148 ha of the lands. Year-round supply of irrigation water is possible from the Himalayan rivers like Koshi, Karnali, Gandakui, and their major tributaries. But, irrigation systems are yet to be developed.

Farm lands that are supplied with irrigation water are principally rice-growing areas during the rainy season. Winter and spring seasons are not favorable to grow rice in these lands. A diversified cropping pattern, therefore, is required to keep these lands productive. Nepal's experience during the last two decades has been very rich in this direction. National crop coordination programs were initiated in 1972 for rice, maize, and wheat and in the subsequent years for oilseeds, sugarcane, pulses, citrus, and potato. At the same time, cropping systems programs under the Integrated Cereal's Project of Winrock International and the United States Agency for International Development in collaboration with the Government developed various rice-based cropping patterns for about five years. Extensive field-testing conducted to test the pattenis. The results of these tests have been encouraging.

Based on these tests and trials, the Government has begun a crop diversification program to cultivate 7 tons per year on more than 100,000 ha of irrigated lands. With rice as the base crop, partially irrigated or unirrigated lands were kept at five tons a year. Encouraged by this, the Ministry of Agriculture has launched a farming systems approach to include fodder and livestock in the research area so that diversified cropping practices get more attention in the Government's plan and production program of the departments concerned for the benefit of Nepalese farmers.

Some of the varieties of rice, wheat, maize, and potatoes released by the various national crop development programs are given in Table II.5.3.

Table II.5.3. Varieties of foodgrains andporaros released by the national crop development programs.

Crop	Hill	Tarai
Rice	Taichung-176, Chainan-2 Tainan-1, Chainung-242 Himali, Kanchan	CH-45, Chandina, IR-24 Durga, Jaya, Janaki IR-22. Sabitri, Masuli
Wheat	Lerma-52. Lermaroho	IR-21, NL-30, UP-262 Lumban, Tribeni, HD-1982
Maize	Khumal Yellow, Hetauda Composite	Rampur Yellow, Rampur Composite, Janaki, Sarlahi White
Potato	Kufrijoyti, NPI-106 Hy-bride-14, Cardinal	Kufrisundari, Cardinal Kufrijoyti

Until recently, institutionalized irrigation developnent was the task of various ministries and departments. Irrigation systems were developed basically for rice. Field-level water distribution and management was the responsibility of the growers in the majority of these cases. In 1972, the Ministry of Agriculture started a farm irrigation and water utilization program (FIWUD) which initiated farm-level water distribution and water utilization program on a small scale. Results of FIWUD activities were encouraging and practical. In 1987, the Government restructured the organization and placed all the institutions engaged in creating and developing irrigation facilities under the Ministry of Water Resources and the Department of Irrigation which have been made responsible for the institutionalization of irrigation ,development in the country.

The Agricultural Development Bank and foreign aided projects under the Ministry of Agriculture also take up the development of irrigation works. A major shift in irrigation policy has been introduced recently which takes into account small-scale irrigation for non-rice crops, especially for vegetables and other horticultural crops. Tars (dry-upland plateaus) and terraces which constitute more than 90 percent of the crop-lands in the hills and mid-hills grow maize and other non-rice crops as principal crops. Rice basins are planted to maize, rotated with rice. This practice is traditionally followed by the farmers because these *tars,* terraces, and river basins in the up-hill countries have high percolation losses when planted *to* rice. Southern plains which stretch from east to west in varying width are mostly suitable for growing irrigated rice. These plains have less percolation losses and require less expenditure to make rice plots Also Tarai farmers are traditionally rice growers and tend to grow rice as their principal crop.

The shift, however, to non-rice crops is eminent. Most of the excess rice is exported to India which is becoming self-sufficient in rice. India would like to import pulses and oilseed crops from Nepal.

The constraints to irrigation management for diversified cropping practices are categorized as follows:

* Although institutional constraints do not exist for the major non-rice crops, technical and economic constraints do exist.
* In terms of physical constraints, national programs have been started but suitable and sufficient manpower has yet to be developed and trained. At the same time, areas best suited for non-rice crops are not yet fully identified.
* Institutional linkages are yet to be strengthened.
* Pricing and marketing are the most prominent constraints for non-rice crops such as vegetables, fruits, and potatoes. These crops need either controlled storage facilities or quick consumption channels at reasonable prices.

There are a numher of problems and researchable issues in Nepal to accommodate non-rice crops in rice-based irrigation systems. Some of the pertinent issues are given below:

1) So far no work has been done on water requirement of non-rice crops like tobacco, sugarcane, oilseeds, pulses, vegetables, potatoes, etc.
2) Areas suitable for non-rice crops on the basis of agroclimatic factors such as soils, fertility level, etc., are yet to be ascertained based on research findings for crops other than tobacco and sugarcane. Tobacco and sugarcane are being grown on certain Tarai areas. Further areas of plantation of these crops also need exploration.
3) Crops of oilseeds and pulses are still in an early stage of consideration. Their needs of soils, climate, and water have not yet been determined.
4) Lands that are shaped and sized for rice crops may suit non-rice crops as the growing period is different, but drainage has to he provided if there crops are to he grown under irrigated conditions. Non-rice crops, however, are considered to be nonirrigated crops.
5) Vegetables and potatoes are some of the most promising alternative crops in terms of value and need. The importance of water for vegetables and potatoes, however, may be only second to rice. Moisture supply has to he assured along with market guarantee as these are perishable crops and need efficient and quick disposal in terms of production and consumption.
6) Fruits that are most promising on the terraces and slopes of the hills and mid-hills also need an assured water supply and market facility, and the areas for the production and sales from the point of view of quick consumption need further investigation. One favorable factor, however, for the

cultivation of all these crops in Nepal is that Nepal already has national programs headed by qualified and experienced scientists for cultivation of tobacco, sugarcane, oilseeds, pulses and legumes, citrus, and potatoes as well as full-fledged research divisions for the cultivation of vegetables and fruits, besides rice, maize and wheat.

7) So far the Department of Irrigation has been engaged in developing facilities for irrigation of rice without conducting research work on the management of irrigation water. Lately, the Department of Irrigation has initiated the Irrigation Management Program and the Irrigation Management Centre to investigate the water-management arpect of various crops, and to train farmers and technicians to use and design systems to suit the cropping patterns of the proposed irrigated areas. This is a milestone in achieving the goal of developing an irrigation facility for diversified cropping. Moreover, a high-level policy planning committee for irrigation development and prioritization, and coordination was formed urder the chairmanship of the Water Resources Minister. Categorical development of irrigation projects as small, medium, and large has been begun.

Prioritization of problems and issues are categorized as follows:

1) Non-rice crops that are well established in the country need to be further investigated in the field on the basis of soils and fertility level and accessibility to the consumption centers.
2) The farmers' belief that only rice can satisfy their needs should be invalidated hy convincing them of the fact that non-rice crops need less water which means less production cost and more profit.
3) Irrigation development should not always be done with the sole idea that rice is the main crop.
4) Existing national programs and institutions for non-rice crops need further equipment and modernization in terms of trained manpower and efficient research management.

Assistance in terms of manpower training, supply of modern equipment and instruments, training for the growers' behavioral change. and creation of storage and market facilities are needed to strengthen existing institutions and practices. Research work is mainly conducted by a core group of qualified scientists and technicians. Numerous research scientists with first or masters degrees and postgraduate degrees from universities are permanently employed by the Department of Irrigation. They ace placed at various farms and at the divisions of different disciplines in Kathmandu (Central Research Farms). Most of the agricultural research is conducted in government centers and farms located at various agroclimatic and ecological zones in the country. The Government Agricultural Research Centres are at Tarahara, Rampur, Jiri, Jumla, Parwanipur, Paripatle, Khajura, Surkhet, Lumle, and Pakhribas. The Agricultural Farms are at Hardinath. Kakani, and Khumaltar. Verification trials and management practices are also conducted in the farmers' fields. The majority of research work is conducted in a replicated basis both in locations and treatments. Some of the specific research works are conducted in selected locations and tested for reproductibility at various locations in the absence of research scientists at the selected location. Some researches are also conducted under optimized/controlled environments.

The duration of a specific research program is dependent upon the type of research. Ordinarily, the minimum duration of a research program is three years on the farms and stations and one to three years on the farmers' fields. The time period for the research program is decided upon the precision of the results required.

Funding for the research programs comes in the form of government grants, academy grants, donor agency grants and loans, private donations, etc. Major funders are governments of countries such as Japan, the Federal Republic of Germany, the United Kingdom, and Switzerland or donor organizations like the United States Agency for International Development and the International Development Research Center of Canada. Budgetary constraint is the most limiting factor to conduct research. Although the cost of a research work with complete facilities may run to hundreds of dollars per project, on a shared-facility basis the cost may not rise very high. No sacrifice is made, however, to test and tryout certain practices owing to lack of funds or manpower.

SUMMARY

This paper has dealt with the crop diversification potential in irrigated and rain-fed areas of Nepal. The importance of agriculture in terms of its contribution to Nepal's gross domestic production and the high percentage of the population dependent on it have been presented. The growth rate of the population in Nepal provides agriculture with a real challenge to increase the growth rate of food production.

The need to have a proper cropping pattern to obtain maximum production from an irrigated land gives rise to various problems. Some of the most important of these problems are the need for suitable varieties of the various crops, basically, rice, wheat, maize, lentils, mustard etc., that will tit in the cropping pattern while being resistant to disease and insect pests. Supply of inputs, especially fertilizer, and credit must be timely and in the right quantity. Other problems are the need for adequate labor at the peak season of rice harvest and at sowing of wheat or pulse crops. If labor is insufficient, then there is a need to fill the insufficieicy with appropriate farm machinery.

There are departments, corporations, companies and projects that deal with specific problems within the 14 units of the Government's Ministry of Agriculture. Results, however, were inadequate and where they were favorable, the methodologies to transfer these appropriate technologies to the farmers were lacking. This means that the mechanism for the supply of inputs, credit, and appropriate agricultural technologies through the Agricultural Inputs Corporation, Agricultural Development Bank, and the agricultural extension program has to be strengthened in terms of manpower, mobility, and in supplying power and facilities. There is a tremendous potential to increase food production in Nepal by using the available irrigated area to meet the food needs of an expanding population. The Government of Nepal is gearing its manpower and implementation strategy on diversified cropping system to meet this challenge under its Basic Needs Program.

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CHAPTER 6

Policies and Issues on Diversified Cropping in Rice-Based Systems in the Philippines

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BACKGROUND

THE **PHILIPPINES** is basically an agricultural country, with 70 percent of the population living in the couutryside and depending on agriculture-related activities for their livelihood. The agricultural sector's contribution to the Gross Domestic Product was around 30 percent in 1986. The average annual growth rate of agriculture's Gross Value Added from 1972 to 1986 was 3.8 percent compared with the 3.5 percent Gross Domestic Product rate of growth for the national economy. Despite the unfavorable world market conditions, agricultural products continue to contribute substantially to the country's export earnings. For example, the sector contributed approximately 30 percent of the country's export earnings in 1986. In 1987, agricultural foreign trade receipts amounted to US$1.5 billion, with a trade surplus of US$704 million.

Agricultural production is traditionally concentrated on a few main crops. Rice and corn are the major food crops, whereas coconut and sugarcane are the major commercial crops which constitute the important export commodities. The country's total crop production steadily increased at an annual average rate of 6.8 percent from 1972 until 1980 after which it stagnated and then declined starting 1983. During the same period, rice production registered small increases, although not in sufficient amounts, to meet increased requirements. That is why the country through the National Food Authority imported 191.02 and 540.83 metric tons of rice in 1984 and 1987, respectively.

Rice Production in the Philippines.

Rice dominates the Philippine agricultural food crop sector. About one-third of the country's farmers are engaged in rice production, mostly on a subsistence basis. In 1980-1987, rice contributed 25 percent of the total production value of major crops. In the same period, it had an average share of 25.7 percent in total harvest area.

Of the total harvested area of approximately 12.8 million hectares in 1987, around 3.3 million hectares were devoted to rice production. Of this area of rice land, about 1.9 million hectares were irrigated and 1.4 million hectares were rain-fed. For irrigated rice, the National Irrigation

Administration (NIA) expects to generate some 592,620 hectares (ha) and rehabilitate 828,760 ha in existing systems during the period 1988-1998. It is projected that by 1998, 65.8 percent of the total irrigable area (3,126,330 ha) nationwide, will have been provided with irrigation facilities.

Until the 1960s, rice production was increased primarily by expanding the physical area under cultivation. After the 1970s the increase was achieved by improvement in productivity, mainly through the use of high yielding varieties. The country attained self-sufficiency in rice in 1977 and exported the surplus for the first time in 1978. It maintained this position until 1983.

The National Food Authority regulates the rice (*palay*) market by setting a support price and, until 1985, a ceiling price for rice. It attempts to purchase approximately 10 percent of the rice crop to stabilize the price of rice in the market. Farmers often liquidate their crops at a discounted price level to the private buyers especially at peak production seasons.

Rice production is aimed at self-sufficiency but exportation will be pursued whenever necessary to unload surplus stocks. In 1980 and 1981, the Philippine government entered into export contracts to unload substantial stockholdings. Rice export was therefore a government monopoly. Grains exportation has now been opened to the private sector which undertakes the actual exportation, while the government develops foreign markets for grains including the preparation of in-country systems, standards, and facilities for use in the grain export activity.

Role of Crop Diversification

The production goals in the crop sector are embodied in the three corollary objectives of the Philippine agricultural development plan: 1) to ensure security in basic food items, 2) to increase and stabilize earnings from agricultural exports, and 3) to reduce import dependence on products where the country has comparative advantage without losing sight of the primary objective of increasing farm income.

The country has been facing low world market prices of most of its main export commodities, i.e., sugar, coconut, and banana. Sugar prices declined in 1983 to their lowest level in 13 years. In view of this very low price, sugar planters reduced the area planted to sugarcane. This led to social and economic problems. Efforts to overcome this precarious situation have initiated the shift from monocrop production to crop diversification.

In rice-based areas, diversification may also be a logical approach to address the issue of optimizing the utilization of the limited resources, particularly land and water resources. A large portion of the rice areas is left idle, especially during the dry season when there is a short supply of water. This is true not only in rain-fed but also in irrigated areas. Planting non-rice crops which require a lesser amount of water will expectedly increase the utilized area.

Crop diversification is supposed to be a step towards agricultural development. It has the effect of reducing the risk in crop production caused by fluctuations in market-related variables. Diversification is also a step towards market-oriented production which means farmers will not only he producing for his family's consumption, hut for the market as well. There is thus an increased effort in making the farmer realize that what is important is not the level of production *per se*, but the level of income that he will derive from his small farmholding. Crop diversification is thus seen as a means by which farm income can he increased, given a resource constraint such as land.

Market-led crop diversification that will optimize the use of the resource base is the major production program currently being promoted. Opportunities in the domestic and foreign markets and the specific characteristics of the resource base are determinants of the production priorities in the specific areas.

Policy Environment for Crop Diversification.

Considering the broad base of the agricultural sector for economic growth potentials and its impact on development, policymakers are looking for ways and means to pursue an economic growth process wherein the agricultural sector will take the lead. The general strategy is the development of programs and projects by which the farmers' net income can be raised from the current P=1235 (US$59)/month to P=2000(US$96)/month (at 1987 prices) by 1992. Policies have therefore shifted emphasis from merely increasing agricultural productivity to raising farm profitability. This will provide a broader policy framework which considers not only productivity but all other factors that affect the farmers' income, such as prices, other inconie-generating activities, inputs, credit, etc.

Pricing policy. The pricing policy may be the single most important factor that influences rice farmers to diversify out of rice fanning. The Philippine government currently maintains a price support for rice, based on cost of production, to protect the income of the farmers from adverse market conditions, such as the highly fluctuating farm prices of most agricultural commodities, due, mainly, to the seaso~lity of production In order to encourage farmers to plant crops other than rice, incentive mechanisms have also been adopted for crops like cotton and corn. For example, price stabilization measures are being implemented for coin at farmgate level to give farmers some assurance that they will get a relatively favorable price for their product.

Tux and tariff policy. Major agricultural exports have previously had nominal taxes ranging from 4-10 percent which in a way curtailed the volume of export. The new policy removes these export taxes. This policy may encourage the production of crops with export potential. Furthermore, it will make our products more competitive in the world market, i.e., to the extent that export taxes are passed on to the buyers in the form of higher market prices.

The reduction in the tariff rates for imported agricultural inputs is foreseen to motivate a shift toward the adoption of modern technologies. With a minimal tariff rate ranging from 0-5 percent *ad valorem*, the costs of agricultural inputs are expected to decrease, resulting in an increase in the use of better fertilizers, chemicals, and seeds, which in turn results in increased productivity.

Import liberalization measures in agriculture were done on a selective basis, depending on the domestic ability to produce and the overall impact on the sector. With the new trade policy, it is expected that agricultural productivity will increase, since cost constraints have been reduced if not totally scrapped. This means that the country can now be directed towards the production of crops with a natural comparative advantage. For instance. although the country has a comparative advantage in corn production, it is not produced sufficiently in the sector, and therefore it has been imported. With the move towards more competition in the domestic market, there is an increasing incentive to produce commodities that use domestic resources more efficiently and corn is one of them.

Land tenure policy. Security of land tenure is essential if landholdings are to be developed and for capital to be invested. The government's land reform program is designed to give farmers the security of tenure in order to encourage them to intensify their crop production. Since any income gain resulting from intensified production activity will accrue only to them, the farmers now have an incentive to adopt income-increasing technologies. Thus, crop diversification, particularly in rice and corn areas, is expected to proceed favorably following the implementation of the Comprehensive Agrarian Reform Program (CARP).

Subsidy and credit policy. The gradual elimination of all subsidies is a national policy. The removal of subsidies in favored commodities is an attempt to allow more competition in the market by removing policy and institutionally-initiated distortions that penalize the other (non-favored) commodities.

Irrigation is one input that is subsidized by the government. Subsidy comes in the form of eqnity contributions to the NIA and budgetary appropriations for construction and maintenance of facilities and interest charges on capital costs in the construction of irrigation facilities.

These actions, complemented by NIA's record of low irrigation service fee collection efficiency, are threatening its financial viability. NIA is now contemplating improving its services through the restoration of irrigation facilities which anticipate an increase in the efficiency of irrigation service fee collection will follow. This is the major focus of the Irrigation Operations Support Project which the **NIA** is now implementing nationwide.

Scrapping the preferential and highly subsidized credit program for rice is another indication of the government effort to push crop diversification out of rice. The current policy is for interest rates to follow market rates. Credit programs are along the concept of the Integrated Rural Financing Project of the Department of Agriculture. This is a credit facility for the farm household based on a whole **farm** budget for a multicrop/livestock enterprise.

POTENTIALS OF AND CONSTRAINTS TO DIVERSIFIED CROPPING IN RICE-BASED SYSTEMS

Crop diversification is not new in the Philippines. 'Technologies have been developed in line with the production of non-rice crops as alternatives to rice. The appropriate crop and its care after rice have been established for most of the regions of the country, particularly for the rain-fed cropping systems. In some irrigated areas, crop diversification has also been practiced.

While recognizing the need to produce more rice to keep pace with the demand, the production of non-rice crops offers opportunities for increasing the productivity of irrigation systems during the dry season. Despite these opportunities, the widespread adoption of irrigated crop diversification is not practiced in most irrigation systems in the country. This is possibly due to technical, institutional, or socioeconomic factors, or a combination of them.

Technical Issues

The technical issues related to diversified cropping in rice-based systems put emphasis on the difference between the physical characteristics and environmental preference of rice and non-rice crops. This **is** further complicated by the fact that most irrigation systems are designed, built and constructed mainly for rice. Thus, the complex relationship among the soil, climatic, hydrologic, biotic and agronomic properties found in the lowland rice environment has to be addressed to accommodate non-rice crops in rice-based areas. This can he broadly categorized into 1) crop-soil-water environment; 2) climatic pattern; and 3) technical and operational characteristics of existing irrigated rice systems.

Crop-soil-water environment. In crop diversification in irrigated rice areas the cropping pattern involves both rice and non-rice crops, usually rice in the wet season and non-rice in the dry season has to be considered. However, these two crops grow well in very contrasting environments. Non-rice crops grow best in aerated and well-drained soils, while rice requires puddled and flooded fields which need heavy textured soils to minimize water losses. The change from rice to non-rice and vice versa will therefore require some modifications in this environment.

Both the heavy soils and the puddling method of land preparation in most irrigation systems can compound the constraint to crop diversification. Hence, soil-water management practices and tillage methods to increase porosity of puddled soils are needed to complement main system water distribution strategies for dry season non-rice crops. These practices, however, should not result in too much increased water requirements by the following rice crop. Rice is still the major crop for the wet season and in no case must requirements of lion-rice crops for water prevail over those of rice in increasing soil air porosity.

Although water-retentive clay soils generally dominate in most irrigated systems, soils with good internal drainage can also he found, sometimes to a considerable extent. For example, in the Laoag-Vintar River Irrigation System, about 35 percent of its service area of 2,377 ha is found highly suitable for irrigated diversified crops during the dry season, using soil type and topography as the main criteria.

Climatic pattern. The distribution and pattern of rainfall promote or constrain crop diversification in irrigated rice-based systems. Given the farmers' partiality to rice when water supply is adequate, they would grow rice rather than diversified crops in rice-based systems under agroclimatic regimes which either have evenly distributed rainfall, or are relatively wet throughout the year. Thus, in the Philippines, rice-rice pattern is expected in rainfall Types II (no dry season with very pronounced maximum rainfall from November to January) and IV (rainfall more or less evenly distributed throughout the year).

On the other hand, depending on the type of soil irrigated, rice farmers under a unimodal rainfall distribution, as in rainfall Type I (two pronounced seasons: dry from November to April and wet during the rest of the year), will either shift from rice to non-rice, or let their lands lie idle during the dry months when water supply in the system has become inadequate for another crop of rice, In so far as soil and climate are concerned, crop diversification has high potential in irrigated rice systems with well-drained soils under unimodal rainfall distribution.

Characteristics of existing irrigated rice systems. Most irrigated rice systems lack physical control facilities and structures to effect rotational or intermittent irrigation for diversified cropping. Irrigation systems designed, built, and constructed mainly for rice, which requires continuous irrigation, generally have a fewer control structures.

On-farm facilities to produce the level of control needed for appropriate diversified crop irrigation technique are also lacking. In addition, irrigation operations involved in diversified cropping i.e., rotation, are more intensive and require more personnel than the present practice of continuous irrigation.

Institutional Issues

Institutional factors deal mostly with the interaction among the government, the non-government organizations, and the farmers. This relationship can be assessed in terms of the linkage between research andextension, support toresearch anddevelopment, role of financial institutions, and other support services.

The linkage between research and extensior is relatively weak. This is based on the slow adoption **of** technologies developed through research and development. The existence of a large number of government and semi-government agencies dealing with specific aspects of agricultural production has also hampered an integrated approach to rural development. This constraint may even have a stronger manifestation on the adopticn of crop diversification technologies because of their more complex nature as compared with those for single commodities.

Certain changes have been initiated by various institutions which may promote the potentials of crop diversification. The stronger linkage among related agencies tackling specific aspects of agricultural production i.e., the Philippine Coconut Authority, Fertilizer, and Pesticide Authority, the National Food Authority, Philippine Cotton 'Corporation etc., has paved the way for a more integrated approach. Measures have also been taken to facilitate people participation in the rural areas. The needed hottom-up planning has heen initiated. Consultations with the private sector through the local agricultural and fishery councils including farmers have been conducted at the regional, provincial, and municipal levels.

Government support to research and development in agriculture and natural resources is one of the lowest among the developing countries. Although government expenditures have steadily increased through the years, the level remained at barely 0.07 percent of the total Gross National Product. Other Asian countries spend on the average.0.3 percent to 0.8 percent of the Gross Value Added (GVA) while developed countries spend more than 1.5 percent of it.

Funding for research and extension is projected to increase from the present 0.2 percent of the GVA in agriculture to 1 percent of the GVA by 1992. The additional investment calls for a stronger linkage between research andextension. This will be accomplished by decentralizing research and extension systems taking into consideration the needs, demands, and potentials of the farmers. Moreover, the private sector will he encouraged to conduct their own research. In relation to this, crop diversification is one of the areas that will he looked at.

The government, under the old regime, had pushed for the establishment of agricultural cooperatives that basically aimed to improve market opportunities by increasing the fanners' bargaining power. Small farmers on their own, find it difficult to exhaust market opportunities available considering aspects like the cost of information, bargaining power, etc. Economies of scale in a number of these aspects may he realized if these small farmers would act as one. This also saves a lot of time and other resources from the government side since services can he delivered to groups of farmers instead of individuals. However, the sector has yet **to** see a successful cooperative that has indeed helped increase the income of these small fanners.

Where large welfare gains are expected, hut for one reason or another, no private individual embarks on the conduct of such an activity, the government should be ready to react. For example, if diversified cropping will be adopted, the government through the Department of Agriculture, should provide the appropriate support systems necessary to make the program a success. If small farmers are to engage in such **an** activity, there must he a way by which their activities can he synchronized with national plans. For example, the export market, especially for non-traditional exports that are products of diversified cropping systems can possibly he tapped. This is a good opportunity for the local farmer, but he alone cannot accomplish such a task. The government in this case should coordinate activities to maximize the **gains** from adopting a crop diversification program. Appropriate policies must he designed to strengthen the linkage between the farmers and the government.

Economic Issues

Several research studies have already been conducted on the alternatives of dry season crops. Among the possible dry-season crops identified to have economic potentials are onions, garlic, corn, and mungbean. However, it should be noted that, given a particular market condition, the profitability of growing these crops depends largely on the location of farms, i.e., in consideration of weather and soil conditions. plus the availability of water.

One of the main constraints toward full adoption of diversified cropping is the attitude of the farmer towards what he perceives as risk. Because of the perceived uncertainty of market conditions which may affect the living condition of the farm family, the fanner becomes extremely risk-averse and is therefore unable to adopt a farming practice entirely new to him. There is, therefore, a tendency to stick to his old reliable monocrop techniques as long as this practice has not failed to deliver the family's food requirements — regardless of the magnitude of potential gains from a new farming technique. All these result only from information asymmetry. Since this is basically an imagined rather than a real/institutional constraint, it would not be difficult to change this practice. An appropriate and effective extension service would be enough to remove the asymmetry.

Another possible constraint that could be considered is labor availability. However, if one looks at diversified cropping in the context only of dry season irrigated farms, then the constraint may not really be binding. Labor is usually abundant in the second crop because of the seasonal migrant workers from rain-fed areas. It must be noted, however, that if labor-intensive crops like onions and garlic are planted on a large-scale basis, labor may eventually prove to be a constraint.

Considering the high cost of inputs to the production of alternative crops like onions, garlic and corn, capital may in fact be a constraint towards the adoption of diversified cropping. However, with the government's credit programs such as the Consolidated Agricultural Loan Fund, fanners can avail of funds needed to finance their production activities — that is, at market-determined interest rates.

The problem of the lack of an efficient marketing and other post-harvest systems that would ensure the transport of goods from the production centers to demand centers is indeed a constraint as far as the domestic market is concerned. For example, although corn production level is high in areas such as Mindanao, supply shortages are still experienced in the market. This is due to the inability to transport these grains, mainly attributable to the inefficiency of the domestic ships. This problem is aggravated by the fact that post-harvest technology is not really developed for non-grain products. The effect is seen in the highly fluctuating price of these products, a condition that is unfavorable to the farmers.

From the macropolicy perspective, the government is also providing incentives, through the Board of Investment, to undertake production activities that are in line with the current thrust. Direct production as well as post-production activities in selected commodities is encouragcd. The list of preferred areas of investments is summarized in the 1988 Investment Priorities Plan. Aniong the suitable crops for rice-based farms listed under this Plan are cotton, yellow corn, sorghum, and soybeans, i.e., for direct production purposes.

PROMISING IRRIGATION MANAGEMENT PRACTICES FOR DIVERSIFIED CROPPING

Preliminary results of studies undertaken by the International Irrigation Management Institute in collaboration with selected members of the National Research and Development Network, particularly the NIA, the Department of Agriculture, Mariano Marcos State University, Central Luzon State University, University of the Philippines at Los Banos, University of Southern Mindanao and Pampanga Agricultural College show some promising practices which can be related to crop diversification in irrigated areas. These findings could serve as bases for improving irrigation management for diversified cropping.

Irrigation Practices at the Farm Level

Studies of farm level irrigation methods and practices for several upland crops like corn, onioti, garlic, and mungbean grown after irrigated rice havt: shown that no major land *or* field transformation is necessary to irrigate the upland crops. **For** onion fields, whether they are raised bed *or* mulched, all the accessory ditches are made within the existing rice configuration. Results have also shown that border flooding with raised beds produce the optimum yield.

Furrow irrigation for corn has been found to be more effective in terms of water use and duration of irrigation than the traditional practice of basin flooding.

Irrigation Management at the System Level

In terms of irrigation management at the system level, the results of several studies indicated that there are practices that can serve **as** cases for amving at a set of guidelines which can be used in systems where irrigated crop diversification is **a** viable alternative in the dry season. The following practices are considered effective in irrigation management of upland crops in irrigated rice-based areas:

1) Planning with accurate records of river flows, rainfall, and canal discharges; better estimate of water demand considering soil properties and the condition of the irrigation facilities; use of parcellary maps;
2) Joint system management of NIA and the Irrigators' Association for water allocation and distribution through meetings; and
3) Implementation of rotational schedule.

Other Promising Approaches

There are other opportunities for improvement in order to prevent moisture deficits, assure reliable water supply and increase irrigated area in the national irrigation systems. They include, among others, the following.

Irrigation facilities restoration/modification. The majority of irrigation systems in the Philippines were designed to irrigate rice. Using these facilities for upland crops will entail some modification, especially the control structures and the canal capacities.

Facilities at the farm level like the farm ditches also need restoration or modification to attain a more effective irrigation of upland crops. A methodology for determining the optimum density of farm ditches and size of turnout service areas has been arrived at but still needs further verification.

Improvement in procedures and practices. The present practices and procedures being used by **NIA** are designed only for the irrigation of rice. Improvement or modification of these procedures will provide NIA with a set of guidelines to effectively irrigate both rice and non-rice or mixed cropping in systems where irrigated diversified cropping is viable. This improvement concerns the aspects of the existing planning, implementation, monitoring and evaluation procedures.

As a tool in identifying parts of systems suitable for irrigated non-rice crop production, a computer-aided mapping program can be used. This will improve the planning procedure in allocating water for rice and non-rice crop areas.

In the determination of water availability from both river and rainfall sources, a more frequent assessment of river flows and a more powerful rainfall probability method are suggested. If a weekly assessment is used in predicting rainfall, the incomplete gamma function analysis is being recommended which is more accurate than the 5-year moving average, provided *20* years of record are available.

Regular yearly inventory of irrigation facilities will provide an accurate assessment of the capability of the system of providing timely and adecuate water to the farms.

RESEARCH GAPS AND PROBLEMS

There is still a dearth of information and/or technologies pertaining to the management of irrigation systems with non-rice crops. Most studies are on rain-fed rice-based cropping systems with the focus on how to suit cropping patterns to rainfall dislribution. Therefore, research should focus more on irrigation systems in which manipulations, practices, and technologies can be applied with the least cost and high efficiency to an alternate rice and non-rice cropping pattern.

New water application methods or modifications of the existing ones must be tried at the farm level. Small successful irrigation units or systems must be studied closely regarding their merits for possible transfer of the technology to the other areas.

Under the Accelerated Agricultural Production Project, NIA has identified a number of operational problems for priority research for three regions in the country. The identified research areas emphasize documentation, evaluation, and improvement of existing procedures NIA is presently following. These include studies on: 1) the implementation of the Farmer Irrigators Organization Program, 2) sustaining irrigator's associations in communal and national systems, 3) enhancing training materials, training staff, and training programs, 4) improving the performance of jointly managed national irrigation systems, 5) improving procedures for designing communal irrigation systems, and 6) strengthening the operations and functions of the provincial irrigation offices. All of these can also be studied from the point of view of crop diversification.

A crop zonification scheme may have merit in identifying the specific areas of the country where a particular crop exhibits a comparative advantage. Once the comparative advantage has been identified, the appropriate support services can be provided for. The Department of Agriculture has already initiated activities in this direction and some research efforts are needed to identify what support systems are necessary and appropriate in a specific region. For example, it has been established that the south has a comparative advantage in corn production. In this case, the support needed in that area constitutes grain drying and storage facilities, farm-to-market roads and efficient inter-island vessels.

Since most of the dry season crops suitable for rice-based farming are labor-intensive. smaller areas are usually planted. Labor-saving tools and implements are needed to take care of the possible problems of labor shortage, should non-rice crops be produced using the whole farm area. For example, the labor requirement of onion on a per hectare basis is four times that of rice. If all rice-based irrigated farms plant onion as a second crop, then labor availability may prove to be a constraint. However, if this has been anticipated prior to expansion of area planted, i.e., through the development of labor-saving tools used in onion farming, then labor will not be too much of a constraint.

Extension services must be strengthened in order to solve the problem caused by information asymmetry. Extension programs must be designed to support the government's thrust of increasing farm income. They should therefore include services related to post-harvest technology, marketing, and other job opportunities, in addition to enhancing of productivity which has been the main focus of the past extension programs.

There is also a need to determine where and how exactly the private sector can come into the picture in order to give the diversification program its needed push. The Department of Agriculture now has a program to encourage private sector participation in coming up with viable agribusiness enterprises that would increase farmers' income. However, there is a need to spell out the projects that would indeed be viable for the domestic farmers. A simple benefit-cost analysis for several business propositions may as well do the job of giving the small farmers an idea of the opportunities available to them.

The issue on the management cost involved in diversified cropping in irrigated rice-based systems needs to be addressed. It has been said that there is an added cost to managing the irrigation system for non-rice crops considering that a more stringent control of the limited water supply is needed. However, this is just an assumption, with no concrete basis yet. Quantifying this cost will be helpful in assessing the productivity of irrigating non-rice crops. Likewise, it will provide a better understanding of the implications of diversified cropping in irrigated areas on the Irrigation Service Fee to be charged for non-rice crops and the overall program of the government on crop diversification.

STRATEGIES FOR CONDUCTING RESEARCH

The need for a more coordinated and relevant research and development activities led to the creation of the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development in 1972. The council, in the past one and a half decades has provided a strong sense of purpose and direction so that research in the Philippines today is focused on development, through a more coordinated and relevant research and development planning, implementation, monitoring and evaluation.

Planning and Priority Setting

Planning and priority setting have been both top-down and bottom-up (Figure II.6.1). The national goals and policies are embodied in the medium-tern Philippine development plan, the formulation of which is coordinated by the National Economic and Development Authority. These are further spelled out by the Department of Agriculture, the Department of Environment and Natural Resources and the Department of Science and Techno ogy for the agriculture, forestry and natural resources, and science and technology sectors, respectively. At the local level, the needs and opportunities are identified through the farming systems' approach. These are then analyzed in relation to the national and secloral goals and then consolidated into the research and development program for agriculture and natural resources.

Figure 11.6.1. Priority setting for Research & Development in Agriculture, Forestry and Natural Resources (1988-1992).

NATIONAL DEVELOPMENT GOALS
(National Economic and Development Authority)

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SECTORAL GOALS

- Agriculture (Department of Agriculture)
- Forestry and Natural Resources (Department of Environment and Natural Resources)
- Science and Technology (Department of Science and Technology)

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NATIONAL RESEARCH AND DEVELOPMENT PROGRAM

(NARS-Philippine Council for Agriculture, Forestry and Natural Resources Research and Development)

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REGIONAL RESEARCH & DEVELOPMENT ACTIVITIES
(Members of NARS, Regional Integrated Agricultural Research System)

↑

PROVINCIAL PLANS

The farming systems' approach features a bottom-up procedure in planning and implementation and emphasizes self-reliance and efficiency in the use of agricultural resources. It enhances a multiagency and multisectoral participation. The farmer and his household are always involved in all phases of technology development from the identification of gaps and needs up to the design, implementation and evaluation of activities that address the identified problems and concerns.

Implementation

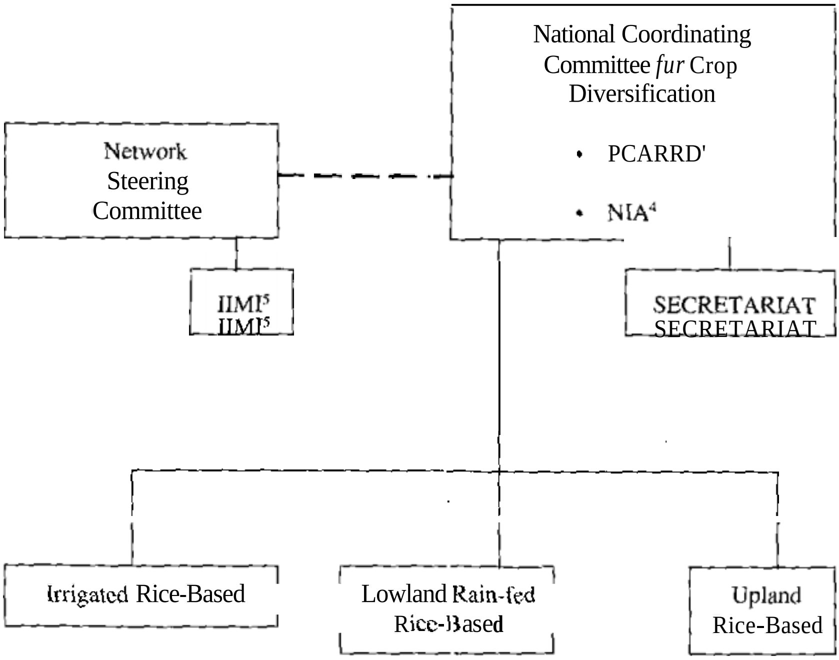
The implementation of the research and development programs and projects is conducted by the members of the National Research and Development Network, which is composed primarily of the state colleges and universities, the Department of Agriculture and the Department of Environment and Natural Resources research stations, and other agencies like NIA. The stale colleges and universities play a major role in the process of providing technological support for agricultural development. They have the scientific manpower strength while the Department of Agriculture and NIA have the country's better equipped field stations. A stronger collaboration between the Department of Agriculture and NIA is necessary, especially for studies on crop diversification. While the more basic and sophisticated researches are usually conducted by the universities and colleges, the more applied experiments are conducted by the Department of Agriculture through the Regional Integrated Agricultural Research System which integrates agricultural research in crops, livestock, soils, fishery and socio-economics at the regional level. It conducts adaptation and verification trials in farmers' fields under existing farm conditions. Today, the network has 92 provincial technology verification sites where improvements in the existing cropping patterns of farmers are being done. These trials are replicated across several farms and conducted by extension workers who provide a direct link between the Department of Agriculture and the farmers.

Researches Under the Network

Research projects that will be conducted under the umbrella of the proposed network may be done by NIA, the Department of Agriculture and/or the state colleges and universities in the National Research Development Network. As mentioned earlier, a stronger linkage and coordination particularly between NIA and the Department of Agriculture will be most useful. Support may come from foreign donors through the assistance of IIMI with possible counterpart funding from the government.

Review and evaluation will follow the mechanism set by the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development and the Bureau of Agricultural Research. While the Philippine Council for Agriculture,Forestry and Natural Resources Research and Development coordinates all researches at the national level, the Bureau of Agricultural Research does it for the Department of Agriculture with a strengthened regional arm, the Regional Integrated Agricultural Research System. It is the intenlion of both offices to see to it that research results filter down and be utilized by the target users.

Figure II.6.2. Proposed linkage of the Philippines with the network on crop diversification in irrigated rice-based systems.



[1] National Economic and Development Authority

[2] Philippine Council for Agriculture, Forestry and Aatural Resources Research and Development

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CHAPTER 7

Irrigation Management for Diversified Cropping in Rice-Based Systems in Sri Lanka

Jayantha Jayewardene

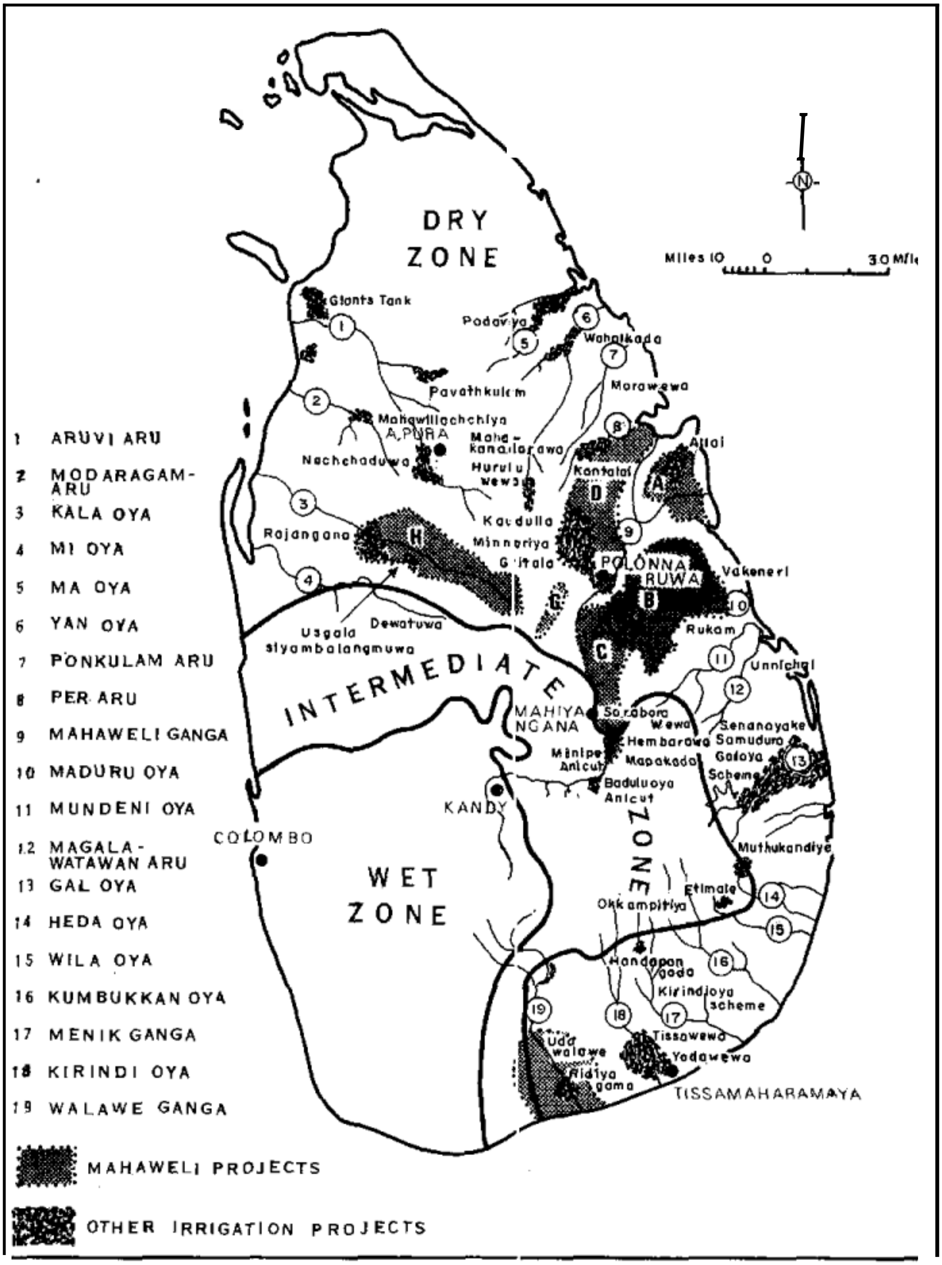
BACKGROUND

THE MOST COMMON argument in favor of diversified cropping in rice-based agricultural systems is the achievement of national rice self-sufficiency targets and the implications of a domestic surplus situation (IIMI, 1987). The recent emphasis on crop diversification in Sri Lanka was also brought about by similar reasoning. **A** study undertaken by the Ministry of Finance and Planning (1984a) concluded that "Sri Lanka will probably achieve sustainable rice self-sufficiency within the next five years" (i.e., by 1989). Further, it was also concluded that "Sri Lanka does not have exportable quantities of varieties of exquisite quality at the correct prices to match foreign demand." Hence, the optimum agricultural strategy for the future appeared to be the diversification of cropping in the irrigated well-drained lands in Sri Lanka's Dry Zone.

> The optimum means of obviating potential ric: surpluses is through a program favoring increased rice consumption and a simultaneous diversification of production in the major irrigation schemes. These schemes facilitated the rapid breakthrough in rice production. On well drained (sic) soils of these schemes, paddy (sic) production is not the most economic use of the land, and its production will have to be discouraged. The extent of these lands is estimdted at about 150,000 acres and can be advantageously used for the cultivation of sugar cane, chilies, commercial vegetables and bananas in the *yala* (dry) season (Ministry **of** Finance and Planning, 1984b).

The above policy recommendation was followed **up** with two studies directed by the Ministry of Agriculture. One was the feasibility study of a project for the promotion of "Minor Export Crop Cultivation" in the mid-Country. The other was an action plan for the production of coarse grains (maize), oilseeds (soybean, groundnut, and sesame), pulses (green gram, black gram, and cowpea) andcondiments (chiliand onion) under irrigated as well as rain-fed conditions. Therecommendations of the latter (Ministry of Agricultural Development and Research, 1987)are of direct relevance to the subject under discussion. This study concluded that irrigated areas presented no restriction with regard to the tvpe of crops which could be grown, especially during the yala season. However, apart from potatoes and onions, the domestic demand was to he limited to permit significant expansion in the area cultivated. In other words, the present domestic demand was more or less satisfied with the current levels of production. Hence, the need for appropriate pricing, research, and extension in order to make Sri Lankan exports of these crops competitive in the world market was stressed.

In view of IIMI's observation that in its research sites in Indonesia, the Philippines and Sri Lanka irrigation systems properly designed for supplementary irrigation for wet season rice do have enough canal capacity for non-rice crops (IIMI, 1987), the above statement that "irrigated areas presented no restriction with regard to the type of crops which could he grown, especially during the yala dry season" appears to he justified. The recent experience in the successful large-scale cultivation of chilies in Mahaweli System H (Figure 11.7.1) lends support to the above viewpoint.



The national agricultural diversification policy was framed to counter the adverse effects of a potential domestic rice surplus. In other words, due to the inability to enter the international market, overproduction will lead to an oversupply of rice and cepressed prices. This is detrimental to the producers who constitute a major segment of the population. The likelihood of a rice surplus in Sri Lanka in the near future is doubtful considering the rice production trend since 1984. The slow rate at which new lands are developed for rice production, the unfavorable weather conditions and ethnic disturbances have contributed to a slowing down of the trend in achieving self-sufficiency. Given the present rate of population increase and the increasing consumption of rice with increasing incomes of the population, recent studies have shown that even with the addition of new lands under the Mahaweli Project, Sri Lanka will he an importer of rice in the year 2000 (Japan International Cooperation Agency. 1988).

The interest of the Mahaweli Authority, the agency in charge of the largest multipurpose water resources projecl in Sri Lanka, in diversification lo non-rice crops was created for different but equally or more important reasons. It has been observed that real profits from rice cultivation have been declining over the years in spite of increasing yields mainly due to increasing costs of production (Attanayake and Wijayaratne, 1988; Wanigaratna, 1987). This has important effects on the economic status of the farmers as well as on the national economy. When farm incomes are low, the consumption demand does not expand and therefore, the domestic market remains small and undeveloped. Low incomes also result in low savings and therefore, low rates of investment. Hence, a self-sustained process of growth cannot he initiated. The expansion of the rice growing area and the increase in the number of growers will result in an increase in subsistence level households in the economy.

It has also been observed that rice cultivation offers fewer backward and forward linkage effects which can generate further value added off the farm relative to cash crops (Senanayake, 1987).

To maximize economic returns from the physical and human resources of project areas, the Mahaweli Authority launched an Employment, Investment and Enterprise Development Strategy in late 1986. A major focus of this strategy is to diversify agriculture into the cultivation of cash crops for the domestic and export markets and to develop related processing, packaging and other industries. The types of crops which are now receiving the attention of the Mahawcli Authority are different from those considered by the Ministries of Agriculture, and Finance and Planning. While these national bodies are emphasizing the cultivation of traditional non-rice crops, the Mahaweli Authority favors export-oriented crops. A'recent study suggests that considering the comparative advantage of Sri Lanka in terms of climate (the ability to grow a wide range of crops throughout the year), location (equidistance to markets in Western Europe and the Pacific Rim), and low cost of labor, the best crops are grapes, strawberries, asparagus, pineapple, bananas, mangoes and melons (Daines and Parwar, 1988). Careful analyses have shown that the technology was already available to grow these crops in the Mahaweli areas. However, the lack of year-round availability of irrigation water was identified as a critical constraint. Although some of these crops could he grown seasonally to coincide with the present waler issue regime for rice, such seasonal cultivation negates the comparative advantage in terms of the ability to penetrate international markets with production during the off-season.

The accommodation of such irrigation needs within the available infrastructure poses a major challenge to the irrigation specialists. The research undertaken so far in diversification of rice-based systems in Sri Lanka is limited to the production of traditional subsidiary food crops (coarse grains, legumes, and pulses) during the yala season. Although the importance of these crops should not he discounted, this approach severely restricts the range of crops which can he economically cultivated. Apart from chilies, potatoes, and onions, other crops such as legumes, coarse grains, etc.

have a very limited domestic market. Their export can only become feasible if unit costs of production can be substantially reduced while improving their quality. At present, they are also financially less remunerative than rice, and are therefore not likely to be accepted by the farmers in irrigation schemes. The types of crops the Mahaweli Authority is interested in are highly profitable but require higher inputs and more labor. Since these are aimed for the export market, their processing, packaging, and marketing offer significant downstream linkages for the generation of income.

COUNTRY DETAILS

General

Sri Lanka **is** a tropical island situated between the latitudes $5'' \, 55'$, $9^{0} \, 51'$ North and longitudes $79^{0} \, 41'$, $81^{0} \, 54'$ East. It has a total land area of 65,610 square kilometers (sq km) of which 958 sq km are occupied by large inland waters. The population in 1987 was **16.4** million (midyear estimation) with an average annual rate of population increase at 2.8 percent. About 75 percent of the population live in the rural areas and are engaged mainly in agriculture and related activities. The economy is mainly dependent on agriculture as the country's main resources are land and water. In 1987, the agricultural sector accounted for 23.6 percent of the gross domestic product. Tea, rubber, and coconut are the country's major export crops.

Physiography and Climate

There are three different physiographic regions within the island which are distinguished on the basis of elevation. The lowlands with an elevation ranging from sea level to 305 meters above mean sea level (MSL) is the first peneplain. It makes **up** four-fifths of the country's land area. The midlands and the highlands (which are the second and third peneplains) occupy a fifth of the land area and lie in the south central part of the island. This is the mountainous area over 300 meters in elevation. The 6.56 million hectares of the land in Sri Lanka fall into three climate zones; **a** Wet Zone of 1.53 million hectares in the southwest quadrant, **a** Dry Zone of 4.16 million hectares comprising the hulk of the island, in the north, east, northwest and southeast sector and an Intermediate Zone of 0.84 million hectares sandwiched between the two (See Figure II.7.1).

The annual precipitation over the island follows a distinctly bimodal pattern receiving rainfall from the northeast monsoon (October-January) and the southwest monsoon (May-September).

Topography plays a major role in determining the rainfall distribution. The entire island benefits from the northeast monsoon. The mountains intercept the southwest monsoon and as a result the highlands and the southwest portion of the country receive 1900-5000 millimeters (mm) of rain per year. This is the Wet Zone. Rainfall probability data show that in the Wet Zone, rainfall is adequate and sufficiently reliable to grow crops during both seasons.

The remaining 75 percent of the country comprising lowlands, to the north and east, benefit little from the southwest monsoon and receives 890-1903 mm rainfall per annum. This area is divided into the Dry and Intermediate Zones. In the Dry Zone, the bulk of the rainfall occurs during the north-east monsoon. In the Dry and Intermediate Zones there is adequate rain in the maha (wet) season (October-March) for crop production under rain-fed conditions. The yala season (April-September) permits the cultivation of only short-season, drought-resistant crops.

Temperature and Humidity

The mean temperature varies from 70-89^0 **F.** The difference between the mean temperature of the hottest and the coldest month rarely exceeds 10^0 **F.** Temperature is not a limiting factor in crop production at higher elevations except where frosts occur for short durations. Humidity in the island is high and variable. The average relative humidity s between 70 and 80 percent. The relative humidity in the coastal regions **is** slightly higher than in the lowland stations.

Water Resources

Due to the relatively high total annual rainfall, rainfall intensities, and runoff, conditions are favorable for surface water storage for irrigation purposes. The potential for surface water storage for irrigation has long been recognized **and** a large number of reservoirs or tank irrigation systems have been in existence for over 2000 years. River diversion schemes have been undertaken. The groundwater resources in the northwest of the Dry Zone are the major potential sources of imgation water and, with the use of tube wells in this area, a fairly large extent of laud is being brought under cropping.

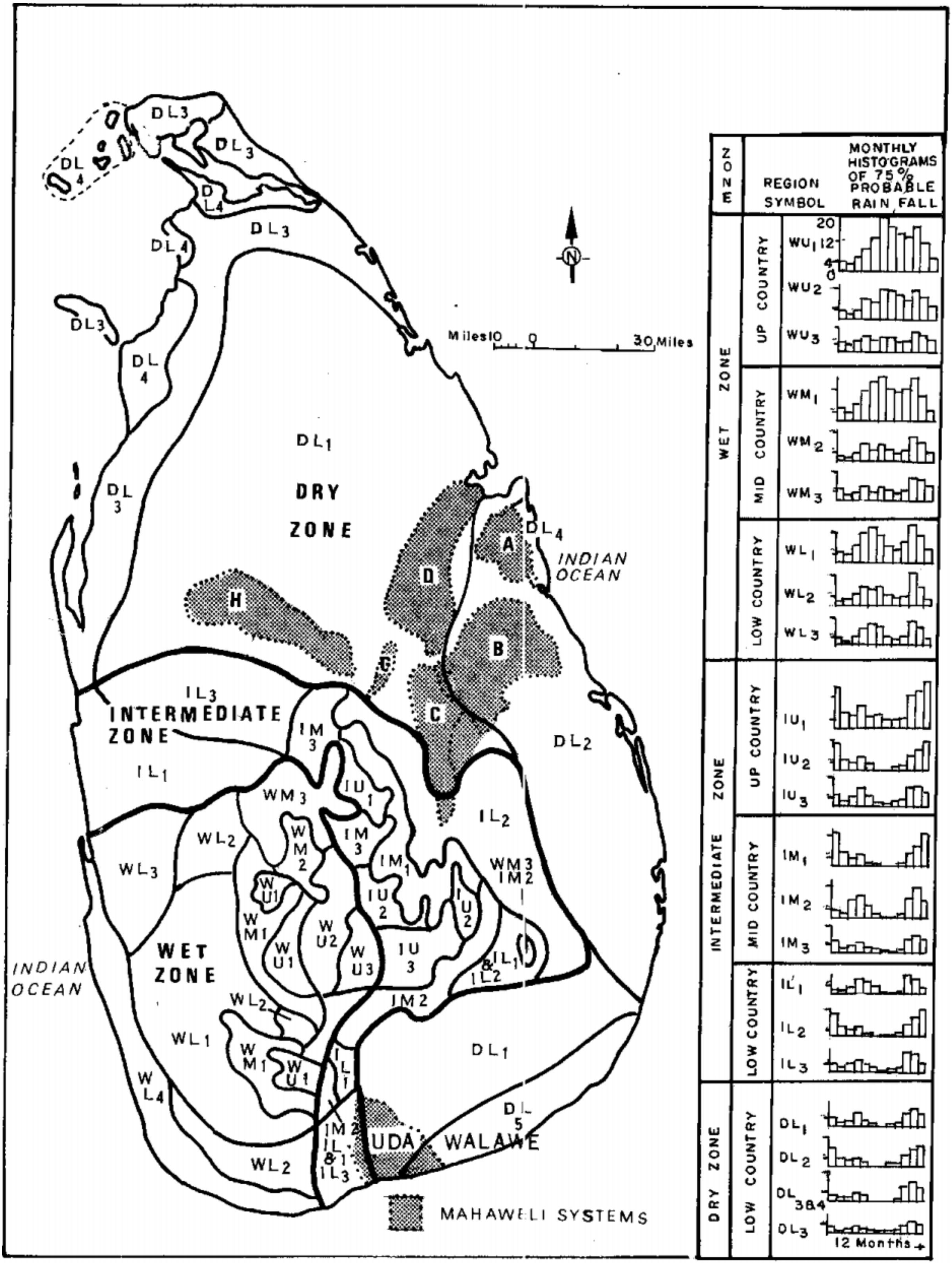
Agro-Ecological Regions

The country is divided into three climatic zones: Wet, Dry and Intermediate. These zones are demarcated on the basis of annual rainfall as given be ow:

Dry Zone	–	below 1905 mm (75 inches)
Intermediate Zone	–	1905 - 2540 mm (75-100 inches)
Wet Zone	–	above 2540 mm (100 inches)

The three climatic zones are further subdivided by a titude and landform into seven major agro-ecological zones. Both wet and intermediate zones range from the low country (up to 305 meters above **MSL),** the mid country (305 - 915 meters above MSL) and the up country (greater than 915 meters above **MSL).** The entire Dry Zone **is** in the low country (see Figure II.7.2).

Figure II.7.2. Agroecological **regions of** *Sri Lunka.*



Soils

The most important and widespread soil orders found in the country are as follows:

Alfisols	– Reddish brown earths, non-calcic brown soils, some low humic gleys, solonetsic soils.
Ultisols	– Reddish brown latosolic soils, different groups of red yellow podzolic soils.
Oxisols	– Red yellow latosols.
Histosols	– Bog and half bog soils.
Vertisols	– Grumosols.
Entisols	– Sandy regosols, alluvial soils.

Dry Zone Soils

The reddish brown earths in association with the low humic gley soils occupy about **30** percent of the total land area in the north and south dry zones. The second most important soil group is alluvial soils and it accounts for about 0.41 million hectares (1.0 million acres) of land. The red yellow **latosols,** non-calcic brown soils, sandy regosols, alkaline, saline, and grumosols also occur in the Dry Zone.

Intermediate Zone Soils

The soils of the intermediate zone show the transition from the Dry Zone to the Wet Zone soils. The northern part **of** the Intermediate Zone belongs to the Dry Zone and has the typical reddish brown earth and low humic gley soils. The southern part is dominated by the red yellow podzolic soils, typical of the Wet Zone, in association with low humic gley soils in valley bottoms. Apart from these soils, the immature brown loams, reddish brown latosolic, can also he seen in the Intermediate Zone.

Wet Zone Soils

Red yellow podzolic are the dominant soil groups in the Wet Zone covering about 1.42 million hectares (3.5 million acres). Plantation crops (tea, rubber, and coconut) and spice crops are grown in these soils. It also covers a substantial part of the beter-drained rice fields and home gardens of the Wet Zone. Along the southwest coast there are bog soils and sandy regosols.

CROP PRODUCTION IN THE DRY ZONE IRRIGATED LANDS

In Sri Lanka, most of the major irrigation schemes 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 Zone whereas other climatic factors have a mixed effect.

The precipitation having a bimodal pattern influences the crop production, mostly in the Dry Zone. The major rainy season, maha, receives around 950.5 mm and the minor rainy season, yala, receives around 360.0 mm. The yala rains are very erratic and lung dry spells are common. During the latter part of the yala season, wind velocity increases and the rainfall is very low; thus, the cultivationof rain-fedcrops becomes virtually impossible. Therefore, any type of cultivationduring the yala season needs irrigation, whether within rice lands or highlands.

Diversification during the maha season is somewhat difficult owing to the conditions prevalent in the Dry Zone during that period. The cloudy skies, very wet soils, and high rainfall create an unfavorable atmosphere for field crops unless they are established before the high rainfall period and after necessary drainage facilities have been provided. Since rice can accommodate standing water, it survives easily under those conditions.

The yala season is comparatively more favorable: for non-rice crops which can withstand water stress to agreater extent than rice. Rice needs irrigat on at frequent intervals under suchconditions. The yield of rice is usually low in yala and the risk of crop loss is higher. Hence, the cultivation of non-rice crops is more economical. Furthermore, this allows a greater area of land to be cultivated than when rice is cultivated with the scarce irrigation water. However, such crops need protection from the sudden high-intensity rains which may occur during yala; this need could be satisfied by providing the necessary drainage according to the land class or in general, the soil type. Drainage requirements are greater in poorly drained soils.

In addition, the continuous moderate winds, which have a dessicating effect is another physical factor affecting crop growth in yala. This, in effect, increases evapotranspiration which makes it necessary for the crop to have an efficient root system fur effective moisture extraction.

Theconditionsduring the yalaseason are very favorable for biomass production ifprovided with high amounts of nutrients and adequate water. Yet the major constraints in this season are the extensive and proliferating weedgrowth which smothers the crop if uncontrolled and the associated pests and diseases. The soils of the Dry Zone are abundant with disease-carrying organisms as well as voracious pests. Yet, equally prevalent are the symbiotic organisms which increase the yields, especially of leguminous crops.

IRRIGATION PROBLEMS ASSOCIATED WITH CROP DIVERSIFICATION

Seasonal Cash Crops

The soil is broadly categorized as:

a) ill-drained – not suitable for upland crops
b) moderately-drained – upland crops may be grown with the risk of being waterlogged. Additional drainage arrangements necessary.
c) well-drained – suitable for upland crops.

As each turnout area in the Mahaweli and most other irrigation systems generally consists of the above three categories of soil, both upland crops and rice will have to be cultivated simultaneously in a turnout. Since the irrigation frequencies for the different crops differ from each other, problems arise in the preparation of irrigation rotational schedules within the turnout and along the field channel.

When upland crops are cultivated in moderately drained soils, special care has to be taken to control the water table at a sufficient depth. Seepage from the well-drained areas could have damaging effects. If the well-drained soils are all cultivated with upland crops, then there is no problem.

Upland crops can be grown only during the yala season, as the heavy rainfall during the maha season could damage crops due to waterlogging. Therefore, the best method of land preparation recommended for upland crops is ridge and furrow, so that the excess rain water can be drained out fast. However, the same land has to be prepared as bench terraces during the maha season for rice cultivation. These changes in the method of land preparation cause a lot of problems in implementation. Research is necessary on upland cropping in maha.

As the different types of upland crops have different durations, either the Land will have to be fallowed during some period of the cultivation season, (e.g., cowpea) or water has to be issued for a longer period than for rice (e.g., chili). This causes greater conveyance losses. Hence, allocation of laud for upland crops has to be on a contiguous area basis.

Perennial Crops

Generally, perennial crops will have greater root zone depths. Hence, the water storage capacity of soils is higher and the irrigation frequency intervals are longer. Conveyance losses and direct surface runoff losses will be less.

As the water requirement for land preparation is less because dry plowing can be done and such activities can be staggered, required canal capacities will be less than that of rice irrigation systems.

Water has to be provided during the whole year except during the rainy season. This poses the problem of finding a canal closure period to do maintenance work. If the areas under perennial crops are confined to a particular locality, the relevant canals can be maintained during the closed period in the rainy season. However, if a part of the irrigable area is under cash crops, it would be difficult to find suitable closed periods for the maintenance of the main canal. These problems can he minimized if the areas selected for perennial crops are in the upper reaches of the main canal.

Operational and conveyance losses will be less when only a part of the irrigable area is issued with irrigation water. This situation too can he redressed somewhat if the perennial crops are confined to the upper reaches of the main canal.

OTHER RELEVANT ISSUES

Pricing

Any discussions on crop diversification will invariably touch on the prices received for different crops. It has often been pointed out that an agronomic optimum in crop cultivation can be obtained if the prices are attractive for specific crops. Hence. the frequent call for state intervention in the markets for price regulation, i.e., production subsidies. However, it is well known that developing economies cannot afford subsidies at significant levels over long periods due to the inability to generate the necessary resources from the other sectors of the economy. In addition, distortions resulting from subsidies may incur great efficiency losses. Perhaps, the most realistic approach is to look for crops that have attractive markets and then to try and improve on profits by enhancing their productivity and thus lowering unit costs. Another option is to tie up processing activities with production and, therefore, increase the demand for them on the one hand, while increasing their total value added on the other. Thus appropriate research has to be undertaken in areas such as marketing, post-harvest technology as well as varietal improvement for increased yields.

Production Organization

Most cash crops require working capital much higher than that for rice. Experience has shown that small farmers are often unable to generate sufficient resources for their cultivation. This is more critical in the case of perennial crops which have a long gestation period — often several years. It is also a fact that state agencies in developing countries have not been successful in the provision of rural credit and other inputs and services at adequate levels. Hence, it is imperative to undertake studies on alternative forms of production management to cope with the special need of non-rice crops. There is a range of group production models that need to be tested and adapted to particular natural-sociopolitical environments.

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CHAPTER 8

Irrigation Management for Diversified Cropping in Rice-Based Systems in Thailand

Nukool Thongthawee, Siripong Hungsperug, and Prasaert Kanoksing

INTRODUCTION

OVER THE PAST two decades, Thailand's rice has become an important source of foreign exchange. In 1985, exports rose to 4.6 million tons. However, as many countries in the region became self-sufficient in rice, prices slumped and Thailand experienced difficulties in disposing of its surplus production. This resulted in the low farmgate price of rice of Baht 2,000/ton in 1986.

This development has prompted the Ministry of Agriculture and Cooperatives to formulate a program to increase average yield, improve the quality of rice for export, reduce the agricultural inputs, and use water more efficiently in certain rice-priority areas. In other more favorably located areas, with regard to export harbors or consumption centers, crop diversification programs are to be initiated. The farmers will switch part of their production to other cash crops for the domestic and export market. The study area on the west hankofthe Chao Phya River was designated a priority area for this type of development in crop diversification.

In 1986, the Ministry of Agriculture and Cooperatives proposed the program of promoting agro-industrial development in the irrigated areas to support the above policy. This proposal was in line with the current national economic and social development plan under the topic of "production development, marketing, and job promotion." The said program emphasizes involvement of the private sector in the production stage, in research and development, and in marketing. The results of this program will lead to the reduction of the area devoted to rice during the second cropping and to the increase in farmers' income owing to the introduction of high-valued cash crops. It is also expected that the program will help the farmers in taking risks in the world market. This is particularly true when the farmers do not have to depend on the value of one crop alone. Such a program was initiated at Nam Oon Project in Northeastern Thailand. It is also planned to expand such a pilot project to the other three regions of the country, the North, the Central Plains, and the Sooth.

GENERAL CHARACTERISTICS AND PERFORMANCE OF EXISTING SYSTEMS

In most cases, the system was primarily developed as a semicontrolled irrigation during the wet season. Surface runoff is the major source of water for irrigation. The use of groundwater is still limited. The system is of gravity type. There are large-, medium-, and small-scale irrigation schemes. Most of the water resources development for irrigation in Thailand has been carried out by the Royal Irrigation Department. The irrigated areas of large- to medium-scale projects, benefited areas of small-scale irrigation projects, dike and ditch projects, land consolidation and groundwater projects are shown in Table II.8.1.

Table II.8.1. Accumulated area in hectares (ha) of irrigation development projects implemented by the Royal Irrigation Department, 1981 to 1985.

Year	Irrigated area of large- to medium-scale projects	Benefited area of small-scale projects	Dike and ditch projects	Land consolidation projects		Groundwater irrigation projects
				Interior	Exterior	
1981	2,797,214	385,238	177,137	69,900	11,246	5.600
1982	2,855,632	464,541	1,177,209	81,870	21,109	5,600
1983	2,913,377	546,602	1,193,817	82,702	33,230	5,600
1984	3,024,078	634.502	1,215,197	82,702	52,741	6,758
1985	3,089,561	704,521	1,252,820	82,702	63,678	6,758

There are two levels of infrastructure in the system, main and on-farm systems. The main system conveys water from the source to the on-farm system by main and lateral canals. The on-farm system, comprising tertiary canal (farm ditch) and related structures, delivers water from the tertiary directly to the farms.

Traditionally, farm areas adjacent to supply points have priority to irrigation water. After their requirements are met, water is released to the other farms. This practice, however, has beeuchanged for improved systems in which each farm has direct access to the water in the tertiary. Rotational irrigation at the farm level is consequently applicable to and practiced in improved systems.

The performance of irrigation projects 'in Thailand varies considerably from one project to another and from region to region due to physical and nonphysical parameters such as the rainfall pattern; topography; potential for regulation of water resources; condition of infrastructures: qualifications and dedication of operations and maintenance staff; availability and dependability of water resources; access to the market; soil suitability; and farmers' participation.

In the North the farmers are blessed with good soil and favorable weather suitable for almost any kind of crop. Previous generations have taught them organized irrigation system management. These farmers form strong water users' groups and make the best use of the irrigation system. The efficiency of this system management is reportedly high, but has not yet been measured.

In the Central Plain, the Royal Irrigation Department has succeeded in establishing operating procedures for the main canal system in the Greater Chao Phya Irrigation Project. The overall project efficiency was 70-75 percent during the last few dry seasons owing to water reuse (return flow). On the northern Chao Phya area, efficiency was about 40-50 percent and below owing to the inequity of water received by areas close to and far from the main supply. In the southern Chao Phya area, efficiency averaged 80-90 percent because farmers operated the system efficiently to avoid paying the pumping cost.

In the Northeast. the soil is sandy and the topography is uneven. The overall project efficiency at Lam Pao Project during the dry-season cropping was only 15 percent computed from conveyance, tertiary distribution[1], and farm[2] efficiencies of 45.68, and 51 percent, respectively.

PRESENT STATUS OF CROP DIVERSIFICATION IN THAILAND

Thailand is already practicing diversified cropping patterns during the dry season. The major diversified crops include upland crops, vegetables, sugarcane, fruit trees, and perennial crops. In addition to the cultivation of these major diversified crops, fish farming is carried out during the dry season. Only about 9 percent (294,000 ha) of the total irrigated area (3,179,000 ha) is used for diversified cropping and fish farming (Table II.8.2). There is an increase, however, of the diversified cropping area and the area used for fish farming by 0.25 percent annually.

Table II.8.2. Irrigated areas and areas used in diversified cropping and fish farming, in thousand hectares, 1982-1985.

Area	Year			
	1982	1983	1984	1985
Irrigated area	3,002	3,158	3,160	3,179
Area used for diversified cropping	247	158	303	294
Percentage increase	**8.2**	8.4	9.6	9.2

Tables II.8.3, II.8.4, II.8.5, and 11.8.6 show the distribution of areas planted to diversified crops and areas used for fish fanning throughout Thailand. The Royal Irrigation Department manages Thailand's irrigation system by dividing the country into 12 regions. Regions 1-3 are in the North, 4-6 in the Northeast, 7-10 in the Central Plain, and 11-12 in the South. Upland crops are predominantly planted and account for 40 percent of the diversified cropping area.

[1] Conveyance, distribution, or farm ditch efficiency is the ratio of the volume of water flowing "out" and flowing "in".

[2] Farm efficiency **is** the ratio of the quantity of water placed in the root zone (rainfall deficit) and the total quantity under farmers' control.

Table II.8.3. Dry-season cultivated areas and areas used for fish farming of irrigaled projects, in hectares, 1982.

Region	Rice	Upland crops	Vegetables	Sugarcane	Fruit trees	Perennials	Fish ponds	Total
1	1,850	23,780	2,140	0	0	0	0	27,770
2	13,070	14,290	970	0	0	0	0	28,330
3	3,890	8,060	120	12,780	4	40	2	24,886
4	3,890	1,460	410	40	0	2	2	5,804
5	8,240	8,110	960	0	0	0	20	17,330
6	240	2,020	520	0	0	0	0	2,780
7	355,800	1,260	6,980	6,750	6,200	13,920	340	391,250
8	21,060	10,400	420	10	7,540	3,770	11,770	54,970
9	47,800	4,490	1,620	0	2	5	0	53,917
10	47,480	21,060	6,290	40,010	11,770	15,900	140	142,650
11	1,530	250	220	3	0	0	0	2,003
12	7,390	1,130	90	0	0	0	0	8,610
Total	512,240	96,300	20,740	59,593	25,516	33,637	12,274	760,300

Table II.8.4. Dry-season culrivated areas and areas used for fish farming of irrigated projects, in *hectares, 1983.*

Region	Rice	Upland crops	Vegetables	Sugarcane	Fruit trees	Perennials	Fish ponds	Total
1	3,380	23,040	2,440	0	0	0	0	28,860
2	7,490	11,020	480	540	170	10	7	19,717
3	12,510	11,110	110	16,220	4	40	2	39,996
4	11,710	3,920	760	5	0	0	0	16,395
5	4,440	5,400	830	1	0	0	20	10,691
6	3,530	2,220	360	0	0	0	0	6,110
7	348,710	1,740	6,880	5,450	14,210	1,180	1,440	379,610
8	119,970	19,070	340	20	10,790	3,730	6,870	160,790
9	49,310	4,110	440	0	650	250	40	54,800
10	39,510	26,330	6,020	33,890	16,830	15,860	1,920	140,360
11	690	230	330	0	1,420	770	0	3,440
12	5,570	780	120	0	0	0	0	6,470
Total	606.820	108.970	19.110	56,126	44,074	21,840	10,299	867,239

Table II.8.5. Dry-season cultivated areas and areas used for fish farming of irrigated projects, in hectares, 1984.

	10,150	4,320	760	10	0	0	0	15,240
5	1,300	9,490	730	0	2	0	20	11,542
6	5,460	8,240	1,130	0	0	0	0	14,830

Table II.8.6. Dry-season cultivated areas and areas used for fish farming of irrigated projects, in hectares 1985.

Region	Rice	Upland crops	Vegetables	Sugarcane	Fruit trees	Perennials	Fish ponds	Total
1	2,150	21,330	2,420	0	0	0	0	25,900
2	4,320	11,750	2,030	0	160	0	0	18,260
3	26,670	11,530	660	120	0	0	6	38,986
4	4,780	5,870	550	8	0	0	0	11,208
5	2,700	3,900	590	2	0	0	30	7,222
6	4,060	7,990	1,950	0	0	0	0	14,000
7	311,260	4,910	6,650	10,310	15,470	1,560	3,390	353,550
8	109,290	17,010	950	20	15,380	3,090	12,180	158,920
9	514,40	1,120	600	0	30	20	10,630	63,840
10	36,060	20,370	10,290	38,990	13,080	13,670	2,850	140,310
11	1,420	420	530	7	5,840	4,790	10	14.017
12	14,950	1,160	180	2	30	0	0	16,322
Total	569,100	107,360	27,400	49,459	56,990	23,130	29.096	862,535

PRESENT CROP POTENTIAL

The potential crops for diversification in Thailand are herbs, tobacco, sugar beet, mungbean, groundnut, sorghum, vegetables, fruit trees, and oichids. Herbs include various export-oriented crops such as cardamom, betel leaf, and turmeric. Crops like climbing lily, clove, and nutmeg are also promoted as import-substitution crops. Thailard imported tobacco worth 1,100 million Baht (*about 26 Baht = US$1.00*) in 1980 and 1,320 million Baht worth in 1983. At the same time Thailand exported Virginia, Burley, and Turkish tobacco valued at more than 1,500-2,500 million Baht. Tobacco, therefore, should be promoted.

Domestic demand for soybean is estimated at 600,000 tons against a local supply of only 200,000 tons. Each year Thailand exports about 200,000 ton: of mungbeans to other Asian countries. There is also potential for these crops in the European market.

The country's present annual earnings from exported fruit are about 1,000 million Baht. Durian, rambutan, pomelo, and longan are popular fruits overseas. Horticulture development, therefore, is promising.

Aquaculture has expanded considerably in the Central Plain, Chao Phraya West Bank, the East Coastal area and the Southern regions. The competition between fish farming and rice areas has resulted in conflicts between different interested groups. Presently, the Royal Irrigation Department can provide enough fresh water to ensure the promotion of such fish-farming business.

CONSTRAINTS TO CROP DIVERSIFICATION

Many factors influence the development of crop diversification. These factors may be structural or nonstructural. Suitable areas for diversified cropping are those with good soil which are suitable for upland crops, free from flooding, and with a dependable water supply. Better results can be obtained when the system is well managed and supported by dedicated and qualified operators and extension officers.

Taking into account the above in considering the suitability of various regions of the country for crop diversification, it seems that in each region there exist some suitability factors such as: a cool climate, lighter soil, existing areas suitable for dry-reason cropping without heavy investment for on-farm systems, experience of farmers in growing upland crops and vegetables, and good fanners' cooperation, in the North; a good access to market, better water control and management in the Chao Phraya Basin, suitable land in some areas of the Mae Klong Project, and good support from extension officers, in the Central Plain; and surplus storage water for dry-season cropping and good infrastructure, in the Northeast.

In order to grasp the whole picture of the constraints and the measures to relax these constraints, the factors affecting the development of crop diveisification are listed in Table II.8.7. There are other factors which are not directly related to irrigation but are major constraints to crop diversification. These include marketing and fanners' participation. At present, the Government provides some advice by issuing a publication listing the kinds of crops recommended for diversification. The Government also encourages the private sector to become involved in marketing.

Table II.8.7. *Constraints and promising irrigation management practices for relaxing constraints to diversified cropping.*

Constraints	Promising remedial measures
Unreliability of water distribution	Betler main system management, study of suitable control structures, intensive Royal Irrigation Department training
Soil suitability problem	Research on soil suitability, advice to fanners
Inadequate water storage	Study additional water storage, increase water use efficiency, advice on crops that require a limited amount of wafer
Inadequate existing infrastructure	Improvement of infrastructure to meet changed objectives, improve flexibility
Drainage problems	Improvement of drainage system, advise on crops that are waterlogging sensitive
Lack of good quality seeds	Research for better varieties
Cultural practiccs favoring rice cultivation	Increase fanners' confidence in irrigated crop diversification
Salinity problems	Good drainage and water control
Interference between activities	Water operationplanning,study on the various activities
On-farm development	Farmers' participation in cost sharing and maintenance program

ONGOING RESEARCH

At present, the Royal Irrigation Department's research and work related to irrigated crop diversification emphasizes improving the performance of the irrigation system with the objectives of adequate andtimely distribution of water to farmers. Possible measures include the improvement of system operation and infrastructure. These include **topics** like studies on the existing conditions of the system, operation, maintenance, training /information, main canal, lateral, and on-farm works.

The study suggested that hydraulic parameters presently used in the design are not appropriate with the actual maintenance currently being practiced under a limited budget. More precise canal regulation is required to ensure reliable supply of water. Improvement of the main canal by improving the telecommunication and the mechanization of the motorized gates was the first step taken. Furthermore, the installation of water-level sensors and transmission lines for localized or centralized control of the main check structures is being studied. In the Mae Klong Project, night-storage reservoirs were constructed along the lateral canal in order to pilot test the proper supply of water to non-rice crops. Also, double-gated orifices at the head of laterals were replaced by baffled distributors, There is no unique control structure, however, that will suit all locations. The topography, cooperation of fanners, and operaticn modes seem to dictate the choice of suitable equipment.

On the software side, the Royal Irrigation Department emphasized system operation and management. Computer programs were used to schedule and monitor the water delivery in the entire project areas such as in Nam Oon Project and other projects in the Northeast and in Mae Klong Project in the Central Plain. This facilitates water allocation by operations and maintenance staff. Improvement, however, is still needed in the accurate calibration of structures, modification of programs to take into account the time-lag, etc.

Concerning horticulture promotion, the Royal Irrigation Department has carried out intensive studies on the water requirement of orchard plantations. The water requirement for durian, rambutan, etc. is assessed and checked against field measurements and interviews with farmers. On-farm development in Thailand is primarily left to farmers who are capable of using the system of microirrigation in an effective manner. It should be noted that orchard development involves a major investment. This is, therefore, done on a permanent basis and not cultivated as a diversified crop in rice-based system.

Other aspects under study by the Ministry of Agriculture and Cooperatives and the Royal Irrigation Department are water-operation planning and the proper zoning of various activities such as fish farming and rice fields in adjacent areas. Environmental considerations need to be seriously looked into.

CONCLUSION

In recent years, Thailand's neighboring countries have become self-sufficient in rice production. Thailand, therefore, experienced difficulties in disposing of its surplus production resulting in a decrease in rice prices. This prompted the Ministry of Agriculture and Cooperatives to designate certain areas as rice-priority areas and earmark other areas which are favorably located in relation to export harbors and consumption centers for diversification programs. Under these programs farmers are supposed to switch part of their rice production to other cash crops which are in demand on the domestic or export market. The success of the program is dependent on external factors such as marketing. Although marketing is not related to crop diversification it has been identified as a real constraint. The market must meet the supply of upland perishable crops and vegetables. A national long-term plan in terms of local and international demand is needed for an executing agency like the Royal Irrigation Department to be able to carry out its implementation program.

Soil suitability plays an important role in the development of crop diversification: The Central Plain, which is mainly heavy clay, is not suitable lor upland crops, and therefore not likely to be promoted as a diversified cropping area. In the Northeast where the soil is more suitable for upland crops, the Government has shown that agro-industry, together with the private sector's involvement, can successfully promote irrigated crop diversification to a limited extent.

With regard to irrigation, the executing agency can still improve the managerial and infrastructural capability of irrigation systems to meet the flexibility required by a crop diversification program.

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Summary/Highlights of Discussion: Country Activity Papers

THE PRESENTATION AND discussion of the eight activity papers, one each from Bangladesh, Malaysia, India, Indonesia, Nepal, Sri Lanka, Thailand, and the Philippines brought up a number of issues related especially to imgation management for crop diversification research and research networking.

Diversifying crops in rice-based irrigation systems is viewed as a means for efficient utilization of water, increasing cropping intensity, and ultimately irsreasing farmers' income. With the paucity of information on this topic, research becomes necessary.

Research on irrigation management for crop diversification should consider the technical or scientific aspects of crop production or both as these relate to water utilization, soil moisture environment, etc. The socioeconomic factors should also be considered, especially as these relate to the farmers.

From the technical aspect of growing irrigated non-rice crops water-demand changes over time and space should be considered. Water management should he viewed from the point of whether water can be supplied as demanded by the different upland crops. The capability of both the irrigation agencies and the farmers to jointly manage a more intensive and demanding system for diversified crops should then be considered. Likewise, attention should be given to the adequacy of the irrigation structures to accommodate non-rice crops.

Because the water table is built during rice cultivation, it may not be easy to shift to other crops soon after. Therefore, the suitability of puddled soils for growing upland crops must be assessed.

In addition to the issues of marketing and pricing o inon-rice crops, the role of the farmers has been emphasized. The fanners must be given options to select which crops to grow. They should be the final judges in crop diversification. What is necessary is to demonstrate to them the different technologies. Individual farmer decisions, however, may also be influenced by a group of farmers.

In the establishment of the network, tie-up with other countries carrying out similar work (e.g., Egypt) should be considered. It was reported that in Egypt, Sudan, and Pakistan, the farmers' needs are known by irrigation management institutions and their decisions play a major role in irrigation system management. In Taiwan, the imgation management agency (irrigators' association) has an arrangement with the farmers where water issues, depending on the crops agreed to be grown, are answered in volume and time. The network should craw on the experience of countries where diversification is already being practiced.

Section 111: Workshop Group Sessions

Workshop Group Sessions

To HAVE A more focused discussion, the participants were divided into three groups on the second day of the workshop. The three groups discussed separately the following specific topics.

Group A Research issues and research methodologies.

Group B: Information exchange, publication, and dissemination of research results

Group C: Organization of research network and funding strategy for network activities.

Each group had a discussion leader, a rapporteur among the participants, and a member of IIMI staff as facilitator. Guided by objectives and expected outputs of the workshop, the information from the papers presented, and the subsequent discussions as well as the discussion questions earlier prepared, the groups came up with specific, concrete, and implementable suggestions. The rapporteurs presented the group reports.

GROUP A: RESEARCH ISSUES AND RESEARCH METHODOLOGIES

Group **A** discussed the research objectives that should be addressed by the network. In relation to these objectives, possible research issues were identified. Moreover, the methodology and expected research results were suggested.

Research Objectives

The objectives identified during the 1986 workshop were reviewed and the group came up with the following revised objectives of the network

1) to compare differences and similarities of national objectives related to irrigated crop diversification;
2) to determine existing irrigation management technologies for non-rice crops at the main-system, tertiary-system, and farm levels:
3) to identify technical, institutional, and economic potentials for diversified cropping in general, and for selected crops for each country/region under irrigated conditions: and
4) to determine and evaluate alternative practices and technologies to match the national objectives1 goals.

Research issues

The following issues should be addressed.

1) Technical issues:
   a) irrigation/agricultural inputs,
   b) soil-water-plant environment,
   c) irrigation system operation,
   d) water productivity, and
   e) irrigation practices at field level.

2) Institutional issues:
   a) implications to agencies,
   b) infrastructure requirements, and
   c) financing.

3) Policy issues:
   a) policy environment,
   b) impact of policies, and
   c) markets and incentives

Methodology and Results

As regards the methodology, the research network should develop common data sets and analytical tools as a separate function distinct from undertaking research. The results should be policy-oriented to facilitate adoption of recommendations by national implementing agencies.

GROUP B: INFORMATION EXCHANGE, PUBLICATION, AND DISSEMINATION OF RESEARCH RESULTS

Information Exchange

The workshop has served as a forum for exchange of information on irrigation management for crop diversification in rice-based farming systems. The proceedings of the workshop would serve as a useful publication for disseminating research results.

A newsletter would be desirable for the network. A minimum of one newsletter per year may already be appropriate for information exchange. Exchange of information among the network members will encourage the formation of national groups on irrigated crop diversification. It should be functional between and among national groups, and should reach a wider audience.

Publications. Exchange of publications on irrigation mznagement for crop diversification and other related subjects will also facilitate information exchange. To avoid waste of effort, time, and other resources, a list of related publications can be disseminated through the newsletter and/or during workshops.

Dissemination of Research Results. Filmstrips, slides, and video-cassettes may be prepared for information dissemination, in addition to the workshop proceedings. An annual roving workshop can be conducted in different countries to present the results of the research of each member. These workshops should be complemented with field visits to the research sites in the host country. To the extent that resources are available, exchange visits among network members should be facilitated.

? C: ORGANIZATION OF RESEAR(H NETWORK ANI NG STRATEGY FOR NETWORK A' :TIVITIES

Steering committee

A steering committee was proposed to oversee research network. One representative will be selected from each participating country and IIMI. The ad hoc committee may already be formed from among the participants, except the chairperson and vice-chairperson. They would be selected after IIMI has consulted with the concerned agencies in the two countries suggested to be the venue of the next workshop (i.e., Indonesia and the Philippines). Meantime, IIMI can serve as the secretariat of the committee, which function can be turned nver to the national members later. The committee should meet once before the next Workshop.

Annual workshop. Once the research network becomes operational, one workshop/meeting per year was suggested to review the activities and the results of the research network. The workshop should be timed to coincide with the middle of the dry-season cropping. Indonesia and the Philippines were suggested as the possible venue for the workshop. Considering the dry-season cropping, the workshop can be scheduled for June/July 1989 if held in Indonesia, or January/February 1990 if held in the Philippines.

Participants should include the members of the Steering Committee; three representatives from each country representing the research, agriculture and irrigation sectors; representatives from IIMI; and special invitees from the host country. The research sector is envisioned to represent the colleges, universities, and other research institutions working on irrigated crop diversification and related activities.

The host country should take care of the logistic support for the workshop and fieldtrips. It should also seek additional funding for the activity.

Research Funding. Funding is necessary for implementing the research activities of the network. The IIMI resident scientists could contact possible conors. The research network members could review and comment on the research proposals for funding consideration.

Possible sources of funding for the research activities of the network are as follows:

Bangladesh: The Ford Foundation, the Canadiar International Development Agency, and the Rockefeller Foundation.

The Philippines: The Asian Development Bank, the Japanese International Cooperation Agency, the Australian Council for International Agricultural Research, the United States Agency for International Development, and the Rockefeller Foundation.

Sri Lanka: The United States Agency for International Development and the Asian Development Bank.

Nepal The United States Agency for International Development, the United Nations Development Programme/Food and Agriculture Organization, and WINROCK International.

Thailand: The Ford Foundation.

Indonesia: The Asian Development Bank and the Rockefeller Foundation.

Network Funding

IIMI submitted a proposal to the Ministry of Agriculture, Forestry, and Fisheries of Japan for coordination of the network through the holding of annual workshops and the exchange of visits and publications. Other donors like the Ford Foundation or the United Nations Development Programme may be tapped for multicountry network support.

Section IV: Research Network Organization

Research Network Organization

THE NETWORK

THE GROUP CAME up with recommendations on the nature of the network, its organization, functions, and responsibilities. The network should be able to address the objectives and research issues as identified by Group A. In addressing these concerns, the network should have a mechanism for information exchange and dissemination of research results as suggested by Group B. To be operational and functional, it should have the necessary organizational structure and support as recommended by Group C.

Tbe network should relate its work with existing institutions. It may influence the research methodology to be followed but should not impose on the national institutions what to follow. To facilitate cross comparison, however, it would he helpful to have a common methodology. The use of common data sets would depend on the kind of research. For example, the farmer-managed irrigation systems network did not need a common data set.

Although the presence of IIMI in a country may have other advantages, participation in the network need not be a problem to the countries in which IIMI operations do not exist. Out of the eight-country participants, IIMI has country programs in five. IIMI does not wish to correlate relationship with its presence. It is now establishing nonresidential linkages with the other countries.

It can be noted that the prospective network participants share common factors. For example, the participating countries are in the humid tropics and inigated rice cultivation is dominant. These common factors would contribute to the success of the network.

THE STEERING COMMITTEE

As recommended, the Steering Committee should be composed of representatives from the eight participating countries, plus IIMI representatives. Other interested countries may be included later.

Membership in the Committee should as much as possible have the sanction of the country they are representing. Meanwhile, the members can be nominated and later on communicate the official designation from their country.

The Committee is to be supported by a secretariat which, for the meantime will be IIMI. This function could later be turned over to the national members.

Selection of the Steering Committee Members

After a lengthy discussion, the group proceeded to select the Members of the Steering Committee and came up with the following:

Chairman:	Sehastian I. Julian, the Philippines
Vice-chairman:	Hamudji Waloyo, Indonesia
Members:	M.A.S. Mandal, Bangladesh
	T. Hanumantha Rao, India
	Sardar Ali, Malaysia
	Prakriti Shumsher Rana, Nepal
	Jayantha Jayewardene, Sri Lanka
	Nukool Thongthawet:, Thailand
	Senen M. Miranda, IIMI
	Shaul Manor, IIMI

As there are activities that need to he undertaken regularly, different subcommittees were likewise formed as follows:

Subcommittee	*Members*
Research	M.A.S. Mandal, Sehestian I. Julian, Hamudji Waloyo, Jayantha Jayewardene
Information exchange	T. Hanumantha Rao, Nukool Thongthawee, Senen M. Miranda/Shaul Manor
Funding	Jayantha Jayewardene, Sardar Ali, Senen M. Miranda/Shaul Manor

Future Activities

With the agreement that the next workshop may be held in January/February 1990, depending upon approval of funding support submitted to the Ministry of Agriculture, Forestry and Fisheries of Japan, the Steering Committee decided to meet six months before the scheduled activity. Aside from the workshop organization, the Committee should also consider the strategies for the operation of the network. Information exchange could be a good start.

Highlights of the Closing Session

CHARLES ABERNETHY OF the International Irrigation Management Institute (IIMI) wrapped up the workshop by putting forward three points: 1) irrigation management for crop diversification as an issue, 2) networking as a strategy, and 3) the evolution of IIMI.

The present issue of irrigation management for crop diversification is no different from other programs that have been implemented supposedly to improve the well-being of the farmers. For example, in the case of the program on soil erosion/soil conservation in India, the introduction of new irrigated crops or new technologies to the fanners needs careful consideration. These imgated crops may be agronomically feasible but may neither have the market nor the acceptance of the farmers themselves. There is a need for a multidisciplinary approach to project development and implementation.

There is also a need to clarify the objectives. These objectives should be looked at from the point of view of the farmers vis-a-vis the national goals, and the objectives of the irrigation agency. Irrigation management for crop diversification is not an end in itself, it is a means towards an end.

The workshop has formed a strong committee with regard to networking. This committee should link with national committees which must be formed if not yet existing.

The output of the research network should reach as many people as possible. There must be a mechanism to communicate and interact with those not regularly involved. There is a need to look at a system that will maximize the impact of the network.

IIMI is now at a phase of vigorous growth. It expects to have more funding donors and therefore anticipates to discharge its functions more effectively. It has set up offices and programs in logically selected countries and hopes to enhance its interaction with other countries with no IIMI operations yet, possibly through the network. Because IIMI's efforts are apt and are compatible with the efforts of other countries, a multiplier effect can be expected as a result of the partnership.

There are two distinct thrusts that IIMI has considered. Selected projects are carried out in different countries to understand the specific elements of irrigation management which may vary from country to country. Research should not, however, be limited to this kind of activity. A shift in thrust to an integrated perspective supports the move to set up a Programs Division at IIMI. This Division is expected to integrate, analyze, and make intercountry comparisons.

V.V.N. Murty mentioned that the Asian Institute of Technology (AIT) had similar goals and objectives to those of IIMI. In terms of networking, it has its own "network" which may even be stronger through relationships among its graduates.

Particularly for irrigation management for crop diversification, AIT as an institution can provide continuity in terms of generating new knowledge. It can also provide short-term consultancies and fellowships, and serve as a venue for future workshops.

Appendices

Appendix A

Workshop Program

29 November (Tuesday)

Arrival **of** participants

30 November (Wednesday)

0830 Registration

0900 Opening ceremonies

Welcome remarks	Charles Abernethy Director, Programs, IIMI Chamroon Chindasanguan Senior Expert in Operations and Maintenance, Royal Irrigation Department (RID) H. Eggers Professor and Vice-l'resident for Academic Affairs, Asian Institute of Technology (AIT)
Introduction of participants, workshop rationale, and objectives	Senen M. Miranda, JMI
Master of Ceremonies	V.V.N. Murty, Asia ı Insutute of Technology (AIT)

1000 Coffee/tea break

Session I: Special Papers on Irrigation Management for Crop Diversification

Moderator:	Marietta S. Adriano National Economic and Development Authority (NEDA)
Rapporteur:	Masao Kikuchi, IIMI

1030	Invited paper	Young Kun Shim, South Korea
1100	Highlights of IIMI's research on irrigation management for crop diversification in Indonesia, the Philippines, and Sri Lanka	Senen M. Miranda, IIMI
1130	Discussion	
1200	Lunch	

Session II: Presentation of Country Activity Papers

Moderator: Nukool Thongtliawee, Royal Irrigation Department (RID)

Rapporteur: Donald Parker, IIMI

1330	Bangladesh	M.A.S. Mandal, Bangladesh Agricultural University (BAU)
1400	India	T. Hanumantha Rao, Water and Land Management Training and Research Institute (WALAMTARI)
1430	Malaysia	Sardar Ali, Drainage and Irrigation Department (DID)
1500	Indonesia	Soekarso Djunaedi, Directorate General of Water Resources Development (DGWRD) Budiman Hutabarat, Center for Agro-Economic Research (CAER)
1530	Coffee/tea break	

Moderator: Sebastian I. Julian, National Irrigation Administration (NIA)

Rapporteur: Alfredo Valera, IIMI

1600	Nepal	Prakriti Shumsher Rana, Ministry of Agriculture
1630	Philippines	Marietta S. Adriano, National Economic and Development Authority (NEDA) Sebastian I. Julian, National Irrigation Administration (NIA) Amado R. Maglinao, IIMI
1700	Sri Lanka	Jayantha Jayewardene, Mahaweli Economic Agency (MEA)

1730	Thailand	**Nukool** Thongthawee, Royal Irrigation Department (RID)
		Siripong Hungspreug, Royal Irrigation Department (RID)
		Prasaert Kanoksing, Royal Irrigation Department (RID)
1800	Discussion	

1 December (Thursday)

Session III: General Discussion and Small Workshop Group Sessions

Moderator: Hammond Murray-Rust, IIMI

Rapporteur: Jayantha Jayewardene, Mahaweli Economic Agency (MEA)

0830	General discussion arising from papers and presentations	
0930	Small workshop group briefing	Edward Martin, IIMI
1000	Coffee/tea **break**	
1030	Small workshop group sessions	

Group A: Research Issues and Research Methodologies

Leader: Budiman Hutabarat. Center for Agro-Economic Research (CAER)

Facilitator: Hammond Murray-Rust, IIMI

Group B: Information Exchange, Publications, and Dissemination of Research Results

Leader: T. Hanumantha Rao, Water and Land Management Training and Research Institute (WALAMTARI)

Facilitator: Robert Yoder, IIMI

Group C: Organization of Research Network and Funding Strategy for Network Activities

Leader: M.A.S. Mandal, Bangladesh Agricultural University (BAU)

Facilitator: Edward Martin, IIMI

1200 Lunch

Session IV: Small Workshop Group Output, Research Network Organization, and Wrap Up

Moderator: Charles Abernethy, IIMI

Rapporteur: Amado R. Maglinao, IIMI

1330 Presentation of group output and discussion

Group A: Research Issues and Research Methodologies
By: Group Rapporteur, Sadar Ali

Group B: Information Exchange, Publications, and Dissemination of Research Results
By: Group Rapporteur; Prakriti S. Rana

Group C: Organization of Research Network and Funding Strategy for Network Activities
By: Group Rapporteur, Jayantha Jayewardene

1500 Coffee/tea break

1530 Formal organization of research network

1630 Workshop wrap up

1700 Closing remarks Charles Abernethy, IIMI
V.V.N. Murty, Asian Institute of Technology (AIT)

1730 Leave for Bangkok City

2130 Retum to AIT Center

Session V: Field Trip to Irrigated Rice-based Farming System Areas in the Mae Khlong Area (Organized by Messrs. Nukool Thongthawee, Chantrobol Prasaert Kanoksingh, and other Royal Irrigation Department Operations and Maintenance Staff)

0730 Leave AIT Center
Visit integrated farming system areas along the way

1030 Citrus Farm "Saeng Thong"

1100 Floating Market; Grape plantation

1200 Lunch at Damnoen Saduak

1330 Leave for Mae Khloog Project, Region I

1430	Briefing about **Mae** Khlong Project
1530	Leave for Kanchandburi
1630	Farewell party
2000	Light and **Sound** Performance at River Kwai Bridge/leave for Bangkok
2300	Arrive, Riverside Hotel

3 December (Saturday)

Departure

Appendix B

Workshop Groupings

Group A: Research Issues and Research Methodologies

Leader:	Budiman Hutabarat
Facilitator:	Hammond Murray-Rust
Rapporteur:	Sardar Ali
Members:	Charles Abernethy
	Sebastian I. Juliani
	V.V.N. Murty
	Prasaert Kanoksing
	Alfredo Valera
	J.M. Nielsen
	Rainer Loof
	A. Goto

Group **B:** Information Exchange, Publications, and Dissemination of Research Results

Leader:	T. Hanumantha Rao
Facilitator:	Robert Yoder
Rapporteur:	Prakriti Shumsher Rana
Members:	Donald Parker
	Soekarso Djunaedi
	Senen M. Miranda
	Amado R. Maglinao
	Nukool Thoogthawee
	Young Kun Shim
	Siripong Hungspreug

Group C: Organization of Research Network and Funding Strategy for Network Activities

Leader:	M.A.S. Mandal
Facilitator:	Edward Martin
Rapporteur:	Jayantha Jayewardene
Members:	Hamudji Waloyo
	Marietta S. Adriaio
	R. Gopalakrishnan
	G.N. Paudyal
	Akira Kawamata
	Masao Kikuchi
	Osot Chamvej

Appendix C

List of Participants

Bangladesh

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

2. Dr. Donald Parker
   Head, IIMI Bangladesh Field Operations
   c/o Dr. Charles Bailey
   Representative, The Ford Foundation
   P.O. Box 98, Ramna, Dhaka-2

India

3. Mr. R. Gopalakrishnan
   Director
   Irrigation Management and Training Institute
   'Cauvery Valagam,' Valavanthankottai Post,
   Thuvakudy, Trichy 620015

4. Mr. T. Hanumantha Rao
   Engineer-in-Chief and Director General
   WALAMTARI
   Himayatsagar, Hyderabad 500030.

Indonesia

5. Mr. Soekarso Djunaedi
   Head of Tertiary Irrigation
   Direktorat Irigasi I
   Jl. Patimura 20, Kebayoran Baru
   P.O. Box 435 KBY,
   Jakarta 12001

6. Dr. Budiman Hutabarat
Researcher
Center for Agro-Economic Research
Agency for Agricultural Research and Development
Jalan A. Yani No. 70
Bogor, West Java

7. Mr. Hamudji Waloyo
Head, Planning
Directorate General for Water Resources and Development
Jl. Patimura 20, Kebayoran Baru
P.O. Box 135, KBY
Jakarta 12001

8. Dr. Hammond Murray-Rust
Head, IIMI Indonesia Field Operations
International Irrigation Management Institute
Taman Kebon Sirih I/4
Jakarta

Malaysia

9. Ir. Sardar Ali
Director of Planning
Drainage and Irrigation Department
Ministry of Agriculture
Jalan Mahameru
Kuala Lumpur 50626

Nepal

10. Dr. Prakriti Shumsher Rana
Joint Secretary
Ministry of Agriculture
Kathmandu

11. Dr. Robert Yoder
Head, IIMI Nepal Field Operations
International Irrigation Management Institute
Water Resources Ministry Building
Singha Durbar
Kathmandu

Philippines

12. Dr. Marietta S. Adriano
Director, Agriculture Staff
National Economic and Development Authority
Amber Avenue, Pasig, Metro Manila

13. Mr. Sebastian I. Julian
Assistant Administrator for Systems Operation
and Equipment Management
National Irrigation Administration
E. delos Santos Avenue, Quezon City, Metro Manila

14. Dr. Amado R. Maglinao
Researcher/Coordinator
IIMI-IRRI Project
IIMI Liaison Office
PCARRD, Los Banos, Laguna

15. Dr. Alfredo Valera
Head, IIMI Philippine Field Operations
International Irrigation Management Institute
c/o Ford Foundation
6th Floor, Dona Narcisa Building
Paseo de Roxas, Makati, Metro Manila

Sri Lanka

16. Mr. Jayantha Jayewardene
Managing Director
Mahaweli Economic Agency
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