IRRIGATION MANAGEMENT FOR DIVERSIFIED CROPPING

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Cover photo: Diversified cropping in Mahaweli System B, Sri Lanka. Courtesy of John Colmey.

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Summary: Improvements in rice growing technologies during the last two decades have resulted in a number of countries, especially in the humid tropical regions of Asia, nearing self sufficiency in rice production. Consequently, policies are shifting in these countries toward minimizing the under-utilizaton of land by increasing the cropping intensity of irrigated areas, particularly by growing non-rice crops during the dry season. These workshop papers discuss the advantages of and constraints to crop diversification, in different country situations throughout Asia.

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FOREWORD

A number of countries in the humid tropics of Asia are approaching self-sufficiency in rice production, which in turn has led to a decline in the real price of rice. Many farmers are therefore seeking ways of diversifying their production and income sources, but they face obstacles in growing non-rice crops on land irrigated by systems that were designed and operated only for rice.

Taiwan presents a good example of a country that has been highly successful in diversifying cropping on its rice lands where suitable opportunities exist. Varying degrees of development and advances in diversified cropping are being reported in several Asian countries. In some instances, even the reasons for success in diversified cropping are not clearly understood either by the farmers or agency personnel.

There is thus a clear need to find appropriate management practices for these irrigation systems to enable the efficient and productive use of irrigation for crops other than rice. The International Irrigation Management Institute (IIMI) has, since its establishment in 1984, undertaken a series of studies on this topic. These studies are not designed to displace rice from irrigated areas but to find better ways to produce other crops in association with rice in those parts of irrigated commands most suitable for diversified (upland) crops, and only during the dry season.

Studies are presently underway in collaboration with national institutions in Sri Lanka, the Philippines, and Indonesia. Several other countries have expressed interest in collaborating in a research network on management of irrigation systems for production of non-rice crops in the drier part of the year.

A stage has been reached where a workshop involving interested parties in a number of countries is necessary to review research findings to date, compare differences in irrigation system management, and to develop plans for future activities through one or more forms of a research network.

The main objectives of the workshop were:

1. To determine existing and potential irrigation management practices for non-rice crops at the main system, tertiary, and field levels;

2. to identify the constraints to diversified cropping under irrigated conditions, and to identify ways to relax such constraints;

3. to determine and field test feasible irrigation practices which will make production of selected non-rice crops more effective and profitable; and,

4. to explore the value of conducting research on irrigation management for crop diversification in a network mode.

These objectives were addressed in a Workshop on Irrigation Management for Crop Diversification held at IIMI from 24 to 27 November 1986. It was attended by 31 participants from 12 countries and by several IIMI staff members.

Participants concluded that there is great benefit in research on irrigation management for crop diversification in a network mode, and that the involvement of member countries in the network may vary from active research to a simple exchange of information depending on their stated interest. It was recommended that the research network be organized in a multidisciplinary and multi-institutional framework through appropriate government agencies, universities, and research institutes at the national level.

IIMI wishes to thank the Bureau of Science and Technology (S&T) of the United States Agency for International Development (USAID) for providing the funds needed to host this workshop.

Dr. Thomas Wickham, former Director General at IIMI, deserves special mention for his part in promoting this workshop and supporting the interest in irrigated crop diversification it represents.

Dr. C.R. Panabokke (Agronomist) and Dr. S.M. Miranda (Agricultural/Civil Engineer) on IIMI's Headquarters staff were responsible for convening and coordinating the workshop. They were assisted by Ms. Dewaki Nugawela who served as Workshop Secretary. The proceedings include a concept paper, two special papers, seven country papers, a policy paper, three status research reports, and recommendations of five workshop groups. The papers were edited by Dr. Robert Cowell, with assistance from Mr. John Colmey. Mrs. Sirohmi Botejue prepared the discussion sections. Production staff included Mrs. Shanthi Dissanayake, Mr. L.C. Perera, Mr. M.G.D.S. Priyantha, and Mr. Norman Van Eyck (artist).

Roberto Lenton
Director General
IIMI

SECTION I: CONCEPT AND SPECIAL PAPERS

IRRIGATION MANAGEMENT FOR DIVERSIFIED CROPPING: CONCEPT PAPER

S.M. Miranda and C.R. Panabokke*

INTRODUCTION

Most irrigation systems located within the humid tropical regions of Asia have had as their main objective the assured supply of irrigation water during the wet season for cultivating rice under traditional wet land conditions. During the succeeding dry season, farmers have traditionally used the reduced supply of irrigation water to grow a second crop of rice on a limited extent of the command area. The introduction of shorter duration high yielding rice varieties has resulted in the more efficient use of both wet and dry season rainfall and irrigation supplies, which in turn has led to significant increases in the cropping intensity of rice lands located in more favorable rainfall and water supply regimes.

Rice based cropping system studies initiated by the International Rice Research Institute since the mid-1970s have led to a better understanding of the potential for introducing crops other than rice during the dry season following the main wet season rice crop. More recently, these studies have been modified to accommodate a farming systems perspective but they have not included research on the irrigation system that serves the irrigated crops.

In a few locations, especially in the wet-and-dry tropical environments (as compared with the humid tropics), farmers grow, to at least a limited extent, high value short duration non-rice crops during the dry season immediately following the wet season. This generally occurs where there is an assured market and price for the non-rice crops, and soil and physical conditions suit the switch from puddled rice during the wet season to upland irrigation during the dry. Irrigation during the dry season is carried out with little or no physical modifications to the canal system, but with considerable modification of the operation and management of the reduced stream flow.

Under most Southeast Asian conditions, irrigation systems were designed and operated essentially for rice during the wet season when management needs are less stringent, except during occasional short dry spells. Furthermore, irrigation of rice is usually based on a continuous flow of water whereas irrigation of non-rice crops is based on an intermittent supply of water. Managing an irrigation system to supply water intermittently to non-rice crops raises several important issues. What should be the characteristics of the canal network and the on-farm facilities that will provide intermittent flow in desired quantities at desired intervals? What should be the duration of this intermittent flow? How will the water issues be matched to crop water demand at different stages of crop growth? To what extent will farmers be prepared to do and undo the land shaping and modification in alternating from rice to non-rice crops?

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RATIONALE FOR IRRIGATED CROP DIVERSIFICATION

Improvements in rice growing technologies during the last two decades have resulted in a number of countries, especially in humid tropical Asia, nearing self-sufficiency in rice. As a consequence, policy is shifting in these countries toward minimizing the under-utilization of land by increasing the cropping intensity of irrigated areas. For example, in Java the present cropping intensity index is about 2.2, compared to 1.3-1.6 in other parts of Asia. Complementary to this shift is a push for self-sufficiency in selected non-rice crops, especially those with potential for import substitution.

Many farmers are presently seeking ways to diversify their production and income sources; however, they face several obstacles in growing non-rice crops in irrigation systems that were designed for irrigated rice. In areas within the wet-and-dry tropical environment, farmers have evolved different kinds of irrigation management practices for growing non-rice crops during the dry season. But in environments of the humid tropics where the dry season is less marked and the choice of crops more limited, there is a clear need to find appropriate management practices that will make possible the efficient and productive use of irrigation for crops other than rice.

In some instances, potential non-rice crops are not readily accepted during the dry season because of deficiencies in managing the irrigation system rather than limitations in the climate or soils. Moreover, because less water is usually available during the dry season, more stringent management of the limited supply is necessary to achieve a reasonable level of equity among water users. Achieving equity across the command area of an irrigation system with a restricted water supply is more difficult with a single crop of rice than with other crops. Conversely, in commands that are well-supplied with water, there is little or no incentive to grow crops other than rice.

In our approach to irrigation management for diversified cropping, no attempt is made to shift totally from rice to diversified crops during the less wet or dry season; rather, our approach is one of trying to understand the requirements for growing non-rice crops during the dry seasons. It has been suggested that a higher level of system control is necessary for diversified cropping. This requires a knowledge of how the canal network should be designed or modified to enable better control of the system, and also a knowledge and understanding of how the water should be managed and applied. Correspondingly, we need to look more systematically at the physical water distribution system as well as the cultural system. The latter would involve a close examination of farmer response and behavior, of how agencies and staff operate and behave, and of how existing institutional organizations and structures could support more stringent management of irrigation systems.

In the light of these considerations, IIMI's studies on this subject have the following principal objectives: 1) To determine existing and potential irrigation management practices for non-rice crops at the main system, tertiary, and farm/field levels; 2) to identify the constraints to diversified cropping under irrigated conditions; 3) to identify ways to relax such constraints; and 4) to determine and field test feasible practices which make irrigation of selected non-rice crops more effective and profitable.

DIFFERENCE BETWEEN WATER ENVIRONMENTS FOR RICE AND NON-RICE CROPS

Lowland rice, which is basically an aquatic plant, has been found to perform best if the soil is kept under saturated conditions from seeding/transplanting to about two weeks before harvesting. A water depth up to 10-15 centimeters (cm) is not important; however, beyond that depth yield reductions can be expected (Levine 1970). A flooded condition is the optimum environment for rice, especially considering benefits related to weed control, nitrogen management, temperature control, and chemical application. Light soils with high seepage and percolation rates and soils needing drainage to remove toxic conditions produced by continuous flooding may be exceptions.

A plant is said to be under stress whenever its demand for water exceeds the available supply; the greater the deficit the higher the stress. The effect of stress on yield is thought to be dependent on growth stage, intensity, and duration. Yields of the new rice varieties are sensitive to growth stage, particularly the reproductive stage, during which the stress occurs (Wickham 1972). Soil moisture tension as low as 15 centibars is enough to reduce yield. Part of the reduction in yield is ascribed to the loss of nitrogen under alternatively dry and wet conditions (De Datta et al. 1972).

Non-rice (upland) crops demand a higher degree of soil moisture control because of greater sensitivity to inadequate or oversupply of moisture. Inadequate moisture stresses the crop. Excessive water in the soil retards plant growth due to poor root zone aeration. The optimum soil moisture for upland crops is usually taken as 50-75 per cent of available soil moisture, the amount that is retained between the field capacity and the permanent wilting point. Therefore, non-rice crops are not well adapted to continuous water supply. Water should be applied intermittently to replenish the soil moisture reservoir. The frequency and amount of application depends on the holding capacity of the soil, rooting characteristics of the crop, and evaporative demand. Normally, a heavy-textured soil holds about 200 millimeters (mm) of water per meter of soil depth, a medium-textured soil, 140 mm/meter, and a coarse-textured soil, 60 mm/meter. Shallow rooted crops (less than 60 cm), such as onions, are irrigated more frequently (almost daily) compared to beans and peppers which are moderately deep-rooted (120 cm), and maize, sweet potato, and cotton which are deep rooted (180 cm or deeper; FAO 1979).

WATER BALANCE IN A NON-RICE CROP SETTING COMPARED WITH THAT OF RICE

The three constituents of water required to grow lowland rice are evapotranspiration (ET), seepage and percolation (S&P), and surface drainage (SD). The true water requirement for crop growth in rice as well as non-rice crops is the ET. However, some S&P is unavoidable in supplying the needed water for the desired saturated or flooded environment of rice. The potential ET is directly related to the atmospheric evaporative demand. If water is not limiting, actual ET in rice grown under flooded conditions is essentially equivalent to potential ET throughout the growing season.

In the case of non-rice crops where the cultivated field starts without a crop canopy, actual ET is initially composed only of evaporation from the soil surface. Actual ET increases slowly at first and then rapidly with a more extensive crop canopy cover. Normally, the crop coefficient, which is the ratio between actual and potential ET, varies from less than one to a little more than one at full canopy stage. The potential ET rates in the humid tropics vary from about 2-5 mm/day during the wet season, and from about 4-9 mm/day during the dry season.

The S&P rates vary according to the soils, with higher rates for lighter soils than for heavy ones. S&P rates for good rice land classes are from 0-3 mm/day. Dual land classes suitable for rice during the wet season, and for diversified crops during the dry season have higher seepage rates, but less than 8 mm/day. Diversified land classes which can be cropped to non-rice crops in both seasons would have S&P rates greater than 8 mm/day and as high as 50 mm/day (Abesamis 1974). Examples of the latter are alluvial river levee soils or the well-drained Reddish Brown Earths.

The water balance in Figure 1 illustrates the combined effect of ET and S&P for rice, and, in Figure 2, the single effect of ET on the basic water requirement for non-rice crops. These illustrations explain the reduced basic water requirement of non-rice crops relative to rice. This concept is built into the pasten and the relative irrigation requirement (RIR), a formula used in Indonesian irrigation management. The simplest expression of the pasten concept is shown in the following equation, which relates the quantity of available water to the irrigated area (Pasandaran 1979).

$$P = Q/A$$

where: P = pasten value, Q = rate of water flow in liters per second taken from a discharge curve or from flow discharge data; and A = irrigated area in hectares.

The RIR concept applied to this equation is as follows:

$$P = Q / [\Sigma \text{RIR} (A)] = Q / [\Sigma (\text{RIR}_i A_i)]$$

where: i refers to different crops. Thus, using accepted RIR values:

$$P = Q / (1 A_{pl} + 1.5 A_{sc} + 20 A_{rsb} + 6 A_{rlp} + 4 A_{rtr} + 1 A_{rua})$$

where:

A_{pl} = area of secondary crops

A_{sc} = area of sugarcane

A_{rsb} = area of rice seed-bed

A_{rlp} = area under rice land preparation

A_{rtr} = area of rice after transplanting

A_{rua} = area of unauthorized rice

Care is taken in planning and operation to ensure that the value of pasten at the turnout gates does not fall below 0.20 on heavy soils or 0.25 on light.

Figure 1. Field (basin) water balance for rice.

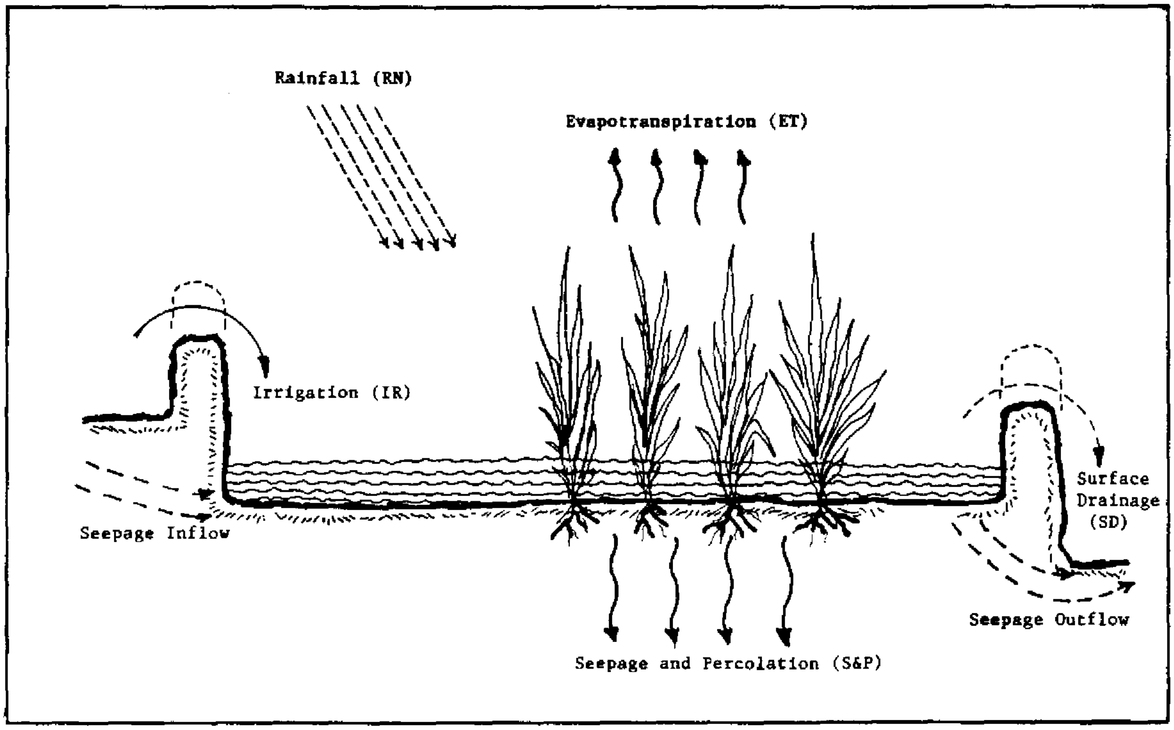
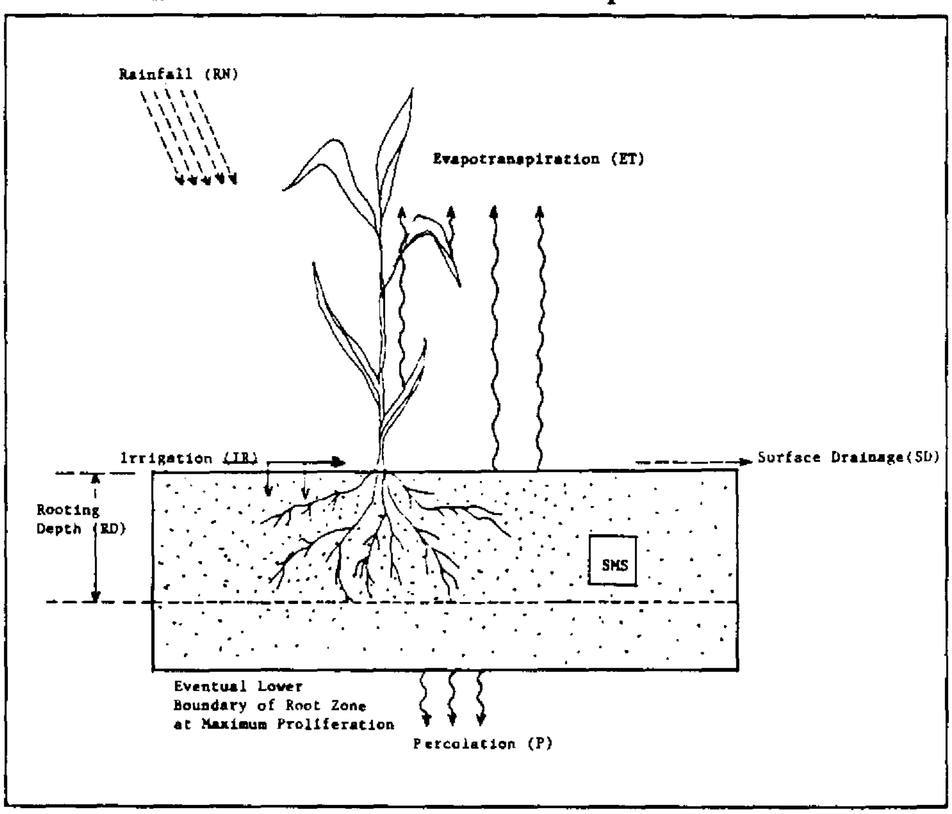


Figure 2. Field water balance for non-rice crops.



ON-FARM IRRIGATION METHODS

Levelling and bunding of land with subsequent formation of basins provides the necessary conditions for growing flooded rice under wetland conditions. The size of basins varies according to the topography of the land and the technology adopted in the original land levelling and shaping. Even in recently developed systems, inadequate attention is given to proper bench terracing and constructing basins of a size that would permit optimum use of water and time spent on irrigation. This has special importance for irrigating non-rice crops, especially when the furrowed-basin method is employed.

Given that each farm parcel or allotment is usually made up several individual basins of varying shape and size, and where the normal irrigation practice for rice is basin-to-basin spilling, farmers try to avoid any extra effort and expense in reshaping the existing basin layout to accommodate non-rice crops. At the initial stages, minimum modifications in the form of simple on-farm ditches with raised beds of various sizes serve the needs of irrigation and drainage. The costs of reconverting these ditches and beds to flat seed beds within the basin for the subsequent rice crop are minimal when compared with sophisticated methods of land shaping for the graded furrow-type irrigation.

Although this rudimentary system of simple farm ditches and raised beds meets the minimum set of on-farm requirements for growing non-rice crops, it is probably not the most efficient in terms of water use and time taken for irrigation. Moreover, when the stream size exceeds 15 liters per second (lps), erosion in the ditches and basins located in the lower aspects of the farm allotment can be severe.

A promising on-farm irrigation layout that can be easily handled within the resources of small farmers in Asia is the furrowed basin system (Joshua 1980 and Dimantha 1984). Its advantage is in its use for conventional rice cultivation during the wet season and non-rice cropping during the dry. With this system, the land is levelled to form benched terraces of very mild grade along their length and zero cross slope. Basins of appropriate size are constructed in each terrace with ridges and furrows within the basin. Criteria for basin dimensions, irrigation stream sizes, irrigation procedure, and duration of irrigation according to soil and topographic characteristics and crop needs have been outlined by Joshua (ibid).

For Reddish Brown Earth soils in Sri Lanka, a 10 meter by 10 meter basin planted with non-rice crops with furrows at 60 cm spacing can be irrigated with a stream size of 5 lps in 20 minutes. This provides a 60 mm depth of water on the basin. This combination of basin dimension and stream size ensures minimum deep percolation loss and prevents soil erosion and breaching of the field ditches; it also provides a stream size small enough to be easily managed by the irrigator. This demonstrates the simpler innovations that can be made to the on-farm irrigation layout within the resource capability of the typical rice holding in Asia. It also illustrates the need to apply known general principles of soil physics and water movement in soils in the design and testing of simple innovations that can lead to improved on-farm irrigation practices.

Choice of on-farm layout and irrigation best adapted to different environmental regimes will, no doubt, be determined by the nature of the topography, soils, rainfall, and water supply, and the kind of crop to be grown. On-farm layouts commonly recommended for the larger farms in drier environments of countries with a highly developed agriculture have limited applicability under the small-farm conditions found throughout Asia. Instead, simple innovations and practices that permit incremental changes over a longer time are more appropriate.

Although the basin irrigation system used for wet-land rice is applicable across a wide range of conditions, more selective on-farm systems are needed for irrigating non-rice crops. The application of basic principles to the different land qualities encountered over the wide range of rice growing conditions will lead to improved on-farm layouts. These should be tested under existing farmstead conditions before recommendations are made.

IMPLICATIONS FOR MAIN SYSTEM MANAGEMENT

Adjustments Necessary for Irrigating Non-rice Crops

With rice, the supply of water to farm parcels or allotments can be either continuous or intermittent provided the fields remain saturated or flooded. As suggested earlier, non-rice crops require intermittent or rotational supply. Assuming that non-rice crops are grown only when water is in short supply, the limited flow has to be managed differently from when supply is adequate. The canal capacity of the typical system is based on supplementary irrigation for rice in the wet season.

The type of delivery used (continuous or intermittent) at various levels of the canal system for the wet season depends upon the configuration and carrying capacity of the canals and the degree of regulation available for flow control. Where continuous distribution is normally practiced from water source to farm outlets, this canal system has a tapered configuration with the canal cross section greater at the head and smaller towards the tail. Where some form of rotation is practiced in portions of the main canal, distributaries, or field channels, more uniform rather than tapered canal cross sections from head to tail are needed for that particular level of canal where the rotation is done. The rotation also has implications on the extent of canal regulation and gate control.

It has been observed, so far, in our research sites in Indonesia, the Philippines, and Sri Lanka that irrigation systems properly designed for supplementary irrigation for wet season rice do have enough canal capacity for the desired intermittent flow at the outlet or turnout level (head of field channel). This is due in part to the smaller water requirement of non-rice crops, which permits a reduction in the total volume of water supplied per delivery interval. However, if the full flow capacity of that portion of the canal system is to be utilized in delivering the reduced volume of water, the duration of delivery has to be reduced correspondingly. The exact interval of water delivery depends ultimately upon soil moisture storage characteristics and the crop consumptive use for the specific region and seasons.

During periods of unusual water shortage, some supporting measures may be instituted. From our example of pasten use in Indonesia, when the pasten values fall below 0.20 or 0.25, giliran (rotational irrigation) is done. The most common forms of rotational irrigation are among: a) secondary (distributary) canals served by a main canal; b) tertiary (field) channels served by the distributary; c) field outlets along a tertiary; and d) farm parcels. Each succeeding form of rotation serves successively smaller blocks of land. The form of rotation depends on the severity of the water shortage as reflected by the pasten value. In general, the more severe the water shortage, the more localized the form of rotation (Pasandaran 1979). Implied here is the presence of adequate regulation control and measurement facilities to make possible improved precision in the delivery of water on an intermittent basis at various levels, especially at the level of the turnout.

Constraints to Irrigated Upland Crop Production

The cultivation of non-rice crops in irrigated areas has not spread as fast as the proverbial "wildfire" because farmers act rationally. Although policy makers wish to expand the percentage of non-rice crops grown over an irrigated area, this policy has encountered many constraints. For example, water deliveries are rarely precise and reliable. Irrigation control and measuring facilities to deliver the required intermittent water supply are frequently inadequate, nonfunctional, or absent. Appropriate irrigation management techniques have yet to be demonstrated to the full satisfaction of both the water users and managers. The on-farm modifications carried out by farmers in their attempt to rapidly apply and remove excess water on their fields needs evaluation under varying soil, topographic, and crop conditions.

Due to the uncertainty of dry season water supply, changes in the expected schedule and rate of water deliveries are almost inevitable. Changes are very often not communicated properly to the farmers and sometimes not even to the field level agency personnel, with the result that confidence in the reliability of water delivery erodes. This is an example of an institutional constraint that can discourage irrigated crop diversification.

Farmers who have grown only irrigated rice before are usually unfamiliar with agronomic practices for non-rice crops. This is particularly true in places where crops such as corn, mungbean, and groundnuts are grown only under rainfed conditions. Farmers are also unfamiliar with the crop husbandry of some important crops such as soybeans and white beans.

Another set of primary constraints that inhibit irrigated diversified cropping even when the aforementioned problems are absent are connected with the profitability of producing rice and non-rice crops. Unfavorable prices and marketing structure, and the higher cost of crop care and cash inputs frequently reduce profitability of non-rice crops compared to rice.

Emerging Irrigation Management Practices to Relax Constraints

While noting the various constraints to crop diversification, the present irrigation management practices used in irrigated crop diversification are being carefully observed in terms of their deficiencies and potentials.

The section on the water environment for non-rice crops discussed the logic of the intermittent or rotational application of water as a desirable irrigation practice. If water were freely available and supplied in a continuous manner, the farmer would use it to grow rice. A high degree of water control is necessary to provide reliable and timely intermittent water supply from the main system to the farm. The irrigation agencies must have the institutional capacity to provide a reliable supply at the outlets or turnouts serving field channels. The farmers should adopt equitable and fair water sharing techniques acceptable to them and appropriate to the peculiarities of the field channel facilities, crops, and cropping patterns.

At the allotment level, the farmer should use appropriate irrigation methods that facilitate the timely application of water to his fields and removal of unwanted excess water. The latter can be attained by the provision of on-farm irrigation and drainage facilities including some reshaping of the land. The farmers are already trying to provide these facilities, as discussed in the "on-farm irrigation methods" section, by a rudimentary system of farm ditches and beds. A land consolidated area where each field plot is served directly by a farm and drainage ditch, and a farm road can be considered the ultimate in a spectrum of on-farm development possibilities.

Incentives to Promote Crop Diversification

Comparative profitability of irrigated non-rice crops seems to be the primary incentive that influences a farmer to adopt crop diversification. Government intervention through subsidy policies often makes this possible. Even in countries like Taiwan -- with its advanced stage of irrigated crop diversification, scarce water, favorable soils, and well-managed and functional irrigation systems -- the government still provides subsidy incentives. To encourage the production of irrigated grain cereals like corn, soybean, and sorghum, the government gives the farmer a subsidy of one metric ton of rice per hectare and an assured market and price for his produce.

Other economic incentives to increase the profitability by way of increased yield and reduced cost of production could be explored. Lower costs of farm inputs and irrigation fees as well as availability of low-interest credit for non-rice crops are possible options for government intervention.

DISCUSSION ISSUES

The primary purpose of this concept paper is to highlight some of the issues perceived by the workshop organizers as important for the success of irrigated crop diversification, with particular focus on irrigation management. Some of the key issues which are now submitted for discussion follow:

1. If we accept that greater management control over limited water is necessary for irrigated non-rice crop production, how do we go about effecting this control? Would designing and field-testing operating procedures for publicly-managed portions of irrigation systems for crop production be the right approach in effecting the desired control?

2. It appears that practical guidelines on irrigation methods for successfully growing non-rice crops are still not available to farmers, extension agents, and irrigation or agricultural officers. How do we bridge this gap?

3. To optimize the use of limited water in the irrigated command area, it is important to identify those parts of irrigated commands with a comparative advantage for selected non-rice crops. Is the current state of knowledge on this subject adequate to come up with a conceptual methodology to identify such areas for field testing in selected research sites?

4. Assuming that relaxing constraints to irrigated diversified cropping includes policy interventions by governments, is an appropriate research issue the various policy options to intervention? If so, what are these options?

5. Is there value in conducting research on irrigation management for crop diversification in a network mode? If there is, how should the research network be organized and structured to be effective?

REFERENCES

Abesamis, L. 1974. Method of irrigation in lowland conditions. Paper presented at the Training Course in Water Management for National Irrigation Administration Superintendents, University of the Philippines, Los Banos.

De Datta, S.K. et al. 1972. Water stress in flooded tropical rice. Paper presented at the Water Management Workshop, International Rice Research Institute, Los Banos, Philippines.

Dimantha, S. 1984. On-farm water management for Sri Lanka. Colombo, Sri Lanka: Land Use Division, Irrigation Department.

Food and Agriculture Organization. 1979. Yield response to water. Irrigation and Drainage Paper No. 33. Rome, Italy: FAO.

Joshua, W.D. 1980. Furrowed basin system of irrigation for upland crops. In Proceedings of the National Water Management Seminar. Maha Illuppalama.: Department of Agriculture, Government of Sri Lanka.

Levine, G. 1970. The water environment and crop production. Paper presented at the Cornell Workshop on Some Emerging Issues Accompanying Breakthroughs in Food Production. Ithaca, New York: Cornell University.

Pasandaran, E. 1979. Water management decision-making in the Pekalen Sampean Irrigation Project, East Java. In Irrigation Policy and Management of Irrigation Systems in Southeast Asia. Bangkok, Thailand: Agricultural Development Council.

Wickham, T. 1972. Predicting yield benefits in lowland rice through a water balance model. In Water Management in Philippine Irrigation Systems: Research and Operation. Los Banos, Philippines: International Rice Research Institute.

ADOPTION OF DIVERSIFIED CROPPING IN RICE IRRIGATION PROJECTS[1]

Ko Hai-Sheng*

INTRODUCTION

In the wake of perceived rice surpluses and market price fluctuations, the controversy over further investment in rice-oriented irrigation projects has received increasing attention. The World Bank in 1982, for example, recommended to the Philippines a slow-down in irrigation projects unless the government could regularly tap export markets. As a result, Phase I and II of the "Study of Food Demand and Supply and Related Strategies for Developing Countries" were undertaken. Policy dialogue between the Asian Development Bank and Indonesia regarding the agricultural sector, including irrigation, began in late 1982 from which came a two-year technical assistance grant on "Study of Food Production and Irrigation Strategy in Indonesia" starting in 1985. The World Bank also conducted the on-going Water Master Plan Study in Bangladesh and the "Thailand Irrigation Sub-Sector Review." These studies reflected the need for change in irrigation investment strategy in Asia.

A principal objective of these studies was an appropriate compromise between cost effectiveness and rice production for national food security. The adoption of irrigation schemes for diversified cropping is considered one of the best compromises for irrigation investment. Such a scheme would be able to continuously support rice production to assure food security. In cases of rice surplus and where non-rice crops have a comparative advantage, the irrigation system could be adapted to support non-rice crop production. Ideally this would maximize exports and/or minimize agricultural imports. In view of the widespread skepticism about future investment in rice irrigation systems, diversified cropping in irrigation schemes would permit a rational use of land and water resources. Since the additional investment for diversified cropping is small in comparison with the total needed for an ordinary rice irrigation system, it would be worthwhile to explore the possibility of adopting diversified cropping in irrigation schemes.

This paper briefly reviews existing diversified cropping in Asia. It then describes the physical operation and maintenance (O&M) requirements for diversified cropping, and identifies constraints to implementing diversified cropping. Finally, it furnishes suggestions on the approach to implementing diversified cropping in irrigation systems.

REVIEW OF EXISTING DIVERSIFIED CROPPING IN ASIA

Non-designated Diversified Cropping

The common practice of diversified cropping on irrigated land is to grow non-rice crops after harvesting irrigated rice at the beginning of the dry

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season. Those crops use residual moisture from irrigation for germination, and then grow in semi-rainfed conditions. Two or three periods of irrigation from the system may be used depending upon the availability of water resources. In some cases, farmers manage to find their own water resources from shallow tubewells, small ponds, or creeks. Crops not obtaining sufficient water from irrigation or rainfall may produce low yields or suffer damage. The farmers who practice this kind of diversified cropping are usually aware of the risks; however, through long-term trial-and-error, they eventually gain enough experience to carry out the most profitable diversified cropping.

This cropping practice may be found in many Asian irrigation systems. Adoption is generally piecemeal and on small areas, but some systems have a significant portion of total irrigation in this pattern. For example, in Bangladesh, around 40 per cent of the potential wheat acreage is already grown under rice-wheat rotation, and that area is expanding at an annual rate of 14 per cent. Thousands of hectares of tobacco are grown after the harvest of monsoon rice under intensive irrigation by using individual wells in the Teesta Irrigation Scheme[2] in northwest Bangladesh. In Nepal, wherever water resources are still available in the irrigated areas from the hills to the Tarai, wheat, mustard, or maize are grown in the post-monsoon season.

A Case Review of a Designed Diversified Cropping System

<u>System design</u>. One of the most sophisticated diversified cropping irrigation systems in Asia, the Chin-nan Irrigation System is located in southern Taiwan. It began operations in 1927 (construction period from 1921 to 1930) and covers an irrigated area of about 150,000 hectare (ha), of which about 8 per cent comprises clay soil and the rest sandy loam to silt loam. Annual precipitation over this area averages 2,500 millimeters (mm). Since the available water resources during development were only enough to irrigate one-third of the total area to grow one crop of monsoon rice, a three-year rotation cropping pattern (rice (monsoon)-upland crop-sugar-green manure) was carried out. In order to implement rotational or diversified cropping, the entire irrigated area was divided into 150 ha units; each rotation unit was divided into 3 rotation sub-units each of 50 ha; 3 crops, rice, upland crops, and sugar, were planted in each sub-unit by rotation in 3-year cycles. The layout of the irrigation/drainage system was also designed to fit the required rotation cropping. In particular, each 50 ha sub-rotation unit had its own separate off-take gate(s) from the irrigation system, so that irrigation water could be delivered separately to each unit.

<u>Support services</u>. To ensure the success of diversified cropping, Water User's Groups and Sub-Water User's Groups were carefully organized, based on the crop rotation units and their sub-units. Several experimental and demonstration stations were organized and operated during the construction period; and other support services such as extension, research, credit, post-harvest facilities (rice mills, sugar refine factories, and seed oil factories) were established parallel to the construction of the irrigation system.

<u>Government intervention</u>. With strong support from government, the operation of this irrigation system gradually moved toward diversified cropping after six years of trial-and-error. For the most cost-effective use of

limited water resources, the government gave the first priority to rice, the second to sugar, and the third to upland crops. As a result, rice usually received sufficient irrigation water in its growth period; sugar was irrigated on average only twice in one dry season with 90-100 mm of water. Fifty percent of the time, the upland crop was irrigated once with 60 mm of water, and for the remainder received no irrigation. This water utilization policy has been followed by farmers and policy makers for more than 60 years and is expected to continue in the foreseeable future.

Acceptance of designated diversified cropping. The main thrust of government intervention in operating this system was in expediting the project objectives, mainly achieving self-sufficiency in rice and minimizing imports of agricultural products. Ten years completion, sugar exports provided the largest amount of foreign exchange earnings. Living standards of farmers were significantly improved as well. The farmer's response to government arrangements was positive, and the designated diversified cropping pattern was strictly followed. This response was attributed to the project design successfully accommodating the aim of national food self-sufficiency and the farmer's natural profit motive. This government-designated diversified cropping pattern was strictly followed by farmers until World War II.

There has been tremendous change in the economic, social, and political environment of the last 30 years. Substantial improvements have been made in water resources and irrigation facilities since 1950. However, the three-year diversified cropping rotation technique remains unchanged; the only difference between the existing designated cropping patterns and the previous ones is that one more crop of rice and one more upland crop have been inserted into the three-year cycle. Previously, the crop rotation was grown consecutively in a three year cycle; this has been replaced by the rice-upland crop-rice-sugar-upland crop pattern (Figures 1 and 2).

Farming is a business in Taiwan, and the further it advances beyond subsistence agriculture, the more it becomes so. The officially designated diversified cropping pattern is no longer compulsory for the Taiwanese farmers. The farmer has full authority to decide his own cropping pattern, and the designated pattern is often ignored by farmers. However, this does not necessarily mean that the official cropping pattern should be abolished. On the contrary, it deserves to be maintained as the guideline for formulating water delivery schedules. From the official cropping pattern, farmers will be aware when and how much irrigation water will be available for their land; and they can select the most profitable crop to be grown by optimizing the use of available water.

The farmer's decision on his cropping pattern is usually based on profit maximization and risk aversion. The designated diversified cropping pattern followed is highly correlated to the price fluctuations in both input and output products. In general, about 80-95 per cent of farmers will follow the official cropping pattern if their lands are in turn for growing rice, because rice has a comparatively stable price and thus a reliable profit. Furthermore, the land will be too soggy for individual farmers to grow upland crops if the majority of lands are growing rice.

Figure 1. Irrigation for three year crop rotation. (Note: From November to March, sugar cane will be irrigated two to three times according to water supply and actual need.)

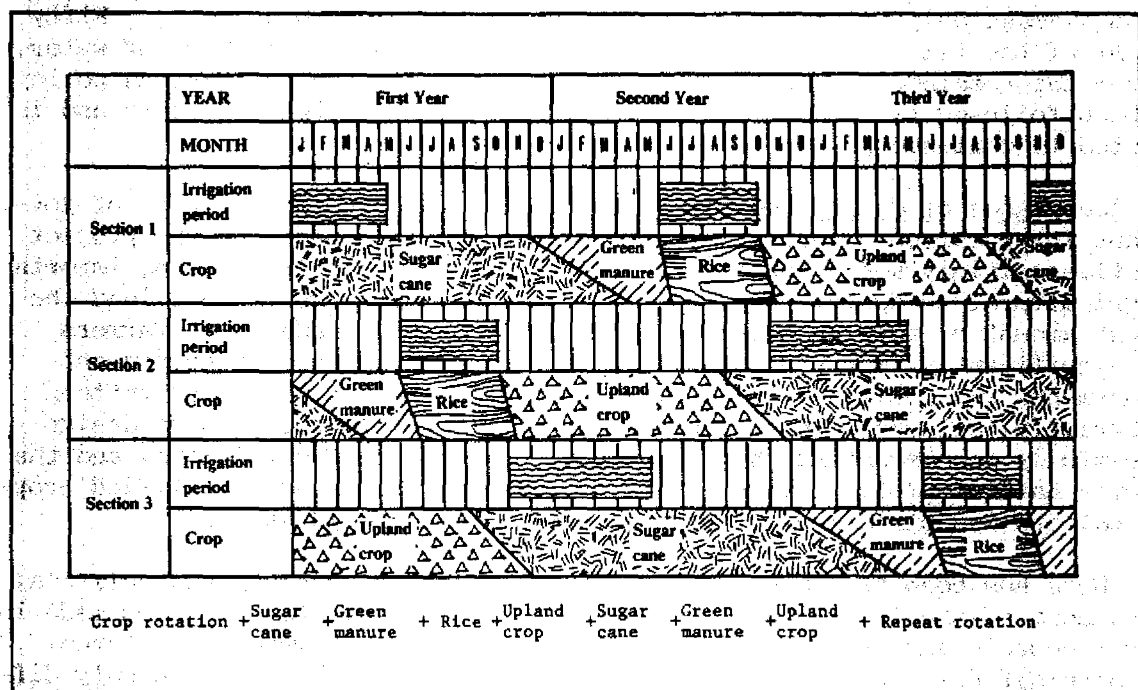
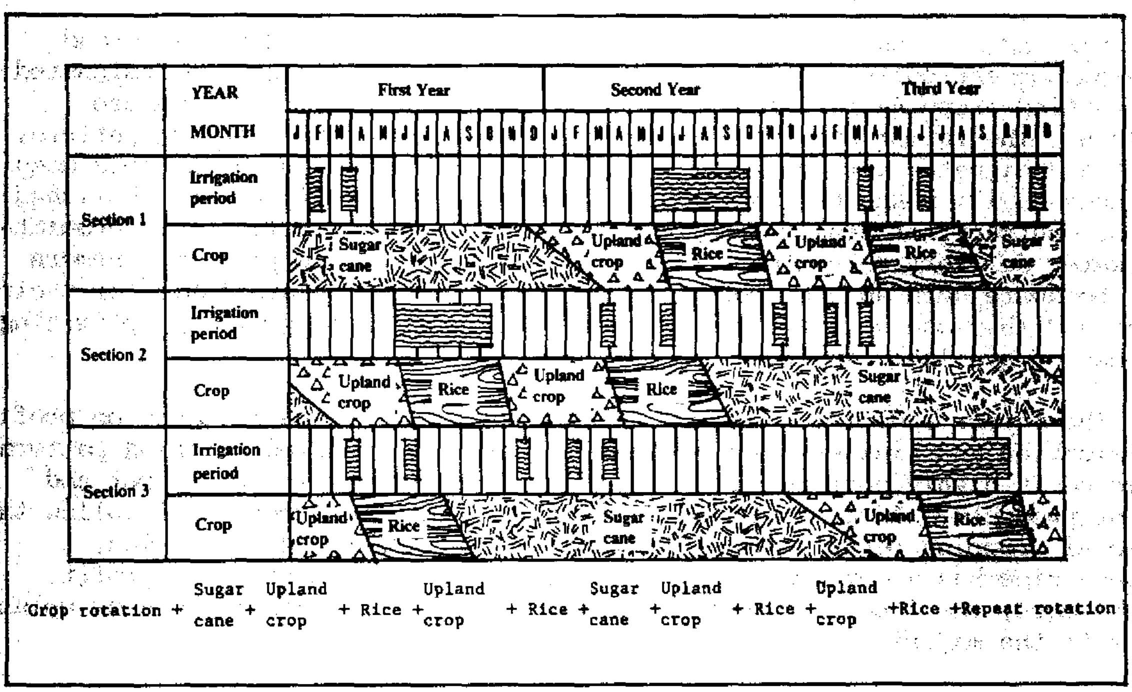


Figure 2. Modified irrigation schedule for three year crop rotation of the Wu-Shan-Tow system after completion of the canal lining. (Note: The upland crop will be irrigated once in March-April and once in late June. Upland rice will be irrigated twice.)



On average, less than 30 per cent of the area selected for sugar will actually be planted due to its low price. As a result, about half the refineries in that area have closed in the last 20 years. Two to three upland crops can be grown on these lands to substitute for one crop of sugar. More than 80 per cent of the area is scheduled for upland crops because the land will not support rice unless the land owners have their own water resources.

Status of Adoption of Diversified Cropping in Irrigation Projects

Notwithstanding widespread skepticism about adopting diversified cropping in rice-oriented irrigation systems, many international agencies financing irrigation projects in Asia have already adopted diversified cropping to some extent. A typical irrigation project usually has sufficient water to irrigate the entire area in the wet season; however, in the dry season, the availability of water may not be adequate to irrigate the whole area, so part of the available water will be allocated to upland crops. Moreover, between the two main rice crops, a small portion of the project area will grow some upland crops. As a result, 210-250 per cent of the multiple cropping index can generally be found in such irrigation projects.

However, diversified cropping is adopted in those projects mainly to enhance the economic viability of the project. Because the capacity of the irrigation facilities is usually dominated by the requirements of wet season irrigation, inserting upland crops either between the two main rice crops or concurrently with rice in the dry season will not affect the capacity of the system. Thus the incremental investment cost to the project for adopting diversified cropping is often considered negligible (though this may not always be true) and a significant benefit will be obtained. Therefore, diversified cropping has been broadly adopted as the guiding project cropping pattern in recent irrigation projects. Whether the necessary inputs have been properly supplied for the implementation of diversified cropping or to what degree the designated cropping pattern has even been realized still remain to be seen.

DECISION MAKING AND ITS CONSTRAINTS FOR CROPPING PATTERN

Adopting a cropping pattern is influenced by three levels of decision making: government, system (irrigation associations), and farmers. Farmers base their decisions on the natural environment and on the economic, social, and structural environment created by public institutions, including agricultural sector policy, land reform, commodity pricing, long-term investments, and special subsidy programs. Identifying how farmers make their decisions must consider the role of these public institutions and the government and irrigation association decision makers. Each group has its own objectives and its own constraints which limit objectives. While their objectives may not necessarily be contradictory, their priorities may differ. The objectives, constraints, and responsibilities for each group are described below.

Government Level

This is the national policy-making level. Agricultural policy objectives formulated at this level usually aim at increasing national, regional, and farmers' net incomes; achieving equitable distribution of income; improving social welfare; and providing food self-sufficiency. Balancing all of these objectives is complicated by the long list of constraints acting on the agricultural sector. Among the most pressing constraints are: finding available cultivable and irrigable land; lack of money for investment, subsidy, operation, repair, and maintenance of infrastructure; poor land tenure system; weak foreign and domestic demand for commodities; and small farm size.

System Operator Level

The primary objectives for cropping patterns and water use at this level are to: distribute water equitably to farmers, use available water efficiently, improve crop yield, and maximize irrigation service fee collection. The constraints which limit these objectives are institutional -- limited budget, lack of control over government subsidies and loans, uncertain agricultural support, inadequately trained or lack of personnel, and weak enforcement and arbitration of water rights -- and physical: uncertain water resources, poor soil and topographic variations over the region, and poor condition of existing irrigation/drainage facilities.

Farmer Level

It is universally true that farmers in an irrigation system still have latitude to make independent decisions on cropping patterns and water use. Their decisions are often guided by the following objectives: a) to increase net income, b) to minimize their exposure to risk, c) to maintain control over farming decisions, and d) to preserve traditional practices. There are a number of factors which limit the farmer from attaining the theoretical maximum of his objectives: soil type, farm location in the irrigation system, condition of irrigation/drainage facilities, designated cropping pattern, availability of water resources, previous experience, level of education, available credit; working capital, and available agricultural information. The crop production and gross income may be limited by one or more of these constraints, or several constraints may be simultaneously binding on a particular farmer's decision-making.

PRIMARY REQUIREMENT FOR DIVERSIFIED CROPPING

While recognizing the possibility of adopting diversified cropping in rice-oriented irrigation projects, the next question is what inputs are needed in the stages of project preparation, project implementation, and project operation. Based on experience gained in the operation of the sophisticated rotation cropping scheme in Taiwan, the physical and institutional inputs necessary for diversified cropping are described below.

Institutional Inputs

Guiding cropping pattern. To realize the government's investment objectives in the irrigation sector a guiding cropping pattern is usually formulated during the project preparation stage as the basis for determining the development scale, cost estimate, and project benefit monitoring evaluation.

In the project operation stage, it serves as a guide to the system operator to carry out the irrigation program; the irrigation water will be delivered mainly according to the farming activities proposed in this pattern. The farmer may, therefore, know when and how much water will be available in the field in advance and can thus plan his farming activities accordingly. This pattern is subject to modification in the project operation stage in accordance with changes in national short term agricultural strategy. Thus, the pattern must be so well prepared that completed irrigation/drainage facilities, whose designs are based on that cropping pattern, can be flexible to accommodate any possible modification.

Agronomists for water management. The complexity of the plant-soil-water relationship for non-rice crops requires advice from an agronomist. For an intensive diversified cropping irrigation system, one agronomist for every 500 ha of diversified cropping is considered necessary.

Experiment and demonstration stations. The tendency to preserve tradition always inhibits farmers from accepting new cropping patterns. A demonstration is one of the best ways to convince the farmer to experiment; and a successful demonstration of farming practice and irrigation management must be supported by field experiments. Therefore, the establishment of field experimental and demonstration stations in the project area should be one of the project components for a diversified cropping irrigation project.

Agricultural support services. The need for agricultural support services, including extension, input supply, storage and marketing, by-product utilization, and agricultural credit in a diversified cropping irrigation system is more critical than in a rice-only irrigation project. The more support services the government provides, the more intervention power the government holds and the more the government's objectives will be realized.

Access to agricultural information. Better access to agricultural information on prices of inputs and outputs, supply and demand of agricultural commodities raise the quality of the farmer's decision-making. This input may be considered as a part of agricultural support services; however, it is so important to a commercialized farming system that it needs highlighting.

Physical Inputs

In essence, the major physical inputs required are the same as for any other irrigation project though sensitivity to the various physical inputs between rice and non-rice crops may differ. Proper physical inputs must be provided for both rice and non-rice crops simultaneously. The additional physical inputs required for diversified cropping are recommended[3] below.

Drainage facilities. Drainage as well as irrigation facilities are essential to growing upland crops. Most upland crops cannot sustain growth in saturated soil for more than one or two days. Without good drainage, an irrigation system cannot adopt diversified cropping effectively. Moreover, the principle of a better yield from a better drainage system also applies to rice. Good drainage facilities may be considered as an incremental investment in diversified cropping. The design capacity for drainage facilities is governed by rainfall, soil characteristics (infiltration rate), ground water table, and how long a plant root zone can remain saturated without adversely affecting the plants, which in turn depends principally on temperature, type of plant, and growth stage. In some cases, the investment cost for drainage facilities may take up a large portion of the total project cost, preventing the adoption of diversified cropping in that project.

Irrigation facilities. Theoretically, the capacity of facilities designed for rice irrigation should be sufficient for irrigating upland crops. Although additional irrigation facilities for diversified crops are usually considered unnecessary, in some extreme cases, if the designed capacity of canals is based on lengthy land preparation (longer than 30 days) and the irrigation cycle for upland crops requires a shorter period (shorter than 10 days), then the canal needs a higher conveyance capacity to meet the requirements of upland crop irrigation. This may happen more often in lateral or sub-lateral canal systems than in main or lateral systems. Temporarily using part of a canal's freeboard for conveying water will adequately meet the requirement of the highest discharge in upland crop irrigation. If the required quality of irrigation management is the same for irrigating rice and non-rice crops, there is no justification for additional water measuring devices.

IRRIGATION MANAGEMENT IN DIVERSIFIED CROPPING SYSTEMS

The Characteristics of Upland Crop Irrigation

Basic differences between rice and upland crop irrigation. The objective of irrigating rice and upland crops is the same, but the concept and characteristics of irrigation is very different for each. Rice is an aquatic plant and can survive or even thrive when its root zone remains saturated. Irrigation water is applied to the paddy in sufficient amounts to keep the right depth of water above the ground surface and to meet the consumption of soil percolation and plant evapotranspiration in one irrigation cycle. The two governing factors for rice irrigation are the soil's final infiltration rate* and plant evapotranspiration.

Upland crops survive only for a short period if the rootzone remains saturated. Upland crops extract moisture stored in the soil of their root zone; thus the water depth and frequency of water application in upland crop irrigation varies with the depth of rootzone and distribution as well as with the moisture-holding characteristics of the soil. The rooting depth and the distribution of roots depend mainly on the kind of crop, the growing stage, and the soil profile. The available moisture-holding capacity (i.e., the difference in volume percentage between field capacity and wilting point is predominantly determined by the texture and structure of the soil). There are more variables in upland crop irrigation than in rice irrigation.

Compensation for lack of data. The complexity of upland crop irrigation may inhibit many irrigation projects from extensively adopting diversified cropping if the above-mentioned phenomena have to be identified and relevant data must be collected in the preparation of a diversified cropping irrigation project. Fortunately a lack of such data can be compensated for in two ways. In the project planning stage, data from comparable areas can be used and in the project implementation stage, the adopted data in the project preparation stage can be verified via demonstrations at local experiment stations. More accurate data can be obtained through trial-and-error in the project operation stage leading to improvements in irrigation management.

Formulation of a Cropping Pattern to Guide the Project

Irrigation water requirement. Basic data on the irrigation water requirements for rice and upland crops is required for formulating the optimal cropping pattern to guide the project. If fundamental information is lacking, the modified Penman method can be used to calculate a crop's consumption of water. The fundamental information needed to estimate consumption, such as crop coefficient, climatic data (like temperature, relative humidity, wind velocity, sunshine hours, and evaporation), and effective rainfall should be available. The additional information needed for upland crops is the soil field capacity. The overall irrigation efficiency for upland crops may be assumed to be about 35-45 per cent. The residual soil water content before irrigation can be obtained by sampling the field soil.

Trial-and-error procedure. The optimal cropping pattern can be formulated through trial-and-error by assuming acreage of various crops, multiplying this acreage by their corresponding irrigation requirement and net benefit. Then the annual project net benefit and annual water requirement can be obtained. The feasibility of each trial can be judged against the annual water requirement and water availability. Then the optimal cropping pattern can be selected from those trials.

System analysis approach. The optimal cropping pattern can be directly calculated by using operational research. Government's long-run objectives can be formulated by using areas of various crops to be grown as the decision variables. The net benefit of each unit area of crop is used as the parameter for each corresponding decision variable. It is possible to establish a group of constraint equations for the objective function from the available water resources, available area, the capacity of irrigation facilities as well as the irrigation requirement for each crop. By solving the objective function and the group of constraint equations simultaneously by linear programming, the optimal cropping pattern can be obtained.

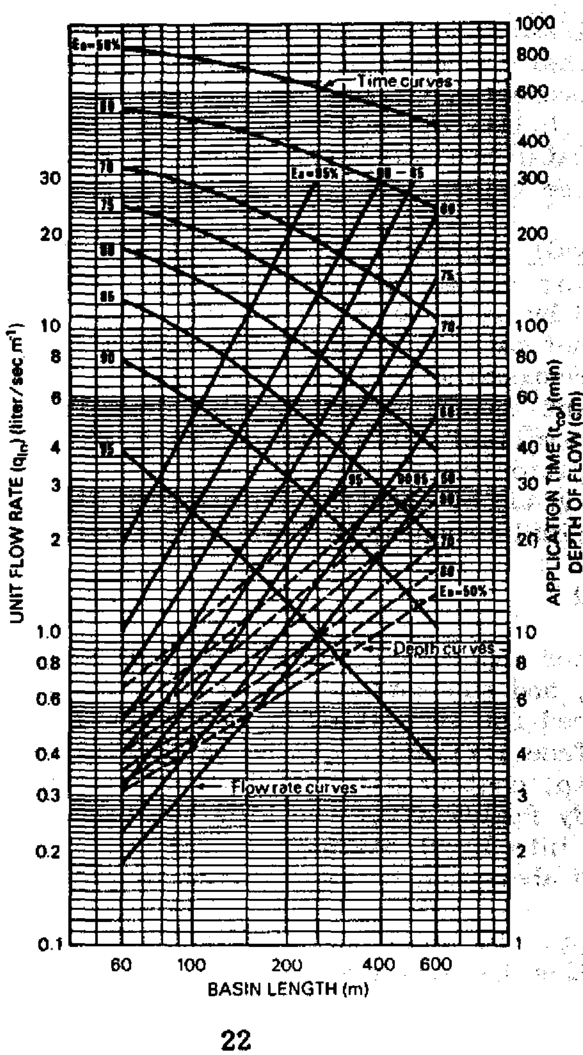
Irrigation Method

There are four major categories of upland crop irrigation: sprinkler, trickle, surface, and sub-surface, among which only the surface irrigation method is practiced for irrigating upland crops in paddy fields. Depending on the crop, surface irrigation can be categorized as: furrow and corrugation; border strip; contour ditches flooding; and basin. When upland crops are grown in paddy fields after the rice has been harvested, the land will have been graded into level basins. Therefore, all the surface irrigation methods indicated above can be implemented in the condition of level-basin.

Basic concept. In level-basin irrigation, the water flows over the basin first and then becomes static. For attaining infiltration uniformity, the water is generally applied to cover the field in a relatively short period on a volume basis. The main portion of the water infiltrates during static flooding. This is different from sloping border irrigation, in which flow rate is balanced against application time to provide uniform and coverage. Without ponding in sloping irrigation, the infiltration occurs while the water is moving, i.e., has dynamic status. Thus, it appears that level basin irrigation is less complicated than sloping surface irrigation.

<u>SCS Design Manual and its application</u>. The factors which govern level-basin irrigation are: unit flow rate, basin length, flow depth, application time, application efficiency (distribution uniformity), Manning roughness value, soil infiltration rate, and net application depth. Correlating all these factors is complicated. The SCS Design Manual[5] is recommended for examining length and design capacity of farm ditches in the project preparation stage, and for determining irrigation time in the project operation stage.

Figure 3. SCS design chart for a 7.6 centimeter net depth of application, roughness coefficient "n" of 0.15 and an intake family of 0.5.



In order to familiarize readers with the Manual, an example is given as follows: referring to Figure 3, for a basin length of 200 meters to attain an application efficiency (distribution uniformity) of 80 per cent, the required unit flow rate would be 3.3 liters per second (lps), the application time (Tco) would be 96 minutes, and depth of flood would be 10.4 centimenters (cm). If total flow were 150 lps, the basin width should be about 45 meters. To increase the basin length to 400 meters with the same distribution uniformity, the corresponding values would be qin = 11.2 lps, Tco = 55 minutes, and the depth of flow would be 18.8 cm. For the same flow rate into the basin, the basin width should be decreased from 45 to 13 meters. The example indicates that the only information required for measuring in the field is the intake rate of the soil; with this information, the Manual can be easily used for the design of on-farm systems as well as for irrigation planning.

Crop and irrigation method. The method of irrigation is mainly determined by the type of crop. An improper irrigation method not only decreases irrigation efficiency but also may adversely affect crop growth. In general, close-growing crops such as peanut and wheat are irrigated by corrugation, borders, border ditches, basin and contour ditches, while row crops such as sugarcane, corn, and sweet potato are irrigated by furrows and borders.

Physical Operations and Maintenance (O&M)

Irrigation planning and execution.

a) Guiding crops. Although there may be more than one crop grown in the upland field, irrigation cannot be planned based on the exact crops in the field. If the project uses an officially designated cropping pattern, the crop or crops proposed would be adopted as the guiding crop or crops for the calculation of irrigation requirements.

b) Water delivery schedule. Based on the guiding crops of the officially designated cropping pattern, availability of water resources and field weather conditions, the water delivery schedule should be formulated one month before the date of delivery. The farmer and relevant agricultural agencies must be informed of the details of the irrigation planning and water delivery schedule as early as possible.

c) Preparatory works. When the water delivery schedule is announced, the farmer should make up his mind what crop to grow and commence land preparation, procurement of seeds and other inputs. Meanwhile, the agricultural extension agency should make all agricultural inputs available before the commencement of water delivery.

d) Water application. Level basin irrigation needs a higher discharge to maintain higher irrigation efficiency, so within one tertiary canal system, water should be concentrated for application on a plot-by-plot basis. If there is a constant water discharge, the volume of water applied to each plot will be based on the irrigation time; each plot of land will share irrigation time in proportion to its acreage. The summation of each plot's irrigation time must be equal to the time of one irrigation cycle. Keeping tertiary canal discharges constant within one irrigation cycle period is important for an equitable distribution of water. The irrigation time allocated to each plot must be strictly followed without any interruption during irrigation. Incidentally, the water may not reach the end of the basin within the allocated time of irrigation. This may occur due to improper basin length, too high a percolation rate or wrong irrigation method, poor land preparation causing a high flow resistance (Manning Value) is often found in this case. There is no excuse for increasing the irrigation time for those who do not prepare their land well.

e) Frequency of irrigation. The frequency of irrigation should be determined according to the moisture content of the soil if water resources are not a constraint; however, in most cases, the available water is often limited, and so irrigation may only be given in the critical period. In areas with 2,500 mm of annual precipitation, three to four irrigation applications will be enough for sugar cane; two to three are adequate for corn, peanut, potato, and soybean. Short root zone crops such as vegetables, melons should be irrigated every 5-10 days; but it is impractical to adopt such frequent irrigation as the standard practice for upland crop irrigation in an extensive irrigated area. This kind of irrigation must be arranged in a small area.

Maintenance of irrigation/drainage facilities. One serious maintenance problem in an extensive, diversified cropping irrigation system is that it is difficult to find enough time to undertake major maintenance of irrigation and drainage facilities. In order to overcome this difficulty, the main maintenance program including necessary investigation, survey, design, cost estimate, and contract tendering should be completed in the last stage of rice irrigation. Then the main maintenance can be launched immediately after the end of rice irrigation.

Aside from the major maintenance required between rice and upland irrigation, regular minor maintenance during the irrigation period is important to assure the security of irrigation and drainage facilities. This regular maintenance for off-farm systems is usually undertaken by contract labor under the supervision of O&M personnel; for on-farm systems, farmers should be encouraged and assigned to carry out regular maintenance, mainly clearing farm ditches. Farm ditch clearing, including drainage and irrigation systems, should be carried out at least once before every irrigation cycle.

Incremental O&M staff. Comparing the number of O&M personnel required for a diversified cropping irrigation to that required for a non-diversified cropping irrigation system, about 30-40 per cent more staff are needed in a diversified cropping area. The actual number of O&M staff required will depend on the quality of O&M expected; on average, one person per 200-300 hectares of irrigated area is considered to be a reasonable allocation.

Farmer's participation. The enhancement of farmers' participation in O&M works is the best guarantee of success, particularly for a diversified cropping irrigation system. The O&M of irrigation systems needs farmers' participation in the following areas.

a) Farming activities. Since the water is delivered according to a schedule, not on farmers' demand, farming activities must strictly follow the irrigation schedule.

b) Proper land preparation. The efficiency of upland crop irrigation greatly depends on land preparation and the right selection of irrigation methods; upland crop irrigation will not be successful unless farmers prepare their land well.

c) Contribution to the maintenance of on-farm system. It is extremely difficult for the system operator (irrigation association) to maintain on-farm irrigation and drainage systems. Usually farmers are encouraged to provide the labor for the maintenance of those canal systems.

d) Cooperation in irrigation activities. The planning of a water delivery schedule cannot be prepared without shortcomings; smooth irrigation requires cooperation among farmers themselves and between the system operator and the farmers.

e) O&M fee. The O&M work will be significantly increased due to the adoption of diversified cropping; the correspondingly increased O&M fee should be generated from the benefits of diversified cropping, in other words, from the farmers' additional payment of O&M fees.

CONCLUSION

The practice of diversified cropping or growing irrigated non-rice crops in irrigated rice areas has prevailed in Asia for centuries. About 60 years' operation of crop rotation in the Taiwan's Chin-nan area demonstrates the potential of adopting diversified cropping in modern irrigation systems. A diversified cropping irrigation system is characterized by more flexibility in adjusting to a variety of crops. Policy-makers should be informed that the technology is available to develop an irrigation project which can simultaneously meet the objectives of assuring national food security, maximizing exports, and minimizing imports in the agricultural sector.

The main physical constraints on the extensive adoption of diversified cropping is heavy clay and poor drainage. However, excluding heavy clay soils and low-lying poor drainage areas, it is approximately estimated that about 50-75 per cent of irrigated land and potentially irrigated areas in Asia are physically suitable for adopting diversified cropping.

Institutional constraints on diversified cropping are: lack of financial incentive and agricultural supports; shortage of competent personnel and operational capital; inadequacy of cultivation techniques; and unavailability of management techniques. These can be counterbalanced to some extent by the efforts of agricultural agencies and by appropriate support from government. In particular, past experience in upland crop cultivation in the West and in some Asian countries has yielded enough technology for irrigation management and agronomic supervision to justify immediate application. As for economic constraints, governments' long-run policy and short-term strategy in the agriculture sector would play the most dominant role in influencing economic and financial constraints. Therefore, only governments can take the initiative in extensively adopting diversified cropping in irrigation projects.

Each government has its own development priority and its own constraints in supporting any specific development. For the long-run objective, if new irrigation projects are still necessary for assuring future national food security, diversified cropping is worthwhile in this kind of new irrigation project, considering that the incremental investment cost of diversified cropping is very limited. In the operational stage, if diversified cropping is not the national priority, government may minimize its intervention in crop diversification, and let the international and domestic market mechanism determine the degree of diversified cropping required. Whenever the national economic situation requires, the government can quickly step in to intervene in diversified cropping by providing more agricultural support services, and price guarantees. The immediate national objective in the agriculture sector can then be realized with less difficulty.

Although the technology required for adopting diversified cropping is available in Asia, the research and experiments for resolving local and immediate problems need to be undertaken in parallel with project implementation and operation. If the diversified cropping irrigation system is acceptable as a standard for future irrigation projects, it is time to invite the attention of international donor agencies and research institutes so they can use their initiative to conduct the necessary research in the most suitable countries prior to commencing new irrigation projects.

NOTES

1. This paper represents only the author's personal views and does not necessarily reflect the views or policy of the Asian Development Bank.

2. This is still under construction.

3. The inputs needed for sprinkler and trickle irrigation are excluded due to rare adoption of these two irrigation methods in paddy fields.

4. Constant value.

5. Soil Conservation Service. 1974. Design manual for border irrigation system. US Department of Agriculture.

IRRIGATION MANAGEMENT FOR DIVERSIFIED CROPPING IN TAIWAN

Li-Jen Wen*

INTRODUCTION

Irrigation in Taiwan is mainly for rice cultivation. It began in the 14th century on a small scale by immigrants from China. With a few exceptions, systems were built and managed by the farmers without any external control or assistance from the government. By 1895, over 200,000 hectares (ha) had been developed for rice cultivation, of which about 100,000 ha were under irrigation. From 1896-1945, the existing systems were remodelled, consolidated, and enlarged, and new systems were constructed. The irrigation area was increased to 562,000 ha producing 1.4 million metric tons (MT) of rice in 1938. In 1945, 502,018 ha were harvested producing 639,000 MT of rice. Since 1945, both irrigated area and rice production have increased. In 1976 production increased to 786,343 ha with a 2.7 million MT.

Such progress can be attributed mostly to advances in technology, including improved irrigation and drainage (L.J. Wen 1981a; Taiwan Provincial Department of Agriculture and Forestry 1986). For many years Taiwan was self-sufficient in rice and exported the surplus. However, this situation changed as the demand at home and abroad decreased. As a result, a diversified cropping program had to be enforced due to over-production of rice.

Technological innovation played an important role in the diversification of agriculture. The success of early maturing crop varieties, relay interplanting, plant protection measures, fertilization, dense planting, new farm machinery, and extension of upland crop irrigation have increased efficiency of water, land, and labor use which in turn substantially increased the adaptability of diversified cropping, thus maximizing resources use.

NATURAL ENVIRONMENT

Taiwan, located in the subtropical zone, has a total area of 36,006 square kilometers (km), and is about 394 km long from north to south and 144 km at its widest point. Two-thirds of the island is sloping and mountainous. A central range divides the island into eastern and western coastal plains. The western part is characterized by advanced agricultural and industrial activities. The total cultivated land was 883,106 ha (25 per cent of the total area) in 1985. Rice occupied 493,641 ha and upland crops 389,465 ha (ibid. 1986; Council of Agriculture 1986). The total irrigated area of the 17 irrigation associations was 385,423 ha in 1985, of which the double rice-crop area occupied 257,177 ha; the single rice crop, 27,036 ha; the rotation cropping area (including 2- and 3-year rotations, 84,115 ha; and the upland crop area, 17,095 ha. There are other areas totalling 31,500 (ibid. 1986).

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Figures 1 and 2 show that temperatures average 18°C in winter and 28°C in summer on the coastal plain and rainfall averages 251 centimeters; about 78 per cent falls from May to October (National Taiwan University & Joint Commission on Rural Reconstruction 1970).

Figure 1. Average temperature in different parts of Taiwan (1950-69).

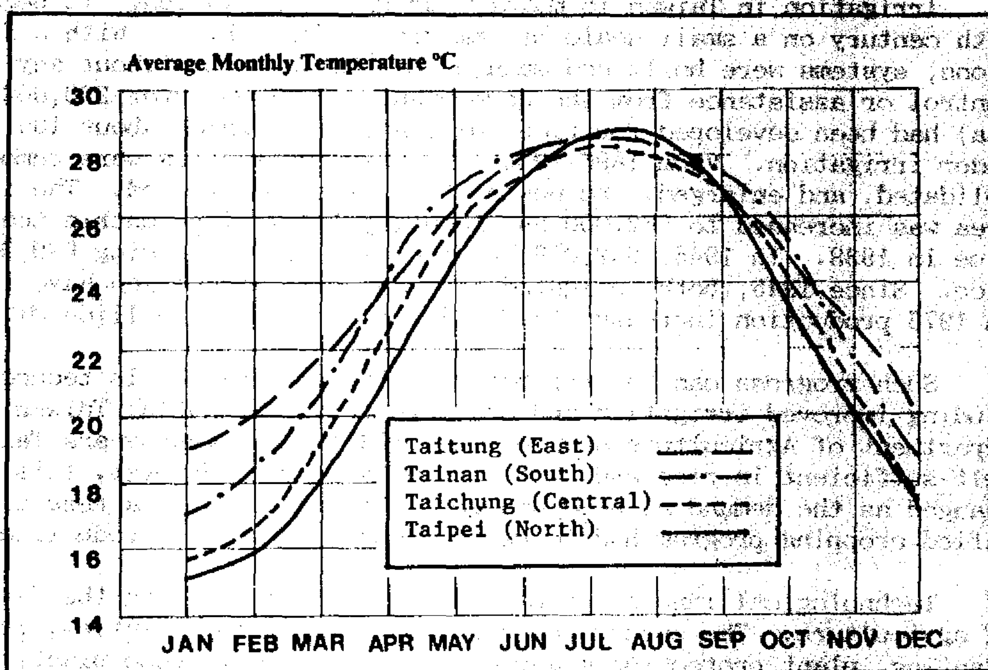
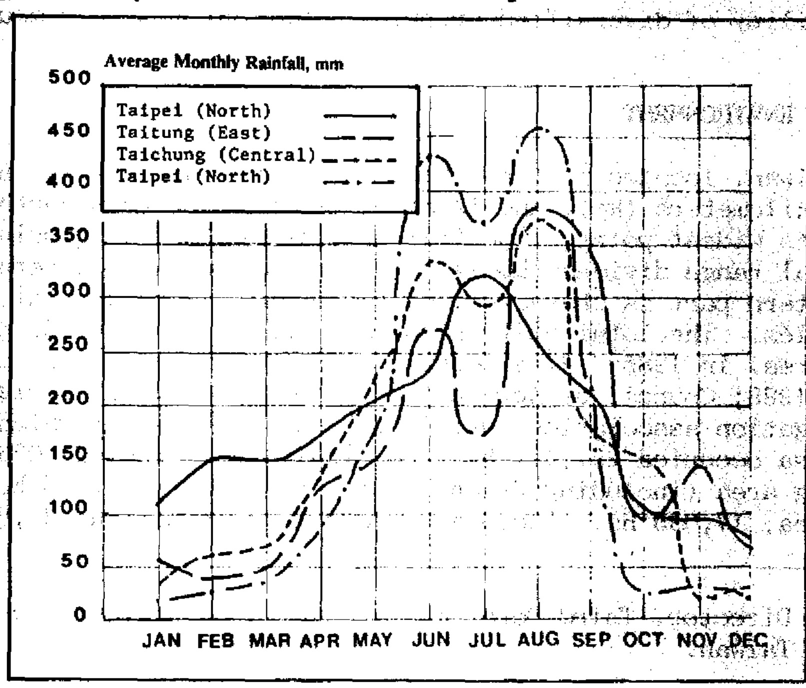


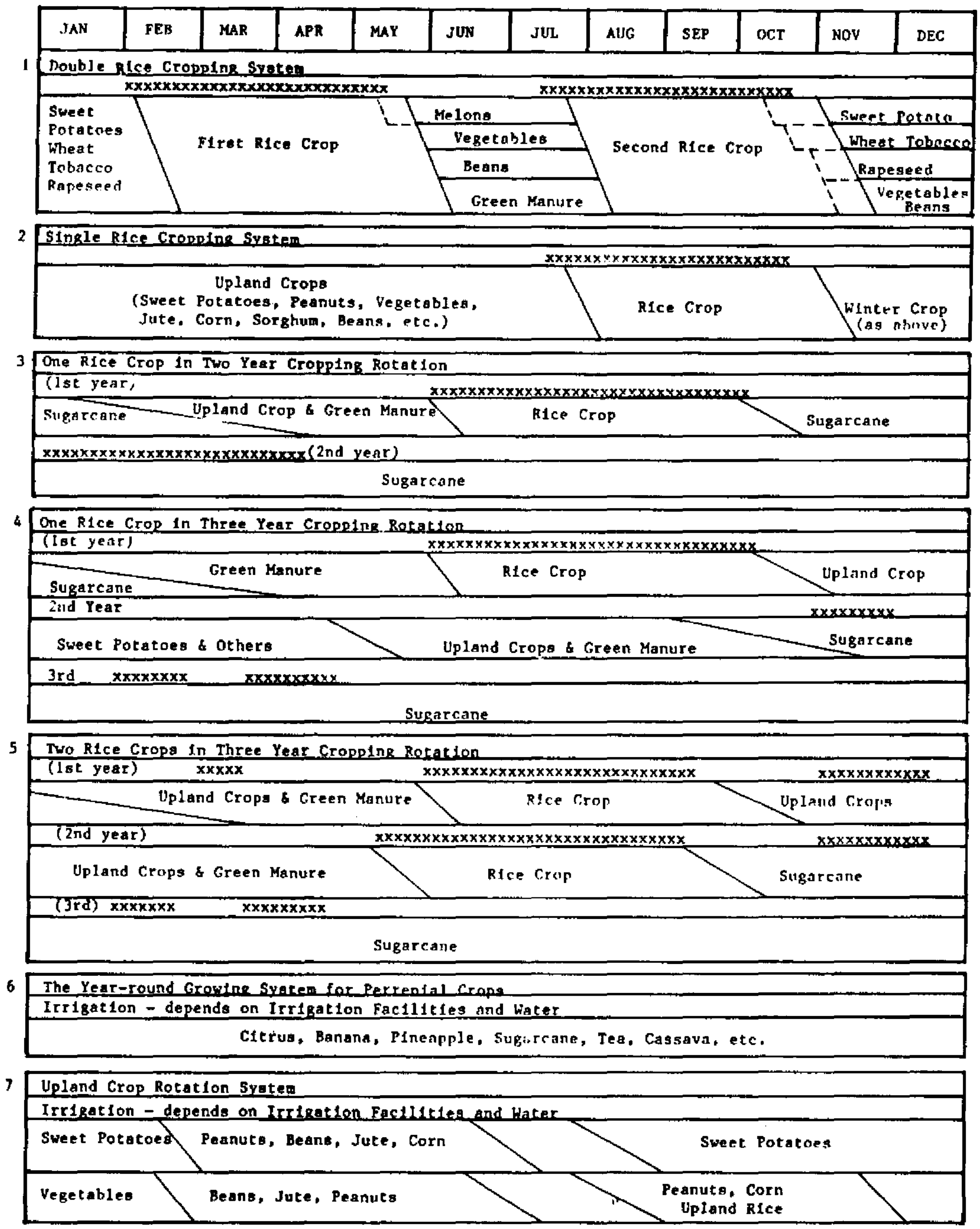
Figure 2. Average monthly rainfall in different parts of Taiwan (1950-69).



Cropping Patterns

Figure 3 shows that Taiwan's cropping systems and irrigation patterns may be classified into seven groups (Yuan H. Djang 1978; L.J. Wen 1981a). Ordinarily there are three or four crops a year, with rice as the main crop.

Figure 3. Various cropping patterns adopted in Taiwan.



Cropping Index

The motives for intensive diversified cropping are mainly limited land, water and labor resources in Taiwan. Owing to the relatively small size of private farm plots, farmers adopt intensive cropping to increase income, especially in the early stages when family labor is available. The utilization rate of the cultivated land or the multiple cropping index rose from 134.2 in 1939 to 189.7 in 1964 (Table 1; Taiwan Provincial Dept. of Agriculture and Forestry 1986, Yu-Kang Mao 1975). Later, rapid industrialization caused considerable labor migration, and farm labor became short, pushing up production costs. On the other hand, owing to the rapid growth of Taiwan's economy, increasing demands for high protein food items and fruits have encouraged the farmers to grow more perennial crops (Y.T. Wang 1975). Consequently, the multiple cropping index gradually decreased from 189.7 in 1964 to 142.4 in 1985 (Taiwan Provincial Dept. of Agriculture and Forestry 1986).

Table 1. Multiple cropping index (MCI) and agricultural employment (in thousands), 1939-1985.

Year	Crop area	Cultivated area	MCI	Agricultural employment	Employment/ha cultivated land
1939	1154	860	134.2		
1941	1183	859	137.7		
1943	1121	839	133.6		
1945	833	816	102.1		
1947	1249	834	149.8		
1949	1438	865	166.2		
1951	1502	874	171.9		
1953	1488	873	170.4	1647	1.89
1955	1508	873	172.7	1667	1.92
1957	1566	873	179.4	1689	1.92
1959	1590	878	181.1	1722	1.96
1961	1613	872	185.0	1747	2.00
1963	1613	872	185.0	1775	2.04
1965	1680	890	188.8	1748	1.96
1967	1696	902	188.0	1723	1.92
1969	1679	915	183.5	1726	1.89
1971	1620	903	179.4	1665	1.85
1973	1567	896	174.9	1624	1.82
1975	1659	917	180.9	1681	1.82
1977	1566	923	169.7	1597	1.72
1979	1549	918	168.7	1380	1.52
1981	1398	900	55.3	1257	1.39
1983	1334	894	149.2	1317	1.47
1985	1257	883	142.4	1297	1.47

Ibid. 1986; Council for Economic Planning and Development 1986.

ADJUSTMENT OF FARMING SYSTEMS

Group Farming

Migration of rural labor to urban-industry sectors has induced changes in cropping systems, depending on farm size. Small farms (less than 0.5 ha) continue to intensify land use. Two to three harvests of fruit, or seven to eight vegetable crops a year are common. Small farms of around one hectare or larger cannot be managed with family labor alone. Owners have to cut down on crop acreage. Group farming to accelerate farm mechanization has gradually been adopted. Thus, diversified multiple cropping systems tend to change to monoculture and the multiple cropping index declines with increased group farming (Kuang-Chi Su 1983).

There are two common types of group farming activities in Taiwan: joint operations and entrusted farming. Both are based on voluntary cooperation in cultivation and management activities without any change in land ownership within the family farm system. The first trial on joint operation began in 1963. Farmers organized themselves into a group of 20-30 with a total area of 20-30 ha to jointly carry out farming operations including field preparation, planting, weeding, fertilizer application, irrigation and drainage, pest and disease control and harvesting.

Entrusted farming is also popular, and has two types: entrusted cultivation and entrusted management. In the former, a farmer entrusts another farmer to carry out a part or all farming operations by paying an agreed wage. In the latter all farming operations and management are carried out by the entrusted farmer, who acts as an owner/operator/manager and pays the return on land investment in lieu of land rent.

Change in Crop Production

In Taiwan, farmers grow rice, common crops (sweet potato, barley, wheat, millet, corn, sorghum, and soybean), special crops (tea, sugarcane, and tobacco) and horticultural crops (vegetables, banana, pineapple, and citrus fruit). Among these, rice and sugarcane have been the two most important crops. Rice production enables a self-sufficient supply of staple food; sugar is mainly for export.

Increasing per capita income has altered the structure of food consumption. Per capita consumption of rice dropped from 138 kilogram (kg) in 1960 to 96 kg in 1982. On the other hand, production of fruit, vegetables, hogs, and chickens increased tremendously and per capita daily nutrient availability increased (Table 2). The local supply of corn, soybean, and sorghum as feed was insufficient. Consequently, imports of these crops increased, and the acreage of the same kinds of crops locally produced with high production costs decreased year after year.

There is a large rice surplus because of limited domestic and export markets. The best solution is to shift some rice acreage to cultivate corn, sorghum, soybean and other crops by adjusting farming systems.

Table 2. Per capita daily protein availability (in grams), 1952-84.

Year	Calories	Total	Animal	Vegetable
1952	2078	49.04	11.73	37.31
1953	2283	53.42	12.49	40.93
1955	2247	53.15	13.30	39.85
1957	2369	56.80	14.09	42.71
1959	2340	56.57	14.59	41.98
1961	2430	60.34	15.79	44.55
1963	2325	58.76	16.81	41.94
1965	2411	61.20	17.58	43.62
1967	2504	64.47	19.30	45.17
1969	2639	69.06	21.20	47.86
1971	2674	72.42	23.87	48.55
1973	2754	73.68	25.67	48.01
1975	2772	74.70	24.56	50.14
1977	2805	76.59	28.68	47.91
1979	2845	78.72	31.85	46.87
1981	2765	76.43	32.33	44.10
1983	2792	79.16	33.93	43.77
1984	2811	80.22	37.07	43.15

Council of Agriculture 1985b.

Six-year Rice Crop Substitution Program

This program was initiated in 1984 to reduce the rice surplus by shifting to other crops. The target was to reduce rice area from 645,855 ha in 1983 to 515,500 ha in 1989 and to decrease production from 2.48 million MT to 2.0 million MT. Two subsidy measures were adopted: 1) 1.0 MT/ha of rice for shifting to corn, sorghum, soybean, or sugar cane; 2) 1.5 MT/ha of rice for shifting to vegetables, fruit, or for fallow or aquaculture. Rice area and production decreased in 1984 to 587,186 ha and 2.24 million MT, and in 1985 to 564,392 ha and 2.17 million MT, respectively (Table 3).

Table 3. Rice crop substitution program (in hectares) in Taiwan, 1984-85.

	1984		1985	
Items	Area	% target	Area	% target
Corn, sorghum	10,137	40.5	15,905	72.2
Vegetables, fruit	23,104	888.6	24,017	128.6
Aquaculture	204	17.0	435	36.3
Misc crops & fallow	30,359	204.0	55,758	272.1
Total	63,804	146.0	96,115	154.0

Council of Agriculture 1986.

PRESENT POTENTIAL AND PROBLEMS

The total irrigated area in Taiwan decreased from 518,915 ha in 1968 to 416,880 ha in 1985 due to changes in land use for industrial and urban development (Table 4).

Table 4. Irrigated area (in thousand hectares) in Taiwan, 1965-85.

		Service area of 17 irrigation assoc						Private irrigated area				
Yr	Grand total	Total	Dbl crop	Single crop	Dry crop	Rot crop	Other	Total	Dbl crop	Single crop	Uplnd field	Rot crop
65	494	478	300	41.0	15.9	121	-	16.4	12.3	1.6	2.3	0.02
66	500	482	300	45.4	11.6	125	-	17.5	12.3	3.0	2.2	-
67	506	490	308	48.8	13.2	120	-	16.2	12.8	2.1	1.4	-
68	519	500	321	44.0	12.0	123	-	19.3	15.7	2.3	1.3	-
69	485	465	284	47.2	3.5	121	12.3	19.2	15.6	2.3	1.3	-
70	500	468	283	47.2	3.5	126	8.1	32.1	29.4	2.2	0.2	0.02
71	510	453	283	45.4	0.9	125	-	57.0	29.9	16.3	10.0	0.82
72	506	449	280	44.1	1.1	123	-	57.0	29.9	16.3	10.0	0.82
73	453	441	274	45.0	0.9	121	-	11.6	3.1	0.8	6.8	0.92
74	468	442	281	42.0	4.4	115	-	26.1	13.2	3.2	8.8	0.99
75	457	428	281	38.5	5.9	103	-	28.5	14.9	3.5	9.3	0.87
76	453	427	282	38.8	3.7	103	-	26.2	11.8	4.1	9.3	1.03
77	439	420	280	36.5	3.7	100	-	18.1	7.5	2.3	7.3	1.03
78	435	417	278	34.9	3.5	100	-	18.2	7.5	2.3	7.5	0.92
79	436	411	277	31.2	12.6	91	-	24.4	11.2	2.7	9.4	1.12
80	428	404	271	29.2	12.8	90	-	24.5	11.2	2.8	9.4	1.12
81	423	398	269	27.8	12.2	89	-	25.4	9.2	4.1	11.0	1.01
82	416	394	269	28.4	13.4	90	-	25.4	8.2	3.8	9.7	1.01
83	411	389	257	28.2	14.5	89	-	22.7	8.1	3.8	9.7	1.03
84	420	388	259	26.9	14.9	88	-	31.5	8.6	7.0	14.8	1.06
85	417	385	257	27.0	17.1	84	-	31.5	8.5	7.1	14.8	1.06

Note: dbl = double, rot = rotational; Taiwan Provincial Dept. of Agriculture and Forestry 1986; Taiwan Provincial Water Conservancy Bureau 1986.

The average annually decreased acreage of 5,669 ha is considerable compared to Taiwan's limited land resources. The decrease of the irrigated area should not be overlooked in predicting rice production for self-sufficiency and estimating acreage for diversified cropping in the future.

Maximum Imaginary Production Area

The maximum imaginary production area (MIPA) of imported crops may be calculated from the following assumption.

MIPA = (local crop production + imported crop quantity) / yield per hectare

The MIPAs of corn, sorghum, soybean, and wheat in 1985 are too large for the limited land in Taiwan (Table 5; ibid.). Therefore, it is impossible to increase production to reach self-sufficiency in feed and edible oil.

Table 5. Maximum imaginary production area (MIPA) of imported crops.

Crop	(1) Cultivated area ('000 ha)	(2) Production ('000 MT)	(3) Unit production (MT/ha)	(4) Imported quantity ('000 MT)	(2+4) Consumption ('000 MT)	(2+4)/(3) MIPA ('000 ha)
Corn	61.6	226.0	3.67	3016.8	3242.8	883.6
Sorghum	19.0	86.7	4.56	564.4	651.1	142.8
Soybean	7.1	12.2	1.72	1469.8	1482.0	861.6
Wheat	1.0	2.1	2.02	754.7	756.8	374.6

Ibid. 1986.

Regional Rice Land Adaptability Survey

To map out a regionally suitable crop system for reference in carrying out the crop substitution program, the Council of Agriculture, in cooperation with the Provincial Department of Agriculture and Forestry and District Agricultural Improvement Stations, initiated a survey project in 1984. An adaptability survey of major crops is based on data concerning water, soil, climate, and other crop production factors. The major crops included corn, sorghum, sweet potatoes, peanuts, grapes, tomatoes, and asparagus. By the end of 1985, the preliminary adaptability survey of corn and sorghum was completed and the survey of other crops was in progress. Table 6 shows the preliminary results for corn in different counties of Taiwan.

Problems Encountered

Small farm size. The average farm size decreased from 1.29 ha in 1952 to 1.12 ha in 1985 (Council for Economic Planning and Development 1986). The smaller the scale of farming, the higher the cost, especially when labor is scarce and machinery cannot be used. Small farm size is a constraint to increasing operational efficiency of family farms (Y.T. Wang and Y.H. Yu 1975).

Shortage of farm labor. A high labor-land ratio is favorable for multiple cropping. Taiwan's experience indicates that the farm labor per hectare of cultivated land is positively correlated to the multiple cropping index (Y.T. Wang 1975; Yu-Kang Mao 1975). Agricultural employment per hectare of cultivated land decreased from 1.89 in 1952 to 1.47 in 1985. Shortage of labor causes high wages resulting in the high cost of crop production.

Market fluctuations. The uncertainty of crop prices affect production of non-rice crops in monsoon agriculture. Setting up processing facilities and marketing channels to collect from numerous farmers scattered over large areas (Chen 1975) is the only solution but complicates management.

Table 6. Estimated areas (in thousand ha) adaptable for regional corn cultivation in different counties in Taiwan.

Counties	Spring crop				Autumn crop			
	Adapt-able	Rel adapt	Sub-total	% of field	Adapt-able	Rel adapt	Sub-total	% of field
Ilan	4.0	3.1	7.1	36	1.4	-	1.4	8
Taoyuan	1.3	5.5	6.8	17	11.3	1.4	12.8	33
Hsinchu	1.3	0.5	1.9	10	3.0	-	3.0	15
Miaoli	3.0	2.7	5.7	27	1.1	0.4	1.4	7
Taichung	1.4	2.5	3.9	11	1.8	4.6	6.5	18
Nantou	0.2	0.3	0.4	3	0.8	0.5	1.3	7
Changhua	3.6	11.7	15.3	28	.9	24.0	24.9	46
Yunlin	-	-	-	-	6.4	21.1	27.5	44
Chiayi	14.6	0.6	15.2	73	12.9	22.9	35.8	78
Tainan	10.8	7.2	18.0	83	23.2	18.2	41.5	82
Kaohsiung	-	-	-	-	2.9	7.2	10.1	36
Pingtung	-	-	-	-	4.8	15.7	20.5	51
Taitung	4.3	1.7	6.0	52	5.5	0.4	5.8	49
Hualien	2.0	4.4	6.4	44	2.4	6.0	8.4	59
Total	46.5	40.2	86.8	-	78.5	122.4	200.9	-

Note: rel = relative; Council of Agriculture 1986.

Competition with imported crops. Large quantities of corn, sorghum, and soybean were imported in 1985 (see Table 5). Their prices are much less than the locally produced crops. Government is considering methods to increase crop yields, and developing new and suitable farm machines to reduce production costs, minimize the price difference, and help the small farm economy.

Income disparity between farm families and non-farm families. The widening income disparity between farm and non-farm families has encouraged the rapid outflow of agricultural labor to the industrial and commercial sectors resulting in a shortage of farm labor, high farm wages, increased cost of production, depressed farm income to subsistence level, and low return on agricultural investment is low. In recent years, the disparity between the two families-type was narrowed to 30 per cent through government efforts.

Some technical problems. Mechanization for corn, sorghum, soybean, and peanuts is far behind that of rice. Farmers lack machines for harvesting diversified crops. Through cooperative efforts, government research institutes and farm machine companies have developed new types of sorghum combines and corn ear-harvesters. Varieties and cultural techniques of diversified crops should be improved to adapt to new conditions, especially rainy season.

Improvement Measures for Feed and Horticultural Crops

Measures to improve feed crops include: a) guiding farmers to establish entrusted machine farming centers for production of feed crops; b) promoting labor-saving cultivation methods without land preparation for planting other crops after harvesting rice; c) guiding farmers to adopt group farming without any change in land ownership within the family farming system; and d) guaranteeing the prices of locally produced corn, sorghum, and soybean.

Measures to improve horticultural and special crops include: a) improving varieties of new heat and pest resistant crops; b) strengthening research and experiment activities to improve cultivation techniques; c) promoting extension, adjusting the harvest season, or increasing the output of fruits; d) promoting research development on protective horticultural cultivation; and e) establishing vegetable-specialized areas with emphasis on summer.

IMPROVEMENT OF IRRIGATION SYSTEMS

General Description

In the past 20 years, development has focused on the economic use of water resources in relation to agricultural production. The development covered large-scale irrigation, multi-purpose reservoirs, ground water development, tidal land reclamation, and waste land reclamation. Rotational irrigation, canal lining, and land consolidation projects. Automatic remote control systems were installed and tested on several major canals for release, rating, and recording flows. Computer programming was applied to water distribution planning. Mechanized transplanting of rice was possible with better coordinated water distribution. Installation of water measurement and recording facilities at major headworks and canals was nearly completed. On the other hand, experiments and extension of dry-farm crop irrigation were undertaken. Drainage improvement was also conducted.

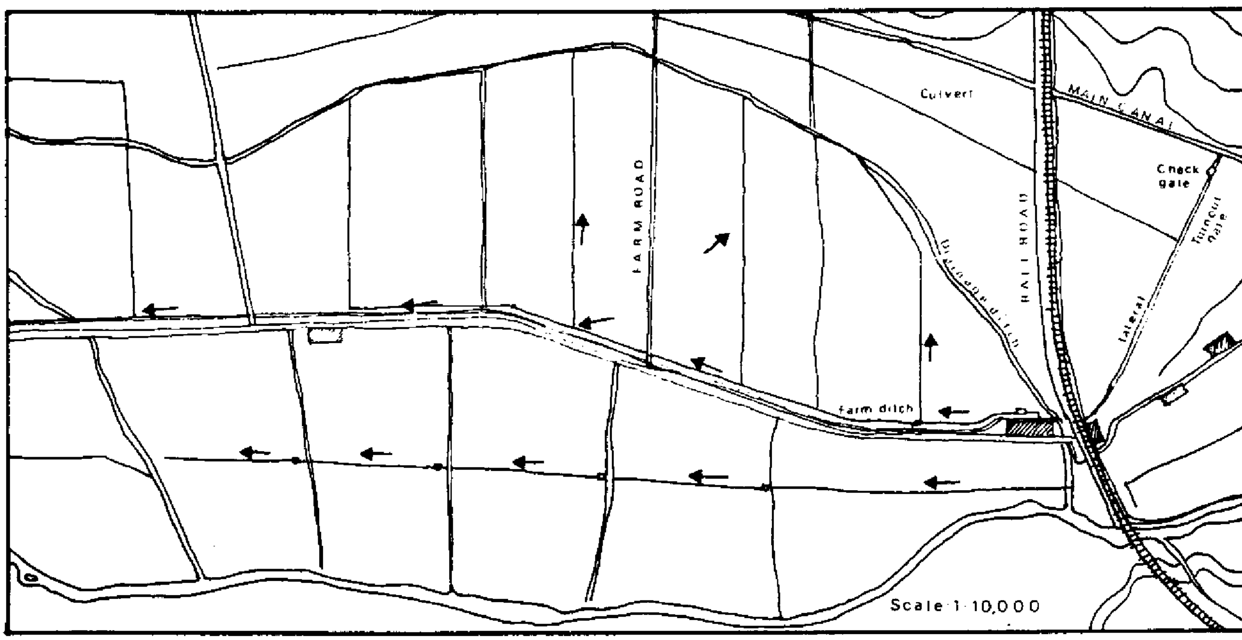
At present there are 18 reservoirs and 1,912 main canals taking water from rivers for irrigation. The total length of the main and lateral and sub-lateral canals is 15,811 km. The average length of supply ditches per hectare is about 57 meters. In addition to irrigation systems using surface water sources, there are 10,370 wells including 1,869 deep wells, most of which are used for supplementary irrigation (L.J. Wen 1981a).

Rotational Irrigation

A rotational system of water issue to farmers in appropriate quantity of water at the right time and in proper order has been adopted for rice cultivation. It is also applicable to other crops, but is different in quantity, time, and method of field irrigation. To facilitate this method of irrigation, the irrigation system has been improved so that irrigation water can be simultaneously delivered into each individual rotation area of about 50 ha. Each rotation area is subdivided into four or five rotation units, about 10 ha each in size. Every rotation area is provided with one turnout gate, one measuring device, and several division boxes. Water flowing through the turnout is measured and rotated among the rotation units with the amount of water and interval of irrigation adjusted according to the actual rotation unit size, soil and crop conditions, effective rainfall and conveyance losses (L.J. Wen 1977 and 1981a).

Continuous irrigation may be applied to rice cultivation but it will cause water-logging which harms other crops. However, rotational irrigation favors plant growth, saves fertilizer, reduces water disputes, and saves labor especially during drought. Since the rotational irrigation practice was initiated in 1956, more than 126,000 ha of paddy fields have been improved. A layout of a rotational irrigation system is shown in Figure 4.

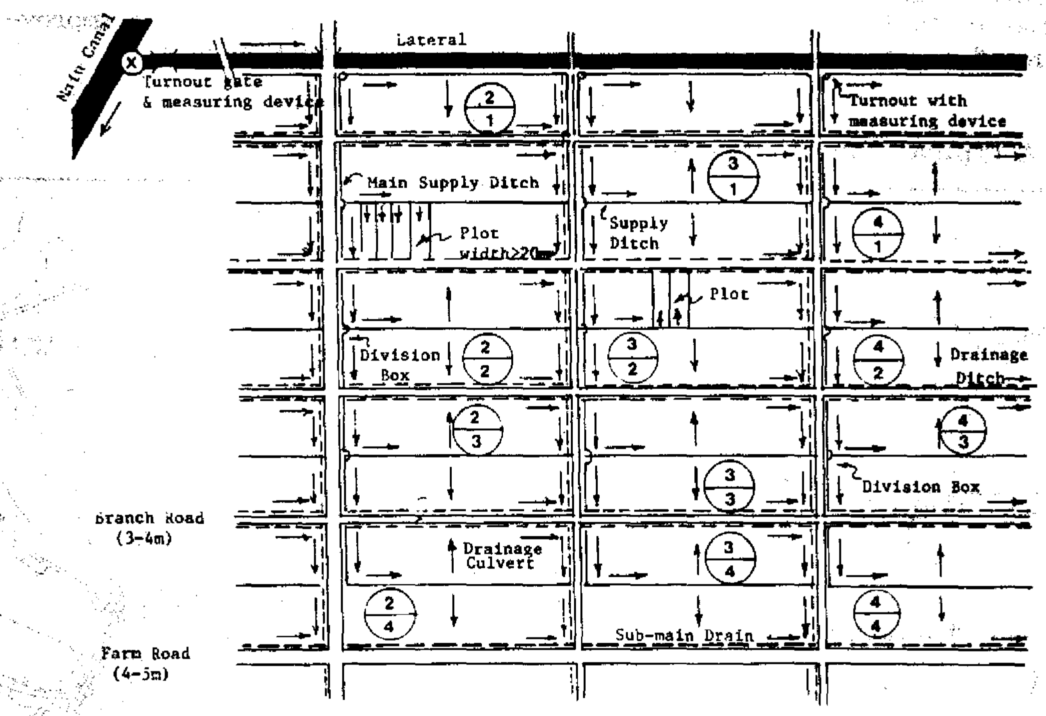
Figure 4. A typical layout of a rotational irrigation system.



Land Consolidation

Since a land consolidation program was initiated in Taiwan in 1961, some 250,000 ha of farm lands, about 80 per cent of which is paddy fields, have been consolidated. Paddy fields were readjusted into rectangular blocks surrounded by farm roads 3-5 meters wide, to facilitate transportation. Each block is about 500-600 meters long and 200-240 meters wide. In a typical layout of farm-level irrigation systems, each farm supply ditch runs in the middle, parallel to the long edge of the block and delivers water to both side plots, each a rectangular shape of 100-120 meters long and 20-40 meters wide depending on local conditions of soil, topography, size of land holding, and farm mechanization. Farm drainage ditches are usually built on both sides of the farm road. In case the topography does not permit a desirable layout, the drainage ditch may be located in the middle of the block and the supply ditch on both sides of the farm road so that the drainage ditch runs lower and the supply ditch higher in order to minimize land levelling costs. As a rule, supply and drainage ditches are at right-angles to contours to reduce the cross-sectional area of water flow, minimizing construction costs. Consequently, supply and drainage ditches are arranged along the short edge of each plot and the main supply ditches along the long edge of the plot to connect the lateral or sub-lateral and supply ditches. A typical layout of land consolidation is illustrated in Figure 5 (L.J. Wen 1977 and 1981a).

Figure 5. Typical layout of water distribution system for land consolidation in Taiwan (upper number = rotation area; lower number = rotation unit).



In land consolidation, consideration is given to separating supply ditches from drainage ditches; direct irrigation for free water management; easy access to each plot; suitability of water reuse; minimum space for farm roads, canals, ditches, and earth dikes in paddies; minimum earth work for levelling by adjusting the alignments and elevations of supply and drainage ditches; and conditions of the downstream drainage channels. Irrigation water can be freely delivered into each plot directly from the supply ditch (without passing from field to field), and the controlled border or furrow method can easily accommodate diversified cropping. For rotational irrigation, each block of about 10-14 ha may be regarded as a rotation unit, and 4-5 units along a main supply ditch form a rotation area. Water flowing continuously through the turnout gate into the rotation area is properly rotated among the units. When water supply is limited, especially during drought, intermittent irrigation may be adopted by rotating water delivery among units. After land consolidation, the farm land will have good irrigation and drainage conditions for rice cultivation and diversified cropping.

CROP IRRIGATION EXPERIMENTS

Historical Review

The actual irrigation requirements of various upland crops in Taiwan were not known to most irrigation and agricultural personnel in Taiwan before

1961. From 1961 to 1963, the first irrigation experimental project under the technical and financial support of the Joint Commission on Rural Reconstruction (JCRR) was carried out at Hsuechia of the Chianan Irrigation Association in southern Taiwan. In 1963, an island-wide irrigation experiment and demonstration project on trial basis was started by the Taiwan Provincial Water Conservancy Bureau (PWCB) with assistance of JCRR the Provincial Department of Agriculture and Forestry, Agricultural Engineering Research Center, the National Taiwan University, local irrigation associations and district agricultural improvement stations. The Agricultural Research Institute, Sugarcane Research Institute, and district agricultural improvement stations were also conducting research and experiments on crop improvement, cropping systems and irrigation. The basic studies on irrigation may be grouped into three categories: experiments on water requirements, adaptation tests on cropping patterns, and experiments on irrigation methods.

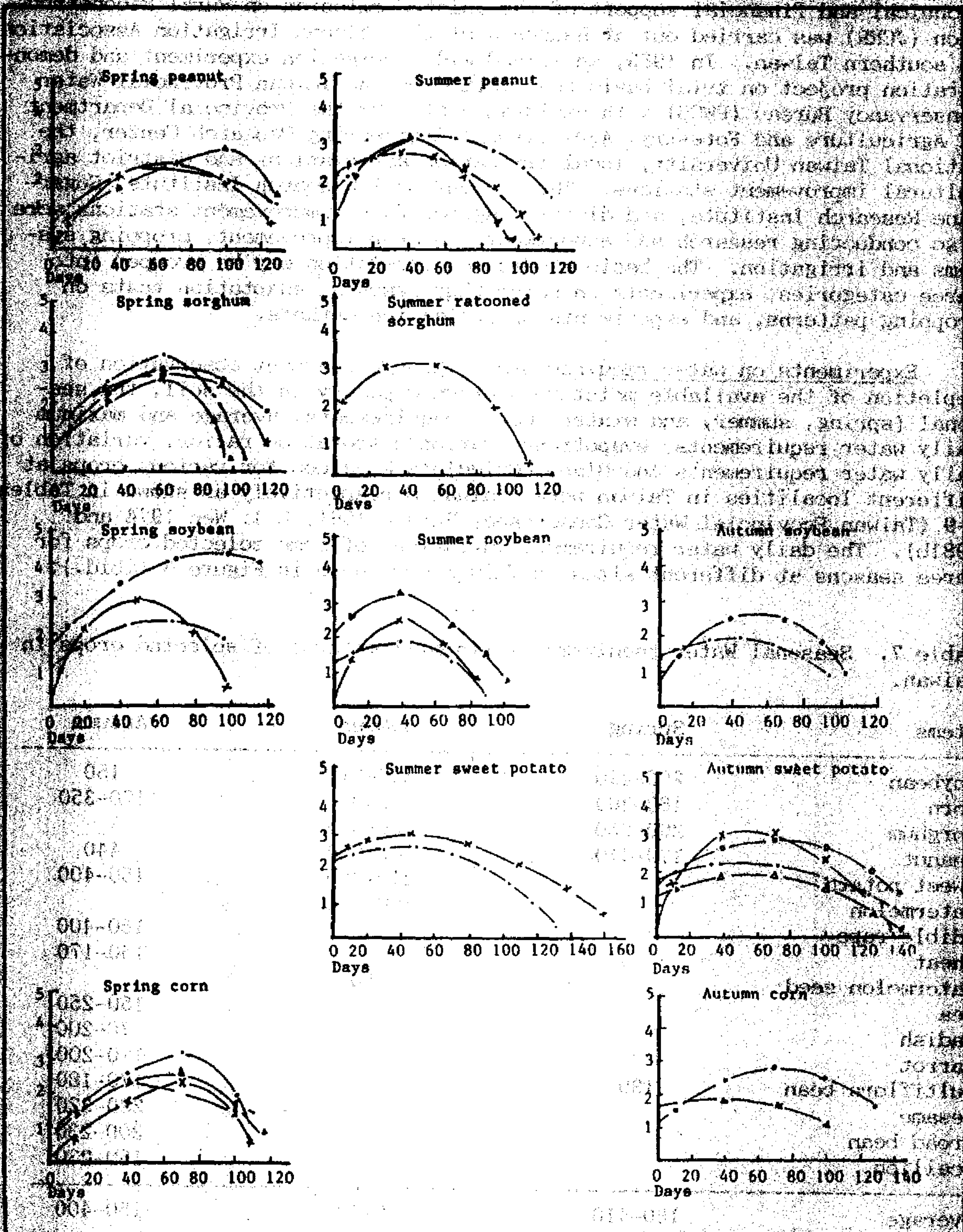
Experiments on water requirements. Through constant observation of depletion of the available moisture storage capacity in the soil, the seasonal (spring, summer, and winter) water requirements, average and maximum daily water requirements, evapotranspiration/evaporation ratios, variation of daily water requirements and Blaney-Criddle's K values for various crops at different localities in Taiwan were evaluated respectively as shown in Tables 7-9 (Taiwan Provincial Water Conservancy Bureau 1961; L.J. Wen 1974 and 1981b). The daily water requirement variations of some selected crops for three seasons at different sites in Taiwan are shown in Figure 6 (ibid.).

Table 7. Seasonal Water requirements (in millimeters) of selected crops in Taiwan.

Items	Spring	Summer	Autumn
Soybean	200-440	230-310	150
Corn	160-300	250	170-350
Sorghum	200-350	250-370	
Peanut	170-410	160-300	440
Sweet potato		210-380	150-400
Watermelon		180-200	
Edible rape			150-400
Wheat			160-170
Watermelon seed		150	
Pea			150-250
Radish			70-200
Carrot			170-200
Multiflora bean	130		170-180
Sesame			280-320
Broad bean			200-230
Scallion			160-230
Average	160-410	160-380	150-400

Taiwan Water Conservancy Bureau 1966.

Figure 8. Daily water requirements (DWR) for selected crops in Taiwan.



Days = accumulated number of days for plant growth; x = Miaoli, northern; . = Changhua, central; o = Kangshan, southern; = Juishui, eastern Taiwan.

Table 8. Maximum and average daily water requirements (WR; in millimeters) of selected crops in Taiwan (1964-70).

Location	Season	Crop	Max WR	Avg WR
Northern Taiwan				
Shihmen	Spring	corn	5.3	2.8
		peanut	4.6	2.6
		sorghum	5.4	2.9
	Summer	ratooned sorghum	4.6	3.0
		soybean	4.7	3.2
		sweet potato	5.9	3.0
	Autumn	broad bean	2.9	2.0
Miaoli	Spring	corn	2.6	1.9
		peanut	3.6	1.9
		sorghum	5.0	2.0
	Summer	ratooned sorghum	3.9	2.2
		watermelon	3.8	2.3
	Autumn	sweet potato	4.2	2.0
		scallion	3.0	1.8
Central Taiwan				
Changhua	Spring	corn	5.5	2.2
		peanut	3.6	2.2
		sorghum	3.5	2.3
		soybean	3.0	2.0
	Summer	soybean	4.9	2.8
		sweet potato	4.8	2.5
	Autumn	wheat	1.8	1.6
Southern Taiwan				
Kangshan	Spring	corn	3.4	2.5
		peanut	5.7	3.1
		sorghum	3.7	2.6
		soybean	6.0	3.0
	Autumn	corn	3.1	2.3
		soybean	3.0	2.3
		sweet potato	3.3	2.4
Eastern Taiwan				
Juishui	Spring	peanut	3.3	2.0
		sorghum	3.1	2.0
	Summer	peanut	3.7	2.5
		soybean	4.1	2.6
	Autumn	sweet potato	4.3	1.6
		spring pea	2.6	1.7
		corn	2.8	2.9

Taiwan Provincial Water Conservancy Bureau 1961.

Table 9. Daily water requirements, evapotranspiration-evaporation ratios, and Blaney-Criddle's K values for different months in Taiwan, 1964-70.

Location	Crop	Value	Jan.	Feb.	Mar	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Planted period
Central Taiwan (Shihmen)	Corn	U				2.12	4.03	3.93	3.08						Early Apr.-Mid. July
		C				0.72	1.22	1.47	0.71						
		K				1.15	0.69	0.64	0.41						
	Peanut	U			2.05	3.44	2.38	3.11	1.81						Mid. Mar.-Late July
		C			1.47	1.18	0.76	0.82	0.54						
		K			0.60	0.68	0.41	0.54	0.38						
	Sorghum	U				1.53	4.02	4.21	2.95						Early Apr.-Late July
		C				0.71	1.22	1.33	0.67						
		K				0.30	0.69	0.68	0.46						
	Ratooned Sorghum	U								2.17	3.47	4.10	1.72		Early Aug.-Mid. Nov.
		C								0.63	0.90	1.39	0.72		
		K								0.35	0.63	0.72	0.45		
	Soybean	U			0.90	3.13	1.67	1.81		2.74	3.84	4.01	2.11		Early Mar.-Late June Early Aug.-Mid. Nov.
		C			0.19	0.60	1.06	0.29		0.45	0.70	0.84	0.47		
		K			0.19	0.60	1.06	0.29		0.45	0.70	0.84	0.46		
	Sweet-potato	U						2.06	3.63	4.15	4.10	2.81	1.83		Early June-Early Nov.
		C						0.49	0.56	0.70	0.79	0.62	0.41		
		K						0.49	0.56	0.70	0.79	0.61	0.40		
	Broad-bean	U	2.89	2.35	1.28								1.25	2.52	Early Nov.-Early Mar.
		C	0.75	0.64	0.46								0.87	0.64	
		K	0.75	0.64	0.46								0.87	0.64	
Northern Taiwan (Miaoli)	Corn	U			0.67	1.42	2.55	1.67							Mid. Mar.-Late June
		C			0.18	0.45	0.48	0.23							
		K			0.15	0.28	0.43	0.17							
	Peanut	U			0.99	2.45	2.84	1.96	1.62	2.48	2.48	1.27	0.75		Early Mar.-Mid. July Late July-Late Nov.
		C			0.39	0.70	0.60	0.47	0.16	0.34	0.57	0.25	0.09		
		K			0.23	0.49	0.50	0.33	0.08	0.25	0.42	0.17	0.07		
	Sorghum	U				0.78	2.78	3.88	2.66	0.74					Early Apr.-Mid. Aug.
		C				0.29	0.53	0.70	0.40	0.24					
		K				0.20	0.42	0.49	0.42	0.16					
	Ratooned Sorghum	U								1.85	3.97	2.84	1.73		Mid. Aug.-Late Nov.
		C								0.48	0.66	0.52	0.54		
		K								0.38	0.75	0.65	0.35		
	Soybean	U			1.00	1.99	3.14	2.30	1.90	1.37	2.77	1.78	1.21		Mid. Mar.-Early July
		C			0.48	0.60	0.59	0.57	0.53	0.34	0.69	0.61	0.50		
		K			0.08	0.38	0.56	0.38	0.06	0.18	0.54	0.42	0.13		
	Sweet-potato	U	1.12	0.95							2.71	2.93	2.85	1.54	Mid. Sept.-Mid. Feb.
		C	0.46	0.28							0.50	0.62	0.81	0.76	
		K	0.29	0.32							0.50	0.73	0.66	0.45	
	Water-melon	U							3.58	2.71	1.51				Early July-Early Sept.
		C							0.32	0.54	0.52				
		K							0.40	0.45	0.38				
	Scallion	U	1.20	1.37	2.53	0.80								0.27	Late Dec.-Early Apr.
		C	1.22	0.71	0.86	0.25								1.18	
		K	0.35	0.40	0.60	0.17								0.08	

Table 9 (cont).

Central Taiwan (Changhua)	Corn	U			1.73	2.52	3.72	1.84							Early Mar.-Mid. June
		C			0.50	0.69	0.82	0.43							
		K			0.36	0.49	0.56	0.32							
	Peanut	U			1.57	2.24	2.96	2.07							Early Mar.-Late June
		C			0.47	0.60	0.75	0.58							
		K			0.37	0.53	0.49	0.32							
	Sorghum	U			1.64	2.55	3.45	1.59							Late Mar.-Late June
		C			0.41	0.70	0.75	0.59							
		K			0.56	0.58	0.71	0.35							
	Soybean	U	1.47		1.46	1.31	2.47	1.33	2.08	3.17	2.96	1.51	1.84	1.66	Early Mar.-Mid. June
		C	0.36		0.51	0.49	0.65	0.48	0.42	0.59	0.60	0.32	0.46	0.65	Early July-Late Sept.
		K	0.36		0.79	0.38	0.50	0.39	0.29	0.48	0.35	0.31	0.47	0.65	Early Oct.-Mid. Jan.
	Sweet-potato	U	1.33	1.05				1.52	3.48	3.27	3.10	2.24	2.11	1.68	Mid. June-Early Oct.
		C	0.58	0.59				0.25	0.70	0.70	0.48	0.46	0.59	0.62	Mid. Oct.-Late Feb.
		K	0.72	0.63				0.27	0.61	0.57	0.48	0.37	0.45	0.59	
	Wheat	U	1.38	0.97								1.32	1.66	1.58	Late Oct.-Early Feb.
		C	0.48	0.32								0.35	0.51	0.61	
		K	0.43	0.34								0.24	0.39	0.52	
	Radish	U	2.19	1.45										1.20	Early Dec.-Mid. Feb.
		C	0.95	0.81										0.65	
		K	0.63	0.66											
Southern Taiwan (Kangshan)	Corn	U	2.17	1.35	1.51	1.71	1.58					1.82	2.34	2.98	Early Feb.-Mid. May
		C	0.75	0.76	0.61	0.89	0.31					0.35	0.77	0.97	Mid. Oct.-Early Feb.
		K	0.75	0.46	0.53	0.63	0.26					0.37	0.60	0.80	
	Peanut	U		2.27	2.62	4.75	5.01	4.45							Mid. Feb.-Mid. June
		C		1.32	0.91	1.18	1.23	1.33							
		K		0.53	0.56	0.91	0.89	0.60							
	Sorghum	U		1.81	2.33	3.00	1.73								Mid. Feb.-Late May
		C		0.36	0.51	0.80	0.46								
		K		0.29	0.50	0.60	0.39					1.82	2.35	2.98	
	Soybean	U	1.62	2.58	3.17	3.89	2.74					0.29	0.54	0.68	Mid. Feb.-Late May
		C	0.84	0.60	0.56	0.74	0.75					0.36	0.81	0.95	Early Oct.-Mid. Jan.
		K	0.54	0.35	0.46	0.63	0.37								
	Sweet-potato	U	2.41	1.77								2.23	2.64	2.50	Mid. Oct.-Mid. Feb.
		C	0.93	0.82								0.49	0.74	1.02	
		K	0.66	0.50								0.45	0.56	0.75	
Eastern Taiwan (Juishui)	Peanut	U		1.05	2.56	2.66	2.02	0.93	2.67	3.72	1.57	1.04			Mid. Feb.-Mid. June
		C		0.51	0.64	0.73	0.78	0.50	0.52	0.69	0.72	0.40			Mid. July-Mid. Oct.
		K		0.20	0.55	0.42	0.34	0.16	0.39	0.51	0.41	0.20			
	Sorghum	U			1.20	1.90	2.77	1.57							Mid. Mar.-Mid. June
		C			0.51	0.65	0.92	0.56							
		K			0.26	0.36	0.48	0.27							
	Soybean	U						1.88	3.02	3.47	2.51				Early June-Late Sept.
		C						0.16	0.47	0.74	0.68	0.85			
		K						0.22	0.53	0.58	0.36				
	Sweet-potato	U	1.52	1.11								1.09	1.87	2.06	Late Oct.-Mid. Feb.
		C	0.78	0.62								0.58	0.82	1.04	
		K	0.41	0.20								0.23	0.39	0.44	
	Pea	U	2.24	1.58									1.56	1.76	Early Nov.-Late Feb.
		C	1.06	0.64									0.73	1.11	
		K	0.52	0.32									0.38	0.46	
	Corn	U	1.35	0.98	1.35	2.40	2.66	1.52				1.54	1.79	1.92	Early Mar.-Late June
		C	0.85	0.56	0.44	0.71	0.77	0.61					0.80	0.82	Mid. Oct.-Late Feb.
		K	0.33	0.26	0.31	0.37	0.39	0.15				0.29	0.40	0.37	

U = Daily water requirement (mm); C = evapotranspiration-evaporation ratio; K = Blany-Criddle K value. Source: Taiwan Provincial Water Conservancy Bureau 1961.

Tables 10 and 11 (L.J. Wen 1981b; Joint Commission on Rural Reconstruction n.d.) show the evapotranspiration/evaporation ratios and monthly water requirements, and Blaney-Criddle's K values, respectively, of sugarcane in southern Taiwan.

Table 10. Average raised A pan evaporation (E), transpiration (T), and evapotranspiration (ET) rates in millimeters, and evapotranspiration/pan evaporation ratios (PR) of sugarcane in Taiwan (1963-66).

Month	E	Clay loam T	Clay loam PR	Sandy soil T	Sandy soil PR	Clay loam ET	Clay loam PR	Sandy soil ET	Sandy soil PR
Feb	107.0	42.1	0.39	112.7	1.05	50.3	0.47	112.0	1.05
Mar	131.4	42.9	0.33	80.4	0.61	56.0	0.43	82.6	0.63
Apr	135.1	49.3	0.37	80.1	0.59	57.6	0.43	80.2	0.59
May	182.3	104.6	0.57	135.8	0.75	158.0	0.87	187.6	1.03
Jun	136.4	139.5	1.02	155.5	1.14	222.1	1.63	242.6	1.78
Jul	148.7	148.2	1.00	162.6	1.09	207.0	1.39	245.1	1.65
Aug	158.3	150.4	0.95	172.2	1.09	169.7	1.07	200.6	1.27
Sep	134.5	152.8	1.14	168.1	1.25	180.1	1.34	195.7	1.46
Oct	121.7	144.0	1.18	147.2	1.21	134.2	1.10	161.6	1.33
Nov	91.2	126.0	1.38	144.0	1.58	112.9	1.24	180.8	1.98
Dec	70.6	74.8	1.06	78.1	1.11	68.8	0.98	98.7	1.40
Tot	1417.2	1174.6		1436.7		1416.7		1787.5	
Avg			0.83		1.01		1.00		1.26

Taiwan Sugarcane Research Institute 1968.

Table 11. Monthly water requirements (WR; evapotranspiration in millimeters) and Blaney-Criddle's K values of sugarcane in Taiwan (clay loam soil).

Month	Mean temp (°C)	Daytime hrs (%)	Factor	WR	K value
Feb	18.2	7.18	118.1	50.3	0.43
Mar	20.7	8.40	147.8	56.0	0.38
Apr	24.6	8.57	166.0	57.6	0.35
May	26.5	9.22	186.6	158.0	0.85
Jun	27.0	9.13	186.9	222.1	1.19
Jul	27.7	9.35	194.4	207.0	1.06
Aug	27.8	9.03	188.1	169.7	0.90
Sep	26.6	8.31	168.6	180.1	1.07
Oct	24.8	8.13	158.2	134.2	0.85
Nov	22.2	7.48	136.7	112.9	0.83
Dec	19.0	7.52	126.4	68.8	0.54
Total			1,777.8	1,416.7	0.80

Joint Commission on Rural Reconstruction n.d.

Adaptation Tests on Cropping Patterns

Tests on the frequency of irrigation were conducted in 1963-64. The results of one experimental application of irrigation at the critical stage for selected crops at different localities showed that there was production increase ranging from 21-228 per cent (Table 13).

Table 12. Experiments on one application of irrigation at the critical stages of plant growth in Taiwan (1963-1964).

Crop	Critical Stage	Season	Days after planting	Irrigation (mm)	Per cent increase
Sweet potato	Rapid root expansion	Autumn	60	60	21
Peanut	Flowering to pod expansion	Spring	50	50	68
		Autumn	75	50	32
Soybean	Flowering to initial pod	Spring	60	50	114
	growth stage	Autumn	55	50	26
Corn	Silking to filling	Spring	60	50	228
		Autumn	60	50	52
Wheat	Young panicle to heading	Autumn	45	50	48

Chinese Institute of Civil and Hydraulic Engineering 1985.

Through precise soil, water, plant, and fertilizer management jointly established by irrigation and agricultural personnel at the standard plots of each station, the varied requirements, yield, and cost figures of different crops were closely recorded for overall evaluation of the recommended crop rotation systems. Results revealed that an increase of production by irrigation might exceed 500 per cent (Table 13; ibid.). As far as the total net income is concerned, it may not be profitable to irrigate fields frequently.

As for cropping systems, the total net incomes of different cropping patterns tested in recent years in the irrigated double-rice fields of southern Taiwan are shown as an example in Table 14 (Chih-Kang Chao 1985). It can therefore be concluded that vegetables are more profitable than other crops. In North and East Taiwan, corn-rice, peanuts-rice, sorghum-rice and rice-peanuts are suitable for double rice cropping. Considering the high unit yield of the first rice crop in central and southern Taiwan, the feasible alternative cropping patterns for these areas will be rice-short duration crops-corn, and rice-short duration crops garlic. The short duration crops include green manure crops, vegetables, melons, mungbean, vegetable soybean and early maturing soybean (ibid.).

Table 13. Production increase by irrigation for various crops in Taiwan.

Crop	Critical Stage	Season	Time and Quantity of irrigation	Production increase (%)
Sweetpotato	Rapid root expansion stage	Autumn	60 days after planting 60 mm one application	21
Peanut	Flowering Stage to pod expansion stage	Spring	50 days after seeding 50 mm one application	68
		Autumn	75 days after seeding 50 mm one application	32
Soybean	Flowering stage to initial pod growth stage	Spring	60 days after seeding 50 mm one application	114
		Autumn	55 days after seeding 50 mm one application	26
Corn	Silking stage to filling stage	Spring	60 days after seeding 50 mm one application	228
		Autumn	60 days after seeding 50 mm one application	52
Wheat	Young panicle stage to heading stage	Autumn	45 days after seeding 50 mm one application	48

Source: Irrigation and Drainage, Chinese Institute of Civil and Hydraulic Engineering, 1985

Table 14. Total net income (in US$/hectare) and unit yield (MT/hectare; in parentheses) of different cropping patterns tested in irrigated single-rice fields at Mei-Nung, Kaoshiung, Taiwan, 1984.

1st crop	2nd crop	3rd crop	Net income	Index
Rice (5.92)	Vegetables (22.0)	Corn (5.57)	9,020	298
Rice (6.22)	Soybean (2.96)	Corn (5.69)	2,980	98
Soybean (1.91)	Rice (4.74)	Same red bean (2.83)	1,374	45
Rice (6.38)	Rice (4.83)	Same red bean (2.95)	3,027	100

Council of Agriculture 1985a.

Experiments on Irrigation Methods

Observations on advancement and penetration of irrigation water over the fields were made for furrow, border, and corrugation methods. The converted water depth required for various irrigation streams to cover different field lengths up to 100 meters were higher than needed. Nomographs for determining the stream sizes, run length, and cutback time of border and furrow irrigation for various crops and soil properties have been identified for Taiwan (National Taiwan University 1976; Taiwan Provincial Water Conservancy Bureau 1980). Data on water depths and stream sizes of border and furrow irrigation for corn, sorghum, peanuts, and sweat potatoes on different soils with and without machine plowing are shown in Tables 15 and 16 (ibid. 1976).

Table 15. Factors affecting border irrigation for given applications (in millimeters), unit discharge rates (in liters per second/meter for plots approximately 10 meters between borders), and cutbacks (per cent).

Soil types	Plowing	Crop	Application	Discharge	Cutback
Sandy loam	Animal	Peanut	80	0.30	80
Silty loam	Animal	Peanut	85	0.35	80
Sandy loam	Animal	Corn, sorghum	75	0.30	80
Silty loam	Animal	Corn, sorghum	80	0.33	80
Loam	Animal	Corn, sorghum	78	0.32	80
Sandy loam	Animal	Prepared land	100	0.40	90
Silty loam	Animal	Prepared land	90	0.35	90
Loam	Tractor	Corn, sorghum	90	0.42	90
Loam	Power tiller	Corn, sorghum	81	0.40	90
Loam	Tractor	Prepared land	110	0.60	90
Loam	Power tiller	Prepared land	105	0.50	90

National Taiwan University and Joint Commission on Rural Reconstruction 1976.

Data on irrigation efficiency of border and furrow irrigation for some crops in the Wushantou reservoir irrigation area in southern Taiwan are listed in Table 17 for reference (ibid. 1980).

Table 16. Factors affecting furrow irrigation of sweet potato for given applications (in millimeters), unit discharge rates (in liters per second/meter), and cutbacks (per cent).

Soil types	Plowing	Application	Discharge	Cutback
Sandy loam	Animal	60	3.0	80
Silty loam	Animal	60	3.5	80
Silty clay	Animal	60	4.0	80
Sandy loam	Machine	80	7.0	80
Sandy loam	Power tiller/animal for furrows	70	6.0	80

Table 17. Experimental data related to irrigation application efficiency in the Wushantou irrigated area, Taiwan.

Crops	Irrigation method	Land preparation	Farm length (meters)	Water depth planned (millimeters)	Water depth actual (millimeters)	Irrigation efficiency (per cent)
Garlic	border	excellent	116.0	34	62.9	54.1
"	"	good	117.5	34	62.9	54.3
"	"	"	136.5	34	43.9	77.4
"	"	excellent	114.0	34	54.4	62.5
Sugarcane	furrow	inferior	97.0	51	63.9	79.8
" "	"	excellent	70.0	51	29.0	100.0
Corn	corrugation	good	70.5	45	58.5	76.9
"	border	excellent	100.0	45	82.0	54.9
Barley	"	inferior	143.0	45	91.8	49.0
Sweet potato	furrow	"	71.0	45	81.2	55.4
" "	"	"	26.0	45	52.1	86.4
" "	"	"	117.0	45	49.2	91.5
" "	"	excellent	90.0	45	31.4	100.0
" "	"	inferior	97.0	45	63.9	70.4
" "	"	"	100.0	45	77.6	58.0
" "	"	good	120.0	45	96.6	46.6
" "	"	"	90.0	45	58.9	76.4
" "	"	"	100.8	43	77.0	58.4
" "	"	inferior	100.8	45	56.4	79.8
" "	"	good	88.0	45	59.8	75.3
" "	"	"	100.8	45	49.5	90.9
" "	"	"	100.8	45	51.7	87.0
" "	"	excellent	145.0	45	30.4	100.0
" "	"	"	158.0	45	49.5	90.9
" "	"	"	51.0	45	24.2	100.0
" "	"	"	51.0	45	37.9	100.0
" "	"	inferior	114.5	42	96.3	46.7
" "	"	good	100.0	45	79.8	56.4
" "	"	excellent	160.0	45	45.6	98.7

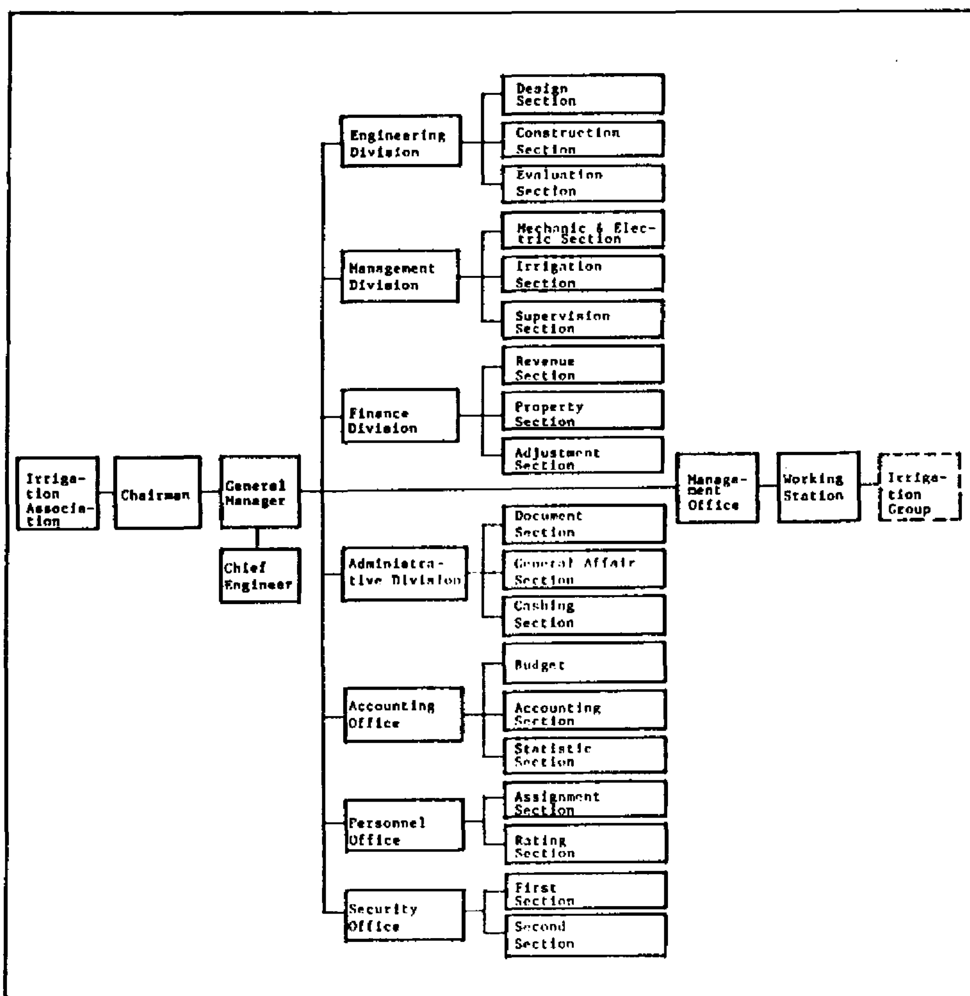
Final report of upland crop irrigation experiments at Hsue-chia Station, 1976

Experiments on different methods of sprinkler and drip irrigation have also been carried out. A simple low cost vinyl-perforated-pipe sprinkler irrigation method was recommended for practical application (Council of Agriculture 1982). For drainage especially in the rainy season, a method of crop production on raised beds with furrows has been developed.

IRRIGATION ASSOCIATIONS

Irrigation associations are corporate bodies organized by farmers to improve facilities, construct new irrigation works, and supply water to farm lands in their designated service areas. They also assist the government to plan and develop new large irrigation projects. At present, there are 17 irrigation associations; the largest is the Chianan Irrigation Association covering about 82,000 ha in the southern part of the island, and the smallest is the Liukung Irrigation Association covering only 279 ha. The organizational setup of a typical irrigation association is shown in Figure 7.

Figure 7. Organization chart of typical irrigation association.



The total service area of the 17 irrigation associations in 1985 was about 390,000 ha as shown in Table 18 (Taiwan Provincial Department of Agriculture and Forestry 1986).

Table 18. Service areas (ha) of irrigation associations, 1985.

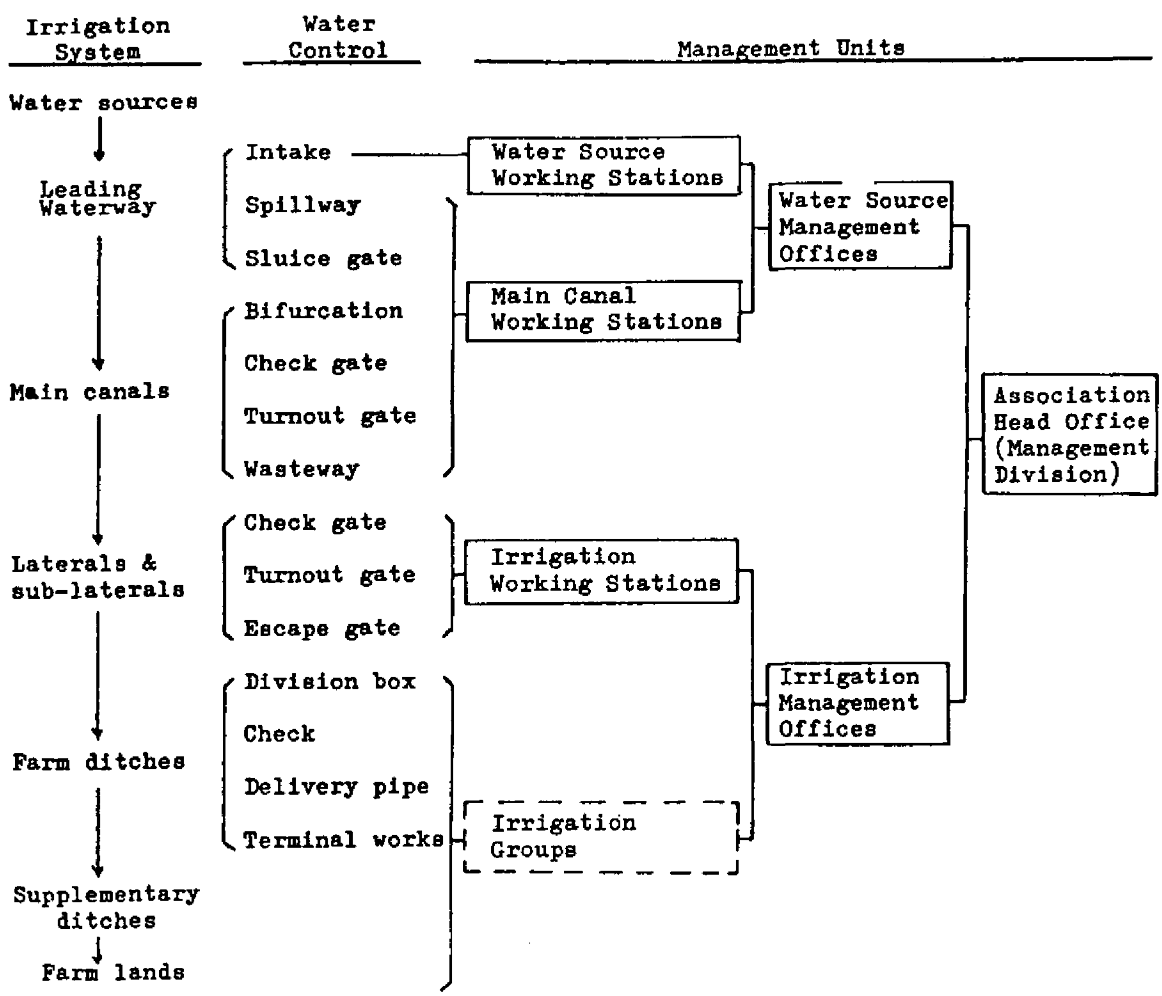
Irrigation association	Total	Double rice crop annually	Single rice crop annually	Cropping rotation	Dryland
Taiwan Province	383,908	255,831	27,036	84,115	16,926
Ilan	19,399	18,608	462	-	329
Peichi	5,457	4,498	959	-	-
Taoyuan	27,756	27,756	-	-	-
Shihmen	13,164	13,164	-	-	-
Hsinchu	7,086	7,086	-	-	-
Miaoli	10,007	9,870	-	-	137
Taichung	33,816	32,757	-	-	1,059
Nantou	12,688	11,509	1,179	-	-
Changhua	47,179	43,776	1,050	2,353	-
Yunlin	62,043	15,016	6,435	40,592	-
Chianan	81,523	24,666	9,867	38,496	8,494
Kaoshiung	19,470	11,938	3,927	2,674	931
Pingtung	21,880	14,257	2,238	-	5,385
Taitung	10,851	9,726	919	-	206
Hualien	11,589	11,204	-	-	385
Taipei City	1,515	1,346	-	-	169
Chihsin	1,236	1,236	-	-	-
Liukung	279	110	-	-	169
Total	385,423	164,852	19,944	79,088	12,318

Note: The above figures do not include about 31,500 ha of private canal systems and about 43,000 ha of the Taiwan Sugar Corporation's farmers. Taiwan Provincial Dept. of Agriculture and Forestry 1986.

Management System

The irrigation association has a management division at its head office to handle irrigation management policy, water planning, and statistical studies on water sources and irrigation requirements. In a typical irrigation association, the management division has local water source and regional irrigation management offices. The former may have some water source and main canal working stations for water control and supply; the latter has a number of irrigation working stations to operate and maintain the irrigation system. The water management system of a typical irrigation association is shown in Figure 8.

Figure 8. Management system of a typical irrigation association.



Remarks: In a small irrigation association there may be no water source management offices, and the irrigation working stations may take responsibility for the water source and main canal working stations.

Irrigation Group

The irrigation groups are organized by association members themselves on the basis of farm-level irrigation systems. A group covers an area of 50-150 ha and consists of several teams, each with 10-15 members who maintain irrigation and drainage ditches, distribute water, establish common seed-beds for members, and help the working station collect membership fees. The group has a chief and the team has a leader through election. They receive no salary. Group meetings are held to discuss irrigation plans at least twice a year with the farmers' association participating and the district agricultural improvement station providing technical guidance.

IRRIGATION OPERATION AND MAINTENANCE

Prior to the irrigation season, a guideline is worked out by the management division at the head office according to government policy, production targets, existing reservoir storage and water release, water flows, past irrigation requirements, canal conveyance losses, rotational intervals, and time of irrigation. These irrigation working stations conduct discussions with irrigation groups to work out detailed irrigation plans. The detailed plans prepared by working stations are submitted to the head office for review and compilation of an annual overall irrigation plan.

The approved water distribution plan has to be strictly carried out by the working stations. Stations are in charge of regulating and controlling water flows along the main canal, laterals, and sub-laterals. The irrigation supervisors are in charge of water control and measurement at turnout gates on laterals or sub-laterals, and of inspections on farm-level water distribution which are undertaken by irrigation groups. One irrigation supervisor usually takes care of 300-500 ha covering 6-10 rotation areas. Within a rotation area, one or two irrigators may be hired by the group to distribute water and maintain farm ditches. Measurement of water actually used in the system from source to individual farm turnout benefits future planning.

To ensure adequate service to farmers, irrigation and drainage systems must be maintained in good operating condition. In general, damage is due to flood and human destruction. The irrigation association pays more attention to maintenance than to construction, and to prevention than to repair. Routine patrolling and inspections are important. For instance, the canal operators frequently inspect headworks, main canals, laterals, sub-laterals, and related structures, and irrigation supervisors inspect turnout gates, farm ditches, checks, and division boxes originally built by the association. Maintenance and repair work may be classified as routine maintenance, annual maintenance, or emergency repairs. Routine maintenance covers minor repairs discovered by irrigation supervisors or group members during routine work. Annual maintenance check up is usually during the non-irrigation season.

IRRIGATION FINANCING

Collecting membership fees, financing projects, setting up the Joint Irrigation Fund and other revenues are important financing features of an irrigation association. The annual budget of an irrigation association is drawn up to meet administrative expenses, engineering construction, maintenance and damage repairs. The main revenue comes from membership fees, construction fees for particular engineering projects, and government subsidies.

Membership Fees

The annual revenue of an irrigation association mainly comes from membership fees which are collected in cash from the direct beneficiaries to cover operation and maintenance costs. Government has set up a maximum limit of monetary value equivalent to 300 kilograms (kg) and a minimum limit of 20 kg of rice per hectare per year.

Construction Fees

Construction fees are collected according to the capital cost, interest of each loan project, benefits obtained, and repayment ability of farmers. For improvement or new projects, the cost is financed partly by a grant and partly by a loan, either from government or monetary agencies. The proportion of grant to loan depends on the financial conditions of the association and the source of funds. The grant is usually 60-90 per cent of the total cost. The term varies from 3-10 years; interest is from 6-12 per cent per annum. Collection starts from the second year after the land is benefited.

Joint Irrigation Fund

Established for mutual cooperation among associations, its main source of money is the associations' yearly contribution. A goal of 500 million New Taiwan Dollars (approximately US$11 million) was achieved, and deposited in a special account from which loans are made at 6 per cent interest per annum for emergency projects, restoration projects, and project improvement.

Other Revenues

An association may also collect fees for leasing structures and supplying surplus water. New members in a new project or irrigation extension area as a result of improvement also pay for the engineering cost by proportion. Revenue and expenditure of 17 associations in 1985 is shown in Table 19.

Table 19. Total income and expenditure (in million New Taiwan dollars) of 17 irrigation associations in FY 1984 (NT$1.00 = US$36.60).

	Million NT$	Per cent
Total Income	3,841.47	100.00
Membership fee	1,806.27	47.02
Property income, use of structures and surplus water	295.05	7.68
Interest and rental	555.23	14.45
Property sale	750.18	19.53
Fines and compensation	4.41	0.12
Government subsidies, loan repayments and others	430.33	11.20
Total Expenditure	2,899.59	100.00
Engineering construction	763.14	26.32
Irrigation operations & maintenance	531.84	18.34
Salary and administrative expenses	1,427.11	49.22
Interest	.74	0.03
Property sale	51.37	1.77
Contribution	7.61	0.26
Others	117.79	4.06

Taiwan Joint Irrigation Association 1986.

CONCLUSIONS AND RECOMMENDATIONS

In monsoon Asia, geographical and climatic conditions profoundly influence agriculture. This influence on rice fields includes:

1. Rice fields are equipped with irrigation systems which usually have a long history of improvements with enormous investments (Kejuro Nagata 1984; Mao-Sen Chen 1976).

2. Because rice survives inundation for as long as three days, paddy fields regulate flood peaks of rivers with a large flood detention capacity perhaps several times more than the total flood storage capacity of the existing reservoirs (Ibid.; Toshio Yahata 1984; L.J. Wen 1981c).

3. Paddy fields have the function of groundwater recharge which is important especially in coastal areas where withdrawal of groundwater causes land subsidence (Mao-Sen Chen 1976; Toshio Yahata 1984).

4. Paddy fields protect the environment. They conserve soil and water, and chemically maintain the productivity of land (ibid.).

Many factors have led to a shift away from rice: increasing yields and cultivated area of rice, decreasing consumption due to changes in market demand for farm products at home and abroad, and a surplus rice production across Asia with a consequent decline in rice prices. Farmers seek to diversify their production and income sources. But they face problems in growing non-rice crops on irrigated paddies essentially used for rice production.

Farm improvement has to be carried out continuously for production of diversified crops in paddy fields. It includes not only irrigation and drainage engineering works but soil and water management. Modernized farm improvement work has the following prerequisites (L.J. Wen 1981c):

1. Farm land with high productivity for growing rice and other crops. Land with high productivity or high yield per unit area must be in good condition for plant growth. It must be favorable for plant root systems and photosynthesis with the following conditions.

2. Guarantee of adequate and timely irrigation and water management. Rice cultivation permits continuous irrigation with water flowing from parcel to parcel in paddy fields. This method is not applicable to diversified cropping. The density of farm irrigation supply ditches must be increased to a certain extent. Pipe irrigation may be ideal but expensive both in initial and operational costs. It is suggested that irrigation systems at farm level be improved through rotational irrigation and land consolidation.

3. Soil management and improvement. Physical properties such as depth of soil layers, texture, permeability, porosity and water holding capacity, and chemical properties such as pH values and fertilities are closely related. For instance, soils may be improved by mixing rice husks or chemical compounds or others for different purposes.

4. Good surface and subsurface drainage for free conversion from rice to other crops and vice versa. Drainage is even more important than irrigation for diversified cropping in paddy fields, especially in low areas and in wet seasons. Drainage systems must be separated from irrigation ones. Because subsurface drainage with tile drains is expensive, surface drainage with open ditches must be tried first, incorporating cultural practices such as raised beds with furrows. If subsurface drainage is required, rice husks may be used for tile drains. This is inexpensive and applicable in many places.

5. Facilitating farm operations. Farm operations including field water applications and cultural practices for diversified cropping need more labor than rice farming. High working efficiency of mechanized group farming is required for diversified cropping to reduce farming costs, especially when labor is short. Paddy fields should be improved for farm mechanization with tractors, power tillers, high pressure sprayers, harvesters, and portable irrigation pumps. The following should be kept in mind: a) Land readjustments must make farm parcels as large as possible for joint farming and, if necessary, irregular foot paths must be removed; b) farm roads, supply ditches, and drainage ditches must be properly located to enable efficiency in mechanized farming and water management; c) farm roads must be sufficiently wide and in good condition for transportation of farm products, machines and other materials; d) the length and the width of each farm parcel must be suitable not only for irrigation application but for machine operations; e) soils must have sufficient depths and good drainage conditions for plant growth and machine operations; and f) land and farm road slopes must be improved for transportation of farm machines, especially in hillside farming.

6. Productivity must be stabilized. Special attention must be given to: a) Flood and erosion control (river levees, sea dikes, and regional drainage systems should be properly improved and maintained); b) wind erosion control (windbreaks are necessary especially in coastal areas where monsoon winds are strong); c) strict control on withdrawal of groundwater is necessary to prevent subsidence, especially in coastal areas; d) watershed management and soil conservation are also important in protecting farmlands from being eroded or buried; and e) strict control of air and water pollution is necessary to protecting precious soils and irrigation water.

In addition to these farm improvements, researches and experiments on adaptability of crops, crops improvement, optimal cropping patterns, crop water requirements, irrigation methods, improvement of farm machines as well as low-cost farming practices have to be conducted. Studies on stabilizing prices of crops, production and marketing plans, strengthening farmers' organizations, and farmer incentives are also a pre-requisite to increasing production (Kunio Takase 1973).

In conclusion, the writer cites some research suggestions of Lee, which although made in 1975 are still considered important:

1. To understand differences between types of products and between technological characteristics in the land use of crops, a farm economy survey and research should be carried out on climate and soil requirements and on the input-output relationship of the grain and non-grain crops and livestock.

2. Long-term projections for national food consumption are needed to understand the variety and future pattern of crops and livestock requirements. This study will throw light on the economic considerations of an efficient cropping system.

3. The farmers' response to price changes affecting non-grain crops should be surveyed. This will clarify the feasibility of resource allocation.

4. Research on the domestic and regional production of crops and livestock should be undertaken from the viewpoint of comparative economic advantage.

5. Farmers' organizations for extending new technology, breeding new varieties, and for protecting from natural risks will be important for promoting agricultural diversification. Analysis of the impact of farmers' organizations will also be useful.

REFERENCES

Chao, Chi-Kang. 1985. Progress report on cropping pattern testing in Taiwan. Taipei, Taiwan: Council of Agriculture.

Chen, Mao-Sen. 1976. Translation and remarks on hidden effects of social contribution from agriculture of Kejuro Nagata. Agricultural Information Weekly 70:10-14 (in Chinese).

Chen, Hsing-Yu. 1975. Farming diversification and products marketing. Journal of the Philippine Economic Society 14(1&2): 88-125.

Chinese Institute of Civil and Hydraulic Engineering. 1985. Irrigation and drainage. Engineer Handbook No. 9 (hydraulic engineering). Taipei, Taiwan. (in Chinese).

Council of Agriculture and Taiwan Provincial Food Bureau. 1985. Manual of rice production and the six-year rice crop substitution program. Taipei, Taiwan (in Chinese.)

Council of Agriculture. 1982. Low water pressure upland crop irrigation techniques. In Proceedings of Symposium on Low Water Pressure Upland Crop Irrigation Techniques. Taipei, Taiwan.

Council of Agriculture. 1985a. Progress report on cropping pattern testing in Taiwan. Taipei, Taiwan.

Council of Agriculture. 1985b. Taiwan food balance sheet. Taipei, Taiwan.

Council of Agriculture. 1986. Annual report of the Council of Agriculture, 1985. Taipei, Taiwan.

Council for Economic Planning and Development. 1986. Taiwan statistical data book. Taipei, Taiwan.

Djang Yuan H. and L.J. Wen. 1978. Water resources development in Taiwan. Report of Sino-American Wworkshop on Land Use Planning. Taipei, Taiwan.

Joint Commission on Rural Reconstruction (JCRR). (n.d.). Water requirement of irrigated sugarcane (unpublished). Taipei, Taiwan.

Lee, T.H. 1975. Planning multiple crop diversification for agricultural development -- Some suggestions for developing countries. The Journal of the Philippine Economic Society 14 (1&2): 200-215.

Mao, Yu-Kang. 1975. Implications of Taiwan's experience in multiple-crop development for other Asian countries. The Journal of the Philippine Economic Society 14 (1&2): 216-234.

Nagata, Kejuro. 1984. Hidden effects of social contribution from agriculture. In Proceedings of Agricultural Journalists Conference on "What is the paddy field to Japan?" Movement of Agriculture in Japan. No. 68. Tokyo, Japan: Statistics Association of Agriculture and Forestry (in Japanese).

National Taiwan University. 1976. Final report of upland crop irrigation experiments at Hsue-chia irrigation experiment station. Project: 75(NSC)-C21-E-673. Taipei, Taiwan: National Science Council & JCRR (in Chinese).

National Taiwan University & Joint Commission on Rural Reconstruction. 1970. Paddy irrigation in Taiwan. Taipei, Taiwan: National Taiwan University (in Chinese).

National Taiwan University & Joint Commission on Rural Reconstruction. 1976. Comparison on surface irrigation in animal plowing and machine plowing field. Project: 74-(NSC)-C21-E-639. Taipei, Taiwan (in Chinese).

Su, Nan-Rong. 1977. Changes in soil fertility under multiple cropping systems in Taiwan. Journal of the Chinese Agricultural Chemical Society 15 (3-4):42-52.

Su, Kuang-Chi. 1983. High-input cropping systems. In Proceedings of the Symposium on Potential Productivity of Field Crops under Different Environments. Los Banos, Philippines: International Rice Research Institute.

Taiwan Joint Irrigation Association. 1986. FY1985 data book of irrigation associations. Taichung, Taiwan.

Taiwan Provincial Department of Agriculture and Forestry. 1986. Taiwan agricultural yearbook. Chunghsing Village, Taiwan.

Taiwan Provincial Water Conservancy Bureau. 1961. Discussions on experiment criteria and results of PWCB upland crop irrigation demonstration station. Taiwan: JCRR (in Chinese).

Taiwan Provincial Water Conservancy Bureau. 1980. Manual for upland crop irrigation. Project 79-1.3-E-759. Taiwan: Council for Agricultural Planning & Development (in Chinese).

Taiwan Provincial Water Conservancy Bureau. 1986. Reconstruction statistics of Taiwan Province, part II. Taiwan.

Taiwan Sugarcane Research Institute. 1968. Evapotranspiration and water requirements of sugarcane in Taiwan. Taipei, Taiwan.

Takase, Kunio. 1973. In what phases of water management are we adequate or deficient in knowledge? Proceedings of an International Symposium on Research Needs for On-farm Water Management. Park City, Utah: USAID, Technical Assistance Bureau for Agriculture,

Wang, Y.T. and Y.H. Yu. 1975. Historical evolution and future prospect of multiple-crop diversification in Taiwan. Journal of the Philippine Economic Society (1&2): 27-46.

Water Resources Planning Commission. 1981. Chart on water resources development planning in Taiwan area. Taiwan (in Chinese).

Wen, L.J. 1977. Farm water management for rice cultivation in Taiwan. Symposium on Farm Irrigation Management in Rice Cultivation. Tokyo, Japan: Asian Productivity Organization.

Wen, L.J., Wen-Chang Hu, and Han-Ming Lin. 1974. Pipe irrigation methods and techniques. Taiwan: JCRR (in Chinese).

Wen, L.J., Wen-Chang Hu, and Han-Ming Lin. 1981a. Improvement of irrigation systems and water management. In Proceedings of Eleventh Conference of the International Commission on Irrigation and Drainage, Grenoble, France.

Wen, L.J., Wen-Chang Hu, and Han-Ming Lin. 1981b. Irrigation water management in Taiwan. In Proceedings of International Symposium on Water and Agriculture in East Asia. Tokyo, Japan: Japanese Society of Irrigation, Drainage and Reclamation Engineering.

Wen, L.J., Wen-Chang Hu, and Han-Ming Lin. 1981c. Water and agriculture. In Proceedings of Provincial Reconstruction Conference on Water Utilization and Disaster, N23. Taiwan (in Chinese).

Yahata, Toshio. 1984. Functions and values of paddy fields. In Proceedings of Agricultural Journalists Conference on "What is the paddy field to Japan?" -- Movement of Agriculture and Forestry. No. 68. Tokyo, Japan (in Japanese).

DISCUSSION: CONCEPT AND SPECIAL PAPERS

Cheong Chup Lim invited discussion of the issues posed on pages 11 and 12 of the Concept Paper prepared by IIMI. Both he and **Senen Miranda** emphasized that drainage is a crucial constraint to crop diversification, requiring physical upgrading of drainage capacities and more careful timing of deliveries to prevent flooding. **Banamali Naik** remarked that finding an optimal level at which new field channels would result in adequate and timely deliveries for cultivation and drainage was important.

Robert Hecht requested discussion of water pricing practices and levels as a constraint on crop diversification, and the feasibility of an alternative pricing policy to encourage it. Institutional issues related to crop diversification, such as increased farmer participation in water management, call for further study. **Douglas Merrey** noted that, although not reflected in the Concept Paper, farmer participation and institutional issues were being studied under the Asian Development Bank-financed study on Irrigation Management for Crop Diversification, including the issue of inter-agency coordination. **Honorio Bautista** spoke of the need for government-invoked incentives to farmers to encourage them to plant non-rice crops. This policy would have to be backed up by suitable pricing for crops and water, and assistance in developing marketing structures. Unless farmers can market crops profitably, they will not switch to diversified crops. More research should be done on the non-technical aspects of crop diversification and irrigation management.

Li-Jen Wen mentioned several constraints to diversified cropping in Taiwan: small farm size, labor shortage, market fluctuations, competition with imported crops, income disparity between farm and non-farm families, and technical problems related to farm mechanization. Farmers pay 300-320 kilograms of rice per year for water fees, as well as 10-40 per cent of construction costs beginning 2 years after construction at 6 per cent interest. **Wen** then gave a short summary of **Ko Hai-Sheng's** paper, commenting about phrases like "government intervention to facilitate crop diversification" as unsuitable for supporting the diversification process in a democratic society. Government policy, he felt, should respond to farmer initiatives and adjust water management practices to suit cropping decisions made by the farmers.

Manuel Vergel asked whether farmers did their own land preparation and shaping for non-rice crops in Taiwan or whether they contracted out the work. He also asked if shaping was permanent or seasonal. **Wen** answered that farmers typically prepared and shaped the land themselves on a temporary basis, depending on the selection of crops. **Miranda** asked whether furrows were erased to shift from upland crop to paddy. **Wen** answered that new furrows were cut every season with machines. **Roberto Lenton** asked whether or not Taiwan adopted crop diversification by introducing new technologies and irrigation management practices or if they already existed. **Wen** answered that crop diversification had been underway since the early 1960s and that technologies and management structures were then in place. In answer to a question on whether the cultivation of corn was for import substitution or for export as well, **Wen** commented that the demand for corn at 3 million metric tons (MT) outstripped production at 200,000 MT.

Shawki Barghouti noted that crop diversification should be seen as a process and not as a target. The World Bank, he said, was paying increasing attention to diversified cropping under the assumption that in many countries, including Malaysia, Indonesia, and Thailand, it was seen as a process. The Bank would assess investments in terms of the factors affecting this process, including government policy, technical issues, agriculture and economic policies, exchange rules, import substitution and prices of crops, and marketing information. These factors would be evaluated for signals of benefits that might be expressed in terms of such things as government incentives, improved markets, and more equitable crop pricing.

Sunil Dimantha was interested in the World Bank's policy toward import substitution of sugar cane. He said that there was a glut in the world market but that it was a successful crop in Sri Lanka for diversified cropping. What import substitution meant to a particular country, he concluded, was distinct from the world market and price issues. Hecht observed that at world prices, the cost of producing sugar cane in Sri Lanka was greater than the cost of importing it. The investment in sugar cane could be put to better use in tea or rubber and the resultant import substitution saving would be greater. Dimantha observed that this was true if based on current prices. But he wondered if they should do so, ignoring its future potential.

SECTION II: COUNTRY PAPERS

IRRIGATION MANAGEMENT FOR DIVERSIFIED CROPPING

Manuel M. Vergel, Jr.*

IRRIGATED AREA FOR DIVERSIFIED CROPPING

The Philippines has a total land area of approximately 30 million hectares (ha). Arable land is 11 million ha, and the rainfall-dependent upland farming area is about 8 million ha. Total irrigated area is 1.4 million ha with a program target of 3.1 million ha (see Table 1). About 30 per cent of the arable land is programmed for irrigation development by the National Irrigation Administration (NIA). At present about 600,000 ha have been developed under NIA's "National Irrigation System" category (i.e., large systems that are managed by NIA until farmer beneficiaries have been organized and trained for operation). For the "Communal and Pump" category, about 800,000 ha are being serviced by NIA with farmer beneficiaries organized to manage the irrigation system immediately after development.

Table 1. Potential irrigable area (in hectares) versus service area by type of system, by region, Philippines, 1985.

Region	Potential irrigable area	National	Communal and pump	Total service area	Percent left for irrigation development
I	309,813	55,196	131,802	186,998	39.6
II	539,709	185,337	112,874	298,211	44.5
III	482,215	167,229	105,520	272,749	43.3
IV	263,593	45,624	84,923	130,547	50.5
V	239,646	16,269	88,344	104,613	56.3
VI	197,251	52,455	40,436	101,891	48.3
VII	50,739	457	16,981	17,438	65.6
VIII	84,381	13,229	40,439	53,668	36.4
IX	76,498	10,830	21,954	32,784	57.1
X	230,148	4,167	43,594	47,761	79.2
XI	290,249	30,197	58,221	88,418	69.5
XII	362,077	24,588	59,535	84,123	76.8
Total	3,126,319	605,578	813,623	1,419,201	54.9

National Irrigation Administration 1985a.

Table 2 indicates that 4 per cent of the national irrigable area is in diversified crops; the extent of diversified cropping in the Communal and Pump areas is being investigated. Water use is generally higher in Communal

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Irrigation Systems during the dry season. Table 2 indicates that the present irrigated area under the National Irrigation System category has a dual soil extent of about 20 per cent. Assuming the same 20 per cent in the area under Communal and Pump irrigation, about 250,000 ha of soil suitable for diversified crops is available. The present base for diversified crops is projected to increase substantially under NIA direction to service the upland area.

Table 2. Extent of dual and diversified cropland in national irrigation systems. Philippines. 1986 (in ha).

Region	Irrigated area	Dual cropland	Diversified cropland
I	186,998	31,602	4,472
II	298,211	11,420	10,230
III	272,749	43,357	5,739
IV	130,547	15,299	1,435
V	104,613	4,262	none
VI	101,891	4,411	127
VII	17,438	none	none
VIII	53,668	none	none
IX	32,784	none	none
X	47,763	551	79
XI	88,438	12,506	3,860
XII	84,123	2,798	108
Total	1,419,213	126,206	26,150

Ibid.

Diversified cropping is generally avoided in the wet season because of waterlogged rice paddies. Thus, farmers tend to crop rice during the wet season. Exceptions are paddies with good drainage systems.

For dry season crops, farmers evaluate primarily the prospects of profitability and adequate water control. In spite of the depressed price for paddy, rice farmers in irrigated areas are reluctant to shift to corn because corn yield per hectare can hardly equal that of rice, prevailing price of corn is lower than rice, there is not much difference in levels of input cost and net income, and a market is less assured for non-rice crops.

RESEARCHABLE ISSUES IN IRRIGATED DIVERSIFIED CROPPING

Land Preparation

How should paddy area be prepared to suit various crops for diversification? Farmers should prepare the traditionally flat paddy area to facilitate irrigation and drainage for non-rice crops. The IIMI study on irrigation management for crop diversification in the Philippines has shown that the furrow method can reduce irrigation time by one-third compared to the basin flooding method on a per hectare basis. Theoretically, the paddy area has to be prepared with a slope to facilitate irrigation and drainage. But farmers may find it tedious and cumbersome to reshape the slope of the paddy area in preparation for crop diversification, and to re-level the paddy area afterwards for rice. What may turn out to be compromise on the part of the farmer is to simply prepare the furrows, utilize the hills for planting, and irrigate by flooding of furrows.

Soil Suitability

There is a concern in the Philippines over whether economic crops can be grown in heavy clay soils. This soil regime constitutes about 80 per cent of irrigated systems.

Rate of Water Application

Some findings from the ADB-IIMI Study on Irrigation Management for Crop Diversification suggest the appropriate irrigation required for non-rice crops.

Corn: Loose, friable clay soils with good permeability, and four irrigation applications at a depth of 60 millimeters (mm) each are needed. Irrigation is required from silking to ear formation, but just before tasseling is most beneficial. Furrow irrigation is the most common method of applying water.

Soybean and wheat: Wheat can be grown on medium to fine-textured soils; it is also well adapted to heavier soils, even clays. Average water use is 3.65 every 14 days, and 3.61 mm/day every 20 days, respectively.

Sorghum: Sandy loam to clay loam soils. Drought-resistant and can be grown in rainfed areas. Irrigate 2-3 times in dry areas, the first given 35-45 days after emergence, the second during flowering stage, and the third in milky ripening stage.

Cotton: The earliest possible time at which terminal irrigation could be done without significantly reducing yield is at the beginning of soil formation. Application of water beyond this period tends to prolong the harvest season. During the initial flooding and ball formation stages, waterlogged conditions for 2 days will affect growth and yield. During the vegetative stage, waterlogging for up to 8 days will not affect yield significantly.

Peanut: Prefers light and well-aerated soils, and should be irrigated only to maintain soil moisture at field capacity. Over-irrigation tends to decrease yield.

Mungbean: Minimal irrigation of 4 centimeters (cm) applied every two weeks is sufficient.

Mixed crops: Irrigation of 4 cm every 21 days is recommended for high yield of crops in the garlic-mungbean and garlic-cowpea inter-cropping system. In the garlic-soybean inter-cropping system, soybean yield is highest at 8 cm applied every 7 days.

While irrigation interval can be easily understood by farmers, applying, say 8 cm of water would leave the farmer in a quandary, especially without any means for water measurement. Farmers will appreciate instruction on the water depth required in the furrows and time required to maintain the specified furrow water before closing the inlet for supply of irrigation water.

System Management

Obviously, rice paddies have to be grouped to share irrigation water issued from turnouts. The paddy receiving the first supply must have outlets to neighboring or adjacent paddies so that the latter can be supplied with water. Finally, the last paddy or field at the extremities receiving water should have openings to drain excess water, collected through oversupply of irrigation water or rain, into existing drainage canals.

The optimum grouping of rice paddies to suit irrigated diversified cropping has yet to be determined. The first paddy receiving water will govern the grouping because it has to be watched for waterlogging due to furrow water while adjacent paddies are being irrigated.

Institutional Organization

Cooperation among farmers is necessary to promote diversified cropping in irrigated systems. As discussed above, rice paddies have to be grouped to share irrigation water. Rice paddies are operated by different farmers, hence the need for farmer organization prior to implementation of diversified cropping. In the Philippines, farmer members in National and Communal Irrigation Systems are organized into Irrigation Associations (IA) with legal corporate personalities. IAs operate and manage constructed or rehabilitated irrigation systems.

ADVANCES IN IRRIGATED DIVERSIFIED CROPPING

Government Policy

The Philippine Government recognizes the need for crop diversification, especially in irrigated systems, in order to effect a broad flexible agricultural base for economic stability. Support is provided through soft loans to encourage crop diversification with emphasis placed on small and medium scale agricultural enterprises, particularly those engaged in food production for domestic consumption.

Except for rice and corn, the new government does not engage itself directly or indirectly in domestic agricultural production and marketing. For rice and corn, government control will be on a "least interference" basis limited to price stabilization of these two crops.

Foreign Assistance

The Philippines obtained USAID assistance in October 1986 to pursue a Five-Year Accelerated Agriculture Program to strengthen its economy. The main thrust is crop diversification with the Ministry of Agriculture and Food (MAF) and the NIA as program implementors in upland areas and irrigated systems, respectively.

Support from the Ford Foundation is being negotiated at present to help organize farmer groups for irrigated diversified cropping. A program to federate Irrigation Associations is being pursued by NIA so that concerned farmers could implement appropriate systems for irrigation management.

Related Development Program

The NIA "corplan" for 1987-1996 aims to establish a program for Dry Season Irrigation Management (DSIM) to cope with irrigation water deficiency, especially during the dry season. The program will serve organized farmer groups for block water supply scheduling, low cost and self-help projects, and cooperative irrigated diversified cropping. The latter is the basis for organized water rotation systems and/or the need for augmenting supply. The program is intended to promote primarily non-rice crops prescribed by NIA.

REFERENCES

Asian Development Bank. 1983. IFPRI - IRRI study on food demand and supply and related strategies for developing member countries (Phase 1). Feb 1983-May 1984. Manila, Philippines: ADB.

International Irrigation Management Institute. 1986. Literature review on irrigation management for diversified cropping. Draft, November.

Gonzales, L.A. 1985. Philippine agricultural diversification: A regional economic comparative advantage analysis. Los Banos: University of the Philippines.

Japan International Cooperation Agency. 1986. Summary report on survey for diversified crops' irrigation engineering project in the Republic of the Philippines. Manila, Philippines: NIA.

Ministry of Agriculture and Food. 1986. A short-term recovery plan for the rural sector. Manila, Philippines.

National Irrigation Administration. 1985a. Potential irrigable area versus service area by type of system and by region. Manila, Philippines: NIA.

National Irrigation Administration. 1985b. Extent of dual and diversified cropland in national irrigation systems. Manila, Philippines.

Vergel, Jr. M.M. 1986a. The role of NIA in economic recovery (through national and communal irrigation systems). Manila, Philippines: NIA.

Vergel, Jr. M.M. 1986b. Proposal for regional implementation of NIA's cropland for strengthening farmers capability in dry season irrigation management. Manila, Philippines: NIA.

REORIENTATION OF INDONESIAN IRRIGATION MANAGEMENT: UTILIZATION TOWARD CROP DIVERSIFICATION

Budiman Hutabarat and Effendi Pasandaran*

AGRICULTURE SECTOR IN THE GENERAL ECONOMY

Agriculture is the dominant contributor to Indonesia's Gross Domestic Product (GDP). However, its relative importance continues to decline steadily, from 44 per cent in 1971 to only about 30 per cent in 1983 with a minimum trend of 3.38 per cent/year, even though its growth in absolute value rises at a rate of 3.72 per cent/year (Table 1).

This downward trend also occurs in the rate of labor absorption in the sector, especially in the rice sub-sector over the last 10 years (Collier 1982; Soentoro 1982), and has also been confirmed by national census data of 1980. In 1971 about 66 per cent of the labor force was employed in the agriculture sector, but the percentage dropped to 55 per cent in 1980.

Table 1. Percentage and value changes in Gross Domestic Product (in billion rupiahs at 1973 constant price) by economic sector, Indonesia, 1971-83.

Year	Total	Agriculture Sector						Non-agriculture Sector	
		Sub-total		Food		Non-Food			
1971	5545	2441	44.0	1436	58.8	1005	41.2	3104	56.0
1972	6067	2479	40.9	1415	57.1	1064	42.9	3588	69.1
1973	6753	2710	40.1	1573	58.0	1137	42.0	4043	59.9
1974	7269	2811	38.7	1681	59.8	1130	40.2	4458	61.3
1975	7631	2811	36.8	1696	60.3	1115	39.7	4820	63.1
1976	8156	2944	36.1	1756	59.6	1118	40.4	5212	63.9
1977	8871	2981	33.6	1734	58.2	1247	41.8	5890	66.4
1978	9480	3135	33.1	1836	58.6	1299	41.4	6345	66.9
1979	10165	3256	32.0	1909	58.6	1347	41.4	6909	68.0
1980	11169	3425	30.7	2073	60.5	1352	39.5	7744	69.3
1981	12055	3594	29.8	2261	62.9	1333	37.1	8461	70.2
1982	12325	3670	29.8	2294	62.5	1376	37.5	8655	70.2
1983	12842	3846	29.9	2412	62.7	1434	37.3	8996	70.1
%/yr	7.09	3.72	-3.38	4.33	0.62	2.78	-0.94	8.96	1.87

All per cents are significant at 0.01 level; Kasryno 1986.

Land utilization in Indonesia among various crops, measured by area harvested, is summarized in Table 2.

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Table 2. Harvested area (in million ha) of rice in Java, other islands, and Indonesia (IND) as a whole, 1968-81.

Yr	Irrigated wet land			Unirrigated dry land			Total		
	Java	Other	IND	Java	Other	IND	Java	Other	IND
68	3.86	2.51	6.36	0.41	1.25	1.66	4.27	3.75	8.02
69	3.95	2.60	6.54	0.35	1.12	1.47	4.30	3.72	8.01
70	3.96	2.72	6.68	0.34	1.11	1.46	4.30	3.83	8.14
71	4.05	2.84	6.89	0.37	1.07	1.43	4.42	3.91	8.32
72	4.01	2.60	6.61	0.33	0.97	1.31	4.34	3.57	7.90
73	4.24	2.83	7.06	0.33	1.01	1.34	4.57	3.84	8.40
74	4.45	2.89	7.34	0.29	0.88	1.17	4.72	3.78	8.52
75	4.39	2.95	7.33	0.26	0.90	1.16	4.65	3.85	8.50
76	4.22	3.01	7.23	0.25	0.89	1.14	4.47	3.90	8.37
77	4.13	3.07	7.20	0.24	0.91	1.16	4.38	3.98	8.36
78	4.46	3.23	7.70	0.29	0.94	1.23	4.75	4.18	8.93
79	4.41	3.26	7.68	0.22	0.91	1.13	4.63	4.18	8.80
80	4.53	3.30	7.82	0.25	0.93	1.18	4.78	4.23	9.01
81	4.78	3.41	8.19	0.27	0.92	1.19	5.05	4.33	9.38
Avg	1.30	2.20	1.70	-3.70	-2.00	-2.40	1.00	1.10	1.10
R^2	0.79	0.94	0.92	0.74	0.62	0.72	0.68	0.72	0.80

Avg = average annual growth rate in per cent; World Bank 1983.

For rice, area harvested is growing by 1.7 and -2.4 per cent/year for irrigated and unirrigated land, respectively. Overall, rice area is increasing by 1.1 per cent/year. The annual growth of area harvested for other crops such as corn, cassava, sweet potatoes, groundnuts, and soybeans are 0.2, -0.5, -2.7, 2.9, and 1.3 per cent, respectively (Table 3).

Using data from the national agriculture censuses of 1963, 1973, and 1983, the distribution of cultivated land is presented in Table 4. In Sumatera, sawah[1] land increased by 66 per cent, while dry land increased by 27.3 per cent. Correspondingly, in Java cultivated land area grew by 16 and 10 per cent for sawah and dry land, respectively.

Irrigated service area based on types of irrigation classified as technical, semi-technical, or simple can be observed in Tables 5 to 7 respectively.

Observing the distribution of sawah areas given in Table 8, from national agricultural census data of 1983, it appears that 63 per cent of Indonesian irrigated land is concentrated on Java. The magnitude drops sharply off Java, as Sumatera, Sulawesi, Nusa Tenggara, and Kalimantan have percentages on the order of 18, 8, 6, 3, and 2 per cent, respectively.

Table 3. Harvested area (in million hectares) of secondary food crops in Java (J), other islands (IS), and Indonesia as a whole (IND), 1968-81.

Yr	Soybeans			Corn			Cassava			Groundnuts			Sweet Potato		
	J	IS	IND	J	IS	IND	J	IS	IND	J	IS	IND	J	IS	IND
68	0.54	0.13	0.68	2.31	0.91	3.22	1.16	0.35	1.50	0.32	0.07	0.40	0.25	0.16	0.40
69	0.48	0.08	0.55	1.60	0.84	2.44	1.14	0.32	1.47	0.29	0.08	0.37	0.19	0.18	0.37
70	0.60	0.10	0.70	2.10	0.84	2.94	1.09	0.30	1.40	0.30	0.08	0.38	0.19	0.17	0.36
71	0.58	0.10	0.68	1.86	0.77	2.63	1.10	0.31	1.41	0.30	0.08	0.38	0.18	0.18	0.36
72	0.58	0.12	0.70	1.51	0.65	2.16	1.13	0.34	1.47	0.28	0.07	0.35	0.16	0.18	0.34
73	0.61	0.14	0.75	2.37	1.07	3.43	1.06	0.37	1.43	0.31	0.10	0.41	0.20	0.18	0.38
74	0.60	0.16	0.75	1.93	0.73	2.67	1.16	0.35	1.51	0.33	0.08	0.41	0.17	0.17	0.33
75	0.60	0.15	0.75	1.77	0.67	2.45	1.07	0.35	1.41	0.37	0.10	0.48	0.16	0.15	0.31
76	0.50	0.15	0.65	1.43	0.66	2.10	1.00	0.35	1.35	0.32	0.10	0.41	0.14	0.16	0.30
77	0.52	0.13	0.65	1.71	0.86	2.57	0.99	0.37	1.36	0.36	0.14	0.51	0.15	0.17	0.33
78	0.59	0.16	0.73	2.16	0.86	3.02	1.01	0.37	1.38	0.37	0.13	0.51	0.13	0.17	0.30
79	0.62	0.14	0.76	1.79	0.80	2.59	1.02	0.40	1.42	0.36	0.13	0.49	0.12	0.16	0.28
80	0.59	0.14	0.73	1.81	0.92	2.73	1.00	0.41	1.41	0.36	0.14	0.50	0.12	0.16	0.28
81	0.65	0.16	0.81	2.01	0.95	2.96	0.99	0.40	1.39	0.36	0.15	0.51	0.11	0.16	0.27
Avg	0.90	3.50	1.30	-0.40	0.40	-0.20	-1.20	1.90	-0.50	1.90	6.20	2.90	-5.10	-0.70	-2.70
R^2	0.18	0.48	0.32	0.00	0.01	0.01	0.73	0.70	0.32	0.64	0.85	0.74	0.88	0.22	0.87

Some totals do not add because of rounding; Avg = average annual growth rate in per cent.

Table 4. Distribution of arable land (in thousand hectares), and per cent growth, for 1963, 1973, and 1983, Indonesia.

Islands	1963		1973		1983		Growth	
	Sawah	Others	Sawah	Others	Sawah	Others	Sawah	Others
Sumatera	779	3130	1038	2764	1294	3993	66	27
Java	2558	3119	2631	2874	2946	3448	16	10
Nusa Tenggara	243	701	291	917	360	1174	48	67
Kalimantan	278	1140	434	1434	615	2250	121	97
Sulawesi	247	719	445	1078	523	1862	11	160
Maluku and Irian	na	na	0	259	7	586	na	na
Indonesia	4105	8809	4839	9326	5745	13313	262	361

na = not available; Kasryno 1986.

Table 5. Technical irrigation service area (in thousand hectares), 1970-82.

Provinces	1970	1972	1974	1976	1978	1982
Aceh	0	0	0	0	na	na
North Sumatera	32.6	32.6	5.9	57.2	76.4	70.8
Riau	0	0	0	0	0	0
Jambi	2.3	2.1	0.4	0.7	0.7	0.7
South Sumatera	21.4	15.5	15.1	16.0	16.0	2.6
West Sumatera	17.9	17.4	20.3	25.5	25.5	9.9
Bengkulu	6.6	2.1	6.4	8.7	8.7	7.6
Lampung	29.3	37.4	42.4	56.8	102.0	119.2
West Java	260.3	381.1	502.8	519.7	510.7	245.1
Central Java	395.6	406.8	432.5	449.0	449.0	456.1
Yogyakarta	1.2	1.2	1.2	0	0	0
East Java	576.1	582.1	573.1	587.4	605.4	642.6
West Kalimantan	0	0	0	0	0	0
Central Kalimantan	0	0	0	0	0	0
East Kalimantan	0	0	0	1.2	1.2	na
South Kalimantan	na	2.2	2.3	4.0	3.5	5.6
North Kalimantan	na	na	na	na	na	na
North Sulawesi	13.4	3.5	3.2	3.2	3.2	12.9
Central Sulawesi	na	na	na	na	na	na
Southeast Sulawesi	na	na	na	0	7.7	3.0
South Sulawesi	118.7	118.7	70.8	70.8	50.3	38.9
Bali	na	na	na	na	na	na
West Nusa Tenggara	63.1	53.9	61.0	61.0	58.8	55.5
East Nusa Tenggara	0	1.7	0	0	0	5.6
Maluku	0	0	0	0	0	0
Irian Jaya	na	na	na	na	na	na
East Timor	na	na	na	na	na	na
DKI Jakarta	6.2	8.7	9.1	9.6	9.6	3.9

na = not available.

Table 6. Semi-technical irrigation service area (in thousand hectares), Indonesia, 1970-82.

Provinces	1970	1972	1974	1976	1978	1982
Aceh	16.2	23.2	22.7	22.7	22.7	75.4
North Sumatera	48.0	28.0	71.8	37.3	44.4	102.9
Riau	19.9	21.3	21.3	21.3	21.3	23.9
Jambi	10.7	.8	2.2	2.2	5.1	4.9
South Sumatera	8.0	11.2	22.2	22.2	39.3	25.4
West Sumatera	77.4	74.8	73.9	67.7	83.6	84.2
Bengkulu	9.3	.8	9.4	15.0	15.0	18.8
Lampung	0	2.5	2.6	60.2	16.2	19.9
West Java	408.6	290.0	175.7	176.3	182.2	39.0
Central Java	150.0	1.4	94.8	96.5	96.5	100.3
Yogyakarta	21.9	26.0	28.0	64.0	53.1	41.5
East Java	120.8	118.7	138.5	125.5	125.6	121.1
West Kalimantan	4.2	4.1	4.1	8.5	11.2	9.7
Central Kalimantan	0	0	0	0	0	3.1
East Kalimantan	0.2	0	0.4	0.2	1.2	3.4
South Kalimantan	7.8	4.6	4.8	7.2	12.6	5.3
North Kalimantan	7.8	19.3	18.0	18.0	35.6	29.1
North Sulawesi	na	na	na	na	na	na
Central Sulawesi	4.0	2.5	6.7	6.7	15.0	25.6
Southeast Sulawesi	na	na	2.5	2.5	13.4	17.8
South Sulawesi	63.4	63.4	84.5	77.7	77.7	17.8
Bali	32.8	35.3	38.5	42.1	46.6	65.1
West Nusa Tenggara	7.6	23.9	49.9	49.9	42.4	58.1
East Nusa Tenggara	12.2	4.9	9.8	9.8	9.8	10.2
Maluku	0.1	0.9	0.9	2.3	4.8	6.9
Irian Jaya	na	na	na	na	na	na
East Timor	na	na	na	na	na	2.1
DKI Jakarta	17.1	3.3	3.1	4.6	4.6	5.7

na = not available.

Indonesian Diversified Cropping

Situation in Pre-1984.

Irrigation systems in Indonesia cannot be separated from the history of rice cultivation. Rice was, and continues to be, a dominant crop, from long before the colonial era up to the present day. During the colonial era, the government invested heavily in rehabilitation of existing local irrigation systems and construction of new ones. In that period on Java, irrigation water was also deployed for sugarcane owned by the government. A specific irrigation management system was introduced at that time which later came to be named the glebagan system as a special case of the golongan system.

The availability of water resources in the village community facilitated the farmers' ability to grow secondary crops such as corn, soybean, cassava,

Table 7. Simple (government) and communal (comm) irrigation service areas (in thousand hectares), Indonesia, 1970-82.

Provinces	Simple system (government)						Comm
	1970	1972	1974	1976	1978	1982	1982
Aceh	84.8	85.3	88.8	91.1	91.1	98.8	96.6
North Sumatera	0	0	28.6	36.2	75.2	31.5	19.3
Riau	1.9	4.0	4.0	4.0	8.4	0	25.8
Jambi	0	12.7	12.7	17.2	19.2	21.7	66.7
South Sumatera	40.4	39.9	29.8	30.9	30.9	2.2	110.3
West Sumatera	78.4	82.6	81.1	45.5	98.4	111.7	107.6
Bengkulu	20.7	12.7	16.1	34.9	34.9	19.7	28.1
Lampung	7.9	7.4	16.4	0	0	0	63.5
West Java	132.9	134.1	132.5	128.7	128.7	46.9	310.4
Central Java	183.8	182.9	211.3	203.0	203.0	99.9	0
Yogyakarta	38.5	34.9	34.2	0	33.9	23.9	0
East Java	199.5	198.6	185.8	199.2	186.8	164.8	41.9
West Kalimantan	2.5	5.8	5.8	2.2	2.2	48.4	63.9
Central Kalimantan	0	0	0	0	0	0	6.3
East Kalimantan	16.5	29.6	30.8	30.7	30.2	49.7	63.9
South Kalimantan	0	1.6	1.8	3.6	2.4	4.9	237.9
North Kalimantan	na	na	na	na	na	na	na
North Sulawesi	0	6.4	14.4	18.9	12.2	9.7	26.1
Central Sulawesi	16.2	17.6	11.9	11.9	5.2	7.4	0
Southeast Sulawesi	14.6	14.2	14.2	14.2	0	4.2	24.8
South Sulawesi	0	0	42.6	42.6	79.7	53.3	17.9
Bali	0	2.4	8.9	8.5	6.4	4.0	42.0
West Nusa Tenggara	0	19.7	38.3	38.3	31.9	27.6	43.4
East Nusa Tenggara	na	10.9	13.9	13.9	13.9	15.7	109.9
Maluku	na	0	0	0	0	0.7	0
Irian Jaya	na	na	na	na	na	3.8	na
East Timor	na	na	na	na	na	0	na
DKI Jakarta	0	0	0	0	0	14.5	4.9

na = not available.

and tobacco as traditionally cultivated in Java Timur (East Java). In some parts of the country, West and East Java and Bali, farmers grow vegetables including cabbage, carrot, cucumber, string pea, red pepper, onion, garlic, and horticulture crops such as pineapple.

This history continued until Indonesia first launched its PELITA (Pembangunan Lima Tahun or Five Year Development Program) under which the government stressed the attainment of self-sufficiency in rice and elimination of rice imports. Toward this end, a number of policy decisions and actions during the last 15 years were carried out. Among these are the deployment of new irrigation facilities, intervention in rice and fertilizer prices, a package of appropriate technology under the BIMAS (Bimbingan Massal or Mass Intensification) program including seeds, fertilizers, pesticides, and extension services with credit facilities on very easy terms.

Table 8. Sawah area (in thousand hectares) according to source of irrigation water, Indonesia, 1983.

Provinces	Irrigated rice plantings			Unirrigated		
	Twice	Once	Total	Tidal*	Rainfed	Total
Aceh	22.5	52.1	74.6	3.6	73.8	77.5
North Sumatera	70.4	70.0	140.4	11.7	147.2	158.9
Riau	1.8	2.2	4.0	18.0	38.7	56.7
Jambi	5.3	18.0	23.3	20.3	61.3	81.5
South Sumatera	19.1	25.8	45.8	96.0	117.2	213.2
West Sumatera	76.9	38.3	115.7	5.6	46.3	51.9
Bengkulu	11.7	16.4	28.0	7.3	14.2	21.5
Lampung	53.1	31.5	84.6	18.6	52.5	71.1
West Java	534.4	115.4	649.8	23.5	310.2	333.8
Central Java	381.6	117.9	499.5	9.2	370.3	379.5
Yogyakarta	33.1	4.2	37.4	0.3	14.9	15.2
East Java	454.7	183.3	638.0	9.6	319.5	329.1
West Kalimantan	10.9	39.4	50.2	35.8	144.8	180.6
Central Kalimantan	0.1	1.7	1.9	21.0	61.7	82.7
East Kalimantan	0.5	2.7	3.2	2.9	25.6	28.6
South Kalimantan	0.8	3.9	4.7	42.7	111.9	154.6
North Kalimantan	na	na	na	na	na	na
North Sulawesi	24.7	2.1	26.4	0.8	12.7	13.5
Central Sulawesi	30.8	14.2	45.0	1.1	8.8	9.8
Southeast Sulawesi	7.4	5.4	12.8	2.0	5.6	7.6
South Sulawesi	97.6	58.4	156.1	3.5	194.0	197.7
Bali	63.7	10.2	73.9	0.1	1.5	1.6
West Nusa Tenggara	55.2	63.4	118.6	0.4	56.3	56.6
East Nusa Tenggara	15.1	26.4	41.5	0.9	28.2	29.1
Maluku	0.3	0.6	0.6	0	0	0
Irian Jaya	0.2	0	0.2	0.2	4.9	5.1
East Timor	na	na	na	na	na	na
DKI Jakarta	na	na	na	na	na	na
Indonesia	1971.5	903.3	2876.2	335.0	2222.2	2557.6

*Tidal and swamp irrigated; rounding may affect some totals; na = not available; Kasryno 1986.

After 15 years, self-sufficiency in rice was, for the first time, realized in 1984/85 partly due to farmers' favorable response, good weather, and the unusual absence of insect attack. However, this accomplishment has been at a very high cost to society, with direct costs to the government budget and indirect costs to the economy through fewer secondary crops. For instance, massive investment in irrigation in new areas opens the possibility of creating new paddy fields and, in already established areas, it enhances the cultivation of rice to two or three times a year, thereby, in part, changing the ecosystem in areas where rice diseases and insects could increase.

Situation in Post-1984.

With post-1984 economic conditions Indonesia's past performance in increasing rice productivity and production will no longer be sustainable. Part of the reason may be that budget constraints may necessitate reduction of fertilizer subsidies and irrigation investment. Another reason, to some extent, is that the oversupply and low price of rice in the international market forces the government pay a heavy storage costs, reducing its comparative advantage. If these conditions continue, a systematic approach to campaign for increased diversified cropping may be necessary to increase the dynamism of the agriculture sector and the income levels and welfare of farmers. This can be viewed from either the production or nutritional side by, for example, reducing imports like soybeans and improving the nutritional standard. One attempt in that direction is the utilization of irrigation management for diversified cropping. In a broader context there may also be efforts to introduce a farming system approach with the expectation of partly improving yields and farmers' incomes.

Production Constraints and Potential of Diversified Cropping under Irrigation.

Data about rice yields under different land classifications of irrigated or unirrigated can be found elsewhere. For instance, miscellaneous BPS (<u>Biro Pusat Statistik</u> or Central Bureau of Statistics) reports show that the yield level in irrigated land is more than twice as in unirrigated land (Table 9).

Table 9. Comparison of five-year average yields of rice (tons/hectare) in irrigated and unirrigated areas, Indonesia, 1969-81.

	Irrigated Land	Unirrigated Land	Difference	(%)
1969-73	2.67	1.16	1.51	(130)
1974-78	2.99	1.28	1.71	(134)
1979-81	3.53	1.43	2.10	(147)

Contrary to the case of rice, data on farmer yield levels of secondary (<u>palawija</u>) crops on those types of land is not available even though yield data that does not take into account land classification are always included in BPS reports. For example, soybean yields during the PELITA III (Third Five Year Development Program in 1979-84) were 870-890 kilograms/hectare (kg/ha), about 60 per cent of the average for all developing countries (1,540 kg/ha) and about 75 per cent of those in Thailand (1,190 kg/ha). Likewise, in spite of the increase in average corn yields from 1.11 tons/ha in 1977 to 1.77 tons/ha in 1984, they are still well below the average yield of 2.38 tons/ha for the Asia-Pacific Region and 3.25 tons/ha for the world.

The yield levels of these two crops are still far short of levels achieved by research stations. The soybean variety Orba for example, can yield 1.5 tons/ha and the corn variety Arjuna and Hybrid C-II can yield 4.3 and 5.8 tons/ha, respectively. These research yield levels presumably can be accomplished through a production package adopted in the research stations among which the application of irrigation management is crucial. This list can be extended to sweet potatoes, onions, cabbages, fruits and vegetables.

Important work comparing farm level yields based on land types was done by Taylor et al. (1979) in the Pekalen Sampean Irrigation Project (PSIP) in East Java, where rice is the dominant crop. In addition to rice, farmers also grow soybean, corn, tobacco, cassava, and groundnuts. With soybean, researchers found that irrigated yield in dry season was 0.58 metric tons (MT), about 2.5 times higher that of unirrigated soybeans in the same season (Table 10). This yield was 12 per cent higher than unirrigated wet season yield. For corn

Table 10. Average yield (in kilograms) of various secondary crops in the Pekalen Sampean Irrigation Project (PSIP) areas, Indonesia, 1973-74.

Crop types	Irrigated	Unirrigated
Rice		
Wet season	360	180
Dry season	329	na
Soybean		
Wet season	na	521
Dry season	580	231
Corn	699	414
Tobacco	495	270
Cassava	na	358
Groundnuts	na	133

na = not available; Taylor et al. 1979.

irrigated yields are almost 75 per cent higher than the unirrigated yields. The irrigated yield of tobacco was over 1.8 times the unirrigated yield.

By looking at both the research and farm level yields above, the deployment of irrigated management for crop diversification has great potential. Moreover, crop diversification on irrigated land, in the near future, seems to be imperative due partly to the following reasons:

1. Intensive agriculture on unirrigated upland entails unstable production environment. Using unirrigated upland without following appropriate soil and water conservation will drastically deteriorate land productivity.

2. In the context of Indonesian agriculture, an institutional base for soil and water conservation has not yet come into existence (Hutabarat and Pasandaran 1986).

3. The decision to plant non-rice crops is not only good policy to reduce water stress but also, to a certain extent, to improve the equity of water distribution in the area planted to rice as argued by Pasandaran (1984).

PROMISING IRRIGATION MANAGEMENT PRACTICES

Our concept of irrigation management is implicitly directed toward an efficient and equitable allocation of water resources. At the farm level or village block, water is allocated as outlined below. Two dimensions that are always inherent in the allocation are spatial and temporal dimensions.

Case 1. Foothill Area of Sukabumi, Java Barat

The development of irrigation management in this area has contributed to the high productivity. Water is not a constraint in the area. CAER's (Center for Agro-economic Research) 1985 research observed that farmers are already market-oriented. Crop diversification is reflected in the intensive cropping systems dominantly grouped as follows (Wirawan et al. 1985):

1. Three rice crops per year, each with two applications of fish fertilizer.

2. Three rice crops per year on 75 per cent of the land, each with two applications of fish fertilizer; vegetables on the remaining 25 per cent.

Another system is briefly sketched in Figure 1. Farmers in the area have not only been fully conscious of the advantage of crop rotation but have also understood the benefit of maintaining the balance between chemical and organic fertilizers. Through four years, one-fourth of the farmer's land would again be planted with vegetables. This is important because diversified cropping and rotation could ensure the stability of soil productivity, provide more stable income over time, and generate higher income relative to other systems.

Figure 1. Intensive diversified cropping in Sukabumi, Indonesia.

Year 1				Year 2				Year 3				Year 4			
A	B	B	B	B	A	B	B	B	B	A	B	B	B	B	A

A = Rice crop with two applications of fertilizer; B = two vegetable crops.

Soil fertility is kept stable because the vegetable crop was cultivated in dry conditions using only organic fertilizers. Rice used chemical fertilizer. Several farmers stated that rice grown with fish has a high rate of growth (Wirawan 1985), but this was not scientifically tested. Moreover, observations in the area also suggested that the smaller the size of controlled land, sufficient water seems to stimulate more intensive cropping.

Case 2. Lowland Area of Jatiluhur, Java Barat

Irrigation management in this area efficiently uses water to irrigate rice, and supply is assured. It is common to find farmers cultivating rice three times a year or even five times in two years. Equity in distributing water is neglected, and not optimally allocated due to its rigid and fixed golongan system. The two upstream golongans, and to a lesser extent, the third golongan, take advantage of the abundant water supply to cultivate rice. This happens throughout the year, and this golongan system is fixed over time. The excessive water supply even in the dry season, however, cannot be used for secondary crops partly due to a poor drainage and the lack of short-maturing varieties. This may be why diversified cropping is not popular in the area. On the other side, in the downstream area of the Jatiluhur system gogorancah and sorjan cultivation systems are applied. Therefore, we can assume that the system is still in the early stage of development in terms of social benefits.

Case 3. Fixed Golongan System of Rentang, Java Barat

Study and data on this area have been documented in conjunction with the Rentang Rehabilitation Project (Nataatmadja 1981). The rehabilitation program had a significant impact on farm decision making, including the development of cropping systems. However, appears to impair the development of secondary crops and sugar cane (ibid.). From 1971-80, Rentang's secondary crops area decreased 10 per cent/year; for cane the figure was 10.7 per cent/year. The project team listed several possible reasons for negative growth in the area: a) too much water for secondary crops production; b) lack of labor force; and c) intention to keep the field fallow for a sufficient time.

Case 4. Flexible Golongan System of Pekalen Sampean, Java Timur

The system in the area is quite different from other cases as envisioned above partly due to traditional cultivation practices and established support mechanism. Crop diversification techniques have long been practiced at farm level or village block. The irrigation system is oriented towards an equitable and efficient allocation and distribution of irrigation water and a higher productivity of land. Taylor (1979) also concluded that land and water resources were already being used in a remarkably efficient manner. The practice can be visualized in Figure 2.

Figure 2. Rotation for crop diversification in Pekalen Sampean, Bondowoso, Java Timur, Indonesia.

Year 1				**Year 2**				**Year 3**				**Year 4**			
A	**B**	**C**	**D**	**B**	**D**	**C**	**A**	**B**	**C**	**A**	**D**	**D**	**C**	**B**	**A**

A = Rice planted twice then fallowed; B = rice planted once then secondary crops; C = sugarcane; and D = tobacco.

This type of rotational system has been noted to increase the average cropping intensity to 2.7 crops per year for irrigated land, and 1.5 crops per year for unirrigated land. However, rice was the only crop grown on irrigated land in the wet season, whereas secondary crops were mainly grown in the dry season (Taylor et al. 1979).

Case 5. Cirebon Irrigation System, Java Barat

Cropping systems in Cirebon are basically centered around seasonal rice. In the irrigated area where water is relatively abundant throughout the year three crops of rice are grown, with some overlapping in cultivation stages. In other areas a portion of the area in the second and third season is planted to secondary crops. In the irrigated area where water is relatively scarce, secondary crops are planted. There are some cases where rice is the only crop planted even though water is scarce during the dry season (Pasandaran 1982a and 1982b). These cropping patterns exist in Cirebon because of the difference in the accessibility to water causes a range of feasible alternatives in crop decision making, and because of the difference in locality of irrigation systems results in a certain interdependency in water distribution and consequently in crop decision making. In this kind of area, double rice cropping seems the best alternative to support the farmers' subsistence level given the behavior of seasonal water allocation, the skill available, and land holding.

REORIENTATION OF IRRIGATION MANAGEMENT IN THE FUTURE

There is room to modify practices or even create new ones in accordance with attempts to relax local constraints. These all depend on various aspects of the physical and socio-economic environment, meriting further consideration. Due to the potential complexity of the diversified cropping system relative to uniform rice culture, efforts should be directed to the demand-side rather than the supply-side policy on irrigation as previously dominant in a rice economy. Secondary crop requirements for water irrigation are relatively low but must be available according to the growth stage and types of crops. Consequently, the demand for irrigation water should be originated by the farmer. By doing so, it implicitly offers more flexible farmer decision making. Thereby they can be expected to take more initiative not only at the farmer level but at a broader level to participate effectively in irrigation management. Second, the shift from permanent (or static) farm level or village block ditches scheme to more flexible (or dynamic) configurations, thereby optimally allocating the availability of water resources. Ultimately, equity in the distribution of irrigation benefits is ensured.

From these two approaches, irrigation management in the existing systems could be expected to provide the highest economic returns by fine-tuning the systems, creating optimally available water supplies, water management and technology of rice-based rotation. Two examples from cases above show a tendency for a rigid or fixed giliran system of water distribution to be continually biased toward rice. This approach could lead to an unfavorable crop ecosystem. It is partly sustained by an economic environment exceptionally conducive to rice in the last 15 years.

NATIONAL POLICY ISSUES ON CROP DIVERSIFICATION

After reviewing and analyzing the irrigation management situation with its bias toward rice, and in view of government budget constraints and a low comparative advantage in rice, favorable rice economic conditions are going to be hard to duplicate in the future. Therefore, irrigation management for diversified crops would be one choice among many alternatives to encourage diversification. A dynamic diversified cropping program would not only ease the persistent financial burden borne by the government but also maintain the dynamism of the agriculture sector the income levels and welfare of farmers.

Suitable cropping patterns with consideration of soil, climate, availability of water supplies, and economics of agriculture should be identified. This is difficult and the profitability and viability of improved diversified cropping system is determined to a large extent by the quality of services provided by institutions associated with agriculture. National policy issues that might influence the planning and implementation of the cropping and farming systems are: 1) output and input pricing policy; 2) direct and indirect economic subsidies; 3) research policy designed to develop and improve secondary crop varieties; 4) extension service programs to transfer technology in diversified cropping; 5) availability of more competitive credit fashion; 6) efficient and fairer marketing institutions; 7) sound producer-supported co-operatives; 8) agro-industrial research and development policy.

RESEARCH ISSUES

In view of the complexity of diversified cropping systems, the following list outlines research issues related to irrigation management:

1. To prove or refute the impact of the proposed diversified cropping system on farm employment opportunities or income.

2. To investigate the underlying factors that influence choice of crops, mix of crops, and size of farms.

3. To examine the dynamic economic performance of diversified cropping strategies and existing practices in the context of multi-outputs and -inputs production schemes.

4. To evaluate incentive and disincentive mechanisms for stimulating effective demand for irrigation water.

5. To assess the extent of the demand side approach on diversified cropping, thereby encouraging or discouraging the introduction of water fees for individual crops.

6. To establish the comparative advantage of irrigation water application on various traditional crops.

7. To empirically analyze the extent of a demand side approach on efficient and equitable allocation and distribution of water resources.

NOTES

1. Sawah refers to all rice fields, irrigated or rainfed, which have low banks or bunds to retain water so that rice can be grown under flooded conditions.

REFERENCES

Collier, W.L., Soentoro, G. Wiradi, E. Pasandaran, K. Santoso, and J.F. Stepanek. 1982. Acceleration of rural development of Java. Bulletin of Indonesian Economic Studies 18 (3): 84-101.

Hutabarat, B. and E. Pasandaran. Forthcoming. Diversifikasi Pangan: Analisis masalayh dan strategi pengembangan (Food diversification. Analysis of issues and strategies for development). Jurnal Penelitian dan Pengembangan Pertanian.

Kasryno, F., C. Saleh, and P.U. Hadi. 1986. Pola Pertanian dan usahatani (Agricultural and farm structures). Pusat Penelitian Agro-Ekonomi (Center for Agro-Economic Research).

Nataatmadja, H. 1981. Third phase wet season sample survey benefit: Monitoring study of Rentang Irrigation Rehabilitation Project. Progress Report. Bogor: Agro-Economic Survey, Inc.

Pasandaran, E. 1982a. An evaluation of irrigation performance in Cirebon irrigation systems, West Java, Indonesia. Doctoral Thesis. Bogor: Institute Pertanian Bogor.

Pasandaran, E. 1982b. Water allocation and land utilization in Indonesian irrigation systems. Indonesian Agricultural Research and Development Journal 4: 91-97.

Pasandaran, E. 1984. The status of irrigation management research in Indonesia. Indonesian Agricultural Research and Development Journal 6 (1& 2): 24-28.

Soentoro, F. Kasryno, A.R. Nurmanaf, R.S. Sinaga, S. Bachri. 1982. Perkembangan kesempatan kerja dan hubungan kerja pedesaan: Studi kasus di empat Desa di Java Barat (Changes in working opportunities and relationships in rural areas: Case study in four villages of West Java). Bogor: Rural Dynamics Study, Agro-Economic Survey, Inc.

Taylor, D.C. 1979. Financing irrigation services in the Pekalen Sampean Irrigation Project, East Java, Indonesia. In D.C. Taylor and T.H. Wickham (eds.) Irrigation policy and management of irrigation systems in Southeast Asia. Bangkok: ADC.

Taylor, D.C., W. Prawirodihardjo, and E. Pasandaran. 1979. An economic analysis of irrigation water resources in East Java. Occasional Paper No. 1. Bogor: Rural Dynamics Study, Agro-Economic Survey.

Wirawan, S.H. Susilowaty, E. Pasandaran. 1985. Laporan studi investasi irigasi skala kecil (Research report on small scale irrigation investment). Bogor: Pusat Penelitian Agro-Ekonomi.

World Bank. 1983. Indonesia: Policy options and strategies for major food crops. Washington, D.C.: World Bank.

CROP DIVERSIFICATION WITH EXISTING IRRIGATION MANAGEMENT: A CHALLENGE IN BANGLADESH

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INTRODUCTION

Geographically, Bangladesh forms the largest flood plain in the world. It stretches from the foothills of the Himalayas to the Bay of Bengal, and is washed by the Meghna, Padma, Jamuna, and Karnafuli Rivers and their numerous tributaries. Each year during the monsoon rains the rivers overflow and flood low and outlying areas.

The plain has two elevated tracts -- Madhupur and Barind -- and to the northeast and southeast, rows of forested hills. Almost at sea level in the south and rising gradually towards the north, the plain's maximum altitude is only 45 meters (except in some minor hill areas). The topography varies and divides the landscape into highland (unable to hold water during monsoon); medium land (uniformly flat and manageable in controlling water); low land (shallow submergence with monsoon water); very low land (<u>haors</u>, <u>baors</u>, and deep <u>beels</u>);[1] and hilly land.

Almost 90 per cent of the country's land area is made up of alluvium. Nineteen soil types have been identified on the basis of geological origins and properties. The soils, in general, are deep and well supplied in plant nutrients with good moisture storage capacity.

The climate is tropical monsoon with a warm, wet summer and a cool, relatively dry winter. The rainfall is good enough to support three crops a year on some soils. The agroclimate report reveals that in many areas the total precipitation of 1400-6400 millimeters (mm) occurs from June-October in intense storms that result in high runoff. However, during the dry period from November-February), the rainfall of 40-140 mm is too low to meet crop water requirements. Uncertainties of drought, floods, and lack of appropriate technology to compensate for adverse weather conditions are the major constraints to adopting modern agriculture practices.

The country grows a wide variety of crops broadly classified, according to the seasons in which they are grown, into two groups: <u>kharif</u> or <u>bhadoi</u>, crops and <u>rabi</u> crops. Kharif crops are sown in spring or summer and harvested in late summer or early autumn, while rabi crops are sown in winter and harvested in spring or early summer. Major field crops are rice, wheat, jute, oilseed, pulses, potato, chilli, cotton, and sugarcane.

Bangladesh has an agricultural economy. Of a total population of about 101.7 million people, about 90 per cent live in villages and 80 per cent

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engage in agriculture, which contributes 50 per cent of the Gross Domestic Product (GDP). Approximately 40 per cent of the GDP is derived from crops, of which rice accounts for 30 per cent. With population growth of 2.4 per cent and limited employment opportunities outside agriculture, it is likely that agriculture will continue to be a major source of employment and to play a significant role in the economy. Therefore, the Bangladesh economy is dependent on the development of a modern agriculture sector. Research is needed in the areas of crop diversification and total farming systems to assist farmers' decision-making. This will inevitably increase their contribution to the country's welfare and enhance their own standard of living (BARC 1984).

IRRIGATION AND CROP DIVERSIFICATION

In Bangladesh, the development of irrigation is based on an import oriented technological package. Initially water lifting projects such as the Ganges Kobadak (GK) Project and Thakurgaon Deep Tube well Project were started in northern Bangladesh; later, nation-wide minor irrigation programs introduced low lift pumps, shallow tube wells, and deep tube wells through government agencies under different programs. These were mainly rice-based programs, but subsequently wheat was also partially included.

There was little or no research in irrigation management in the early stages. However, attempts were made in applied research to fit the imposed technological packages into the prevailing social environments. Bangladesh Academy for Rural Development (BARD) is a good example. It initially attempted to study the impact of different technological innovations such as evaluating the performance of low lift pump or deep tube well irrigation programs. Beside BARD, similar studies were undertaken by universities and national institutions such as Bangladesh Institute of Development Studies (BIDS) to evaluate the impact of irrigation programs on the socio-economic environment. However, research could not substantiate the results or benefits of irrigation research except in the areas of irrigation coverage and production increase or expansion using the imported technology.

Research to date has shown that crops other than wheat and rice are rarely irrigated except where irrigation has been introduced through mini-programs by non-governmental organizations (NGOs) or where it is already established in traditional farming practices. Research with non-rice crops in experimental plots indicates better yields with irrigation management; but these irrigation methods differ from those used with rice. Little research from experimental plots on crops other than wheat (to replace boro rice; that is, rice grown during the dry period) has been diffused to the farmers.

The failure to introduce irrigation technology suitable for non-rice crops on a wider scale has been exacerbated by the lack of crop diversification research. Much of the present research seeks to improve irrigation systems. Universities have started modelling irrigation programs to maximize production and minimize costs of water and services. Some scientists concerned with crop improvements have also recognized the need to control irrigation for better crop growth and yield. These efforts can be categorized as bench mark survey type, response-oriented research programs which study the cause and effect of water stress, water requirements, and productivity increase with different inputs. Testing programs on conveyance systems, canal linings, and control structures have been conducted, but they were very much location specific. All these attempts have tended to focus on rice irrigation during the dry season when lift pump technology plays an important role in increasing production. However, such irrigation research lacked social acceptability for promoting the currently popular high yielding variety (HYV) irrigated wheat. The need for crop diversification was never ruled out. An earlier review (Biswas 1975) emphasized the need for multiple cropping to save pumped water. But it was not effected in any program.

Recent findings of the national coordinated cropping system research (BARC 1985) indicated the potential for increasing production by introducing simple changes in the existing agronomic practices in application of fertilizer, seed rates, age of seedlings, and planting dates; however, it failed to specify the management changes in rice-based irrigation techniques suited to different non-rice crops. The Canadian International Development Agency (CIDA, 1985) has implemented a crop diversification program on limited non-rice crops and found good response in potato production with irrigation. But this irrigation is limited to hand tube wells only in flood free areas of western Bangladesh.

Prospects for Crop Diversification under Irrigation

Rice predominates among the variety of crops grown by farmers to suit their own resource availability, and soil and climatic conditions. With different types adapted to each of the three main seasons (winter, monsoon, and autumn), rice is cultivated all year and makes up about 80 per cent of the total cropped area, a proportion which has changed little over the last decade. The distribution of land to different crops in selected years is illustrated in Table 1. The average rice yield is about 1,340 kilogram per hectare (kg/ha). HYV boro rice has yields sometimes exceeding 5 tons/ha (Biswas 1985) but the cost of production is prohibitive, especially for the small and marginal farmers. Equity distribution is hampered and farm wealth is gradually skewed (Mandal 1985). Alternative cropping in combination with the adaptation of economic crop diversification is essential.

Table 1. Percentage distribution of total land area under selected crops.

	1973-74	1977-78	1981-82
Food Grains	81.3	81.6	83.8
Rice	79.6	79.4	79.2
Wheat	0.9	1.5	4.0
Others	0.8	0.7	0.5
Jute	7.2	5.8	4.3
Pulses	2.3	2.7	2.3
Oilseeds	2.3	2.6	2.3
Tubers	1.2	1.3	1.3
Others	5.8	6.0	6.0

Source : CIDA 1985

The cropping schedules of different crops are influenced by land availability, crop growth, and marketing. A partial list of irrigated crops is shown in Table 2. Table 3 describes increase in crop share and reveals some interesting features regarding the role of irrigation in crop diversification in Bangladesh.

Table 2. Percentage of irrigated area grown to selected crops in Bangladesh.

Crop	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
Aus rice	5.0	5.2	6.3	5.9	5.9	5.9	7.3	6.5	7.4	6.8
Aman rice	7.7	6.0	6.9	5.8	6.5	8.2	8.6	10.7	8.4	10.5
Boro rice	15.8	75.8	67.2	71.5	65.9	64.3	60.9	60.4	62.5	61.6
Wheat	1.3	3.6	6.0	6.4	9.5	11.0	11.9	11.0	11.2	10.5
Other cereals	0.3	0.2	0.2	0.1	0.1	0.2	0.3	0.3	0.3	0.2
Pulses	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.1	0.1	0.1
Oilseed	0.1	0.1	0.3	0.2	0.2	0.2	0.3	0.2	0.4	0.3
Potato	3.5	3.9	4.7	4.3	4.4	4.1	4.4	4.5	3.8	3.9
Vegetables	2.5	2.5	3.1	2.9	3.3	2.6	2.6	2.7	2.3	2.7
Sugarcane	0.5	0.6	0.7	0.7	0.6	0.6	0.6	0.6	0.4	0.4
Cotton	-	-	-	-	-	0.1	0.1	0.1	0.3	0.8
Others	3.2	2.6	4.5	3.8	3.0	2.8	2.8	2.9	2.9	2.8
Total (ha)	1439	1405	1216	1455	1493	1567	1637	1724	1846	1915

Percentages may not add to 100 per cent because of rounding; Government of Bangladesh 1985.

Table 3. Percentage change in irrigation coverage based on least square trend line and share of total irrigated area, 1982.

Crop	Trend	Share
Aus rice	6.1	3.5
Aman rice	7.6	5.2
Boro rice	-0.2	-3.8
Wheat	13.7	12.5
Other cereals	6.0	2.6
Pulses	8.3	7.4
Oilseeds	8.7	6.7
Potato	4.9	2.1
Vegetables	3.5	0.3
Sugarcane	3.5	0.6
Cotton	19.3	19.6
Others	0.7	-2.8
Total	3.1	

It is perceived by some that the development of irrigation has changed cropping patterns such as the replacement of wheat and other rabi crops by boro rice. However, though wheat acreage has risen dramatically this does not mean replacement of boro rice by wheat. Similarly the percentage increase of other non-rice crops has remained static with a slight exception in potato growing. Irrigation has evidently increased diversified cropping but has not replaced boro crops.

An inventory of the total irrigated acreage of these selected crops shown in Table 4 gives the respective growth in irrigation. Areas under aus (rice grown in late summer and early monsoon) and aman (rice grown in early summer) hardly need irrigation because of monsoon conditions. But the percentage of irrigation coverage in boro rice is significantly higher. Most irrigation efforts and technological innovations are implanted in boro rice fields. However, as shown in Table 4, wheat also has considerable irrigation coverage (i.e., 32.9 and 35.5 per cent of total area for the years 1980-81 and 1981-82, respectively). For the same period, potato has an irrigation coverage of 41.9 and 44.2 per cent, respectively. A new irrigated crop, cotton has considerable initial irrigation coverage but this is a sponsor-oriented crop and not popular among farmers. The statistics for other crops shown in Table 4 prove that irrigation covers only a part of the total area. It is therefore evident that a considerable area planted with non-rice crops including wheat and potato, the potential replacement for boro rice, are cultivated with local varieties instead of irrigated HYV crops. There is scope here for irrigation research in addition to that of expected changes from rice-based irrigation technology.

Table 4. Areas (in thousand hectares) and relative irrigation percentage of selected crops in Bangladesh, 1981-82.

Crop	1980-81 Total	1980-81 Irri	1980-81 %	1981-82 Total	1981-82 Irri	1981-82 %	Trend
Aus rice	3107.5	119.6	3.8	3142.3	112.8	3.6	Unchanged
Aman rice	6029.9	140.3	2.3	6004.8	183.9	3.1	Increased
Boro rice	1159.7	997.6	86.1	1300.7	1040.4	80.0	Decreased
Wheat	590.2	194.4	32.9	533.6	189.2	35.5	Increased
Other cereals	74.0	4.5	6.0	71.5	5.3	7.4	Increased
Pulses	325.0	4.5	1.4	306.0	2.4	0.8	
Oilseeds	307.2	4.9	1.6	302.7	4.0	1.3	
Potato	169.8*	71.1	41.9	173.8*	76.8	44.2	Increased
Vegetables	-	43.7	-	-	46.9	-	
Sugarcane	148.7	9.3	6.3	160.9	9.7	6.0	Unchanged
Cotton	7.8	1.6	21.3	16.6	2.4	14.7	Decreased
Others	-	41.6	-	-	49.3	-	

*Includes sweet potato.

In reference to the theme of this workshop, there exists considerable potential for replacing irrigated boro rice with non-rice crops, including wheat and maize, in Bangladesh. More than half the surface area of Bangladesh as shown in Figure 1 is flood prone and most of this area except some isolated high spots remain submerged during the monsoon period. This area consists of both low land and very low land. Monsoon water stands in the low land usually more than 1.0-1.2 meters and may reach about 3 meters. The shallow depth areas where HYV boro rice is cultivated with irrigation during the dry period include parts of Bogra, Pabna, Faridpur and Khulna, southern parts of Dhaka, some part of Mymensingh, western parts of Comilla and Noakhali, and parts of Sylhet. Irrigated boro rice is planted from December onwards and is ready for harvest in April or May. During this period, non-rice HYV crops can also be grown with irrigation.

Observing the cropping season of irrigated boro rice, especially on low land, alternative crops such as wheat, maize, potato, groundnut, oilseeds, pulses, tobacco, and vegetables may easily be grown in place of boro rice depending on land availability and soil suitability after the aman rice crop, the most important and traditional crop of the low land. Figure 2 describes how non-rice crops can be timed without disturbing potential crops such as jute, B. aman (broadcast aman) mixed with sesame (i.e., a short duration oilseed crop), Aus, or T. aman (transplanted aman). In this cropping pattern, irrigated boro rice requires more water than the other crops mentioned. Table 5 indicates that water use for all non-boro crops is far less. Consequently with the same amount of lifted water, irrigation coverage for other non-boro crops would be considerably higher, provided appropriate methods of irrigation are used.

Table 5. Water use and irrigation frequency by land category for some selected crops.

	Water use (mm)								Irrigation frequency	
Crop	Nov	Dec	Jan	Feb	Mar	Apr	May	Total	Dry land	Wet land
Boro rice				113	164	195	107	579	regular	regular
HYV wheat		42	87	113	66			308	3 times	2 times
Maize					39	88	72	199	2 times	
Pulses	56	76	78					210	slight	
Oilseeds	60	81	81					222	some	
Groundnut		30	56	75	48			209	some	
Potato	51	80	82					213	3-4 times	2 times*
Tobacco		35	62	70	41			208	2 times	

*at tuber formation.

The above crop diversification is logical in terms of timing and saving water. But the extent of area available (based on suitability of soils, topography, and climatic conditions) in the country for replacing boro rice with non-boro crops must be determined.

Thus the major constraint is the availability of land after receding of flood water in the low land as well as releasing the land after the harvest

Figure 1. Flood-prone area of Bangladesh.

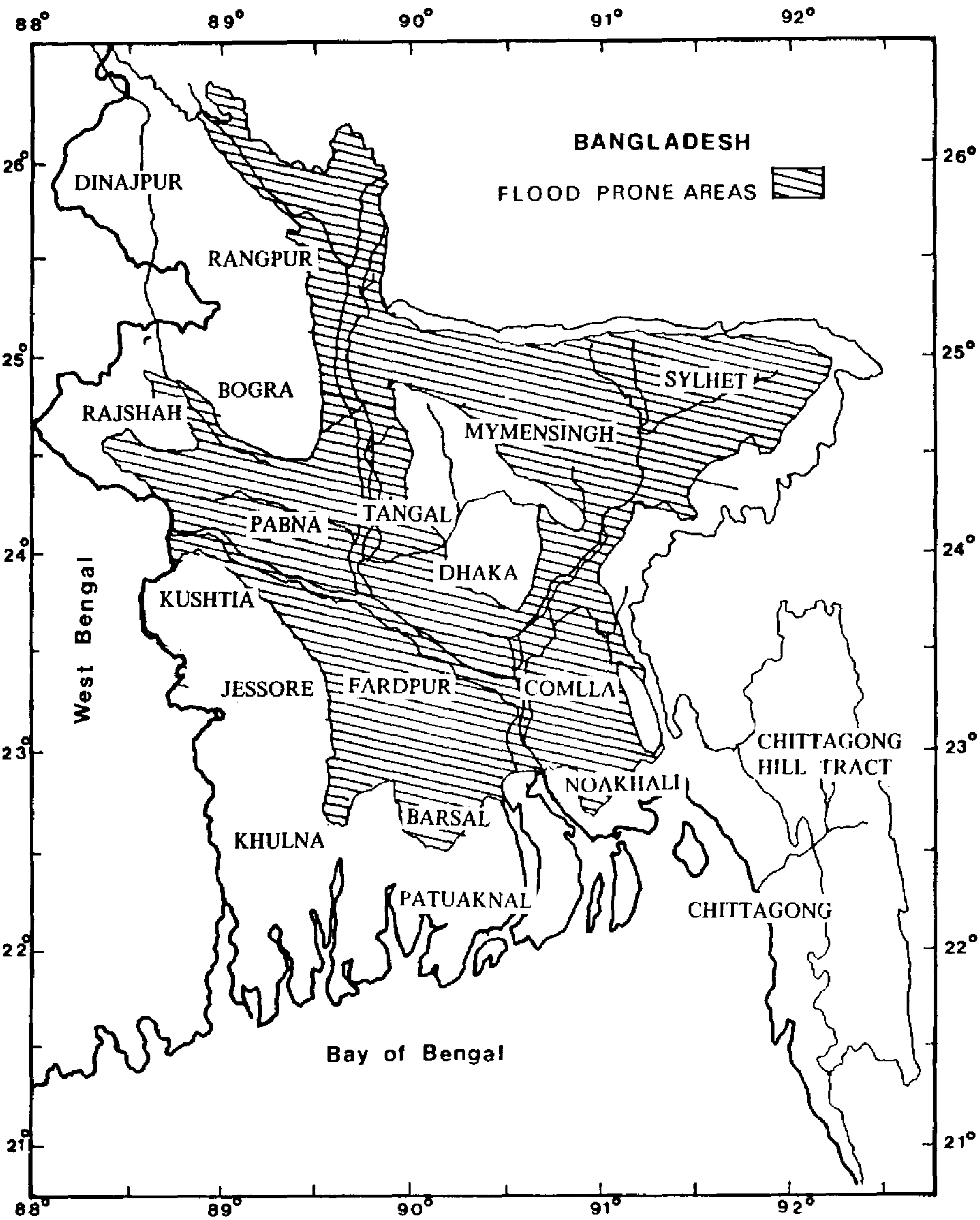
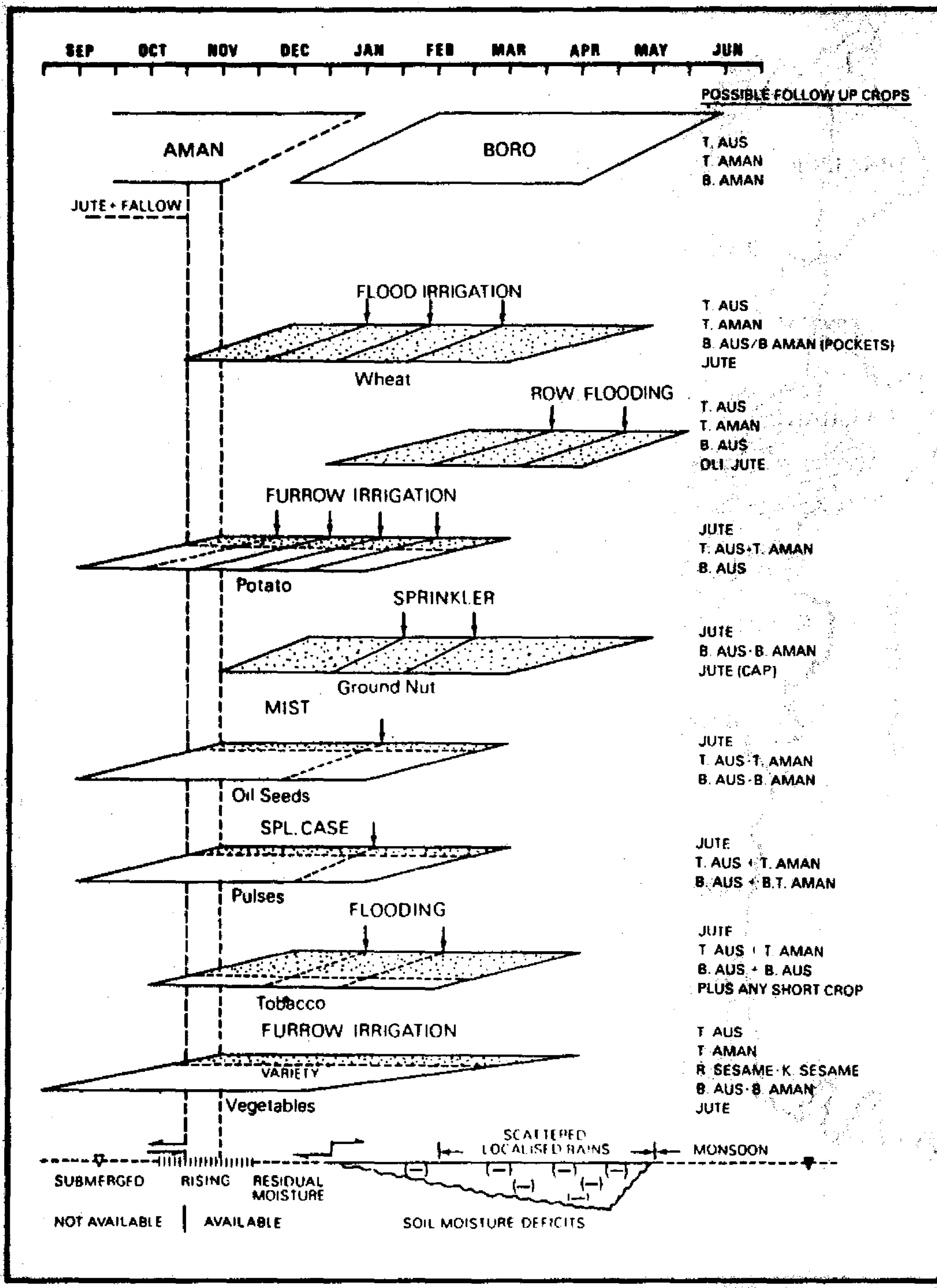


Figure 2. Possible replacement of boro rice in lowland.



of T. or B. aman crops. The land remaining fallow after harvesting jute can be easily utilized for non-rice crops after flood water recedes. Initial moisture reserve is sufficient for meeting the water demand of different crops other than wheat and maize. In low land areas, potato is grown efficiently in sandy loam soils (generally found near river banks) that require some irrigation to replenish soil moisture and dilute fertilizers. Groundnut is also grown in sandy soils especially in the shoal area, where some irrigation is needed but sprinkler irrigation is either difficult or not accepted by farmers due to the cost. In fact, pulses and oilseeds do not require any irrigation, but tobacco needs irrigation when grown on dry land. The frequency of irrigation for some crops is given in Table 5.

Food Deficits

Bangladesh produces 16.3 million tons of food grains of which wheat contributes about 1.2 million tons according to the latest statistics as shown in Table 6. The population of 101.7 million had a total requirement for food grains of 17.7 million tons for the year 1985-86. The shortfall of about 1.4 million tons or 8 per cent of the total food requirement was met by importing 0.3 million tons of rice and 1.1 million tons of wheat. Boro rice, the common irrigated crop in the dry season, contributes about 3.7 million tons of the total food requirement and constitutes about 21 per cent, whereas wheat, a possible replacement of boro rice, contributes about 6.8 per cent.

Table 6. Area (in thousand hectares) and production (in million tons) for selected crops, 1985-86.

Crop	Area	Production	Remarks
Food grain			Total requirement: 17.7 million tons
Rice	10,430	15.07	All rice
Wheat	808	1.20	6.8 per cent of total requirement
Maize	1	0.03	Insignificant
Total	11,239	16.30	Shortfall of 1.4 million tons (8%)
Boro rice	1,698	3.70	21 per cent of total grain requirement
Pulses	424	0.37	Not sufficient
Oilseeds	305	0.25	Import about US$37 million of edible oil
Potato	111	1.20	Replacement of rice
Tobacco	53	0.06	Mostly sponsored
Sugarcane	162	7.20	Not sufficient
Jute	923	7.60	Exportable item

Government of Bangladesh 1986b.

To achieve self sufficiency in food production, Bangladesh will have to increase wheat production substantially. Another alternative is to introduce potato as a substitute for rice in the daily menu.

Methods of Irrigation

In low land areas of Bangladesh where water holding capacity is high and soil is almost clay type, boro rice is usually grown in the dry period, with irrigation water. On the other hand, non-rice crops mentioned in Table 2 as requiring less water, can easily be grown in these soils especially during the dry period. But the method of application of irrigation water would be different. Table 7 describes the desired and commonly practiced methods of required water application.

Table 7. Irrigation method and technology.

Crop	Irrigation method		Technology used		Remarks
	Desired	Used	Device	Limitations	
Boro rice	Ck flood	Flood	LLP, DTW, STW, trad	1	2
Wheat	Border	Flood	LLP, DTW, STW, trad	3	4
Maize	Furrow	Row flood	Traditional	1	5
Potato	Furrow	Furrow	Traditional	1	6
Groundnut	Sprinkler	None		1	6,7
Oilseeds	Mist*	Not known		8	7
Pulses	Mist	Not known		8	7
Tobacco	Furrow	Furrow	Traditional	1	5
Vegetables	Furrow	Furrow	Traditional	1	9

*only in highland; LLP = low lift pump, DTW = deep tube well, STW = shallow tube well; 1 = small area, 2 = high water demand, 3 = distribution loss, 4 = low water demand, 5 = dependent on soil moisture, 6 = needs sandy loam, 7 = uses soil moisture, 8 = pressurized pipe needed, 9 = variable with crop type.

As shown in Table 5, the soil moisture reserve is necessary for growing crops; but for boro rice this component is insufficient. Moreover, the preparation of rice paddies and the application of water are different. Puddling is required for boro rice transplantation whereas field water capacity is sufficient for sowing/transplanting of non-rice crops. Boro rice is also inundated during irrigation in contrast to other non-rice irrigated crops which are not. For example, 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, tobacco, and vegetables. These methods are not applicable for oilseeds including groundnuts which require soft irrigation, mist or sprinkler type, with controlled and high level technology.

There has been considerable advancement in rice-based irrigation technology in the country due to huge investments by donors and public agencies. Presently, 47,483 low lift pumps (LLPs), 19,529 deep tube wells (DTWs), and 60,000 shallow tube wells (STWs) are supplying irrigation water mainly to rice and wheat fields (ibid. 1986). The average area served by these one of these lifting devices is 16.2 ha, 24.5 ha, and 5.0 ha, respectively. Except the area by a STW, the irrigation area covered by an LLP or DTW, seems extensive for achieving efficient water management in non-rice crops.

WATER MANAGEMENT PROBLEMS

Irrigation Constraints

Irrigation methods for non-rice crops are different from those for rice, and the infrastructure developed for the latter is inappropriate for crops such as wheat, potato, tobacco, many of which are now becoming popular in the country. So the consequence of monotype technological development is therefore identified as one of the constraints because the farmers have multifarious activities as well as the desire to grow other crops.

As indicated in Table 7, different technologies for lifting water have different limitations. The bulk water demand in rice fields can be easily met technically and economically by a large stream from a bigger pump (DTW/LLP). Such big streams would be liable to maximum distribution losses in the form of canal refilling losses over a large area through capacity utilization. Moreover, the methods of application for wheat or maize field are different because of its low specific demand at the grain filling stage and lesser frequency of water application. Although flooding is not desirable, border or furrow irrigation is difficult because of land fragmentation as well as micro-topographical variations. Crops requiring furrow irrigation need controlled and measured water application; and a larger stream by bigger pumps cannot be applied unless conveyance structures are provided through additional financial investments. Thus the adaptation of smaller streams for furrow irrigation is desirable and has been practiced by farmers using traditional lifting devices. In fact, CIDA (1985) and other NGOs have attempted to introduce small lifting devices to irrigate non-rice crops in certain parts of Bangladesh, mostly in the north-west high lands. Some diversified crops such as wheat, maize, potato, and in some cases tobacco may be irrigated in place of boro rice with modification of conveyance systems using existing irrigation technology.

Buried pipe irrigation fitted to DTW systems is a controversial issue (Arif 1984, Ahmed 1984). But it has certain advantages to disperse the stream, which can be easily adopted in furrow irrigation for non-rice crops without distribution problems. Alternatively, small pumps can be introduced for lifting water from surface water sources such as rivers, creeks, canals or even ponds for furrow irrigation. This would be a change in technology appropriately suited to the crops and resources of the farmers.

Methods of Cultivation

Since most diversified crops are grown in the dry season using residual moisture, timely cultivation and planting are usually critical to yield potential. Tillage is also essential for proper seed bed preparation and utilization of soil moisture particularly for deep rooted crops. But this component is ignored, because of the acute shortage of draft power and the popularity of growing shallow rooted rice. In fact, wheat and maize can be efficiently grown with less irrigation provided tillage depth is ensured. A wheat yield of 4 tons/ha is achieved with considerable mechanical tillage and two small applications of irrigation instead of the usual three irrigations (Rahman 1982). Besides wheat and maize, intensive, timely, and deeper tillage are preconditions for increased yield in other deep rooted and tuber crops, not only for root-development but also for soil nutrients.

Diversified crops require availability of mechanical power and optimum draft power, enabling land preparation, and stage wise irrigation management. But introducing such mechanical power sources is difficult because of the fragmentation of land holdings and the negative attitude towards the introduction of mechanical power by state planners. The government has, since 1977-78, stopped importing tractors and power tillers. In the early 1970s, the government owned a few tractors and power tillers whose operation were limited to state farms only. Even local industries are not manufacturing or assembling suitable mechanical power tillers. However, there may be power tillers under private ownership but they are inadequate in terms of actual use in the fields. In the absence of appropriate farm machinery, methods of cultivation pose another constraint to crop diversification.

Marketing Bottlenecks

Production is influenced by the marketing bottlenecks in the country. The cost of production of irrigated non-rice crops is high but the yield could be higher in the absence of such bottlenecks. Abrupt increases in production beyond national consumption and export facilities would cause heavy losses to the growers in terms of capital returns. Bangladesh has often experienced export and internal storage problems due to over production of jute and potato even without improved irrigation management. This can apply to other crops too. The major constraints therefore are: depressed prices immediately following harvest, market not conducive to increased production, inadequate storage facilities, poor indigenous processing as well as the absence of modern processing technologies, failures in monitoring of product and prices by the government, and inadequate export policy planning.

Experience in the recent jute market is an excellent example. The growers are selling their jute between US$40-100 per ton depending on location, way below the production cost (generally about US$100 per ton). There are also reports that potato was sold between US$ 15-80 per ton just after the harvest. Small farmers, in fact do not recover their capital and labor investment from these crops. There are also reports that farmers have difficulty obtaining cold storage and that as a consequence potatoes rotted. Providing marketing facilities for the produce is essential for promoting crop diversification in place of rice which already has a demand throughout the country as the staple food.

Institutional Problems

The majority of growers are small and marginal farmers, constituting about 80 per cent of the population. They are dependent on agriculture and the scope for growing crops other than rice has already been established. The farmers prefer to grow and store rice because rice will ensure sustenance through a food crisis, an occasional phenomenon in the country, whereas crops like under-marketed jute and potato, priced low immediately after harvest, make them vulnerable to exploitation. Evidence suggests that sale proceeds of these non-rice commodities is less than their labor and capital investments, the loans for which usually come from either rural banks or local money lenders. The farmers often fall into debt and ultimately become landless. Thus in the prevailing situation, diversified cropping could not be realistically thought of as an alternative for economic emancipation unless and until the growers have a strong bargaining power to trade-off their non-rice produce to buy their marginal food requirements.

Constraints in Crop-Diversification Programs

The foregoing discussions reveal problems in food habits, methodology for growing irrigated non-rice crops, and irrigation management including water distribution and tillage practices. A summary of such constraints is enumerated below.

1. Recurring food deficits discouraging non-rice crops.
2. Availability of land according to cropping pattern.
3. Suitability of soils.
4. Hindrance due to existing rice-based technology.
5. Lack of appropriate water management practices to suit specific crops.
6. Difficulty of converting and using existing water distribution systems.
7. Poor tillage practices and difficulty of introducing mechanical power.
8. Lack of institutional support services.
9. Storing, marketing and export problems.

Actions Needed

The problems enumerated above represent the constraints to organized crop diversification programs in Bangladesh, where rice is the staple crop. In view of the existing poor export and price policies of the government, increased agricultural production and irrigated crop diversification require a carefully planned and implemented action program. The following guidelines will help.

1. The availability of low land suitable for non-rice crop is not officially known. More information is needed.

2. Soil moisture is a major factor for deep rooted crops. The available soil moisture profile for low land crops would make an interesting research undertaking.

3. Appropriate tillage practices should be researched to ensure timely cultivation and sowing/planting of deep rooted and tuber crops and to utilize residual soil moisture from deeper layers by these crops, particularly in the dry season. In the face of gradually declining animal power resources in Bangladesh, mechanical power sources should be introduced for diversified cropping.

4. Appropriate and correct methods of irrigation should be developed. Existing pumping units and associated stream size should be adjusted through technological innovation. Accordingly, adaptive research should be demonstrated to encourage farmers to expand irrigated-cropping area to include more than just boro rice.

5. Develop a more orderly marketing system to ensure that farmers get a fair price for their produce. Opportunities for expanded sales would encourage producers to diversify cropping.

6. Developing farmers' organizations is essential for adopting and promoting crop diversification programs. Developing the capacity to improve trading through national support services such as credit agencies, export and import bureaux is equally important.

Social Impact

Social acceptance is crucial to the success of any program. There are obvious advantages to and difficulties in adapting crop diversification to a traditional society mainly dependent on rice. The preceding sections have already touched on the difficulties that may be encountered in crop diversification.

Regarding positive impact, crop diversification has a significant potential for improving income distribution due to the intensive field activities required for most non-rice crops and the decreasing animal power resources available. This should create employment opportunities for landless laborers (27.1 per cent of the population did not have any land other than homestead in 1977 and the trend is continuing). Landless farmers could feasibly buy agricultural equipment like power tillers and pumps to trade off farm operations with land owners. Developing on-farm, small agro-industries for processing and storing the expanded production brought about by irrigated crop diversification would also create more rural job opportunities.

Additional Scope for Crop Diversification

The availability of land in low lying areas of Bangladesh for crop diversification is subject to the release of land which in turn depends on two conditions. First, most of the low lands lie in the flood prone areas, remain submerged for at least three months, and are not available until November. Second, these submerged lands contain aman rice during this period and cannot be released before early December or until after the harvest of aman crop.

Contrary to this, boro rice is grown abundantly with high rates of irrigation water in the uplands of Bangladesh. In these areas, replacement of boro rice by other crops is constrained by traditional preference of the value of rice. But wheat is gradually invading these areas. Other crops, except tobacco, have not been acceptable. Tobacco is grown mostly under the guaranteed purchase arrangement offered by the tobacco processing companies. In view of the land availability and soil suitability, these uplands are potentially suitable for crop diversification and should be initially used to balance total national food production.

In low lands, many of the DTWs are located in the land tracts above the flood level. The immediate high lands often surrounding these DTWs are suitable for crop diversification, without major changes in conveyance structures.

CONCLUSION

Creating employment opportunities and meeting the food deficit are two fundamental objectives of the Third Five Year Plan 1985-90. Crop diversification, though difficult to implement in existing cropping patterns, can resolve some planning issues. In fact, abundant literature is available on physiological characteristics of irrigated crops in addition to boro rice. Unfortunately a national program does not exist for promoting diversified crops in a planned manner. The existing rice-based infrastructure poses a major constraint to promoting diversification without modifying methods and techniques of water application. National planners are not concerned with this aspect because of lack of proper information and the consequences of balancing market fluctuations. However, some information dissemination has shown remarkable results in achieving yields and attracting growers. Potato offers a good example of a successful extension effort. But this has created marketing and storing problems.

Despite various constraints there are some positive indicators in implementing the crop diversification program. Some of these are: increased total food production, reduced import dependency, development of on-farm agro-based industries, increased promotion of farm machinery and equipment, more private sector involvement, increasing ownership of assets by the landless, and more job opportunities in the agricultural field.

Indirectly some sort of equity of rural income distribution would be achieved and the overall living standard raised. To gain these benefits, farmers have to be educated and organized for planning and implementing crop diversification. Effective institutional effort is, therefore, a pre-requisite for integrating rural people, including women, into these activities.

NOTES

1. The editors regret that definitions for the Bengali, Urdu, and Hindi terms were not provided by the author. In cases where we are sure of meaning, a definition has been placed near the word at first usage.

REFERENCES

Ahmed, C.S. 1984. Bogra underground asbestos cement pipe systems: An economic analysis. In Proceedings of Workshop on Improved Distribution Systems for Minor Irrigation in Bangladesh. Dhaka: Bangladesh Agricultural Research Council/Winrock International.

Arif, M.T. 1984. Distribution system and channel lining for minor irrigation: Adaptive research at Rural Development Academy, Bogra. In Proceedings of Workshop on Improved Distribution Systems for Minor Irrigation in Bangladesh. Dhaka: Bangladesh Agricultural Research Council/Winrock International.

Bangladesh Agricultural Research Council (BARC). 1984a. National Agricultural Research Plan 1984-89. Dhaka, Bangladesh.

Bangladesh Agricultural Research Council (BARC). 1984b. A review of results of the National Coordinated Cropping Systems Research Project in Bangladesh. Dhaka, Bangladesh.

Biswas, M.R. 1975. On investigating the multiple cropping schedule for minimum irrigation need. Journal of the Institution of Engineers, Bangladesh 3(1).

Biswas, M.R. 1985. Performance of minor irrigation under different management institutions at a glance. In Evaluating the role of institutions in irrigation programmes - Some preliminary findings. Mymensingh, Bangladesh: Bangladesh Agricultural University. Pub IWM-11.

Canadian International Development Agency (CIDA). 1985. Implementing a crop diversification programme in Bangladesh. Feasibility Study, Vol. 1. Ontario, Canada: The DPA Group, Inc.

Government of Bangladesh. 1985. 1983-84 year book of agricultural statistics of Bangladesh. Dhaka, Bangladesh: Bureau of Statistics, Ministry of Planning.

Government of Bangladesh. 1986a. Third five year plan (TFYP). Dhaka, Bangladesh: Ministry of Planning.

Government of Bangladesh. 1986b. 1985-86 economic survey of Bangladesh. Dhaka, Bangladesh: Ministry of Finance.

Mandal, M.A.S. 1985. The economics of minor irrigation under different institutions in two areas of Bangladesh. In Evaluating the role of institutions in irrigation programmes - Some preliminary findings. Mymensingh, Bangladesh: Bangladesh Agricultural University. Pub IWM-11.

Rahman, S.M., M.R., Biswas, A.K.M. Habibullah and M. Ahmed. 1982. Studies on the irrigation requirement and yield performance of wheat in the Ganges floodplain soil. Mymensingh, Bangladesh: Bangladesh Agricultural University. Pub IWM-10.

CROP DIVERSIFICATION IS AN UPHILL TASK: A CASE STUDY OF HIRAKUD COMMAND IN ORISSA, INDIA

Banamali Naik*

INTRODUCTION

Agroclimate, Soil, and Topography of Orissa

The State of Orissa is located in the eastern part of India. The topography is generally rugged and most of the terrain slopes gradually into the coastal plain along the Bay of Bengal. There is about 300 kilometers (km) of coast line. Agroclimatically it is divided into four zones: northern hilly plateau (23 per cent), central undulating land (23 per cent), eastern ghat region (36 per cent), and coastal plain (18 per cent).

Soils are largely red laterite and shallow in the highlands of the northern hilly plateau, in the central table lands, and in the eastern ghat regions. Soils are deep alluvium in the coastal plains and valley lands of inland areas. Farm holdings average 1.6 hectares (ha). In the coastal region, holdings tend to be smaller, averaging about 1.0 ha, and highly fragmented, sometimes divided into 8-10 separate plots. In the interior areas, holdings average about 2.0 ha.

Orissa has an average annual rainfall varying between 1200-1700 millimeters (mm); 85 per cent falls between June and October. The tropical monsoon climate favors year-round cropping with irrigation. Traditionally two cropping seasons are recognized: June to December (kharif) and January to April (rabi). With the introduction of duration bound rice and non-rice varieties three growing seasons have become apparent: June to November (kharif), mid-October to the end of January (rabi), and the last week of December to the end of April (summer). Discussion in this paper is based on these three growing seasons. At present rice is the most favored crop in kharif and summer. Non-rice crops are grown in limited areas during the rabi and summer seasons, mostly with available moisture after a pre-sowing irrigation, but yields are at subsistence level. Thus the potential for raising productivity in the irrigated area lies in fully diversifying crops in these two seasons to realize higher yields.

Rice's Advantage Over Other Crops

In areas with high rainfall, rice is the predominant crop during kharif People in these areas are used to growing rice and have levelled and bunded their land to suit its needs. When irrigation is introduced in such areas, rice has a natural advantage over non-rice crops. Economic criteria and high yields favor summer rice and farmers readily take to growing it as soon as irrigation is available, while non-rice crops have yet to be established.

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Irrigation authorities find it more difficult to cater to irrigation needs of non-rice crops and thus prefer saving rice growing areas. It appears that irrigation authorities and the few head end beneficiaries connive to irrigate and grow summer rice at the cost of those in the tail ends, who gradually come to believe that their lack of access to water is caused by design. In such areas crop diversification is an uphill task despite strong arguments in its favor. Several issues must be resolved before appropriate system development, operational procedures, and suitable crop technologies are adopted to exploit the potential of diversified cropping.

Problems Affecting Diversified Cropping

No two commands are exactly alike. This individuality warrants a unique solution to each command, and must be taken into consideration when planning developmental change (Naik 1980). Irrigation authorities often find it more convenient and cheaper to transfer responsibilities, which they find onerous, to farmers. However, authorities often fail to realize that the farmers as a group can be incoherent and diverse. They may not respond adequately to new responsibilities, unless their assignments are consistent with and limited to their capacity to stretch themselves beyond individual considerations. Trial and experiment are required to determine the extent to which farmers should be given responsibility for a community irrigation program (Naik 1983).

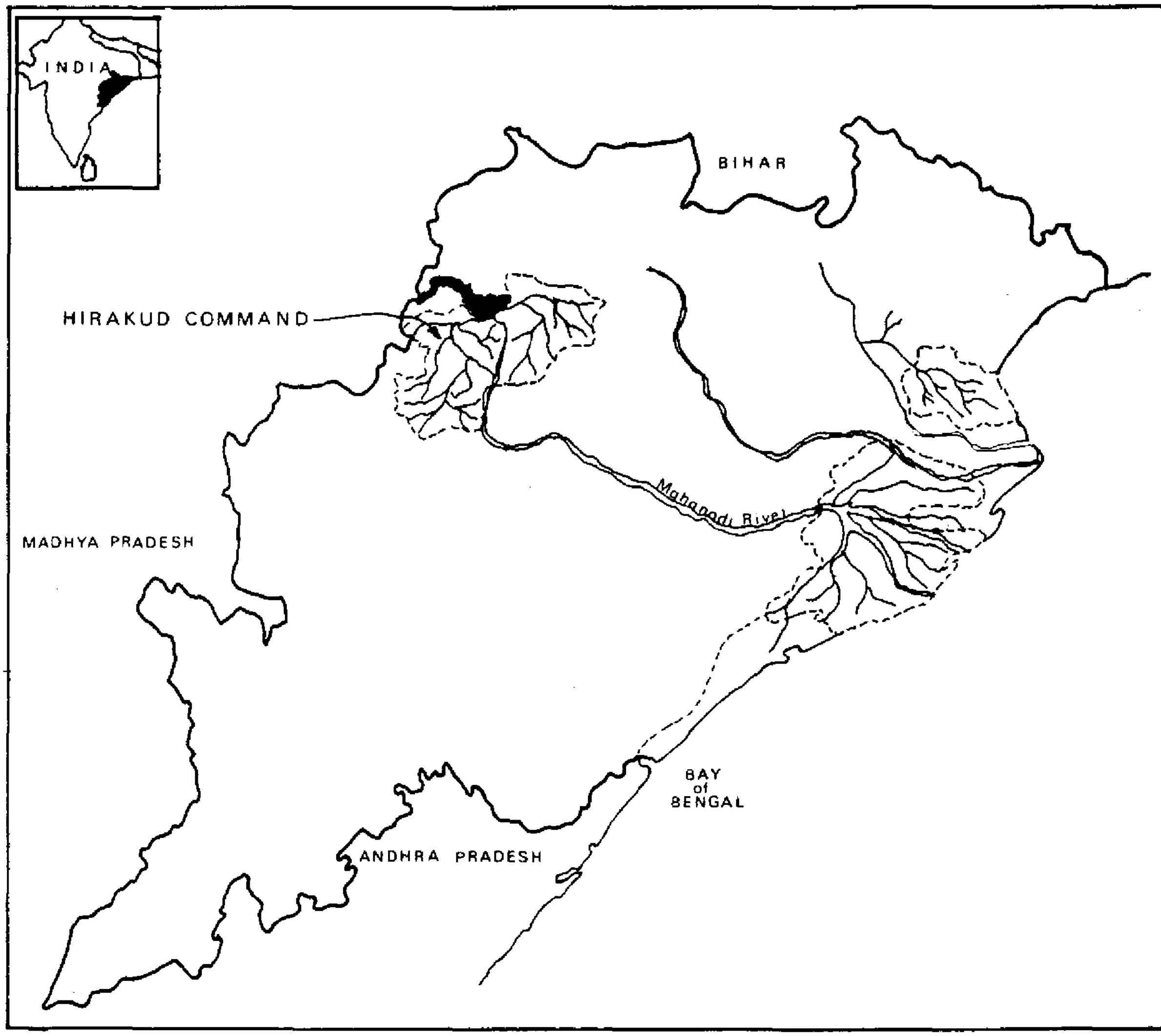
The Agricultural Extension Service, which supports farmers, is incapable of diffusing new irrigation technology and management practices to farmers. Contrary to appearances, they are worried by this. The problem seems to be poor communication between extension and irrigation authorities. Thus, there appears to be a need for developing better understanding of mutual problems so that the farmers' demands can be translated into compatible, practical, and effective solutions. This will require experimenting and working in result-oriented collaborative programs. In most cases one finds substantial deviation between designed and actual crop patterns, yet little effort appears to have gone into correlating the expected and actual performance of the original irrigation infrastructures. This must be resolved before full potential can be realized.

HIRAKUD COMMAND

Description

The Mahanadi is Orissa's major river. Originating in adjoining Madhya Pradesh, it passes through the central table lands, divides the state in half, and empties into the Bay of Bengal (Figure 1). Hirakud Command, created in 1957 following construction of a multipurpose dam on this river, receives water directly from the reservoir. An allocation of 133,000 ha/meters of water with a design stipulation to cover 58 per cent of the cultural command area (CCA) in a composition of 35, 17, and 6 per cent of heavy, medium, and light duty crops, respectively, has been reserved for irrigation. It contains shallow and light soils. The topography is undulating. Water is supplied continuously from 20 June until 30 April with a winter lean supply period (15 November-19 December). Two rice crops are grown during the year.

Figure 1. Orissa and location of Hirakud Command.



Crop Diversification in the Hirakud Command

A particular command is best studied by observing its conspicuous features and then looking for their possible explanation. Such knowledge yields valuable clues for determining appropriate changes. No one visiting Hirakud Command in the rabi/summer seasons could miss the predominance of rice crop and near total absence of non-rice crop. In tail ends, where water is normally scarce and where some non-rice crops would be expected, one sees extensive stretches of fallow lands.

A comparison of the designed provision and actual achievement of water allocation and crop coverage during summer as shown in Table 1 indicates that the crop intensity has risen from 58.0 to 63.9 per cent, and the total rice area has overtaken the land planned for mixed cropping.

Table 1. Comparison between design and actual water allocations (in thousand hectare meters), total planted areas (in thousand hectares) with percentage given to cultural command areas (CCA), and crop intensity (in per cent) for rabi/summer growing seasons.

	Allocation	Crop type	Area	CCA	Crop intensity
Design	133.0	Rice	53.0	35.0	58.0
		Non-rice	35.0	23.0	
		Fallow	64.0	43.0	
Actual	122.0	Rice	93.0	61.2	63.9
		Non-rice	03.1	02.7	
		Fallow	55.9	36.1	

Design and actual data are from government irrigation records. "Actuals" are averages from 1971-79.

By using water planned for medium and light duty crops as well as rice, coverage amounts to about 45.0 per cent[1] of the CCA rather than the present 63.9 per cent. To explain: Naik and Singh established (1983) that this is due to re-use of water which can be represented by the following equation.

$$R \text{ (re-use per cent)} = (X - 45)/45 = (Qh - Q)/Q$$

Where: X = heavy duty crop coverage in rabi as per cent of kharif CCA
Q = Drawal in million acre/feet (MAFT)
Qh = Drawal (MAFT) needed for entire coverage by of heavy duty crops

R has been rising for some time (Figure 2.) At 63.9 per cent crop intensity, R is about 51 per cent. Re-use is an advantage which is a good reason for rice's firm hold in the command. The second conspicuous feature is the large drainage outflow. The natural drainage ways run full during rabi/summer seasons when normally they would be dry. Drainage flows are not mentioned in the project report indicating they are unexpected. Flows have been measured at 25 per cent of the water released into the canals (Table 2; Naik 1979).

Table 2. Results of a study on water balance (in cumec/100 ha) for an irrigated area of 16,000 ha in Hirakud Command.

Description	Measured Values	Inflow (%)
In flow (including seepage)	16.4	100.0
Out flow through drains	4.1	25.0
Consumptive use	5.3	32.3
Direct evaporation	0.6	3.7
Balance (deep percolation)	6.4	39.0

Data provided by the irrigation authorities and the Agricultural Department.

Figure 2. Graphs comparing actual with projected drawal without re-use, area of rice versus non-rice crops, and rise in crop coverage (X) due to rise in re-use (R), Hirakud Command, 1970-79.

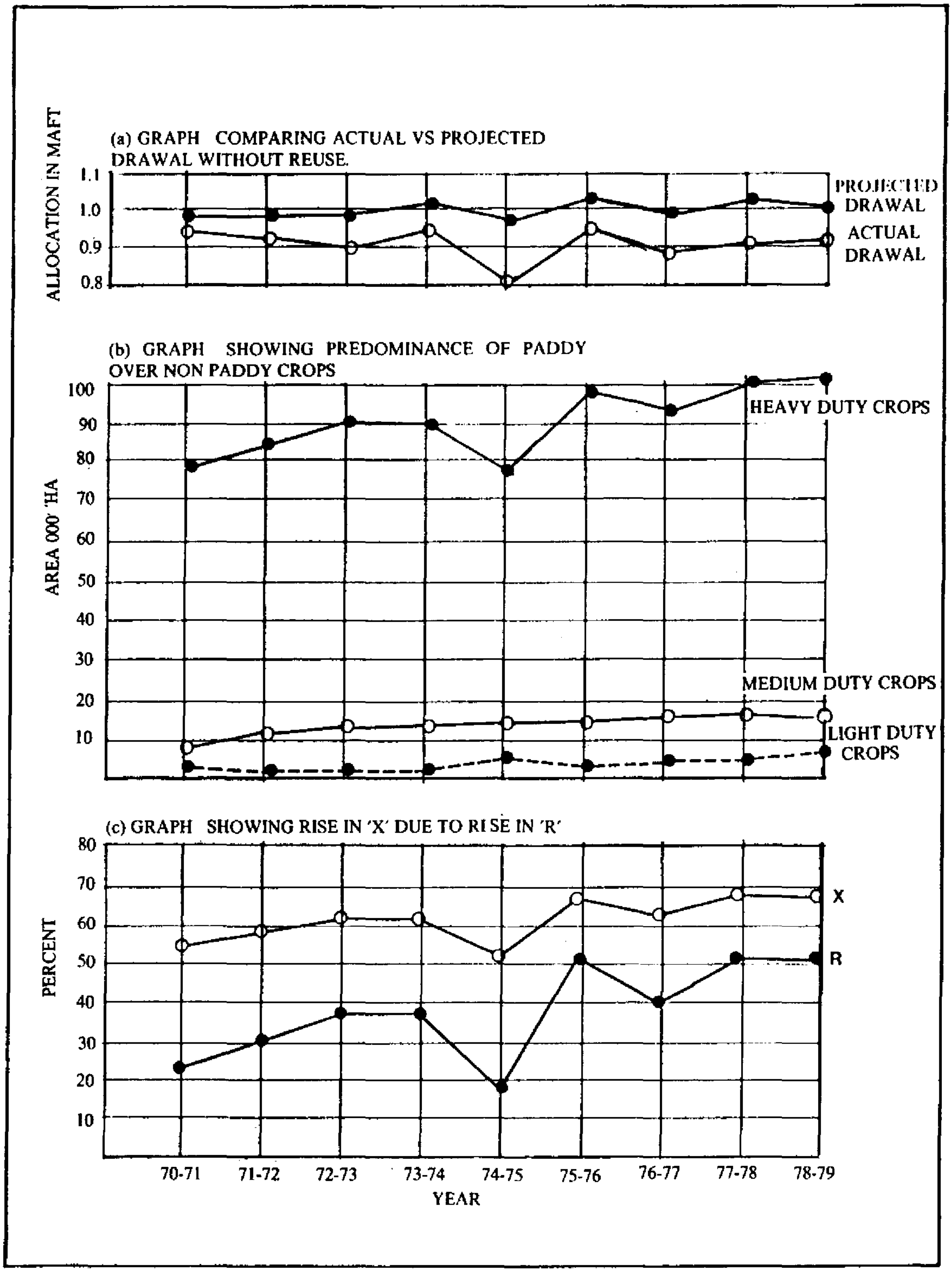
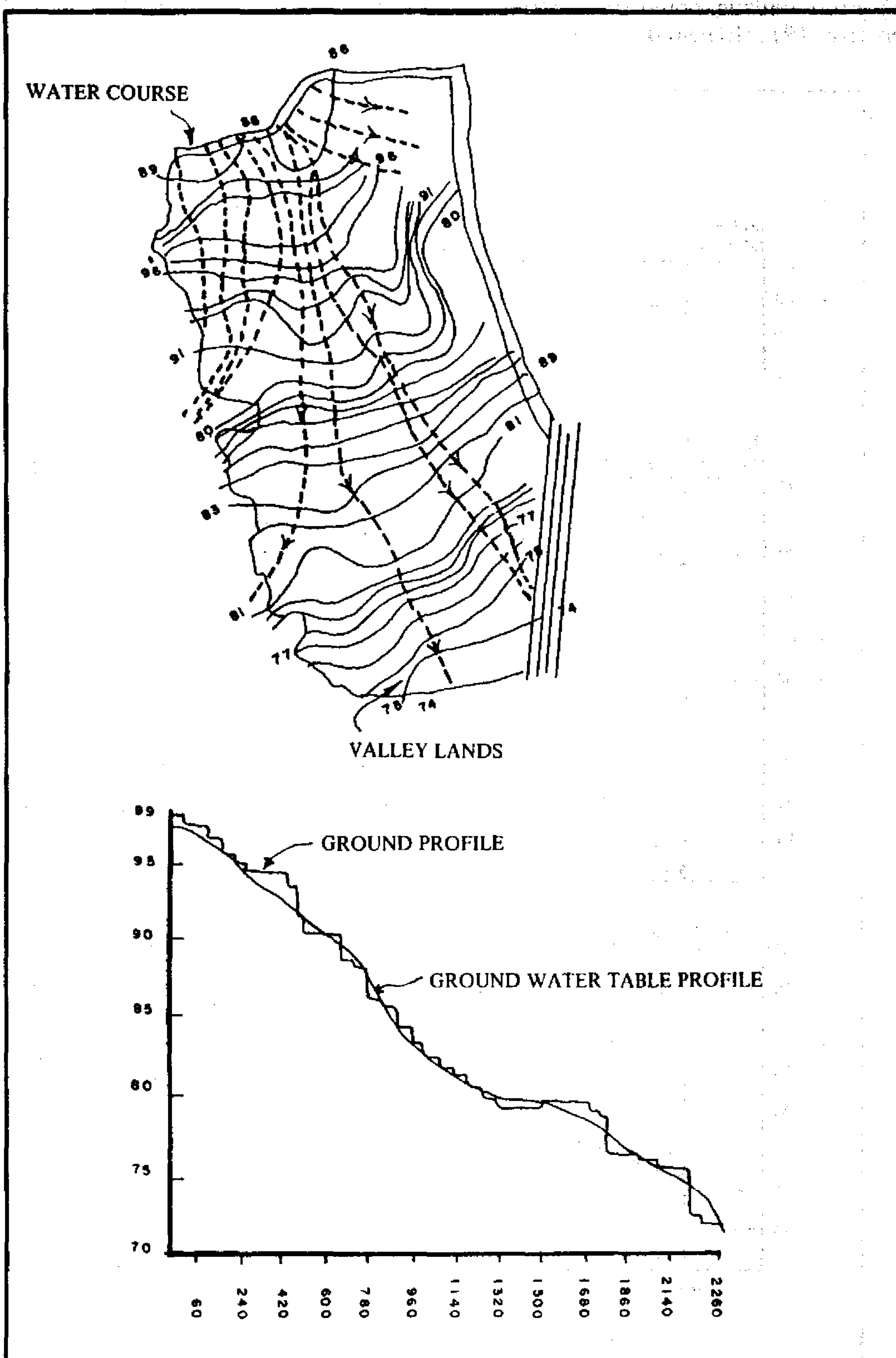
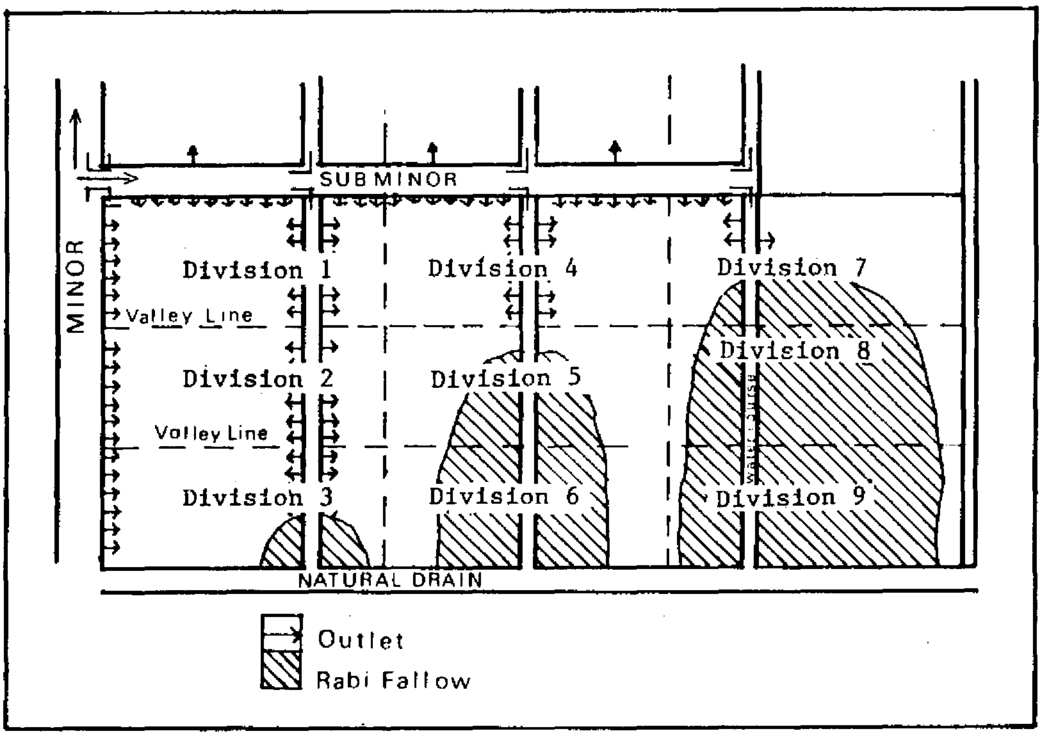


Figure 3. Ground water contours and flow lines, Hirakud Command.



The availability of water for reuse and return flow in natural drainage is explained by the presence of parent rocks at a depth of about one meter, which diverts the percolated water laterally. This water reappears in the valley lands saturating the soil profile irrespective of land types (Figure 3). With such favorable conditions for rice one must consider whether crop diversification is wise in this particular command. If so, the high and medium lands which become wet due to the vertical impediment of percolated water would need to be made suitable for non-rice crops. However, it is logical to consider the rabi fallow for introducing non-rice crops. Learning therefore about the pattern of its occurrence becomes relevant (Figure 4). Land coverage is more or less complete in the head end region irrespective of land types. Fallow lands gradually increase towards the tail of every canal whether it is a distributary/minor/sub-minor or water course (Naik 1980).

Figure 4. Schematic pattern of division adopted for the study of water distribution, Hirakud Command.



Initially, extra water is not needed to cover the fallow areas with non-rice crops. In the normal schedule, a lean period exists during winter due to the low demand of rice. This could be corrected by an intermittent schedule and yet remain within the specified allocation. The number of closure days could be extended to save more water because the kharif demand decreases about a month ahead of the winter cropping period. Then a way must be found to convey water to tail ends. Water scarcity in the tail ends due to higher demand in head end regions must be studied. It should be possible to make water available in the tail ends during low demand period (i.e., toward the end of kharif and before the demand for summer rice has begun; Table 3).

Table 3. Average stream size (in liters/second) at the tail end under normal schedule and as percentage of design flow.

Period	Stream size	Design flow
1 Nov - 14	26.6	92.2
15 Nov - 29	22.4	77.7
30 Nov - 14 Dec	15.7	55.3
15 Dec - 29	15.4	53.4
30 Dec - 13 Jan	12.6	43.7
14 Jan - 28	12.9	44.7
29 Jan - 12 Feb	10.4	35.9

The paradoxical near total availability of water during November and early December in tail ends despite lean supply in the canals creates an incentive to plant long duration rice varieties, and areas where non-rice crops could be grown between November and January remain under rice. After December, lack of water forces farmers to leave these lands fallow. Thus, a strategy is needed for a shorter duration kharif crop to free land by end of October and to schedule a rabi crop when water is available (Tables 4 and 5).

Table 4. Characteristics of rice varieties, including cropping duration (in days) and yield (metric tons/ha) for sowing in last week of June.

Variety	Characteristics	Duration	Yield	
			Broadcasting	Line sowing
CRM 13	very SD, early dry sowing	80-85	1.78	2.81
KAVERI	SD HYV, early dry sowing	100-110	2.45	2.89
PTB 10	SD improved variety, low investment, hard variety	100-110	1.93	2.23

Note: Dry sowing was preferred to avoid possible delay in transplanting.

Table 5. Yield (100 kilograms/ha) for mustard and pulse varieties.

Sowing period		Mustard M-27	Pulse Ratila	Pulse Jhain
Oct	last week	665	408	-
Nov	1st	501	317	-
Nov	2nd	453	-	-
Nov	3rd	415	-	-
Nov	4th	363	-	-
Dec	1st	305	-	-
Dec	2nd	-	-	-
Dec	4th	-	-	450

Note: Data was unavailable for pulses T-44, S-8, HY-12-4, and PB.

A water supply schedule designed to meet this strategy incorporates provisions for intermittent supply from 15 October to 31 December, and a plan for sufficient closure days to save a carry-over supply to advance water releases until 1 June irrespective of the start of monsoon (Table 6).

Table 6. Fitting an irrigation schedule to a selected cropping strategy.

Operating period	Objective	Closing period	Objective
		OLD SCHEDULE	
20 Jun-15 Nov	Supply of Water to kharif rice	-	-
15 Nov-19 Dec	Very low supply in the canals in keeping with very low demand of rice	-	-
20 Dec-30 Apr	Supply to summer rice	1 May-19 June	Annual maintenance 50 closure days
		NEW SCHEDULE	
1 Jun-10 Jun	For nursery raising out of carry over stock	11 Jun-25 Jun	To save water in reservoir
26 Jun-15 Oct	Water for main growing period of rice	16 Oct-31 Oct	To allow high/high medium land to dry; to induce farmers to grow short duration varieties; to allow land preparation for non-rice crops
1 Nov-15 Nov	To give pre-sowing irrigation to those who need it; to give first irriga- to those sowing with old moisture; to give water to needy standing rice	16 Nov-30 Nov	Prevent over irrigation due to seepage; to save water in reservoir
1-15 Dec	To allow another irrigation to those who need it; to enable people to prepare nursery	16-31 Dec	Prevent over irrigation; to save water in reservoir
1 Jan-30 Apr	For growing summer rice	1 May-31 May	For annual maintenance 94 closure days (88% more)

The extension service was informed of the new message and suitable seed varieties were made available. As a result of this effort, the non-rice crop area increased from 3,000 ha to 38,000 ha by the end of 1982 (20 per cent of CCA). Not only does the rabi fallow take up non-rice crop on a large scale but also a large area in the head and mid reaches were converted to a three-crop pattern with a non-rice crop in between two rice crops. The non-rice crop area was expanded where water was easily accessible, and in those lands where farmers could individually plan their crops and manage water delivery. Other areas were left fallow because successful cropping depended on group action to manage and distribute the water equitably. In the absence of organized effort, the available flow was wasted. In order to overcome waste, farmers were informally organized. Authorities learned during that the farmers were highly individualistic: one may join one group and clash with another depending on groups having common or clashing interests.

Organizing Farmers to Establish Discipline in Irrigation

Farmers complain about the general lack of discipline of fellow farmers but avoid taking part in punitive measures against any specific delinquent. In fact every farmer is a potential delinquent when it comes to his own interests. They appear to have a convention of protecting each other against outside actions. The legal provision for punishing canal offenses has never been workable: one can never find a witness. At least two witnesses are necessary for prosecution. On the other hand, unless some discipline is established, expected improvements may not be feasible. Thus it is envisaged that formation and operation of these groups should allow for farmers to discipline their own ranks and that these groups should also be responsible for pre-processing complaints against system operation or deficiencies.

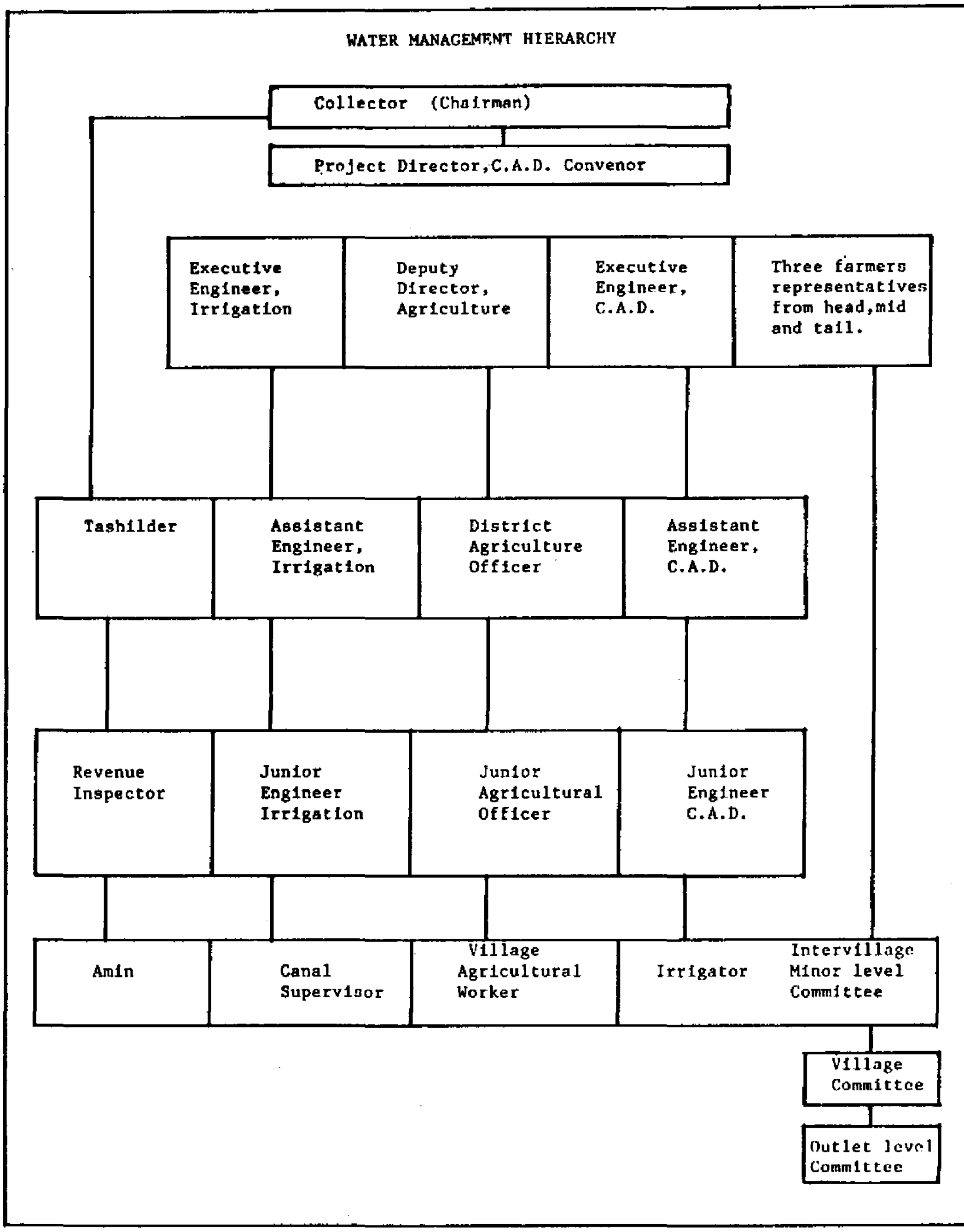
Consistent with this approach were experiments with three tier farmers' committees (Naik 1982). The first tier was at the outlet level. A committee was formed of all farmers at the outlet and a leader and a deputy leader chosen. This committee would look to and seek solutions to problems arising within an outlet command including discharge reaching the outlet.

The second tier was at the village level. This committee was formed by taking two members out of each outlet committee within the village. This committee would solve or seek solutions to problems leading to inter-outlet distribution of water or lack of water into outlets in the village area.

The third tier was organized at the minor/sub-minor/water course level by taking two representatives from each village committee which receives water from the same minor canal. In minor level committees, government officials at grass root level such as village agricultural workers (VAW), irrigators, canal supervisors, were also associated. In this committee the constituent villages would agree on how to share available water, lodge written complaints, and determine whatever infrastructural remedy would be necessary to improve various situations.

Associating government officials at this level with the farmers enabled them to learn about local problems and carry them along the water management hierarchy which was formed to solve farmers' problems (Figure 5).

Figure 5. Schematic of water management hierarchy.



The water management hierarchy formed a Water Management Committee with at least three farmers' representatives. A procedure to form three tier farmer committees has already been created at each project level. The objective is to listen to peoples' complaints, process and classify them, identify solutions, and provide remedies accordingly. It would also, if needed, recommend policy changes for government consideration. Before this, such an agency with statutory powers did not exist nor did a forum for complaints.

One positive result of this experiment was the ability to persuade the head end farmers through committee action to allow tail enders to receive water, at least during the night. A successful application of these results on a large scale has not yet become apparent.

Developing Understanding Between Agricutlure and Irrigation

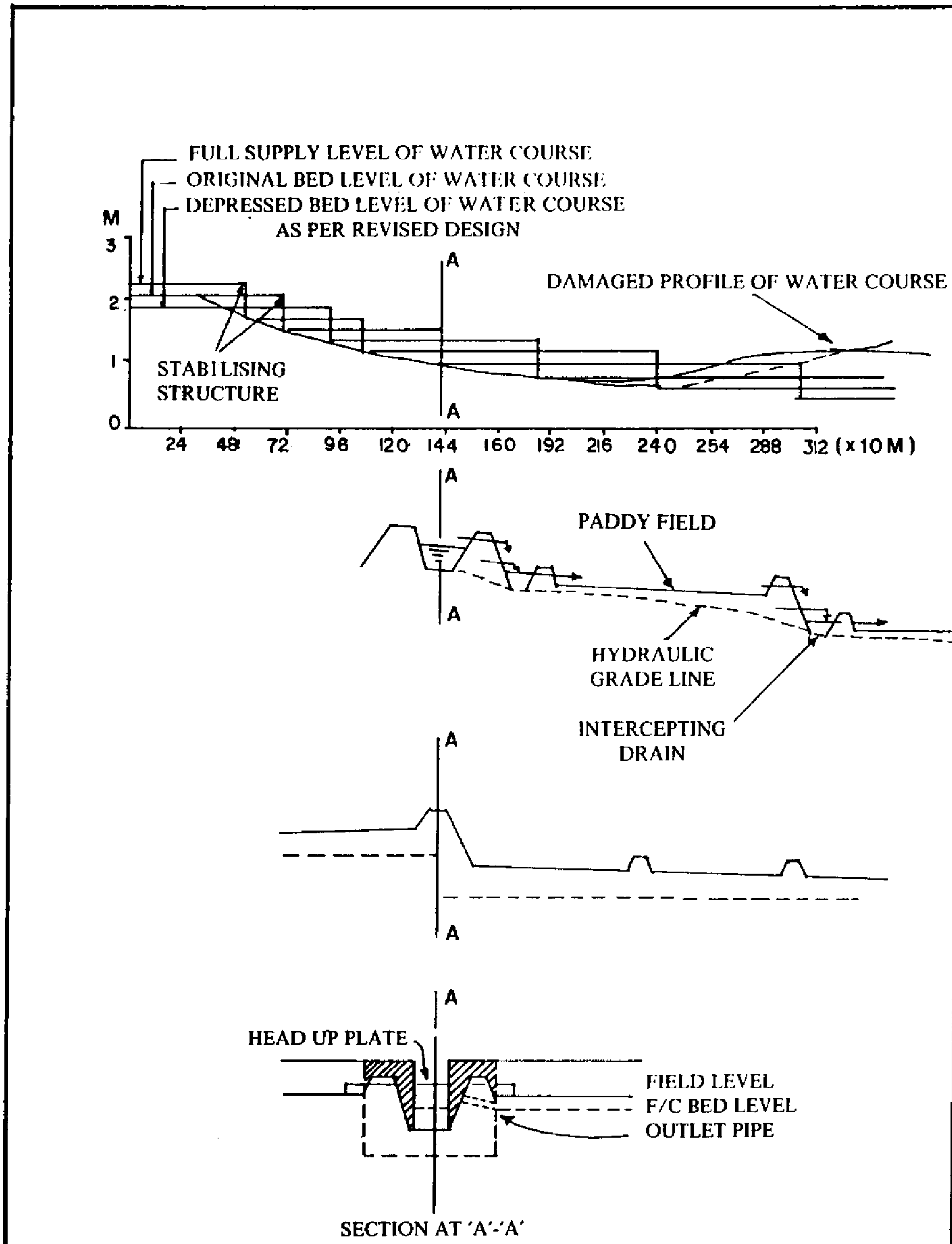
Agricultural scientists speak of crop water requirements on the basis of work conducted on experimental plots. The extension worker, through his own observations and studies, correlates it to agroclimate, depth of water table, application efficiencies, and other factors which might vary within the command, and modifies his recommendations accordingly. There are also socioeconomic factors which motivate the farmers' behavior. The effect of all these reflect a demand pattern which the extension worker poses to the irrigation authorities. They, however, find it difficult to appreciate patterns which vary from the original design assumption. Often local irrigation officers tend to favor operations characterized by minimum regulatory attention and minimum infrastructural developments involving sizeable investment.

At the point of coordination, which is usually at the government level, the irrigation authorities equate changes with large investments, and reject minor management or operation suggestions from the agricultural extension agency. The change in the irrigation schedule discussed earlier was a rare and hard-earned victory in that it represented a concession to a suggestion from the extension agency. The schedule reverted to the old pattern in 1982-83 after the concerned officers changed their positions. The incoming irrigation administration did not accept the views of their predecessors. They saw unnecessary waste in the two intermittent runs as the non-rice crops actually used a small fraction of the water released. This occurred because full discharge was required to convey water flow at full supply levels in absence of cross regulators. It was thought better to save the water for electricity, due to an acute shortage at the time, rather than wastefully supply what was seen as a few hectares of non-rice crop. As a result of this change the area under non-rice crop dwindled to the previous level in two years' time. Thus it is important that mutual understanding be established at all levels between the two organizations.

Infrastructural Development

So far we have discussed cosmetic developments only. No doubt they are forerunners to any major developmental effort. But sooner or later one faces the bare deficiencies of the irrigation system. The shift to rice and consequent concentration of cropping in head and mid-reaches increased requirements in these regions. This was followed by widespread damage to the outlets in an effort to take more water, which led to scarcity in the tail ends. The tail end farmers, reacted to this action by damaging the stabilizing structures particularly on small canals (minor/sub-minor/water courses) thereby making it difficult for the head enders to get appropriate supply head. Damage to stabilizing structures eroded the canal bed warranting cross bunding, which, when broken, carried soil downstream to deposit on flatter slopes. This raised the bed level and rendered the canal permanently inoperative beyond such locations (Figure 6).

Figure 6. Illustration of damage to stabilizing structures which eroded the canal bed and rendered the canal permanently inoperative downstream.



As the matter stands now, unless the original bed slope is restored and the outlet discharges are rationalized according to the newly designed crop pattern, cosmetic improvements will have limited results. This is one reason why an organized effort is needed to guide water to tail ends. Where water courses are damaged as above, alternative paths through the fields are found, probably limiting what can be done.

The possibility of a three crop pattern such as rice-mustard-rice would need some kind of "on farm development" to make all potential land owners adopt such patterns. After adoption of the revised schedule discussed earlier an experiment was taken up to develop an infrastructural development both above and below the outlet to extend the benefit of an additional non-rice crop to as large an area as possible (Figure 7).

The experiment was based on the following (Naik 1981 and 1985):

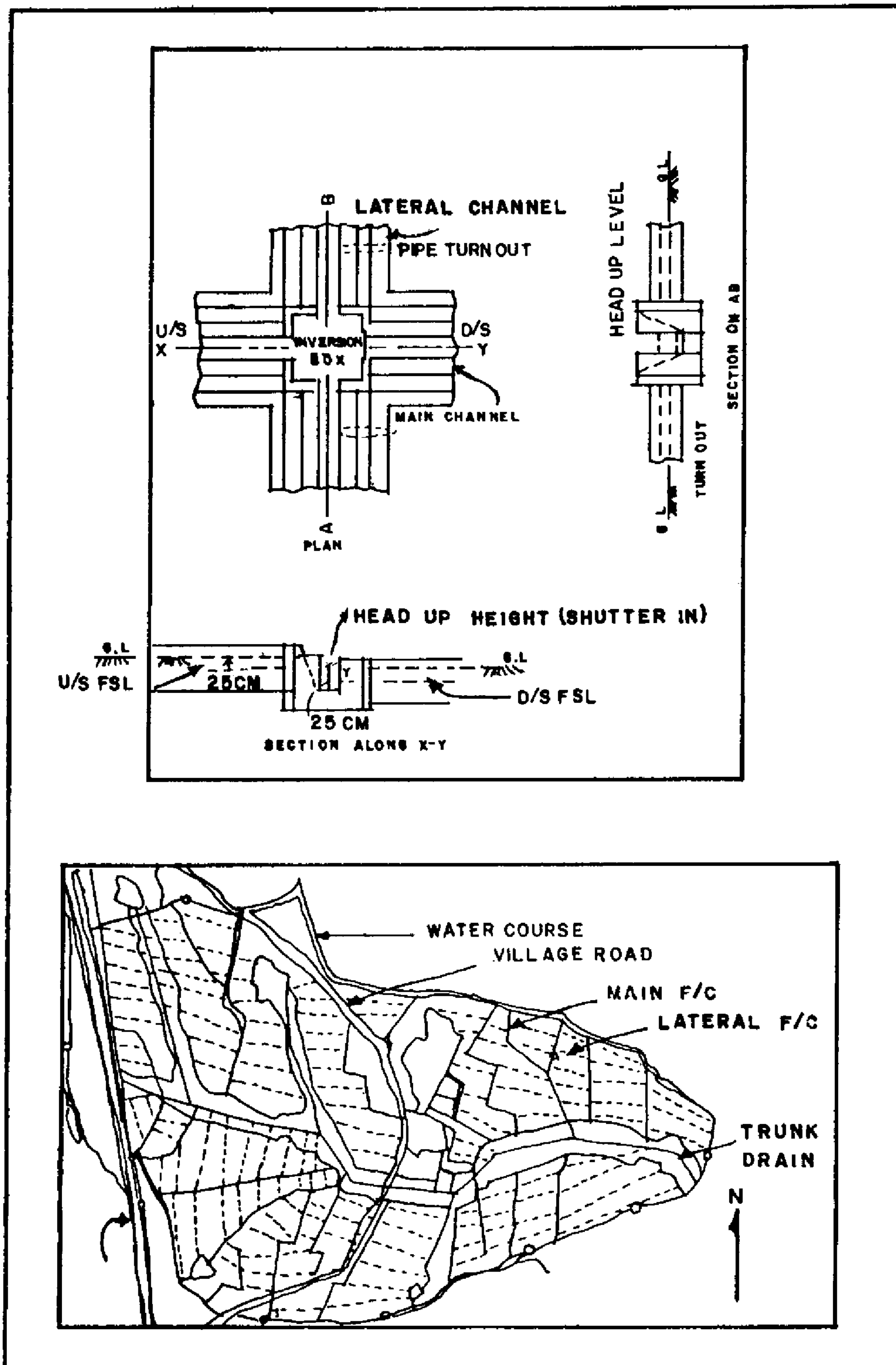
1. All water courses should run below the ground level at a depth equal to full supply depth of the water courses.[2] Irrigation would be by heading up of water through dual purpose structures. This would help the farmers' committees to prescribe an effective plan for sharing water. It would also depress the seepage line originating from water courses.

2. A system of field channels consisting of mains and laterals basically designed as a drainage network would further depress the seepage line (transient water table) and would drain any excess water arising out of over irrigation. Main field channels would be constructed along the principal slope and the lateral would be laid along the secondary slope below each terrace. As a result of such a design, in a village of 150 ha it was possible to convert 75 per cent of the land to a three crop pattern (Table 7).

Table 7. Rise in multi-crop coverage in an area of 150 ha, where water course was improved to new design norms and on farm development was carried out below the outlet.

Year	Multi-crop pattern	Coverage in per cent
1978-79	Rice-rice	100
1979-80	Rice-rice	80
	Rice-mustard-rice	20
1980-81	Rice-rice	50
	Rice-mustard-rice	45
	Rice-pulses-rice	5
1981-82	Rice-rice	25
	Rice-mustard-rice	62
	Rice-pulses-rice	6
	Rice-groundnut-rice	3
	Rice-groundnut-pulses	4

Figure 7. Illustration of infrastructural development both above and below the outlet to improve water distribution.



CONCLUSIONS

In most older commands farmers prefer a particular crop. In any development effort this should be taken advantage of, which requires an intimate understanding of the command. Experiments must continue to fill gaps in understanding. Acceptability of any one strategy should be tested with cosmetic improvements. One positive reaction is to identify the infrastructural improvements appropriate to the tested strategy. Like adoption of any new management plans, understanding and belief in the process must begin at levels where decisions are made. Without that, little is likely to happen regardless of the efforts of people at the lower levels. People must be carried along with an idea via their path of interest. If they are opposed to all plans, no matter how well conceived, such plans are rendered ineffective by the interference of the persons concerned.

NOTES

1. Assuming that medium duty crops require 50 per cent and low duty crops 25 per cent as much water as rice, only 35 + 17/2 + 6/4 = 45 per cent coverage with the same quantity of water seems to be theoretically justified.

2. Water courses are the smallest canals of irrigation system on which 75 per cent of outlets are located. They are usually of about five cusecs capacity.

REFERENCES

Naik, B., D.P. Mishra and P.K. Guman Singh. 1979. Drainage of wet area in Hirakud Ayacut. Paper presented at the Symposium on Winter School on Integrated Agricultural Development in the Command Areas of Irrigation Projects, New Delhi, India, Indian National Science Academy.

Naik, B. 1980. Analysis of clinical characteristics - A suggested approach for water management system design. In Proceedings of the Third Afro-Asian Regional Conference. New Delhi, India.

Naik, B. and B.C. Behera. 1981. A study of a water management system basically designed as a drainage system. Journal of Agricultural Engineering. Indian Society of Agricultural Engineers.

Naik, B. and P.K. Guman Singh. 1983. Irrigation system analysis in relation to on farm development. Bhubaneswar, India: Orissa Engineering Congress.

Naik, B. and S.K. Parija. 1982. Synthesizing productive, social and legal rules for evolving an agency for water distribution. Paper presented at the Workshop on Productivity and Equity on Irrigation Systems, Lucknow, India.

Naik, B. and S.K. Parija. 1985. Appropriate canal operation schedules and complementary cropping - An inexpensive way to raise cropping intensity. A case study of Hirakud Command. Souvenir. Shubaneswar, India: Orissa Engineering Congress.

AGRICULTURAL CONSTRAINTS IN PRODUCTION OF DIVERSIFIED CROPS ON IRRIGATED PADDY FIELDS IN KOREA

Sang-Hyuk Synn*

AGRICULTURAL SETTING

Country Statistics

Of Korea's total land area of 99,117 square kilometers, only 2,152,357 hectares (ha) were cultivated in 1984. About 61 per cent of the cultivated area consisted of paddy fields and the remainder was classified as uplands. The farm population of Korea in 1984 was 22.2 per cent of the total population of 40,578,000. The average farm household is 4.6 persons. The 1.973 million farm households had an average allocation of 1.09 ha of cultivated land of 1.09; about 31 per cent of these farms were less than 0.5 ha and less than .01 per cent were larger than 3 ha. Thus, it is obvious that Korean farms are small scale operations (Table 1; MAF 1985a).

Table 1. Land use (in million hectares) and average farm size (in hectares) in Korea, 1975 and 1984.

Classification	1975	1984
Total land area	9.881	9.912
Cultivated land	2.240	2.152
Paddy field	1.277	1.320
Upland	0.963	0.832
Forest land	6.635	6.539
Wooded	5.981	6.279
Denuded	0.647	0.242
Unclassified	0.007	0.019
Others	1.006	1.220
Average size of farm	0.94	1.09
Paddy field	0.54	0.67
Upland	0.40	0.42

In 1985, agriculture, forestry, and fisheries accounted for 14.3 per cent of the gross national product of US$81.3 billion at current prices. The growth rate of the agricultural sector increased from 0.2 per cent in 1984 to 5.9 per cent in 1985 due to increased production of garlic, onion, orange, hot pepper, and grape, despite decreasing production of rice, together with the favorable situation of the fisheries and forest sectors.

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Table 2 shows the growth rates, 5.5 per cent in agricultural production, 9.9 per cent in forestry, and 6.7 per cent in fisheries. An especially high rate of 29.7 per cent appears in the livestock sector. Table 3 indicates the overall status of agricultural production in 1985 (MAF 1986).

Table 2. Growth rates (in per cent) of agriculture, forestry, and fisheries.

	1981	1982	1983	1984	1985
Agriculture, forestry, and fisheries	22.4	3.3	6.5	0.2	5.9
Agricultural production	24.3	4.4	6.3	-1.0	5.5
Section of cultivation	27.3	4.8	5.2	-2.4	3.1
Livestock	0.0	0.3	18.1	31.1	29.7
Agricultural services	11.8	0.4	14.4	2.4	1.1
Forestry	5.7	-11.9	31.4	7.8	9.9
Fisheries	16.0	1.6	-4.4	8.3	6.7

Note: Data based on the 1980 constant prices; Bank of Korea 1986.

Table 3. Area (in thousand hectares), production (in thousand metric tons, MT), and yield (in MT/hectare), 1985.

Crops	Area	Production	Yield
Rice	1,237	5,626	4.55
Unhusked barley	64	162	2.54
Naked barley	101	225	2.22
Beer barley	73	184	2.53
Wheat	3	11	3.43
Sweet potato	34	787	23.50
Potato	31	575	18.49
Pulses	196	275	1.40
Corn	26	132	5.04
Other cereals	14	15	3.65
Radish	38	1,586	42.28
Cabbage	41	2,790	67.61
Hot pepper	118	165	1.40
Garlic	39	256	6.57
Onion	11	440	40.92
Other vegetables	90	1,846	20.51
Fruit	109	1,464	13.46
Special crops	366	81	0.22
Total	2,592	16,617	-

Only 48.6 per cent of total food grain consumed in Korea during 1985 was supplied from domestic sources. Even though Korea has recently achieved a self sufficiency in rice production. she still had to import 11.02 million MT

(US$983 million) of food and feed grains in 1985. Along with the rapid income growth of the Korean people, demands for fresh produce and animal protein food increased at a rate faster than economic growth, accelerating land allocation to income elastic crops.

The conversion of land from arable land to industrial sites, highways, housing development, and other non-agricultural purposes is acute. The total area of cultivated land increased gradually between 1949-68, and has decreased at an average of about 10,000 ha/year since. This decrease may be greater in the future, and growing industries and urban settlements in Korea will continue to make significant inroads into cultivated areas.

Climate and Soil

Korea is in the temperate zone with a mean annual temperature above 11°C Mean summer (June to August) temperatures range from 20.7 - 25.5°C, and those of winter months (December to February) -0.6 - 2.6°C, showing the highest and lowest in the month of August and January (Table 4).

The mean annual rainfall is more than 1,000 mm except in the Daegu area where it is 979 mm (TAble 5). Most of it is concentrated in July and August which causes shallow soil depth in sloping land due to severe erosion, while deep soils are developed in the plains near rivers and mountain foot slopes by deposition of alluvium. These show different characteristics depending on the parent material. There is considerable fluctuation in precipitation from year to year and losses in production from droughts have been experienced.

About 12°C is considered the minimum temperature for germinating rice seeds, and 18°C is considered the critical temperature for rice pollen cold damage. Rice growing starts in early April and flowering must be finished by late August. Generally, the annual precipitation is more than enough, but its uneven distribution often causes difficulties such as shortage in the period May to June during rice crop transplanting and excess in the period August to September during rice crop flowering and ripening. This is why irrigation engineers are showing interest in the storage of winter precipitation and quick drainage of flooded paddies.

The soils of Korea are generally deficient in plant nutrients and organic matter. The top soil is relatively thin and poor. Korean farms often require substantial treatment with compost or chemical fertilizers to produce adequate crops. The greatest part of the soil is derived from granite and gneiss and is largely sandy with 12-38 per cent clay[1].

Improvement of Farm Land

In rice farming the paddy land must be flooded for a considerable part of the planting and growing season. Irrigation has been used in Korea for centuries and the irrigated area has been expanding as the demand for rice increases. More than seven decades have passed since the regulations of irrigation associations were issued in 1906 and modern irrigation facilities began to be installed in 1908. The main feature of farmland improvement projects until 1945 was to construct irrigation by establishing irrigation

Table 4. Mean monthly temperature (in degrees Celsius).

Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Gangneung	-1.0	0.3	4.7	11.5	16.7	19.7	23.5	24.3	19.7	14.4	8.8	2.4	12.1
Seoul	-4.9	1.9	3.6	10.5	16.3	22.8	24.5	25.4	20.3	13.4	6.3	-1.2	11.1
Chupun-gryong	-3.1	-0.7	4.5	11.0	16.7	20.6	24.5	24.4	19.4	13.0	6.7	0.2	11.5
Daegu	-1.6	0.6	5.7	12.1	17.6	21.6	25.3	25.9	20.5	14.2	7.8	1.4	12.8
Jeonju	-1.7	0.2	5.0	11.3	16.8	21.3	25.7	25.9	20.6	13.9	7.8	1.7	12.4
Gwangju	-0.6	1.1	5.7	11.4	16.8	21.4	25.6	26.1	20.9	14.0	8.2	2.4	12.8
Pusan	1.8	3.5	7.3	12.5	16.7	19.8	23.7	25.4	21.6	16.6	11.1	5.0	13.8
Mogpo	1.0	2.1	5.9	11.5	16.5	20.6	24.8	26.1	21.7	16.1	10.3	4.3	13.4
Cheju	4.8	5.2	8.0	12.3	16.2	20.4	25.1	25.8	21.7	16.8	12.1	7.6	14.7
Mean	-0.6	1.2	5.6	11.6	16.7	20.7	24.7	25.5	20.7	14.7	8.8	2.6	12.7

CMO 1968.

Table 5. Mean monthly precipitation (in millimeters).

Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Gangneung	36.9	73.4	73.1	70.4	64.1	134.9	212.1	190.7	197.5	87.8	88.0	53.2	1282.1
Seoul	17.1	21.0	55.6	68.1	86.3	169.3	358.0	224.2	142.3	49.2	36.0	32.0	1259.2
Chupun-gryong	25.4	30.1	56.5	71.9	75.4	167.4	267.6	190.8	154.9	40.4	36.5	29.9	1146.7
Daegu	15.8	27.1	45.5	64.4	67.4	132.7	200.2	165.5	161.8	44.0	30.1	24.8	979.3
Jeonju	26.6	32.8	61.0	76.4	84.7	154.6	279.4	239.6	156.4	51.5	41.7	35.5	1240.7
Gwangju	31.5	34.4	69.1	82.2	92.0	168.8	222.6	201.2	189.5	51.9	42.9	36.9	1222.8
Pusan	25.3	44.1	88.5	113.5	5139.3	197.5	247.6	165.0	205.1	73.1	43.9	38.5	1381.6
Mogpo	37.4	40.2	58.4	82.9	101.3	136.0	182.8	187.8	156.0	55.4	44.2	43.3	1125.9
Cheju	59.2	75.6	73.1	82.3	88.8	158.1	209.8	226.6	249.5	87.5	69.2	60.2	1439.9
Mean	30.6	42.1	64.5	79.1	88.8	157.7	242.2	[illegible]	179.2	60.1	48.1	38.4	1230.9

CMO 1968.

associations. Until the 1960s, most of the projects involved irrigation water development, farmland consolidation, or farmland development at the individual project basis. Since 1969, when the Geumgang and Pyeongtaeg Comprehensive Agricultural Development Projects began with World Bank loans, most of the farmland development projects have been of the comprehensive or multipurpose type.

At the end of 1985, approximately 949,000 ha of paddy land or 72 per cent of the total paddy land in Korea was fully irrigated. (Table 6) There were about 60,000 irrigation facilities: 18,000 reservoirs, 4,600 irrigation pumping stations, 20,000 weirs, 4,700 infiltration galleries, 11,000 tube wells, and 287 irrigation and drainage pumping stations.

Table 6. Present status of paddy land improvement (in thousand hectares).

	1975	1980	1983	1984	1985
Paddy land area	1,227	1,307	1,316	1,320	1,325
Irrigated paddy area	790	893	929	935	949
Ratio (%)	62	68	71	71	72
Land consolidated area	227	369	415	431	447
Ratio (%)	39	52	59	61	63
Drainage improved area	8	20	30	31	33
Ratio (%)	6	16	23	25	26

Target for land consolidated area is 706,000 ha, that for drainage improved area is 127,000 ha; MAF 1986.

Almost all irrigation facilities are installed for rice paddy cultivation. But in the limited dry fields, mainly distributed near urban areas, irrigation facilities provide for cash crops such as vegetables and fruits. The facilities include sprinkler, drip and other establishments from irrigation canals in the paddy field, or tube wells developed by individuals.

PRESENT STATUS OF DOUBLE CROPPING AND DIVERSIFIED CROPS

The total area of paddies has steadily increased from 1976-85 (Table 7; MAF 1985b), while that planted to rice has slowly decreased. Consequently, cropping intensity on paddies also has decreased from 130.2 per cent in 1976 to 114.5 per cent in 1985. This trend was mainly due to the rapidly decreasing planted area of second crops after rice. However, diversified crops alternated with rice increased slightly. Table 8 (ibid.) shows changes in cultivated area of second crops after rice cultivation in paddies from 1975-87. Barley decreased from 364,634 ha in 1975 to 131,700 ha in 1985. But vegetables such as fruit vegetables, garlic, onion, Chinese cabbage, fodder crops, and other crops increased. Table 9 (ibid.) shows the area given to double cropping systems in paddies selected cultivated areas.

Table 7. Changes in rice cropping intensity (in million hectares), 1975-85.

Year	Total area	Planted area	Rice-rice	Second crop after rice	Diversified crops*
1975	1.277	1.661	1.189	0.389	0.084
1977	1.303	1.610	1.201	0.304	0.105
1979	1.311	1.619	1.221	0.291	0.108
1981	1.308	1.559	1.209	0.230	0.120
1983	1.316	1.561	1.208	0.243	0.109
1985	1.325	1.517	1.218	0.192	0.106

*Alternated with rice.

Table 8. Planted area (in thousand hectares) of second crops after rice cultivation in paddies, 1975-85.

Crops	1975	1977	1979	1981	1983	1985
Barley	364.6	273.2	248.0	193.4	195.5	181.7
Potato (spring)	5.5	4.4	3.1	3.8	4.4	4.1
Fruit vegetables*	5.2	7.4	7.6	9.7	9.4	9.4
Radish (spring)	1.0	1.6	1.3	1.0	1.2	1.1
Chinese cabbage (spring)	1.9	3.1	3.4	3.0	3.0	3.1
Lettuce	0.2	0.3	0.4	0.4	0.5	0.5
Garlic	3.1	4.7	14.5	7.2	10.2	11.1
Onion	1.8	3.8	4.3	3.5	6.3	4.3
Rape	1.1	1.2	0.4	0.1	0.1	0.1
Fodder crops	0.1	0.2	1.6	1.4	3.0	14.5
Other crops**	4.6	4.5	6.1	6.8	8.9	12.3
Total	389.1	304.5	290.8	230.4	243.2	192.0

*Watermelon, melon, strawberry, cucumber, pumpkin, and tomato. **Ginseng, tobacco, flowers, etc.

Table 9. Double cropping area (in thousand hectares) in paddies, 1985.

Cropping pattern	Area	Per Cent	Main cultivated area
Rice-barley	131.7	68.6	Chonnam, Kyongnambuk, Chonbuk
Rice-garlic, onion	15.4	8.0	Kyongnambuk, Chungnam, Chonnambuk
Rice-potato	4.1	2.1	Kyongnambuk
Rice-leafy vegetables	4.6	2.4	Kyongnambuk, Chonnambuk, Chungnambuk
Rice-fruit vegetables	9.4	4.9	Kyongnambuk, Chonnambuk, Chungnam
Rice-fodder crops	14.5	7.6	All Country
Rice-other crops	12.4	6.4	Kyongnambuk, Chungnambuk, Chonnambuk
Total	192.1	100.0	

Table 10 shows changes in planted area of diversified crops alternated with rice crop in paddies. There were increases of vegetables such as radish, carrot, Chinese cabbage, spinach, cabbage, red pepper, and Welsh onion.

In 1985, 1,218,403 ha or 92.0 per cent of paddies were cultivated with rice, 192,035 ha or 14.5 per cent of paddies with secondary crops after rice cultivation, and 106,935 ha or 8 per cent of paddies with diversified crops alternated with rice.

Table 10. Planted area (in hectares) of diversified crops alternated with rice, 1975-85.

Crops	1975	1977	1979	1981	1983	1985
Upland rice	550	796	614	706	1,072	315
Miscellaneous grains*	438	4,221	457	1,436	1,252	1,025
Pulses**	16,058	16,270	12,148	12,363	11,083	9,059
Sweet potato	279	274	163	188	241	153
Potato (autumn)	-	-	51	99	46	36
Radish (autumn)	384	726	745	1,009	679	749
Carrot	101	145	350	338	301	378
Chinese cabbage (autumn)	1,276	2,366	4,255	5,082	3,334	3,049
Spinach	282	365	930	906	585	942
Cabbage	73	104	432	296	106	353
Red pepper	3,011	713	1,055	3,033	2,577	2,469
Welsh onion	1,093	1,164	1,735	1,821	1,528	1,891
Ginger	68	64	125	3	147	166
Other vegetables+	806	905	1,574	2,329	1,870	2,324
Cotton	69	21	8	8	4	5
Sesame	347	431	318	330	1,213	1,143
Pelilla seed	262	220	438	570	857	871
Peanut	154	91	171	146	127	76
Other special crops	476	518	478	610	578	551
Medicinal crops	653	170	220	107	369	304
Permanent crops	2,185	2,617	569	652	1,493	1,465
Seed-bed	55,225	73,024	78,336	79,558	69,958	63,878
Crops under facilities	-	-	2,511	8,047	9,974	15,181
Total	83,790	105,205	107,683	119,637	109,394	106,383

*Millet, sorghum, corn, buck wheat; ** soybean, red bean, green bean; +eggplant, dropwort, leek, burdock, mallow, taro, lotus root, yam, crown daisy, asparagus, spinach beet, wild rocambole; crops under facilities are various vegetables under vinyl houses; MAF 1985b.

CONSTRAINTS IN DIVERSIFIED CROPPING UNDER IRRIGATED PADDY CONDITIONS

Physical Constraints

Low temperature is the most serious constraint to cultivating winter crops such as barley, potato, garlic, and spring Chinese cabbage. Other constraints include: Land conditions such as poor drainage, inferior irrigation facilities, and infertile soil; damage from insects and disease; and competition with other crops.

Economic Constraints

Unstable and low prices are the most critical constraints to cultivating vegetables and food grains in paddies. Other constraints include: Lack of farm labor; additional labor required; high price of fertilizer and agricultural chemicals; and high price of farm machinery.

Technological Countermeasures for Relaxing Constraints

Drainage improvement practices are needed first of all. Cultivating practices and technological systems of diversified crops such as barleys, pulses, vegetables, and fodder crops are completely different from those of rice crop. In order to cultivate diversified crops in paddies, there are many problems relating to physiology and cultivation of crops. Table 11 shows the fundamental difference between dry field and wet paddies in the cultivating environments. Table 12 also indicates that the two fields differ in the ground water table, soil moisture, soil structure, hydraulic conductivity, oxidized condition of plow layer, and decomposition of organic matter and fertility.

Table 11. Characteristics of paddies and upland.

	Paddies	Upland
Slope	Level	Exist
Ridge	Exist	None
Ground water table	High	Low
Soil moisture	Abundant	Rare
Permeability (water, air)	Low	High
Irrigation canal	Exist	None
Hard plow layer	Exist	None
Oxidation and reduction	Oxidate	Reduce
Decomposition of organic matter	Small	Big
Fertility and nutrient	Accumulate	Leach
pH	High	Low
Availability of phosphate	Big	Small
Form of nitrogen	NH_4 NO_3	NO_3
Weed	Few	Many
Damage from insect & disease	Abundant bacteria	Fungi

Japanese Society of Agriculture and Forestry Statistics 1984.

Table 12 shows the target value of subsurface drainage of various crops. Other measures include on-farm irrigation on the ridge and furrow in paddies, and the promotion of soil fertility through applying organic matter.

Table 12. Target value of subsurface drainage.

Drainage item	Unit	Fodder crop	Ordinary vegetables	Gramineae	High-grade vegetables
Design drainage through under-drain	mm/day	50-100	25	40	80
Permissible days of remaining water on the surface	day	1	1	1	1
Falling velocity of ground water table	mm/day	-	60	100	200
Ground water table depth (7 days after precipitation)	cm	60	-	-	-
Hydraulic conductivity	cm/sec	10^{-4}	10^{-4}	10^{-4}	$2.5x10^{-4}$
Vanishing velocity of precipitation (flooding water)	mm/day	50-100	60	100	200

Japanese Society of Agriculture and Forestry Statistics 1984.

Agro-economic Countermeasures

These include stability of prices of diversified crops such as barleys and vegetables; choice of control cropping systems suitable for local environments; large scale management systems; supply of proper farming funds; reduced prices of fertilizer and agricultural chemicals.

NOTES

1. Chemical properties of paddy soils (Hong 1972).

pH	Organic matter %	Available P_2O_5 ppm	Exchangeable cations K	Ca me/100g	Mg	CEC me/100g	Available SiO_2 ppm
5.5	2.6	6.0	0.23	4.5	1.8	11.7	78

REFERENCES

Ban, Sung-Hwan. 1981. A scheme of raising utilization ratio of paddy field. Research Report No. 41. Seoul: The Korean Rural Economic Institute.

Bank of Korea. 1986. Economic statistics yearbook. Seoul.

Central Meterological Observatory (CMO). 1968. Climatic tables of Korea, 1931-60. Seoul.

Hong, Chong-Woon. 1972. The Fertility Status of Korean Soils. Technical Bulletin No. 10. Seoul: Food and Fertilizer Technology Center.

Japanese Society of Agriculture and Forestry Statistics. 1984. Reorganization of paddy field utilization and land improvement, Y. Kato (ed.). Tokyo.

Ministry of Agriculture and Fisheries (MAF). 1985a. Statistical yearbook of agriculture, forestry, and fisheries. Seoul.

Ministry of Agriculture and Fisheries (MAF). 1985b. Crop statistics. Seoul.

Ministry of Agriculture and Fisheries (MAF). 1985c. Yearbook of land and water development statistics. Seoul: Agricultural Development Corporation.

Ministry of Agriculture and Fisheries. 1986. Annual report on agricultural trends. Seoul.

IRRIGATION MANAGEMENT FOR CROP DIVERSIFICATION IN THAILAND

Boonyok Vadhanaphuti*, Nukool Thongthawee**,
and Siripong Hungsperug***

INTRODUCTION

Agriculture dominates Thailand's national economy with values exceeding 64 per cent of the total national export in 1984. About 70 per cent of the total working population is engaged in agriculture and related activities. Rice constitutes the main crop and is cultivated on about 9.5 million hectares (ha) or approximately 62 per cent of the total cultivated land.

Rice has been the largest foreign exchange earner for Thailand with an export value of US$960 million or 15 per cent of the total export value in 1984. In the 1970s, the government promoted agricultural development to increase rice production, partly to feed a growing population and partly to increase exports. In recent years, population growth has slowed down significantly and per capita rice consumption has started to fall. In addition, the sharp drop in the world price of rice during the early 1980s has made rice production less profitable than expected during the food shortages of the early 1970s. Lower rice prices have made it uneconomic to proceed with agricultural/irrigation projects heavily dependent on rice production for their justification.

Crop diversification is essential to avoid over-production of rice in the market and to increase production of crops which appear suitable for export. Cash crop production, such as cassava, sugar, rubber, and fruits are outstanding staples and major supports of the national revenue. However, unstable prices with rapid fluctuation and/or low escalation of prices have caused the export of cassava, sugar, and rubber to slow down. On the other hand, good prices for fruit in recent years and well-established domestic and international fruit markets have made horticulture an enterprising agribusiness. To expand agricultural exports rapidly to improve the balance of payments, the government intends to promote crop diversification especially for export, and for horticultural development in view of its great profitability.

RELEVANT COUNTRY STATISTICS

Thailand has already embarked on diversification of major upland irrigated crops such as vegetables, sugar cane, fruit trees, and other perennial crops. Table 1 shows the regional distribution of the wet season rice cultivated areas from 1982-85. Table 2 shows the cultivated crop diversification in all regions and a breakdown of irrigated areas for dry-season rice, upland crops, vegetables, sugar cane, fruit trees, perennial crops, and fish ponds.

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Table 1. Wet season rice cultivated areas in irrigated projects (in thousand hectares), 1982-85.

Region	1982	1983	1984	1985
Northeast	292	275	299	327
North	252	319	302	333
Central	1395	1405	1463	1480
South	177	194	186	177
Total	2,116	2,193	2,250	2,317

Table 2. Dry season cultivated areas in irrigated projects (in thousand hectares), 1982-85.

	1982	1983	1984	1985
Rice	638	607	607	569
Upland crops	95	106	126	107
Vegetables	21	19	26	27
Sugar cane	60	56	54	49
Fruit	26	44	56	57
Perennial crops	34	22	25	23
Fish ponds	6	10	17	29
Total	880	864	911	861

Table 3 shows the extent irrigated land is used for diversified cropping. Clearly, such use is increasing.

Table 3. Area (in thousand hectares) irrigated and used for diversified cropping, 1982-85.

	1982	1983	1984	1985
Irrigated area	3002	3058	3160	3179
Diversified cropping area	247	258	303	294
Percentage increase	8.2	8.4	9.6	9.2

The Royal Irrigation Department (RID) manages the irrigation system by dividing the country into 12 regions. Regions 1-3 are in the north, 4-6 in the northeast, 7-10 on the central plain, and 11 and 12 in the south. Tables [illegible] show that upland crops are predominant and contribute about 40 per cent percent of the total diversified cropping area.

Table 4. Dry season cultivated areas (in hectares) of irrigated projects, 1982.

Region	Rice	Upland crops	Vege- tables	Sugar cane	Fruit trees	Peren- nials	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	8,050	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
Tot	512,240	96,300	20,740	59,593	25,516	33,637	12,274	760,300

Table 5. Dry season cultivated areas (in hectares) of irrigated projects, 1983.

Region	Rice	Upland crops	Vege- tables	Sugar cane	Fruit trees	Peren- nials	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
Tot	606,820	108,970	19,110	56,126	44,074	21,840	10,299	867,239

Table 6. Dry season cultivated areas (in hectares) of irrigated projects, 1984.

Region	Rice	Upland crops	Vege-tables	Sugar cane	Fruit trees	Peren-nials	Fish ponds	Total
1	2,910	21,350	2,750	1,180	0	0	0	28,190
2	5,580	12,340	700	1	160	0	0	18,781
3	19,570	14,070	380	330	410	110	0	34,870
4	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
7	332,400	6,430	9,920	7,580	13,250	270	2,540	372,390
8	127,150	20,020	580	10	12,390	3,090	7,580	170,820
9	55,170	1,500	310	0	80	320	4,360	61,740
10	37,370	25,680	7,810	44,590	24,170	18,620	2,220	160,460
11	680	1,100	420	3	5,260	2,900	10	10,373
12	9,290	1,100	90	2	0	0	0	10,482
Tot	607,030	125,640	25,580	53,706	55,722	25,310	16,730	909,718

Table 7. Dry season cultivated areas (in hectares) of irrigated projects, 1985.

Region	Rice	Upland crops	Vege-tables	Sugar cane	Fruit trees	Peren-nials	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	16,380	3,090	12,180	158,920
9	51,440	1,120	600	0	30	20	10,630	63,840
10	36,060	20,370	10,290	38,990	18,080	13,670	2,850	140,310
11	1,420	420	530	7	6,840	4,790	10	14,017
12	14,950	1,160	180	2	30	0	0	16,322
Tot	569,100	107,360	27,400	49,459	56,990	23,130	29,096	862,535

Figures 1 and 2 show the boundaries of each region and the rainfall intensity pattern. Considering the rainfall intensity pattern alone, it is difficult to determine its bearing on the cropping pattern and cropping intensity.

Figure 1. Physiographic regions of Thailand.

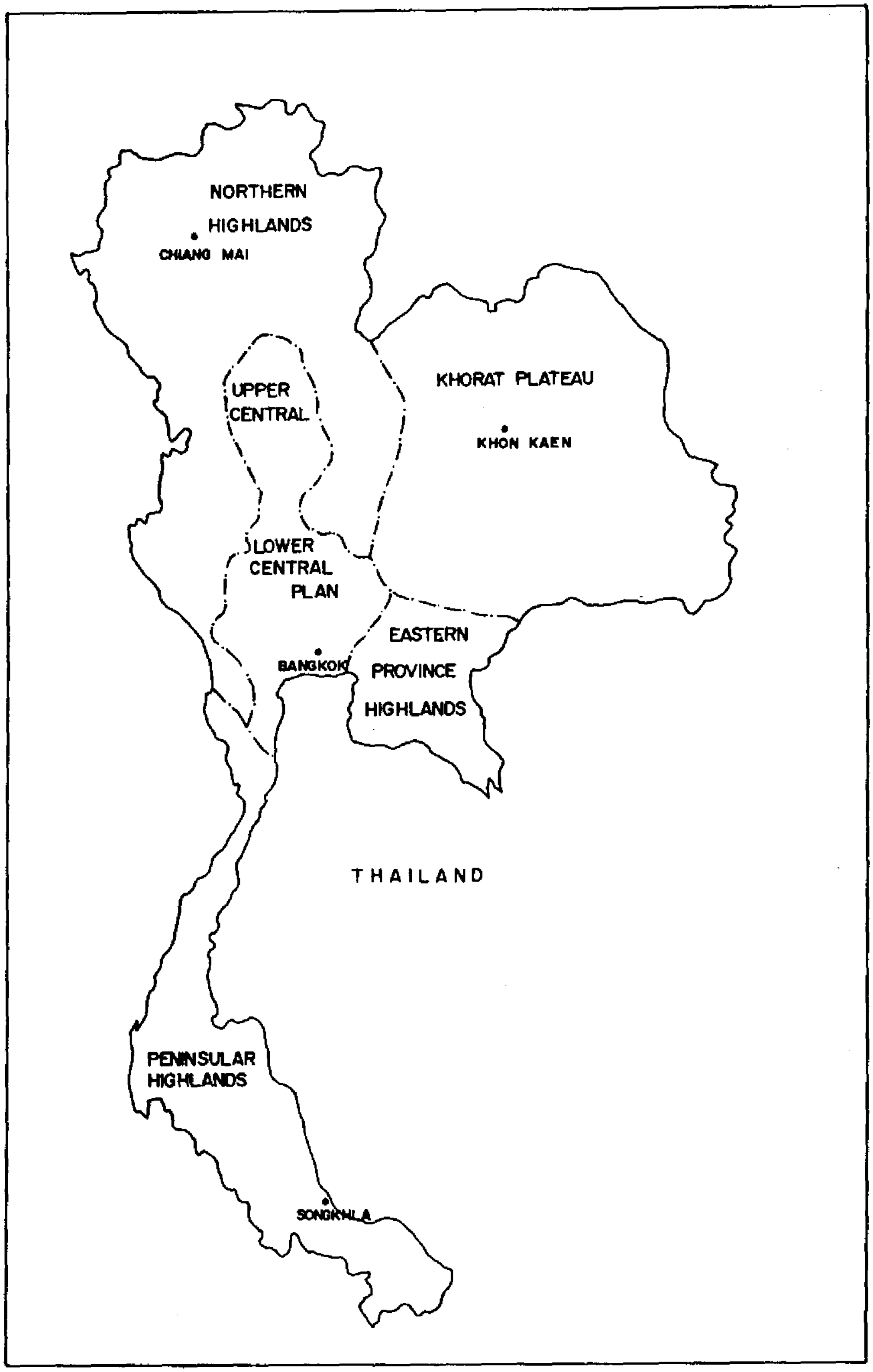
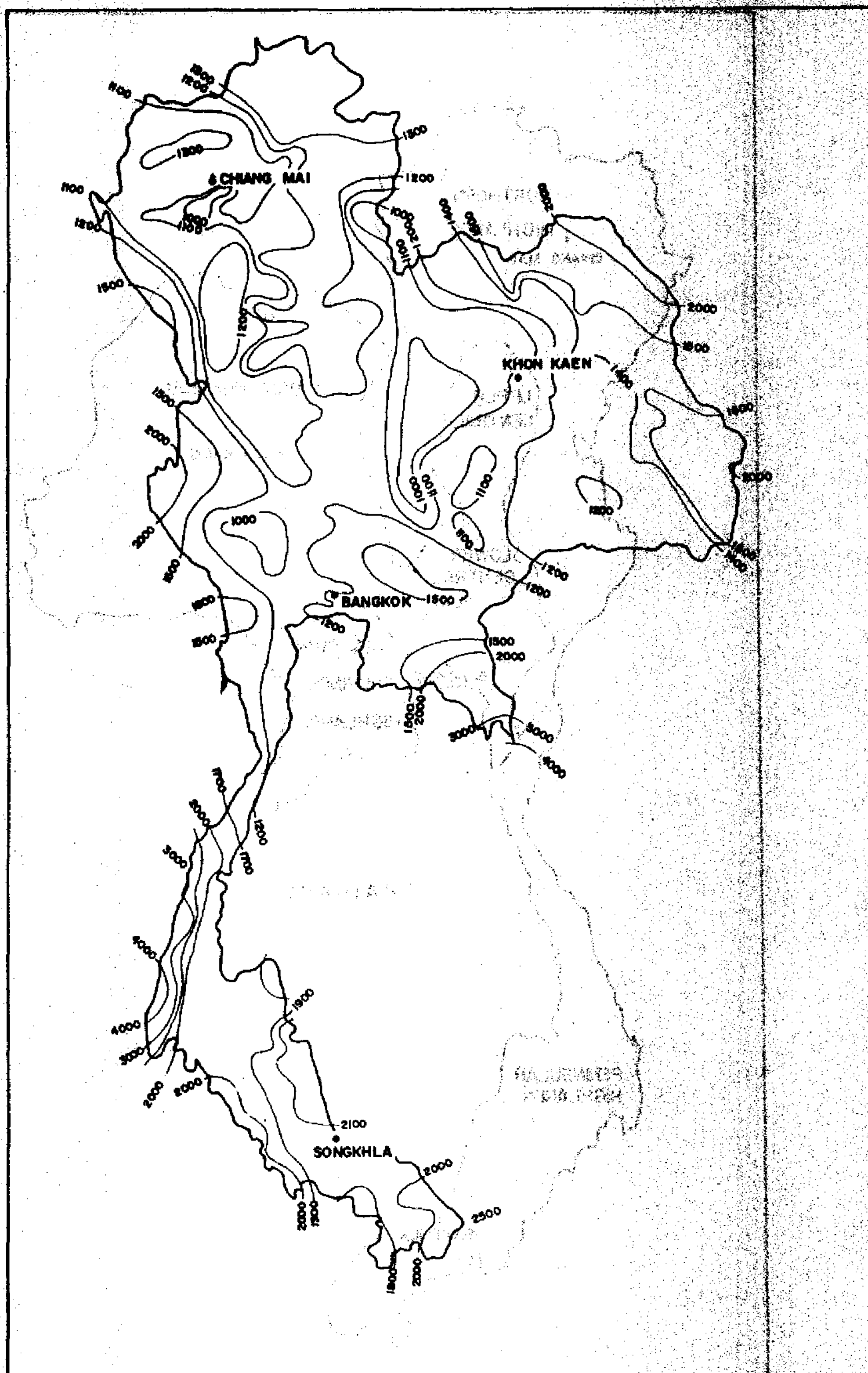


Figure 2. Average rainfall in Thailand (in millimeters)



Present Crop Potential

The present crop potential in Thailand includes herbs, tobacco, sugar bean, mungbean, groundnut, sorghum, vegetables, and fruit trees. 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. Thailand imported tobacco worth 1,100 million baht (about 26 baht = US$1.00) in 1980 and 1,320 million baht 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 approximately 600,000 tons against a local supply of only 200,000 tons. Soybean is to be promoted in the north, northeast, and central regions. Each year Thailand exports about 200,000 tons of mungbeans to other Asian countries. There is also potential in the European market with increasing diversity in consumer taste.

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.

ON-GOING RESEARCH RELATED TO CROP DIVERSIFICATION

The National Economic and Social Development Board's draft master plan for national development recommended support for research on various species of herbs; tobacco; and improvement of seeds and seedling method for mungbean, soybean, kapok, sesame, and job's tear.

The Royal Irrigation Department's research on crop diversification has involved soil suitability, and revision of the design to make the distribution system flexible to changed objectives of water demand. These studies have suggested that technical parameters related to engineering planning and design need revision. Better control of the flow in the distribution system is also needed for irrigation of diversified crops. The choice of suitable control structures is presently under study by the RID staff.

Constraints and irrigation measures to relax them.

A number of constraints hinder the promotion of crop diversification. A listing of constraints and promising irrigation measures for relaxing them are summarized in Table 8. However, there are many other constraints that are indirectly related to irrigation. One is marketing. The present strategy is simply to ensure that production and marketing are compatible.

Issues for Research

Soil suitability. Practically it is possible to improve the existing land to grow upland crops but it is more economical to grow them where the soil is suitable. Research on soil suitability would be useful to advise the farmers and the planning agency.

Table 8. Constraints and promising irrigation practices for relaxing constraints to diversified cropping.

Constraints		Measures
Reliability of water distribution	-	Better main system management system; study of suitable control structures; intensive RID staff training
Soil suitability	-	Research on soil suitability and advice to farmers
Availability of water storage	-	Study additional water storage; increase water use efficiency; advise on crops that require a limited amount of water
Existing infrastructure	-	Improve the infrastructure to meet changed objectives
Drainage problems	-	Improve the drainage system; advise on crops that are water sensitive
Lack of good quality seeds	-	Research for better varieties
Cultural practices favoring rice cultivation	-	Increase farmers' confidence in crop diversification
Salinity problems	-	Good drainage and water control

Marketing. Although marketing is not related to crop diversification it has been identified as a real constraint to diversification. 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 RID to be able to carry out its implementation program.

Distribution system. More research is needed on suitable values of water duty and of Manning's constant, and suitable control structures on the canal system.

NATIONAL POLICY IMPLICATIONS FOR PRICING, MARKETING, AND SUPPORT SERVICES

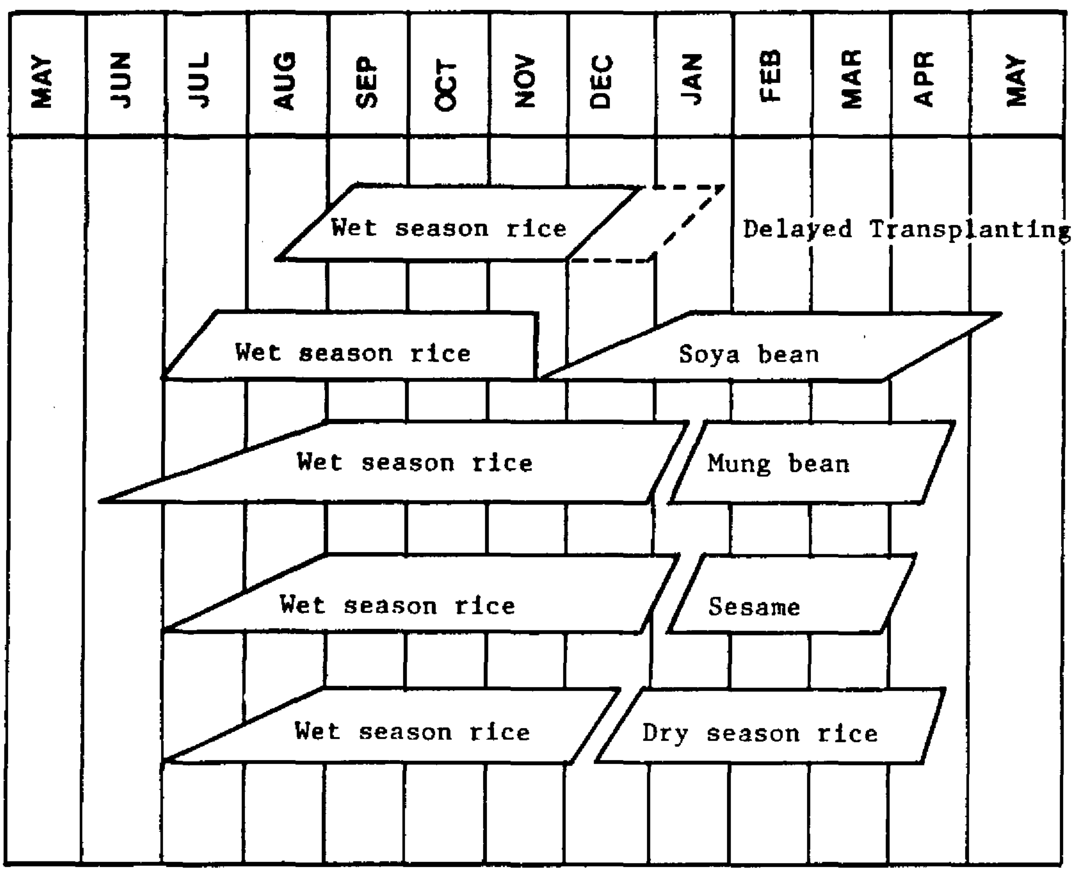
For the past few years, the fluctuating price of regional agricultural products has caused a reduction in the country's earnings. It was further reduced when other countries of the region responded to the price decreases by increasing agricultural exports and decreasing imports. This in turn lead to confusion in the global marketing system.

To cope with the crisis, the government adopted the following general guidelines to reduce farmers risks by not depending on a single kind of crop, to encourage employment, and to alleviate poverty. In order to implement this plan, the government encourages the farmers to carry out mixed farming in the wet season, by growing vegetables and rice, soybeans with cotton or by reducing the cassava plantation and introducing red sorghum.

In the dry season, crops needing little water -- such as mungbean and groundnut -- can be grown just before or after the rice season. Other promising crops currently promoted include various beans or sorghum which can be introduced after the corn season.

Typical cropping patterns suggested in the promising northern part of Thailand are shown in Tables 9 and 10 for the lower north and upper north irrigated areas, respectively.

Figure 3. Typical cropping pattern suggested for use in lower northern areas of Thailand.



commodities like rice, sugar, and coconut is an attempt to encourage the farmers to diversify their farming operations.

Irrigation is one input subsidized by the government. The subsidy to irrigation comes in the form of equity contributions to agencies involved in irrigation development, particularly the National Irrigation Administration (NIA), budgetary appropriations for the construction and maintenance of the facilities, and interest charges on capital costs in the construction of the irrigation facilities.

The subsidy for operations and maintenance (O&M) has already been terminated and allocations for new construction are slowly diminishing. Loans and grants from multilateral and bilateral funding agencies have slowed down. In addition, the government has been contracting its equity contribution to NIA. National equity participation is to be terminated in due time.

These actions are expected to threaten the financial viability of the NIA, considering that the agency has not been strong in collecting irrigation service fees (roughly 50 percent of current collectibles in 1980s; see Small, 1987 for further discussion). NIA has responded by adopting a range of practices: providing technical assistance to water users organizations and allowing them to operate and maintain the diversion structures, particularly those small and financially marginal systems converted into small-scale communal systems; providing monetary incentives in the form of commissions (roughly 2.5-3.0 per cent) to water associations that are able to collect 70-100 per cent; and setting up joint liability schemes with water/farmers associations involved in the O&M for NIA's communal and pump irrigation systems. Despite these measures, NIA has cash flow problems compounded by a dismal collection performance and is now contemplating raising its current irrigation service fees (ISFs), an option which will be enforced three years from now.

The implications of raising ISFs may be viewed in two ways. From NIA's point of view, this policy seems the most feasible and pragmatic solution to improve its services. The rising cost of O&M expenditures can only be compensated by a corresponding hike in ISFs. From the farmers' perspective, the increase in ISFs would mean an added burden which they may be unable to pay unless they diversify their rice farming operations. However, if the incremental service fees can justify satisfactory irrigation services, farmers can be expected to pay for the increased fees and still receive substantial net benefits from irrigation. The study by Small et al. (1987) shows that if irrigation services in a typical situation are satisfactory, the current irrigation service fee is equal to about 10 per cent of net benefits of irrigation and the average O&M costs per hectare are equal to about 7 per cent of net benefits. NIA's micro-farm level studies show that farmers are willing to pay for a price that can provide them good service. The increased irrigation service fees may also be offset by the deregulation of the prices for agricultural products.

NIA's lower ISF for non-rice crops or 60 per cent of the ISF for rice is an encouragement for farmers to diversify to non-rice crops. There may be a need to review this figure to encourage more crop diversification to crops which use much less water.

IRRIGATION MANAGEMENT FOR CROP DIVERSIFICATION IN SRI LANKA

Sunil Dimantha*

INTRODUCTION

As in many other countries of the humid tropical regions of Asia, Sri Lanka, at the current levels of per capita consumption of 100 kilograms (kg) of rice per year, is nearing self sufficiency in rice and may even generate small surpluses in the next few years. The major irrigation schemes have provided a break-through in rice production. Furthermore, it is in these schemes where there is most leeway to avert over-production in rice. Around 80,000 hectares (ha) of land in the major irrigation schemes are well-drained and yet wasteful of irrigation water when used for rice production. Using these lands for crops other than rice would be more efficient. This paper considers issues in promoting crop diversification on irrigated land in Sri Lanka.

COUNTRY STATISTICS

Cultivated Extent

Of the 6.5 million ha of land area in Sri Lanka, 245,000 ha are under tea, 205,000 ha under rubber, 451,000 ha under coconut, 759,000 ha under paddy, 100,000 ha under annual crops in stabilized holdings, 1 million ha under shifting cultivation, 50,000 ha under minor export crops, and 1 million ha under homestead gardens, and 12,000 ha under sugar cane.

About 298,000 ha of land are irrigated under major schemes, and 185,000 ha are under minor schemes in Sri Lanka. Of this extent only 6,000 ha under sugar cane is presently under permanent diversified irrigated crops. Around 20,000 ha under major irrigation schemes were cultivated with short term diversified crops during the 1986 dry season (yala season). The trend is for farmers to increase the extent under diversified crops during the dry season. These lands revert to lowland rice cultivation under puddled conditions during the wet season (maha).

Climate

Agro-ecological regions with uniform climate and soil conditions have been identified in Sri Lanka. Adopted from the agro-ecological map, these regions are presented in Figure 1. Most of the irrigation schemes in Sri Lanka are located in Region 1 (Dry Zone Low Country with reddish brown earth/low humic gley soils), Region 3 (Dry Zone Low Country with non-calcic brown/old alluvial soils), and Region 5a (Intermediate Zone Low Country with reddish brown earths/immature brown loam soils).

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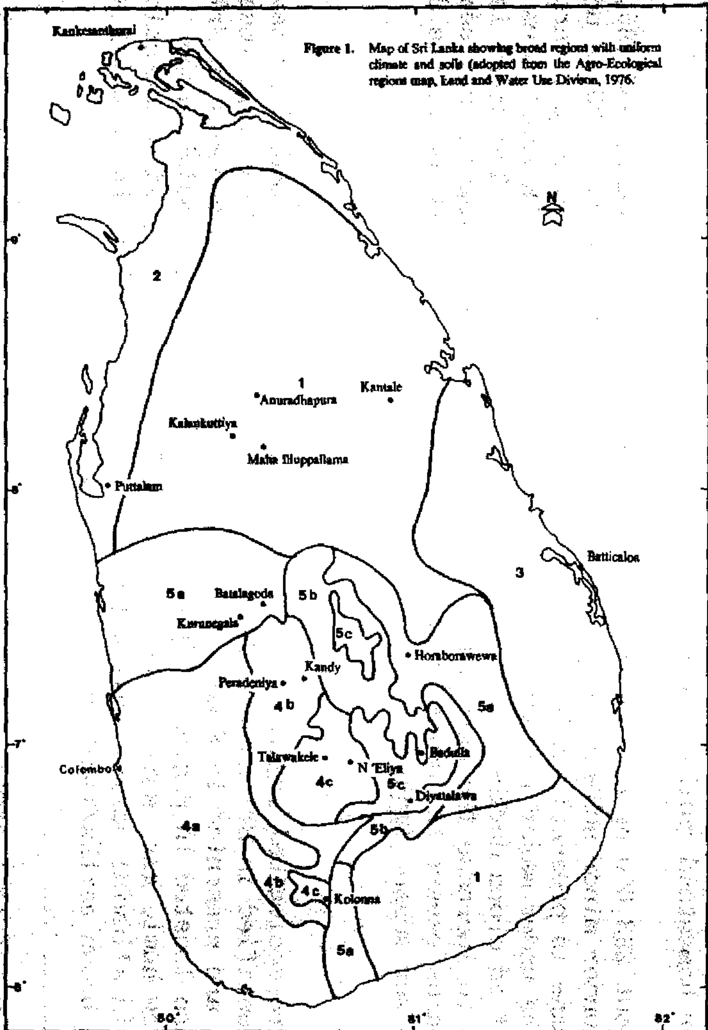

Figure 1. Map of Sri Lanka showing broad regions with uniform climate and soils (adopted from the Agro-Ecological regions map, Land and Water Use Division, 1976.

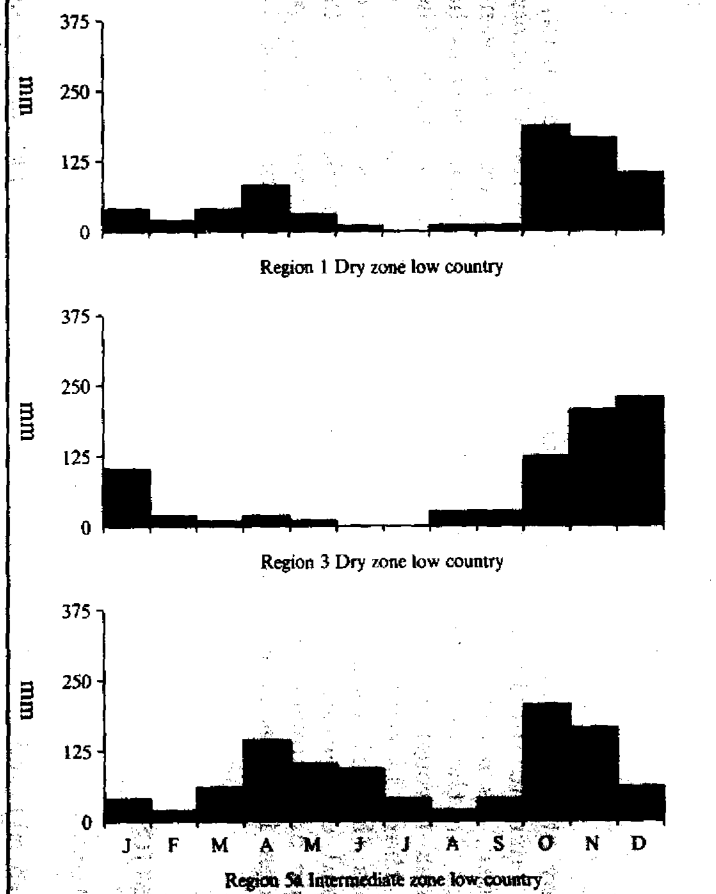

Figure 2. Monthly 75% rainfall probability histograms of the regions where most irrigation schemes are located.

The rainfall patterns of the three regions where irrigation is practiced is presented in the form of monthly histograms of 75 per cent expectancy of rainfall in Figure 2. The evapotranspiration demand for the three regions are estimated by the Modified Penman Method and presented in Table 1.

Table 1. Estimates of reference evapotranspiration (in millimeters) for the regions where most of the irrigation schemes occur in Sri Lanka.

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Anuradhapura	130	143	180	174	186	195	198	202	195	152	123	115
Batticaloa	142	151	189	183	198	198	198	205	192	167	135	124
Batalagoda	140	143	171	162	164	153	152	164	147	133	117	127

Comparison of the rainfall and reference evapotranspiration figures show excess rainfall during the months of October, November, and December and possibly an excess in April or May. There could be surface waterlogging on improperly levelled fields as well as water table build up due to this. But this excess rainfall is sufficient to leach out the salts brought in by irrigation water if good drainage measures are provided and allowed to operate.

Soils

Soil properties influence the choice of crops and irrigation and drainage systems. Brief descriptions of the five "Great Groups" of soils extensively used for irrigated agriculture are given below (Moorman 1961; De Alwis 1972; Soil Survey Staff 1975; Joshua 1973).

Reddish brown earths. These are well- to imperfectly-drained moderately fine textured, reddish to brown soils that occupy upper and mid-slopes of the landscape. They are grouped under Haplustalfs and Rhodustalfs. Their normal depth is about 1.0-1.2 meters. They have moderately slow steady infiltration rates of 1-5 centimeter/hour (cm/hr) and low available water holding capacities of 100-140 mm/meter depth of soil. The erodibility factor is 0.27 (Joshua 1977). The percolation losses on fields wet puddled for the first time exceed 100 mm/day and reduce to 10-20 mm/day after 6 years of continuous paddy cultivation with puddling. These soils have good potential for diversified cropping under irrigation.

Low humic gley soils. These are poorly-drained, moderately fine textured, grayish soils that occur on the lower parts of the landscape and valley bottoms of flat to undulating topography. These are grouped under the Tropaqualfs. They are generally deep, ranging from 1-2 meters. These soils have slow steady infiltration rates of 0.25-3.0 cm/hr and moderate water holding capacities of 140-190 mm/meter depth of soil. The percolation losses of wet puddled fields in the initial years are about 6-10 mm/day and reduce to 2-4 mm/day after 6-10 years of continuous paddy cultivation with puddling. The potential for diversified cropping under irrigation is poor in these soils due to poor drainage. However, in minor irrigation schemes these soils constitute the major area under irrigation. Due to limitations in stored water for the dry season, the only practical possibility is growing of crops other than rice.

Non-calcic brown soils. These are well- to imperfectly-drained, medium textured, brownish to yellowish soils that occur on upper and mid slopes of the landscape. They are grouped under the Haplustalfs. Their normal depth is about 75-100 cm. They exhibit moderate to rapid infiltration rates of 1-20 mm/hr and moderate water holding capacity of 80-120 mm depth of soil. The erodibility factor is 0.35. The trend in deep percolation losses have not been systematically measured. Since these soils are lighter textured than Reddish brown earths, the percolation losses may be higher. The potential to grow diversified crops on these soils under irrigation is very good.

Old alluvial soils. These soils occur on old river terraces. They are coarse textured for a depth of about 30-100 cm and are abruptly underlaid by a moderately fine to fine textured soil horizon. The surface colors are grayish to yellowish and the heavy textured layer is grayish to greenish grayish. These soils are generally imperfectly- to poorly-drained while some soils on higher locations are moderately well drained. These soils exhibit moderate to rapid steady infiltration rates of 5-40 cm/hr and have low available water holding capacity of 40-80 mm depth of soil. The percolation losses are high from soils having deep sandy layers. These soils have low production potential, however, the imperfectly- and poorly-drained soils are more suitable to growing rice while the moderately well-drained soils are more suitable to crops such as sugar cane.

Alluvial soils. These soils occur adjacent to rivers and streams. A small proportion occur on levees and are generally well to moderately well drained, moderately coarse to medium textured and reddish to brownish in color. Soils occurring on the flood plain proper and back swamps are imperfectly to poorly drained, moderately fine textured and grey and black in color. They are grouped under the Tropaquents and Tropofluvents. The alluvial soils are generally very deep, over 2-3 meters. The infiltration rates and available water holding capacities are highly variable depending on the textures, structure, and organic matter content. Most of these soils occur on flood plains and are vulnerable to floods. Also most are poorly-drained and therefore more suitable for growing rice. The soils on levees can be more appropriately used for diversified crops.

Irrigation Water Quality

The water used for irrigation in Region 1, (Dry Zone Low Country, reddish brown earth/low humic gley region) have an electrical conductivity between 225-700 micromhos/cm and a sodium adsorption ratio between 1-2 (Amarasiri 1965, 1973). These waters are rated to have a medium salinization hazard and a low sodication hazard.

The main potential source of irrigation water in Region 2 (Dry Zone Low Country, red yellow latosol region) is from ground water aquifers. These have high salt contents with electrical conductivities ranging from 1000-3500 micromhos/cm and a sodium adsorption ratio between 1-6 (Amarasiri 1978).

They have high to very high salinization and low sodication hazards, and have to be used with extreme care to avoid salinization of the soil.

The water from reservoirs in Region 3 and 5a (Dry Zone Low Country, non calcic brown/old alluvial region and Intermediate Zone Low Country, reddish brown earth/immature brown loam region) have electrical conductivities from 70-200 micromhos/cm and a sodium adsorption ratio between 0.5-1.0. These are Class 1 irrigation water with low salinization and sodication hazard.

Crops

There are many crops besides rice which are easily grown under irrigation and are important for the nutrition and clothing needs of the population: sugar cane, soybean, pulses, maize, cotton, chillies, cassava, fodder, fruits, and vegetables. While the country needs 1.65 million metric tons (MT) of rice to be self sufficient, 1.53 million MT was produced in 1985.

Sri Lanka imports over 90 per cent of its requirements of sugar and cotton (US$50 and 10 million, respectively), and 30-40 per cent of milk (US$20 million). The world market prices for sugar are presently very low; a change could increase the sugar import bill. Besides these main imports, varying quantities of pulses and chillies are also imported.

DIVERSIFIED CROPS UNDER IRRIGATION

Plans were made about 20 years ago for crop diversification under irrigation. The authorities realized that the best returns to land and water resources in irrigation schemes could be achieved by growing crops suited to the various land classes. Most of the non-rice crops of the same class require less irrigation water than rice. Therefore new irrigation schemes were designed according to available knowledge and constructed for growing irrigated upland crops on well-drained lands and irrigated rice on poorly-drained lands. Farmers, however, preferred to grow only rice under puddled conditions because rice was easy to store or market. Recently, farmers on well-drained lands began growing upland crops, notably chilli.

Potential for Diversified Cropping

Diversified crops are grown in Sri Lanka a) to match the more suitable crops in terms of water consumption and economic returns to the various land classes, b) to veer away from rice production to avoid over-production and consequent low returns to farmers, and c) to assure a crop during the dry season when there is insufficient water to do rice cultivation in the reservoirs, especially the minor tanks and occasionally the larger tanks.

To achieve the first two objectives, 80,000 ha of well-drained land under command of the major irrigation schemes are available. Of this, around 6,000 ha is under sugar cane at the three government-owned sugar plantations and a small extent under small holdings. Another 2,000 ha is fallowed in these sugar cane plantations. It should be possible to persuade farmers to grow upland crops on the remaining 72,000 ha at least during the dry season.

The present trend is for farmers to revert to rice cultivation during the wet season, due to their preference to grow at least one rice crop per year and because excess moisture conditions hamper upland crop cultivation.

The third objective could be achieved by growing upland or dry season crops on the 185,000 ha under the minor irrigation schemes during the dry season. The majority of the soils in these schemes are imperfectly- to poorly-drained low humic gley and alluvial soils, which are generally not suitable for upland crops. It may be possible to grow these crops in the dry season by avoiding the short rainy period during April/May and making good provisions for surface and sub-surface drainage in case of unseasonal rains.

The amount of food crops required by the country to ensure balanced nutrition are estimated in Table 2 to assess the extent of lands needed to grow these crops. In the case of sugar, onions, and chillies the present consumption level is used. However in the case of pulses and oil seeds, the consumption levels recommended by the Medical Research Institute is used because grain consumption in Sri Lanka is highly biased towards cereals and requires shifting towards pulses and oil seeds to ensure a balanced diet.

Table 2. Required production (in thousand MT), rainfed and irrigated yields (in kilogram/hectare), and required area (in thousand hectares) of diversified crops to ensure balanced nutrition in Sri Lanka, 1987.

Crop	Production requirement	Rainfed yield	Irrigated yield	Rainfed area	Irrigated area
Cowpea	75	700	150	107	50
Green gram	38	600	100	62	38
Black gram	27	800	150	32	17
Ground nut	30	800	150	36	19
Soybean	9	1500	200	6	5
Chilli	32	400	100	77	32
Onion	112	700	1000	16	11
Sugar	300	400	600	75	50
Total				411	222

To be self sufficient in the more important food items, 222,000 ha of irrigated land is required; this is almost double the available extent under rainfed conditions assuming only one season of cultivation. The annual requirement of cotton is 10,000 MT at a production rate of 1 MT/ha. About 10,000 ha of irrigated land is required to produce the cotton requirement under irrigation. Recent proposals to grow coconuts on a certain extent of irrigated land in the new schemes will provide the coconut requirements of the new settlers instead of transporting coconut to them. Since the extent of well-drained land in the major schemes is only 80,000 ha, crops for irrigated land have to be carefully selected.

Criteria for selecting appropriate upland crops are economic return; crop water requirements; tolerance to occasional water-logging; high incremental production under irrigation over rainfed conditions; dry weather to assure quality of product as in the case of sugar cane, chilli, and cotton; and need to produce perishable crops such as vegetables in dry periods to assure uniform availability in the market.

Although pulses, oil seeds, and soybean have high nutritive value and are ideal crops for irrigation schemes, the market for these products has not picked up in Sri Lanka, and therefore at present yield levels there is little chance that farmers will select these crops. Crops like chilli and cotton need to be produced in dry weather conditions to assure quality of product and crop protection measures against pests and diseases. The flowering and fruiting of grapes are best controlled by controlling irrigation water. Sugar cane is best produced under irrigation to control cane quality. If sugar cane is grown under rainfed conditions, the cane will not mature under continuously moist conditions. If dry weather sets in, all the rainfed cane will mature at one time and can over-mature if they are not harvested within two to three months of dry conditions. Any cane harvested during dry weather will not rattoon uniformly until some rainfall occurs.

Soybean can tolerate certain excess moisture conditions and would be a suitable crops along with other pulses for the poorly drained lands under minor irrigation schemes during the dry season. Presently the demand for soybean is low and according to minimum nutrition standards only 5,000 ha are required. The possibility exists to vastly expand the use of soybeans in the human diet and animal feeds directly or in processed form, and thus the area planted to soybean can be expanded.

There are varieties of fodder grasses which are suited to well- and poorly-drained soils. A livestock enterprise based on stall-fed cattle would be a viable alternative to rice on both land classes.

Constraints to Diversified Cropping and Irrigation

Physical constraints. Most crops cannot tolerate excess soil moisture, waterlogging, and high ground water tables and are typically grown on well-drained lands. Only 72,000 ha of such land is currently available under irrigation schemes. If grown on the poorly-drained lands with a minimum of risk, these fields would need sub-surface drainage and land surface grading, costing about US$1,100/ha. It is difficult for the farmers and officials to recognize the boundary between well- and poorly-drained lands. Crops which were inadvertently grown on poorly-drained lands have been frequently damaged by excess moisture, but have done well when rains did not occur.

Although the more recent irrigation schemes were commissioned to grow diversified crops on well drained lands and rice on poorly drained lands, all farmers at the beginning were bent on growing rice and developed their lands into a series of small basins. No precision levelling was done on these fields. Instead a procedure was carried out (termed basic levelling or rough levelling) which involved levelling off humps and filling depressions with a bulldozer. This type of land levelling and the formation of small basins which have their own different elevations, makes both irrigation and drainage difficult. Farmers make matters worse by either planting upland crops on the flat surface of the basin or on raised beds of about 1.0-1.5 meter width.

It has been observed that seepage of 20-30 per cent occurs in unlined channels on reddish brown earth soils (Corey 1982). This, along with seepage water from rice fields with standing water, increases ground water tables and damages upland crops.

The reddish brown earth soils, the dominant soils in well-drained lands under most irrigation schemes, are friable (easy to till) only through a narrow range of moisture content. The soils are hard when dry and sticky when wet, hindering tillage operations for upland crops. Land preparation for upland crops should therefore be done after a pre-irrigation application of 50-70 mm. Land preparation and inter-cultivation operations for upland crops cannot be done efficiently during rainy periods. The consumption rate of water by diversified crops is less than rice, therefore the capacity of the canal network is generally not a constraint to diversification.

Agronomic constraints. Only a few crops, such as soybean, sugar cane, and coconut are somewhat agronomically tolerant to excess moisture. However, it is possible to develop an upland cropping package for the rainy season by establishing the crop before the rains set in and harvesting after the rainy period is over. For this, the crops should be of the 16-18 week age class. Promising varieties of this age class are not available for soybeans, green gram, black gram, cowpea, or maize. Furthermore, the yield levels of crops like soybeans, cowpea, green gram, black gram, ground nut, and maize are not sufficiently high to be attractive alternative crops for farmers.

The favorite crop of farmers next to rice is chilli. The recommended varieties are 20-24 week varieties, but they need water over an extended period. During the dry season farmers are advised to grow 12-15 week rice varieties to save water, but there are no savings on well-drained lands if it is all planted to long-aged chilli.

Economic constraints. Marketing has been the major constraint to diversified cropping in irrigation schemes during the last two decades. Department of Agriculture Extension Officers persuaded farmers to grow a wide range of crops including pulses, chilli, and vegetables. At harvest, the prices for these crops were deliberately lowered by private traders, and farmers had to destroy their produce. Consequently, Extension Officers found working with the farmers difficult during the next season. Recently this problem has received more attention. The government has fixed guaranteed minimum prices for pulses, soybean, and maize. However, unrestricted imports of competing products such as chilli, onion, and Mysore dhal (lentil) have contributed to the depressed market for local produce.

Diversified cropping under irrigation requires high levels of inputs to be successful. Farmers find it difficult to maintain these levels because capital is generally not available, at least in the initial years. Farmers have found it difficult to obtain credit from formal sources such as banks, and the credit available from non-formal sources is expensive.

Social constraints. Although Sri Lankan farmers are thought to be experts in rice farming, this is not the case for farmers selected as allottees for new irrigation schemes. An objective of new schemes is to give land to landless people. The traditional occupation of a majority of these is shifting cultivation where an variety of non-rice crops are grown. These farmers have a better knowledge of upland crop culture than rice culture. Furthermore, they do not have knowledge or experience in conventional surface irrigation methods for upland crops. Such knowledge and experience is possessed only by a few farmers, especially in the northern districts of Sri Lanka: sugar cane farmers and workers and a few researchers.

Most Sri Lankan farmers prefer to produce their own rice to secure a food supply. Although it is pointed out to farmers on irrigation schemes that farmers on lands with highly permeable soils in the north and northwest, vegetable farmers in the hill country over 1,000 meters, and farmers who engage in shifting cultivation do not grow rice.

Many farmers also complain that they must engage in farming activities almost daily when they take up diversified cropping, whereas they have more free time when rice is grown. This free time is generally used in another occupation, so in effect they become part-time farmers. Consequently they pay less attention to their farms, get low returns, and are forced to seek more and more off-farm jobs. This trend must be reversed in order to achieve higher productivity from the land and water resources. Diversified cropping offers an avenue to achieve this objective.

Another constraint observed in some irrigation schemes is the clash of New Year festivities (mid-April) with the ideal dry season starting date of cultivation activities. In most schemes there is shortage of irrigation water for the dry season. In April/May about 100-200 mm of rain falls which can supply crop water requirements if the crop is established before the rains and the fields laid out to dispose of excess water. Unfortunately the optimum period to plant is around the Sinhalese and New Year festival, and most farmers like to enjoy the festival and do their planting at this auspicious time. Most of the rainfall contribution is wasted by this time. In the Wet Zone, farmers who depend on rainfall engage in these operations when the rain starts whether it is New Year or not.

Management constraints. Because rice requires more water than upland crops, the irrigation system can supply adequate water for diversified crops. However, it is essential to prevent excess supply. With the present system of unlined channels, seepage, and shallow ground water tables, heavy rainfall causes the ground water tables to rise and damage upland crops. Therefore, water issues should be immediately stopped when heavy rainfall occurs. This requires communication between the field and headworks.

In most irrigation schemes farmer organizations are expected to attend to operation, maintenance, and water management at least at the tertiary levels. Although a sort of farmer leader (Vel Vidane) was able to control water issues decades ago, newer arrangements only work in isolated locations due to lack of leadership and training, and because of rivalry. The present management in charge of irrigation schemes has failed to appreciate that radical on-farm irrigation systems, and on-farm drainage are essential for farmers to successfully undertake diversified cropping under irrigation.

RESEARCH

Research on irrigated diversified crop cultivation is underway at several locations. The Department of Agriculture carries out research along these lines at Maha Illupallama, Angunakolapelessa, Girandurukotte, and Tinnevely. The Sugar Cane Research Institute carries out irrigation research for sugar cane at Kantale and Hingurana. The Mahaweli Authority and the Irrigation Department carry out a joint research effort on on-farm water management at Kalankuttiya. Some of the ongoing research and findings are summarized below (Somasiri 1981; Dimantha 1981, 1982, 1985; Lewis 1973; Sivanayagam 1973).

Crops

Experiments have been conducted to select alternative crops to flooded paddy in order to reduce water consumption, increase productivity per unit of water while assuring good economic returns to the farmer. A narrow selection of crops which can assure good economic returns along with a range of water duties is presented in Table 3.

Table 3. Recommended diversified crops for irrigation schemes compared to rice, giving average net returns (in Rupees per hectare*), on-farm water duties (in millimeters), and Water Use Index (in Rupees net return per 100,000 liters applied water**).

Crop	Average range of:		
	Net Return	Water Duty	Water Use Index
Yala season, well-drained lands:			
Sugar cane	15000 - 25000	1000 - 1500	125 - 250
Chilli	15000 - 35000	500 - 700	200 - 400
Brinjal	15000 - 25000	500 - 800	200 - 300
Soybean	5000 - 15000	250 - 450	75 - 150
Cotton	5000 - 20000	250 - 450	125 - 425
Yala season, poorly-drained lands:			
Rice	6000 - 15000	1200 - 1500	50 - 100
Maha season, well-drained lands:			
Soybean	2500 - 6000	50 - 100	100 - 300
Maha season, poorly-drained lands:			
Rice	5000 - 10000	600 - 750	60 - 100

*Sri Lankan Rupee 28.00 = US$1.00; **100,000 liters = 1 ha covered by 1 cm of water.

The returns from upland crops could be further increased by intercropping. Some promising combinations are chilli and soybean, cotton and green gram, cotton and soybean, sugar cane and green gram, and sugarcane and soybean. In addition to providing additional income, intercropping helps to control weeds in the early stages. Additionally, sugar cane intercrops provide an income in about three months while the main income from sugar cane only comes after one year.

Land preparation for upland crops means a pre-irrigation application of 50-100 mm whereas farmers use over 300 mm for land preparation for rice. Demand for irrigation water has been considerably reduced by timing the growth periods to coincide with rainy periods.

Irrigation Layout and Procedures

The furrowed basin system of irrigation layout (Joshua 1980) was developed to grow upland crops in the dry season and upland rice in the wet season on well-drained lands. It is easy for farmers to adopt this system. The furrowed basins are about 10 square meters, with furrows spaced at 0.6-0.9 meters, depending on crop spacing requirements, and at a gradient of 0.2-4.0 per cent. An irrigation stream of 5 liters/second (lps) for 15-20 minutes will supply a 50-60 mm water. An application efficiency of over 80 per cent can be achieved with this method but surface drainage efficiency is poor.

Graded furrows could also be used to irrigate upland crops. However, it is difficult for farmers to adopt this method. To achieve efficient irrigation, water streams of a particular size have to be released into a set of furrows to advance a certain distance over a particular period of time; subsequently this stream has to be cut back to another stream size for another period of time. When the stream is cut back, the remaining water has to be released to another set of furrows. To overcome this complicated procedure, a modified procedure involving "basined furrows" is showing promise. Here the furrows are closed at the bottom of the field to prevent tail water runoff. When this method is adopted the farmer has to open the bottoms of all furrows to drain the fields of standing water during periods of heavy rainfall and close them during periods of irrigation. These operations could be carried out whenever required in small farms where the number of furrows involved is small and where the farmer is theoretically always available on the farm. If upland crops are to be grown in the wet season, the number of irrigation applications is limited, therefore some inefficient irrigation can be tolerated. The more important requirement during the wet season is efficient drainage, and the graded furrow system facilitates efficient surface drainage. The specifications for the graded furrow system is as follows: spacing 60-120 cm depending on the crop; grade 0.4-0.6 per cent; stream size, 2-5 lps per furrow; maximum furrow length 100 meters.

Land Shaping

Proper land shaping or levelling is an essential pre-requisite for good surface irrigation and drainage in furrow and basin systems. Land shaping is required to obtain a smooth surface to present specifications, because most lands have uneven surfaces initially. Heavy rain during a seven to ten day period will drastically damage upland crops due to waterlogging in lands not laid out for proper drainage. Insurance should be taken to avoid this sudden damage by levelling lands.

Joshua and Knierim (1981) developed a method of shaping lands into terraces with mild slopes. The procedure was suitable for conditions in Sri Lanka's Dry Zone: soil depths are shallow, therefore earth cutting must be minimal, averaging less than 15 cm; and typical range of predominant ground slopes is 2-3 per cent. The equipment used for land shaping were rear-drawn bucket scrapers and land planers which could be operated with four wheel tractors of about 60 horsepower rating. This equipment is ideally suited for small farms because of their small size. Specifications for precision land levelling are: terrace grade of 0.4-0.6 per cent; maximum depth of soil cut is 0.15 meter; terrace width depends on initial slope of land (i.e., 1 per cent slope, 30 meters wide; 2 per cent, 15 meters; 3 per cent, 10 meters; 4 per cent, 7.5 meters; 5 per cent, 6 meters; 6 per cent, 5 meters).

Hydrology

Initial studies (Corey 1982) show that ground water levels build up on formerly well-drained lands due to contributions from standing water in rice fields on reddish brown earth soils and seepage from channels. The seepage amounts from various situations are given in Table 4.

Table 4. Seepage from channels and fields.

Site	Range of seepage rate	
	mm/day	m^3/day per kilometer
Secondary channel		320 - 1280
Newly puddled rice field (RBE soil)	70 - 120	700 - 1200
Old puddled rice field (6 years)	10 - 20	100 - 200
Dry plowed field	200 - 1000	2000 - 10000

Further Investigations

Research has to be continued to improve the package of diversified cropping so that farmers earn better returns and the land and water resources are better utilized. New crops, crop combinations, and crop management practices have to be continuously evolved. Because Sri Lankan farmers prefer to grow some rice, a package of upland rice, grown under non-puddled conditions without standing water on the graded terraces, will have to be developed. The important gaps for achieving these objectives are finding suitable varieties with deeper rooting systems and promoting weed management practices. Some promising crop combinations which have to be further developed are cotton and groundnuts, maize and soybean, and sugarcane and upland rice. Some new crops which may be promising for irrigated lands in Sri Lanka are <u>Vinca rosea</u>, <u>Pentadesma butryceae</u> (for the chemical industry), and fruit crops.

Better on-farm water management is required before farmers can easily adopt diversified cropping. Further work has to be done on irrigation layout, irrigation procedures, and timing of irrigation so that farmers can handle the irrigation water with the technology available to them. It is desirable to evolve techniques to enable farmers to control the amounts of application by observing the depths in a furrowed basin. Graded furrow systems should be further defined.

RECOMMENDED PRACTICES

To ensure successful diversified cropping most of the management practices including irrigation management have to be carried out on the farm itself. Crops have to be selected to give best economic returns to land, water, and farmers. These crops should meet national requirements or have export potential. When planned water supplies are available short term crops such as chilli, vegetables, cotton, onion, and soybean and long term crops such as sugar cane should be selected. Crop combinations such as sugar cane/soybean, sugar cane/green gram, cotton/soybean, cotton/green gram, and chilli/soybean can be practiced. If the water supplies are limited, cotton and soybean can be grown with advantage. Farmers should be given guidelines to judge the stage at which crops require irrigation. Diversified cropping can be improved if water is available on demand to farmers and if the main irrigation system can adjust to varying demand.

Further work will determine if it is desirable to alternate between traditional rice culture and diversified cropping on the same land. For rice culture to use water economically, a somewhat impervious layer has to be built up to minimize percolation losses on rice fields with standing water. It takes years of continuous puddling to build up the impervious layer. Dry tillage for upland crop cultivation will destroy this layer.

For short term upland crops, furrowed basins could be used with advantage. If long term crops such as sugar cane run into the rainy season, or if short term upland crops are grown in the rainy season, graded furrows should be used to facilitate surface drainage. The furrow spacing for sugar cane is 90-120 cm and for most other crops is 60 cm.

Initial development of land into graded bench terraces at 0.2-0.6 per cent slope is an essential prerequisite on well drained lands to facilitate efficient surface irrigation, surface drainage, and erosion control. It may be required to re-smooth the land surface once every one or two years. This could be easily done at low cost using a land planer with a float attachment drawn by a 35-40 horsepower four-wheel tractor.

Because the unlined channels allow a lot of seepage with consequent loss of irrigation water and build up of undesirable water tables, channels should be lined. Although additional costs are incurred in lining channels, subsequent maintenance costs are low.

The desired conditions to provide good aeration conditions for upland crops is for the water table to be below 60 cm depth and preferably below one meter for most of the crop growing season. Because the major cause of high water tables is seepage from channels and rice fields, it must be minimized. This can be done by lining channels and not growing rice on well-drained lands. Field drains 1 meter deep with capacity of 13 lps per ha, and main drains of 2 meters with the same capacity can dispose of excess rainfall. Surface drainage can be facilitated by terracing the land at a mild gradient with even surfaces. Furrows will enhance surface drainage.

Well-trained farmer organizations with some authority can ensure good water management at the tertiary and farm level. They can ensure that farmers receive their share of water and advice on good practices on the farm.

NATIONAL POLICY

The government is committed to diversified cropping on rainfed lands, and especially on the 80,000 ha of well-drained lands in the major irrigation schemes. Credit facilities, either through the formal or the informal sectors, are being improved to ensure timely availability of inputs such as fertilizer and pesticides. Research and extension, and seed production programs are being strengthened. Although improvement in the market for diversified crops should come mainly through private sector participation, the government has intervened to fix floor prices and bring market information to farmers. The market could be further improved by controlling the import of substitutes and promoting the export of produce. Assistance given to agro-processing facilities such as animal feed mills, soybean processing plants, fruit and vegetable canning and industrial chemicals will also improve the market for diversified agriculture. It would be economical for the government to subsidize some diversified cropping enterprises which have to compete with imported produce such as sugar and pulses and also enterprises with a long gestation period such as irrigated fruit crops for export markets.

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REFERENCES

Amarasiri, S.L. 1965. A study of some rice irrigation waters of Ceylon. Tropical agriculturist 131: 1-17.

Amarasiri, S.L. 1973. Water quality of major irrigation waters of Ceylon. Tropical agriculturist 139: 19-25.

Amarasiri, S.L. 1978. Water quality of Vanathavillu. Peradeniya, Sri Lanka: Central Agricultural Research Station.

Corey, A.T. and P.H. Jayawardena. 1982. Ground water hydrology in the Mahaweli System H. Colombo: Irrigation Department.

De Alwis, K.A. and C.R. Panabokke. 1972. Handbook of the soils of Sri Lanka. Journal of soil science society of Ceylon 2: 11-97.

Dimantha S. 1986. Kalankuttiya on-farm water management research project research findings. In proceedings of the Workshop on Water Management in Sri Lanka. Documentation series no. 10. Colombo: Agrarian Research and Training Institute.

Dimantha, S., W.J.K.V. Ranjith, and J. Hale. 1981. Yala 1980 results of the on-farm water management research project, Kalankuttiya. Colombo: Irrigation Department.

Dimantha, S. and W.J.K.V. Ranjith. 1982. Maha 1980/81 results of the on-farm water management research project. Colombo: Irrigation Department.

Joshua, W.D. 1973. Physical properties of soils as related to irrigation and water management. Paper presented at the FAO/Sri Lanka National Seminar on Water Management and Control at the Farm Level, Colombo.

Joshua, W.D. 1977. Soil erosive power of rainfall in the different climatic zones of Sri Lanka. In proceedings of the Paris symposium AISH. Publication no. 122.

Joshua, W.D. 1980. Furrowed basin system of irrigation for upland crops. In Proceedings of the National Water Management Seminar. Colombo: Department of Agriculture, Maha Illuppallama.

Joshua, W.D., J. Hale, and W.J.K.V. Ranjith. 1980. Maha 1979/80 results of the on-farm water management research project, Kalankuttiya. Colombo: Irrigation Department.

Joshua, W.D., G.C. Knierim. 1981. Levelling small farms to bench terraces. Colombo: Irrigation Department.

Land and Water Use Division. 1976. Agro-ecological regions map of Sri Lanka. Peradeniya, Sri Lanka: Department of Agriculture.

Lewis, J.A. 1973. Methods of irrigation. Paper presented at the FAO/Sri Lanka National Seminar on Water Management and Control at the Farm Level, Colombo.

Ministry of Agriculture Development and Research. 1984. Crop agriculture development strategy. Colombo: Ministry of Agriculture.

Ministry of Finance and Planning. 1984. National agriculture, food and nutrition strategy. Colombo.

Ministry of Finance and Planning. 1986. Public investment 1986-1991. Colombo.

Moorman, F.R., C.R. Panabokke. 1961. Soils of Ceylon. Tropical agriculturist 117: 2-65.

Sivanayagam, T. 1973. Plant-water relationships and water use by crops in the environment of the dry zone of Ceylon. Paper presented at the FAO/Sri Lanka National Seminar on Water Management and Control at the Farm Level, Colombo.

Soil Survey Staff. 1975. Soil taxonomy. A basic system of soil classification for making and interpreting soil surveys. Publication 1. Washington DC: US Department of Agriculture.

US Salinity Laboratory Staff. 1954. Diagnosis and improvement of saline and alkali soils. USDA agricultural handbook no. 60. Washington DC: US Government Printing Office.

ECONOMIC POLICIES AFFECTING CROP DIVERSIFICATION IN THE PHILIPPINES

Marietta S. Adriano and Virgilio E. Cabezon

INTRODUCTION

Crop diversification emerges mainly from the desire to reduce risk and redistribute the work load. As a strategy, it can be justified as an end in itself -- where land in relation to population is scarce and when shifting production of a particular crop to a combination of crops or to other higher-value crops results in higher farm incomes.

The adoption of crop diversification schemes is dictated by a combination of physical and economic factors. The physical factors associated with resource endowments consist of land (soils) capability, rainfall patterns, water quality, crop suitability, and, more importantly, technology which is a potential shifter of supply of an alternative cropping scheme (Gonzales 1985). On the other hand, economic factors include costs, prices, markets, and economic viability of the alternative cropping schemes. The interplay of economic factors is orchestrated by the government's economic policies.

The diversification of Philippine agriculture began in the late 1970s. However, diversification of specific non-rice crops in irrigated lands began only during the mid-1980s. This stemmed from the desire of the Philippine Government to raise farm incomes and intensify employment opportunities in rural areas. Of late, a series of economic reforms, including measures to hasten crop diversification have been initiated. Special attention is now being given to diversifying out of sugar in view of the low world demand and market price, which is expected to continue.

This paper has the following objectives: 1) to identify and examine the recent economic policies affecting crop diversification, 2) to assess the implications of crop diversification on the government's resource allocation for irrigation and other support programs, and 3) to determine the prospects for crop diversification out of rice on irrigated lands.

ECONOMIC POLICIES

Crop Diversification in the Medium-Term Philippine Development Plan

Crop diversification is identified in the Medium-Term Philippine Development Plan, 1987-1992 (MTPDP) as an explicit strategy to strengthen production systems in the agriculture sector. This strategy is being pursued to

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support food security, greater employment opportunities, increased farm incomes, and reduced dependence on traditional export commodities (i.e., sugar and coconut oil/copra) which are facing declining demand in the world market. As stated in the MTPDP:

> Potentially new viable agricultural crops (based on comparative advantage) shall be promoted in all regions. The substitution of appropriate crops for coconut and sugar cane in areas where these commodities are no longer financially/economically viable shall be initiated. [In a broader context,] the development of alternative production systems supportive of non-traditional crops and complementary processing activities for the conversion of primary commodities into high-value products that have domestic and international demand shall be given priority attention.

The Plan's strategy in the medium-term would be an employment-oriented and rural-based development process to directly address the goals of poverty alleviation and equitable distribution of benefits. As envisaged, rural poverty incidence is projected to decline from 64 per cent in 1985 to 47 per cent in 1992. Rural under-employment, a pervasive problem in the rural areas due to the seasonal effect of labor, will decline from about 41 per cent in 1987 to 32 per cent in 1992. A crop diversification program may contribute to reducing the rate of under-employment during the plan period. Adriano (1981) points out that higher cropping intensity due to the combined effects of irrigation and diversified cropping patterns increases the utilization of land and labor.

Recent Economic Policies to Promote Crop Diversification

The sector-specific policies which may influence the promotion of crop diversification proceed from recently introduced macro-economic policies. The Philippines is now pursuing bold economic reforms which call for less government intervention in areas where the private sector can perform competitively: liberalization in the trading and marketing of essential agricultural commodities, elimination of subsidies and export taxes and the adoption of market interest rates. These policies and programs are expected to dictate the pace of agricultural development in the coming years.

Pricing policy. The price system for rice constitutes the most important policy. Rice is grown by 1.6 million farmers involving an irrigated area of approximately 1.44 million hectares (ha). Consequently, the government maintains a price support for rice to protect the income of the rice farmers. However, the price ceilings on milled rice have been removed.

It has decided to reduce the price support for rice from the current US$171 per metric ton (MT) to about US$147/MT. This was to be announced just before the onset of the second (dry) season crop for crop year 1986/87; however, it was temporarily postponed for political reasons. The decision to subject the price support for rice to a periodic review is expected to become official policy. This can also mean that the price support policy would now be a temporary price protective measure, unlike in the past. Furthermore, while the current price support uses the cost of production as its basis, there is concerted effort to also consider the world market price for determining the appropriate price and allocating resources more efficiently.

The National Food Authority (NFA), the government's central grain marketing arm, procures rice directly from the farmers at the established floor prices during harvests and unloads into the market enough milled rice to support the government's price stabilization scheme for grains.

There are strong economic reasons for an across-the-board reduction in price support for rice. Foremost is the budgetary implication, since price stabilization is costly. At the current level of price support, the US$59 million is allocated for procurement. Other costs, including turn-over and administrative costs, total about US$28 million. On top of this, the NFA manages to procure an annual average of only about 6.3 per cent of the total palay (unhusked, unmilled rice) production, instead of its 10 per cent target. Thus, the ability of the NFA to influence the market is defeated, and only a few farmers benefit from the present price support.

The NFA projects that if the price support is lowered and changes are made in marketing strategy (i.e., buying from private traders instead of only from the farmers), NFA would be able to trade a larger volume of rice in the market, sufficient to stabilize the prices of rice at any given bumper harvest. However, this conclusion holds only if the traders are competitive and their operations are efficient.

The supply-demand outlook suggests that the Philippines is more than self-sufficient in rice. Although rice has been imported, local production is generally more than enough to satisfy total consumption (Table 1). Bullish years occurred in crop years 1978/79-1980/81 when the country exported an annual average of around 200,000 MT.

Table 1. Supply and domestic use of rice (in thousand MT), Philippines, crop years 1975-84.

Yr	Begin stock	Production	Import	Total	Export	Seed	Feed/ waste	Total food	Per capita	End stocks
75	837	3674	238	4769	0	170	240	3430	82.18	929
76	929	4052	71	5052	0	174	263	3837	89.46	778
77	778	4281	24	5083	0	173	278	3791	86.05	841
78	841	4607	7	5455	46	173	299	3725	82.31	1212
79	1212	4847	0	6059	38	172	315	3994	85.92	1540
80	1540	5093	0	6633	236	177	331	4314	90.36	1575
81	1575	5020	0	6595	175	169	326	4594	93.67	1331
82	1331	5279	0	6610	10	168	343	4569	90.87	1520
83	1520	5041	0	6561	11	158	228	4586	88.97	1478
84	1478	5128	0	6606	30	154	333	5099	96.50	990

Seed use is estimated at 1.5 sacks of 50 kilogram (kg) of rice/ha; feed/waste is estimated at 6.5 per cent of total production; Bureau of Agricultural Economics 1985.

Given the annual population growth rate of 2.3 per cent, the annual growth rate in per capita income of 3.9 per cent, and the income-demand elasticity of rice at 0.10, the domestic consumption is estimated to grow annually at around 2.7 per cent in the short to medium term.[1] This is less than the annual growth rate of production (about 3.7 percent) during the same period. Unless the government takes precautions to control rice production, a saturation of the domestic market may appear in the medium term.

Two scenarios may be deduced from the government decision to reduce the price support for rice. First, the government implicitly wants some rice farmers to shift to alternative cash crops. Although there is no empirical evidence showing the supply elasticities of cash crops relative to changes in the price of rice, a further decline in the price support for rice will likely cause a transfer of resources to other crops. A possible indication would be the relative profitability of rice vis-a-vis other cash crops (Table 2).

Table 2. National average yield (in metric ton/hectare), actual price (in Philippine pesos* per kilogram), and relative profitability (in pesos/hectare) of various crops, Philippines, 1985.

Crops	Yield	Price	Total returns	Cost of production	Net returns	Return/ costs**
Sugar cane	53.13	0.22	11689	10435	1254	12.0
Rice	2.40	3.24	7776	5370	2406	44.8
Corn-yellow	1.04	2.80	2912	2078	834	40.1
Corn-white	0.97	2.91	2823	2078	745	35.8
Soybean	0.99	7.30	7227	3697	3525	95.3
Sweet potato	4.62	1.76	8131	2245	5890	262.4
Mungbean	0.69	15.40	10626	3780	6846	181.1
Peanut	0.85	10.10	8585	6959	1626	18.9
Onion	6.66	11.53	76790	30207	46583	154.2
Garlic	2.46	33.44	82262	21787	60338	276.9
Tomato	8.36	4.10	34276	9305	24971	268.4
Cotton	1.01	14.05	14191	6324	7866	124.4

* Philippine peso 20.43 = US$1.00; **per cent returns to cost of production; Bureau of Agricultural Economics 1985.

The government emphasizes this scenario by simultaneously adopting price guarantees for corn, cotton, and tobacco, three promising alternative crops which can be grown in rainfed/irrigated lowland areas. Although the price support for corn is also envisaged to be lowered as with rice, this move is not expected to cause a significant drop in its production. The demand for corn will still perk up in view of the growing needs of the commercial hog and poultry industries. The Philippines has been importing corn at an annual average of 317,000 MT (valued at US$45 million) during the past five years. Total corn production is estimated to grow by 6.4 per cent from 1987-1992.

Second, in the context of fiscal control, the government wants to reduce its direct intervention function in the marketing of rice by relying more on the private sector both to trade (domestic as well as international) and to hold stocks. The government, through the NFA, will only act as a buyer and seller of last resort in the domestic market to prevent undue competition and to achieve the social goal of the price stabilization policy. It is now the intention to put more emphasis on investments which can improve marketing efficiency rather than directly subsidizing the market.

Recently, the Philippines has deregulated prices of agricultural inputs, such as fertilizer and chemicals. These comprise about 35 to 45 per cent of the normal cash production expenses for most crops including rice. With this policy, prices of farm inputs are expected to decrease with the removal of restraints. This deregulation could hasten the adoption of new technologies for crop diversification in the country.

Tax and tariff policies. Tax and tariff policies affect the cost of inputs and exports of agricultural products. The new measures call for "pragmatic and selective import liberalization and constructive protectionism." They have two objectives: to eliminate import quotas and minimize the number of permits required for importation, and to adjust present tariffs so that the average tariff level is significantly lower. The new tariff rates would range from 10-30 per cent on agricultural producer goods (mainly farm inputs) and 40-50 per cent on farm consumer goods. Duties and taxes are not imposed on fertilizers. Safeguards for the liberalized entry of cheap agricultural imports are adequately ensured by imposing quantitative restrictions based on local production forecasts and international market conditions. Another feature of this tax reform is the abolition of all export taxes. Major agricultural export crops have previously had nominal taxes ranging from 4-10 per cent. Export taxes explain the negative effective protection for most agricultural commodities in the past.

Empirical studies in the Philippines show that keeping the cost of inputs artificially high by trade restraints implicitly taxed the agriculture sector at rates ranging from 19-47 per cent. Furthermore, the overvalued foreign exchange kept the peso value of agricultural exports artificially low. The penalty on exports has been placed at 15-20 per cent.

The new tariff rates are foreseen to motivate a shift toward adoption of modern technologies. The costs of agricultural inputs are expected to decrease and, consequently, use of better fertilizers, chemicals and seeds will increase. The net effect will be increased productivity. The elimination of export taxes may similarly encourage the production of crops with export potential. Corn, cotton, and soybeans, all routinely imported, could be grown in-country with comparative advantage (Gonzales 1985). Estimates of the domestic resource costs (DRCs) ranged from 0.29-0.62, which imply that producing these commodities locally is economically more efficient.

Subsidy policy. The gradual elimination of all subsidies is a national policy. The national goal is to make the institutions providing services to all sectors of the economy efficient. In agriculture, the subsidies are being gradually eliminated inasmuch as the pricing of inputs and outputs has already been deregulated. The removal of substantial subsidies in favored commodities like rice, sugar, and coconut is an attempt to encourage the farmers to diversify their farming operations.

Irrigation is one input subsidized by the government. The subsidy to irrigation comes in the form of equity contributions to agencies involved in irrigation development, particularly the National Irrigation Administration (NIA), budgetary appropriations for the construction and maintenance of the facilities, and interest charges on capital costs in the construction of the irrigation facilities.

The subsidy for operations and maintenance (O&M) has already been terminated and allocations for new construction are slowly diminishing. Loans and grants from multilateral and bilateral funding agencies have slowed down. In addition, the government has been contracting its equity contribution to NIA. National equity participation is to be terminated in due time.

These actions are expected to threaten the financial viability of the NIA, considering that the agency has not been strong in collecting irrigation service fees (roughly 50 percent of current collectibles in 1980s; see Small, 1987 for further discussion). NIA has responded by adopting a range of practices: providing technical assistance to water users organizations and allowing them to operate and maintain the diversion structures, particularly those small and financially marginal systems converted into small-scale communal systems; providing monetary incentives in the form of commissions (roughly 2.5-3.0 per cent) to water associations that are able to collect 70-100 per cent; and setting up joint liability schemes with water/farmers associations involved in the O&M for NIA's communal and pump irrigation systems. Despite these measures, NIA has cash flow problems compounded by a dismal collection performance and is now contemplating raising its current irrigation service fees (ISFs), an option which will be enforced three years from now.

The implications of raising ISFs may be viewed in two ways. From NIA's point of view, this policy seems the most feasible and pragmatic solution to improve its services. The rising cost of O&M expenditures can only be compensated by a corresponding hike in ISFs. From the farmers' perspective, the increase in ISFs would mean an added burden which they may be unable to pay unless they diversify their rice farming operations. However, if the incremental service fees can justify satisfactory irrigation services, farmers can be expected to pay for the increased fees and still receive substantial net benefits from irrigation. The study by Small et al. (1987) shows that if irrigation services in a typical situation are satisfactory, the current irrigation service fee is equal to about 10 per cent of net benefits of irrigation and the average O&M costs per hectare are equal to about 7 per cent of net benefits. NIA's micro-farm level studies show that farmers are willing to pay for a price that can provide them good service. The increased irrigation service fees may also be offset by the deregulation of the prices for agricultural products.

NIA's lower ISF for non-rice crops or 60 per cent of the ISF for rice is an encouragement for farmers to diversify to non-rice crops. There may be a need to review this figure to encourage more crop diversification to crops which use much less water.

Credit subsidies for the pampered Masagana 99 Program in the form of low interest rates and preferential access of the rural banks to the re-discounting window of the Central Bank have also been eliminated. The current policy is for interest rates to follow market rates. To compensate for removal of this subsidy, measures to reduce transaction and risk costs are, however, being pursued to improve the accessibility of small farmers to credit. Such measures include improvement in credit documentation, greater investments in transport/communications, and expansion of the coverage of crop insurance to crops other than rice and corn.

Scrapping of preferential and highly subsidized credit programs for rice and other single-crop programs is another indication of the government's effort to push crop diversification. Credit programs are now along the concept of the Integrated Rural Financing Project of the Ministry of Agriculture and Food. The concept is to package a credit facility for the farm household based on the whole farm budget for a multi-crop/livestock enterprise. This approach moves away from the one crop per season type of lending.

Public expenditure policy. As envisaged in the MTPDP, increased public expenditures on research and extension and other rural infrastructure facilities complement other policies in hastening the process of crop diversification. Government funding for research and extension is projected to increase from the current level of 0.2 per cent to around 1.0 per cent of the gross value added (GVA) in agriculture. The additional investment calls for a stronger linkage between research and extension, a perennial problem in Philippine agricultural development. This will be accomplished by decentralizing research and extension systems taking into consideration the needs, demands, and potential of farmers. In support of this, the research thrusts for crop diversification include a) development of high yielding varieties which are resistant to major pests and diseases and which are not input intensive, b) development of technologies for good quality seed production and for off-season production of crops, c) development of viable alternative farming systems technologies (e.g., rice-based cropping patterns) for irrigated and rainfed areas, and d) development of post-harvest and storage technology and processing methods especially for perishable crops, to minimize crop losses and extend product availability year round.

Investment in rural roads, transport, and communications create an efficient price system, a potent promotion for crop diversification. Under the MTPDP, the government intends to rehabilitate and construct 52,348 kilometers (km) of feeder/barangay (smallest political unit in the Philippines) roads and 14,133 km of secondary roads, representing 68.8 and 18.6 per cent of the total physical target for roads, respectively. Total investments alloted to this program stand at US$1.64 billion or 52 per cent of the total investment for the national highways development program.[2] Consequently, the road density is expected to attain 0.57 km/square kilometer (km) of land area and about 3.02 km/1000 population. Furthermore, the road component is given a greater allocation in the Community Employment and Development Program (CEDP). Under this emergency employment program of the government, total investments for roads stand at US $92.26 million or 48 per cent of the total cost of the CEDP.

Other projects include secondary and feeder ports, communal irrigation, drainage and rural electrification -- designed to promote increased agricultural production, encourage small and medium industries, support land reform, and increase rural incomes on a wide scale. The increased emphasis given to rural/agricultural infrastructure is meant to open new market opportunities for farmers through greater access to favorable output and input prices and to lower the cost of delivery of support services to the countryside. This, eventually, will lower the cost of agricultural products to consumers.

The promotion of crop diversification is, likewise, expected to be strengthened with the launching of agricultural information services in the rural areas. This would enable and encourage farmers to shift to the production of more profitable crops on the basis of accurate and timely information (e.g., production technology, prices, market opportunities).

<u>Land tenure policy</u>. Security of land tenure for farmers is essential if landholdings are to be properly developed and for capital to be invested. The conversion of share-crop tenants into leaseholders/owner-cultivators, a major thrust of the Agrarian Reform Program in rice and corn areas, assures the farmers greater flexibility in deciding the best use of their lands. As such, crop diversification, particularly in rice and corn areas, is expected to proceed favorably following the recent adoption of an improved and more comprehensive agrarian reform program.

The essential elements of the program include the resolution of issues on land titling, registration, land disputes, and ownership, and the acceleration of transferring land ownership to about 244,000 rice and corn farmers in two years. Complementary to these is the expansion of the scope of agrarian reform to all arable public and private lands regardless of crops planted, size of holdings, or tenurial arrangements.

PROSPECTS

Emerging Economic Issues and Constraints of Broader Relevance

Despite the appropriateness of the policies discussed earlier, changes under the envisioned diversification are not easy to introduce. Some of the vital economic issues and constraints are briefly presented below.

<u>Matching supply and demand</u>. Production of alternative crops is not much of a problem provided the basic inputs and technologies are available. Some farmers are now devoting portions of their irrigated lands to other cash crops during the dry season, but only on a subsistence level. Matching the output to a market is the more fundamental issue. Except for a few crops like corn, soybeans, and cotton, most alternative crops have limited markets. Either the marketing system is not yet developed or it does not exist. If a market for a particular commodity exists, informed farmers swarm to produce that commodity. Farmers have overproduced whenever favorable prices exist, as shown by onion growers in Central Luzon, the rice granary of the Philippines. Understandably, farmers respond poorly when the price of the alternative crop is erratic. Corn is a typical example. Despite the current price

guarantee for corn, farmers won't plant it because of depressed prices at the farm-gate. In both cases, uncertainty in the market is a function of price, distribution, promotion, and post-harvest handling.

An efficient marketing system is a key element in transmitting price signals to growers to help them make rational decisions on planting alternative crops. If these signals are distorted, crop diversification cannot be expected to make an optimum contribution to agricultural growth. It is important to consider also the level of productivity needed to provide certain consumption levels.

Although the problem of marketing systems is being addressed in the MTPDP, the need for baseline studies on inter-regional marketing flow of major alternative crops becomes imperative. Studies including supply responses, price movements, and post-harvest handling techniques, are necessary in determining which alternative crops should be promoted.

Reallocation of investments. Greater investments in research, extension, marketing, infrastructure, and other support facilities will hasten implementation. This issue is being addressed in the MTPDP, but in the broader context of rural development. However, definitive budget support is necessary so that positive steps will make actual events correspond to the crop diversification strategy.

Research for irrigated non-rice crops is vital as there is a paucity of so-called mature technologies ranging from production to post-harvest handling techniques. A fundamental constraint is the absence of cost-effective/productivity-enhancing technologies for alternative crops in irrigated rice areas which can keep real costs of production under control. Farmers are still unaware of the economics of shifting from rice to other cash crops for lack of information dissemination through extension. An analysis of the cost of production of alternative crops is needed to determine the areas where incentives should be considered and also their comparative advantage. Similarly, the current irrigation facilities are meant for growing rice, and there might be a need to modify them to suit other cash crops. These activities require significant budgetary support from the government to introduce a crop diversification strategy on a large scale.

Strengthening of institutional linkages. Of particular importance is the issue of institutional mechanisms to be adopted so that farmers can take advantage of economies-of-scale. Cooperatives could be the answer, but their viability in remains a problem. Given the inherent bias of farmers in favor of rice production, what sort of institutional linkages should be considered so that they may elect to plant the alternative crops? Where can the government usefully "intervene" to assist the farmers? This involves specific incentives and questions of availability of inputs to be offered so that farmers will be induced to plant alternative crops.

Potentials/Outlook

The prospects for introducing crop diversification favor the policy incentives and the support programs currently being pursued. However, the pace of adoption may not be as fast as expected in view of technical, socio-cultural, and agronomic constraints. Moreover, the impact of these policies and programs must gestate before farmers could reap the expected benefits. Their response is often accelerated by the influence of specific programs and projects which lay out the projected benefits of a particular strategy.

In the immediate future, rice farmers in irrigated areas will have difficulty shifting to alternative crops. Areas most likely affected would come from the sugar lands where current government effort on crop diversification is concentrated. This is facilitated by controlling sugar production just enough to satisfy the domestic demand, the United States market quota and some allowance for reserves. Only about 65-70 per cent of the available sugar lands (320,000 ha) will now be devoted for growing sugar cane and the balance utilized for the production of alternative crops. The government is likewise contemplating irrigation as a means to improve the yield in sugar lands and to compensate for reduction in area.

Moreover, major activities during this period will be confined to further exploratory and pilot-testing on the economic, financial, and technical viability of non-rice crops in irrigated areas which can eventually lead to full-scale implementation by early 1990s. Several related programs and projects are being implemented to accelerate the pursuit of crop diversification. Brief descriptions of the programs/projects are given below.

Agricultural crop zoning. These are designed to provide the base for formulating land management policies. Specifically, it aims to determine the entire range of cropping and other land-use potentials in each province in the country. This will provide a physical agricultural land-use framework for the region that will rationalize the policy formulation for agricultural product development/promotion and marketing. Based on this scheme, attempts will be made to promote only suitable crops with comparative advantage in a particular area. Promotion will be done through the provision of appropriate post-harvest, marketing, and other support facilities to enhance their production. Presently, the project has been implemented in 35-75 provinces.

Sugar land diversification. The presence of the NIA in sugar lands has been limited due to the past priority given to irrigation of rice lands. Irrigation of sugar lands would serve several purposes besides increasing cane yields. By increasing farm productivity and thereby making possible further reduction in the total cropped area for sugar cane, irrigation would lower the transport cost of cane because the mill requirements could be filled by harvests within a shorter radius. Currently, transport is a major cost in sugar production.

Cancellation of nationwide rice and corn programs. This will eliminate past biases in favor of rice and corn production (e.g., Masagana 99 and Masaganang Maisan). This approach is expected to give a balanced emphasis on the development and exploitation of the other untapped potential resources in the agriculture sector. With the impending withdrawal of unqualified support for rice and corn nationwide, it is expected that farmers will engage in the efficient production of other crops.

Analogous programs to reduce risks.

a. Expansion of crop insurance aims to protect farmers from crop losses and the lending conduits against loan defaults. At present, only rice and corn are covered by the program. Eventually, the coverage will be expanded to other crops notably vegetables. This would encourage crop diversification.

b. Integrated rural financing (IRF) is an innovative credit approach aimed at effecting a comprehensive development scheme for agricultural and other specialized clientele communities by financing a variety of profitable projects including production, post-harvest marketing, and small rural non-agricultural enterprises.

c. Quedan Financing Program aims to augment the operating capital of traders/businessmen and encourage their actual participation in the local procurement of milled rice, corn, sorghum, soybeans, mungbeans, peanuts, and basic food commodities. The program also aims to further enhance the price stabilization program of the government. The expansion of the program to other crops is under consideration.

d. Highland Agriculture Development Project is designed to introduce irrigation for growing vegetables in the highlands of Benguet and Mountain Provinces. The project will benefit 6,600 highland farm families. This project is funded by an US$18.5 million loan from the Asian Development Bank (ADB).

e. Diversified Crop Irrigation Engineering Project aims to study the technical aspects of irrigating crops other than rice. The project, to be implemented by NIA, will be supported by a technical assistance grant from the Japanese International Cooperation Agency (JICA).

Implications of the Government's Irrigation and Other Support Programs

There is no doubt that the provision of irrigation is the easiest way to encourage crop diversification. With suitable irrigation management, one gains flexibility to be able to alter the traditional monoculture cropping to a wide array of farming systems. To the extent that a complement exists between irrigation water and the adoption of modern technology, the desired end product of increasing farm incomes is facilitated. However, the growing of alternative crops in irrigated areas will have different requirements. A full-scale implementation will necessitate changes in the priorities of the government in terms of investments in research, extension, marketing and other support facilities. If these requirements are satisfied, a significant contribution to agricultural growth is expected.

As discussed, the broad macroeconomic policies/programs indicate hastened crop diversification into non-rice in irrigated lands. The implications of these directions may be summarized as follows:

Farmers capacity to pay ISF. The government's decision to raise irrigation service fees three years from now is meant to improve the viability of

NIA and to encourage Philippine farmers to diversify their farming activities. With higher ISFs, the NIA should be able to provide optimum service to the farmers so as to allow flexibility for diversification.

The farmers' limited income realized from rice production is caused by factors such as low productivity, poor cropping intensity, depressed prices of rice at the farm-gate and high cost of fertilizers/chemicals brought about by a poor transport system. Recent policy changes instituted by government and the programs/projects designed to encourage crop diversification will most likely improve farm incomes and farmers' capacity to pay higher ISFs.

<u>Expansion of irrigated area</u>. The expansion of irrigated area will be brought about by using the same volume of irrigation water for crops other than rice and by the provision of irrigation facilities in sugar lands. Non-rice crops not only "spread out" the benefits of irrigation but the utilization process in itself is more efficient. Furthermore, the poor maintenance of irrigation facilities also reduces the possibility of achieving a cropping intensity (CI)[3] of 200 per cent. The average cropping intensity of rice lands under national irrigation systems is only 130 per cent which implies that 70 per cent of the service area may be increased if cash crops which use less water are substituted for rice, and/or irrigation service is made optimal through improved facilities.

The use of irrigation facilities for growing sugar cane is generally not a normal practice. It is estimated that 42,000 ha or about 10-12 per cent of the current sugar cane area is irrigated. Government now plans to provide irrigation to increase the yield in sugar lands. The use of irrigation will compensate for the reduction in the area devoted to sugar cane and even allow further reduction as productivity increases. This expansion in irrigated area means intensifying land-use and the enhancing agricultural productivity.

<u>Changes in research priorities</u>. Mature technologies for alternative cash crops are still inadequate. Good seeds and high yielding varieties, with the exception of corn, are hardly available in the market. Appropriate cultural management practices for different cropping systems still need further testing under various field conditions. Applied research is generally inadequate to support a comprehensive diversification strategy.

<u>Post-harvest facilities for other crops</u>. There is a need to design multi-crop post-harvest facilities particularly in processing, to encourage farmers to shift from one crop to another for each cropping season. Likewise, there is a need to convert/modify the existing post-harvest facilities for rice so that these could be used for other crops as well. This equipment should preferably be portable, low-cost, and locally available.

NOTES

1. $C = [(1 + GN)(1 + M)]$, where C = annual consumption growth, G = per capita income growth rate, N = the income-demand elasticity, and M = population growth rate. Estimates for the different parameters were taken from the MTPDP.

2. As compared to past investments, the share of the rural roads averaged only 24 per cent from 1979-83, and further declined to an average of 18 per cent in recent years.

3. $CI = \Sigma$(wet season + dry season + third crop areas)/service areas x 100.

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REFERENCES

Adriano, M.S. 1985. The impact of a Philippine irrigation project on labor intensity and income distribution. In T. Wickham (ed.) Irrigation management: Research from Southeast Asia. New York: Agricultural Development Council.

Agricultural Policy and Strategy Team. 1986. UP agenda of action for the Philippine rural sector. Los Banos: Philippine Institute for Development Studies.

Bureau of Agricultural Economics. 1985. Statistical handbook in agriculture - National data statistical handbook series no. 1. Quezon City, Philippines: BAE.

Gonzales, L.A. 1984. Towards greater efficiency through agricultural import substitution: The case of corn, cotton, soybeans and mungbeans. Paper presented at the 30th Annual Convention of the Philippine Agricultural Economics and Development Associations (PAEDA), Central Bank of the Philippines, Manila.

Gonzales, L.A., et al. 1985. The comparative advantage of diversifying to irrigated non-rice crops in the Philippines: A domestic resource cost approach. Los Banos, Philippines: International Rice Research Institute (IRRI) Agricultural Economics Department paper no. 85-10.

Mellor, John W. 1974. The economics of agricultural development. Ithaca New York: Cornell University Press.

National Economic and Development Authority. 1986. Draft medium-term Philippine development plan, 1987-1992. Manila, Philippines: NEDA.

National Food Authority. 1986. Comparative subsidy/fund requirement at various NFA purchase prices for palay and corn. Manila, Philippines: NFA.

Philippine Council for Agriculture and Resources Research and Development. n.d. The Philippines recommends for irrigation water management. Los Banos, Philippines: PCARRD.

Policy Coordination Staff Technical Group. 1984. Impact of economic policies on agricultural development towards a balanced agro-industrial development. Manila, Philippines: NEDA.

Small, L.S., et al. 1987. Regional study on irrigation service fees. Manila: International Irrigation Management Institute/Asian Development Bank.

DISCUSSION: COUNTRY PAPERS

PHILIPPINES

Charles Strickland commented on the importance of irrigation and drainage in diversification. The labor drudgery of seasonally developing the requisite "slope" for proper drainage is quite high. Perhaps the opportunity cost of family labor used for levelling discouraged diversification.

He also wondered if the Philippines was looking at diversification in terms of crops with export potential or those used for import substitution. **Virgilio Cabezon** answered that both purposes were being fostered. Comparative advantage favored planting lands formerly under sugar to other crops more in demand for export markets. This was the medium term policy.

INDONESIA

Shawki Barghouti said that because diversification increased the overall demand for inputs demanded by a range of crops, it should also increase the general incomes of farmers. Increasing demand would generate more off-farm employment opportunities. He questioned the profitability of mixing rice-rice or rice-other crops in Indonesia. **Budiman Hutabarat** felt that this would differ from region to region, precluding a definite answer at that time. **Barghouti** asked which strategy farmers might favor if subsidies were removed. **Hutabarat** replied that it would depend on relative production costs and product prices affecting profitability. This led to a discussion of the relative profitability of irrigated rice vs other crops. Profitability depended on the crop, the farmer's familiarity with the crop, and factors affecting the site (soil and climatic conditions). The government, **Hutabarat** felt, was not trying to decrease rice production; its main objective was self-sufficiency in rice before shifting to crop diversification.

KOREA

Manuel Vergel asked if crop diversification in Korea was promoted in both large- and small-scale irrigation projects, and what was the nature of the soil in those areas earmarked for crop diversification. **Sang-Hyuk Synn** answered that it was mostly in tubewell-irrigated areas and the soils were coarse-textured.

To **Vergel**'s question regarding Korea's status as an exporter or importer of rice, **Synn** replied that it was a small-scale importer. **Vergel** then asked if Korea was planning to reduce areas planted with rice. **Synn** stressed that the government was not influencing farmers' decisions on crops.

Honorio Bautista asked what factors affected or favored the planting of non-rice crops. **Synn** responded that, usually, the second crop differed from the initial crop which was rice. He commented that both climate and market were favorable in areas where crop diversification was being carried out.

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Ranjit Wanigaratne asked if crop diversification was affected by the shift of labor from agriculture to industrialization. The answer was that its impact was not yet clear.

THAILAND

Adding to the presentation by **Siripong Hungsperug**, **Nukool Thongthawee** stated that cropping intensity under rice decreased from 1.30 to 1.25, that government policy was to reduce the area grown to dry season padi by 160,000 hectares (ha), that the present emphasis was to improve rice quality for export, and that fruits and fish were comparatively more profitable. **David Groenfeldt** wondered why the per capita consumption of rice in Thailand was falling. **Hungsperug** attributed it to the increased consumption of bread. **Thomas Wickham** cited the example that IFPRI studies showed that when incomes rose, there was a switch to new staples.

To Wickham's question about Thailand's need for irrigation technology, **Thongthawee** replied that it was not as much of a constraint as the management of the irrigation system itself. He admitted that fruit growers had traditionally grown and irrigated their own crops but there was as yet insufficient information on irrigation management in general.

Miranda asked if there was on-going research on the choice of suitable water control structures; **Hungsperug** replied that such research was underway. **Joe Alwis** emphasized that coordination of irrigation management functions was needed by most countries in the region.

SRI LANKA

To **Cheong Chup Lim**'s question, **Sunil Dimantha** replied that land re-shaping was essential for non-rice crops and involved a different method to that used for rice. He stressed that the government should undertake land re-shaping because the costs were so much less than those already incurred for land development and irrigation layout.

Achyut Man Singh asked about well-drained soils (nearly 80,000 ha) under major irrigation schemes for rice, and **Dimantha** replied that these grew rice during Maha (wet season), while about 20,000 ha came under non-rice crops in the dry season. He stressed the need to recommend a better package of practices to the farmer, whereby he could get higher returns with less water use. **Dimantha** observed that the paradox in Sri Lanka was that they knew the food value of non-rice crops but still had low consumption, as with soybeans.

PHILIPPINES

The question arose whether the shift in Philippine agricultural policy away from price supports and subsidies could be promoted when no assistance or inadequate assistance was given to non-rice crops. **Cabezon** pointed out that this "elimination of subsidies" was to be carried out gradually.

However, price supports and subsidies, it was observed, were introduced as incentives to producers because they operated within a cash-scarce setting. To the question that, if they were removed, was it likely that diversification for accumulation purposes would ensue, **Cabezon** replied that diversification into non-rice crops by farmers often depended on the farm gate prices of crops, influencing crop selection.

The consensus of the discussion objected to totally removing production subsidies, as envisaged in the paper, if diversification was to be encouraged among farmers. Such action should be introduced gradually with great care.

Bautista remarked that there was no mention of the per capita consumption of non-rice crops in the paper, advising their inclusion. **Cabezon** said that per capita consumption and market flows were needed for any program.

GENERAL DISCUSSION

Edward Martin was concerned with the extent to which an irrigation management institute should go beyond those issues concerned with irrigation management, given their relative importance. **Barghouti** offered the IRRI example which looked at multiple-cropping, including non-rice crops. Irrigation systems, he felt, involved more than the management of water, hence there was a need for a broader perspective.

Ernst Schulze stressed the need for considering the problem at different levels of national policy making and in the environment of farmer decision making. He felt the first was outside the mandate of an international irrigation management institute, but the second was well within its scope.

SECTION III: RESULTS OF ON-GOING RESEARCH

STATUS RESEARCH REPORT: SRI LANKA

C.R. Panabokke* and the IIMI Crop Diversification Group[1]

INTRODUCTION

With Sri Lanka rapidly approaching self-sufficiency in rice production, the government's recently published National Agriculture, Food and Nutrition Strategy (1984) recognizes the imperatives for a major policy shift in the present utilization of the country's irrigated land resources.

The major irrigation systems located in the dry zone have provided the basis for the increases in rice production recorded in the recent decade. These systems are where most of the scope lies for avoiding over-production of rice in the future. Of the 740,000 hectares (ha) available in Sri Lanka for rice, the major irrigation systems presently account for a little over 250,000 ha. A further 60,000 ha of new irrigated land will probably be developed under the Mahaweli program during the next decade.

Prior to the mid-1960s, the major reservoir irrigation systems were essentially designed to provide water for a single crop of rice during the wet _maha_ season; any water that was saved in the reservoir at season's end was used to grow a limited area of rice during the following dry _yala_ season.

Since the late-1960s efforts were made by the different agencies under the Ministries of Agriculture and Irrigation to promote non-rice crops in several major reservoir irrigation systems during the yala season when water supplies were restricted. The main thrust of the approach promoted diversified crops on irrigated land with intensive extension service support that emphasized timely supply and distribution of irrigation water and improved organization of credit and input supply. Because of the lack of a clear understanding of the constraints to diversified cropping as well as an inadequate knowledge of managing the irrigation system for dry season non-rice cropping, this approach had only limited success. Furthermore, in several cases farmers produced non-rice crops with highly variable results, reasons for the success or failure were not well understood either by the extension services or by the farmers themselves.

Subsequent research and pilot testing studies undertaken in the early and mid-1970s by the Department of Agriculture and the Mahaweli Agency led to the development of appropriate on-farm agronomic and water management recommendations (Somasiri 1981). The new design and layout of the distribution system in the Mahaweli H System assumed that farmer/settlers would readily adopt these management practices. But, although farmer/settlers responded to the attractive price incentives for chilli and soybean, important deficiencies were observed in the productive use of land and irrigation resources.

Underlying this study is the assumption that more productive use of existing irrigation infrastructure and associated land resources can be

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accomplished by intensifying diversified cropping systems and through more effective irrigation system management. The studies revealed that there are important technical and socio-economic aspects to irrigation management for diversified cropping which are not yet clearly understood and which have an important bearing on the profitability of cultivation and the return to investment in irrigation. It also points to the need to properly identify the constraints to successful diversified cropping in irrigated areas and to explore ways to relax these constraints.

RESEARCH OBJECTIVES

Crop Diversification

The crop diversification component hopes to identify and develop strategies to facilitate more intensive diversified cropping in areas that have been primarily developed for producing flood irrigated rice. The specific objectives are to:

1. identify existing and potential irrigation practices for non-rice crops at the main system, tertiary system, and farm field levels;

2. identify incentives for and constraints to the further expansion of non-rice crops;

3. identify and pilot-test possible improvements in irrigation management to facilitate the growing of non-rice crops in areas where soil conditions, topography, crop profitability, and other factors generally favor non-rice crops; and

4. make recommendations concerning the adoption of improved irrigation practices in irrigated non-rice crop production, based on an assessment of the impacts on irrigation and crop production performance of the pilot-tested irrigation practices.

Irrigation System Management

The broad objectives of this component are to establish measures for the operational efficiency of the identified irrigation systems; identify any performance deficiencies and assess their relationship to management; and develop, test and recommend management interventions designed to improve systems management. The specific objectives are to:

1. assess the adequacy of water deliveries at various levels, including the farm field level, from the perspectives of both the water suppliers and water users;

2. identify underlying principles of irrigation management (e.g., procedures for decisions on the timing and amounts of water allocated at various levels within an irrigation system-both before the irrigation season begins and during the season when unexpected water shortages may occur;

3. identify the nature of Operations and Maintenance (O&M) activities by the main system management, tertiary system management, and individual irrigators, and the nature of institutional relationships among them;

4. based on the above objectives, identify and pilot-test possible improvements in irrigation management to facilitate irrigated crops; and,

5. make recommendations concerning the adoption of improved irrigation practices in crop production based on an assessment of the impact on irrigation and crop production performance of the pilot-tested practices.

METHODOLOGY

Selection of Field Research Sites

The following factors were considered: a) the type of administration of the system, b) nature of water source, and c) size and age of project. These factors were considered because they cut across a wider range of irrigation systems found in this country than factors such as design, layout, and manner of regulation.

Type of administration. Each irrigation system under the Mahaweli Agency is headed by a Resident Project Manager. The System is subdivided into Block Areas, each under a Block Manager. These are subdivided into Unit Areas each made up of 250 settler families under a Unit Manager.

Each irrigation system under the Irrigation Department is administered by a resident Irrigation Engineer and supported by Technical Assistants. A recent innovation introduced by the newly created Irrigation Management Division (IMD) is the appointment of a Project Manager on major schemes to coordinate all services of line agencies.

Nature of water source. The Mahaweli system represents large local irrigation reservoirs linked to a substantial outside diversion source of water. In contrast, the major irrigation systems under the Irrigation Department have an independent local storage reservoir within its own catchment.

Size and age of project. The Dewahuwa system consists of a reservoir with a capacity of 12 million cubic meters (MCM; 9,898 acre feet) and a channel network commanding a total area of 1,215 ha. The command area is divided into nine irrigation tracts (Figure 1). The main canal is 16 kilometers (km) long and has a design capacity of 2.72 cumecs (96 cusecs) at the head. The transit time for water to reach the tail end of the canal in the filling phase at the beginning of a rotation is around 12 hours. The individual farm allotments of 2 ha each are served via a network of distributary and field canals. Source of supply to farm allotments is from field channel outlets as well as direct outlets either from the main canal or distributary. The issue tree diagram for this system is shown in Figure 2 and field research site features are listed in Table 1.

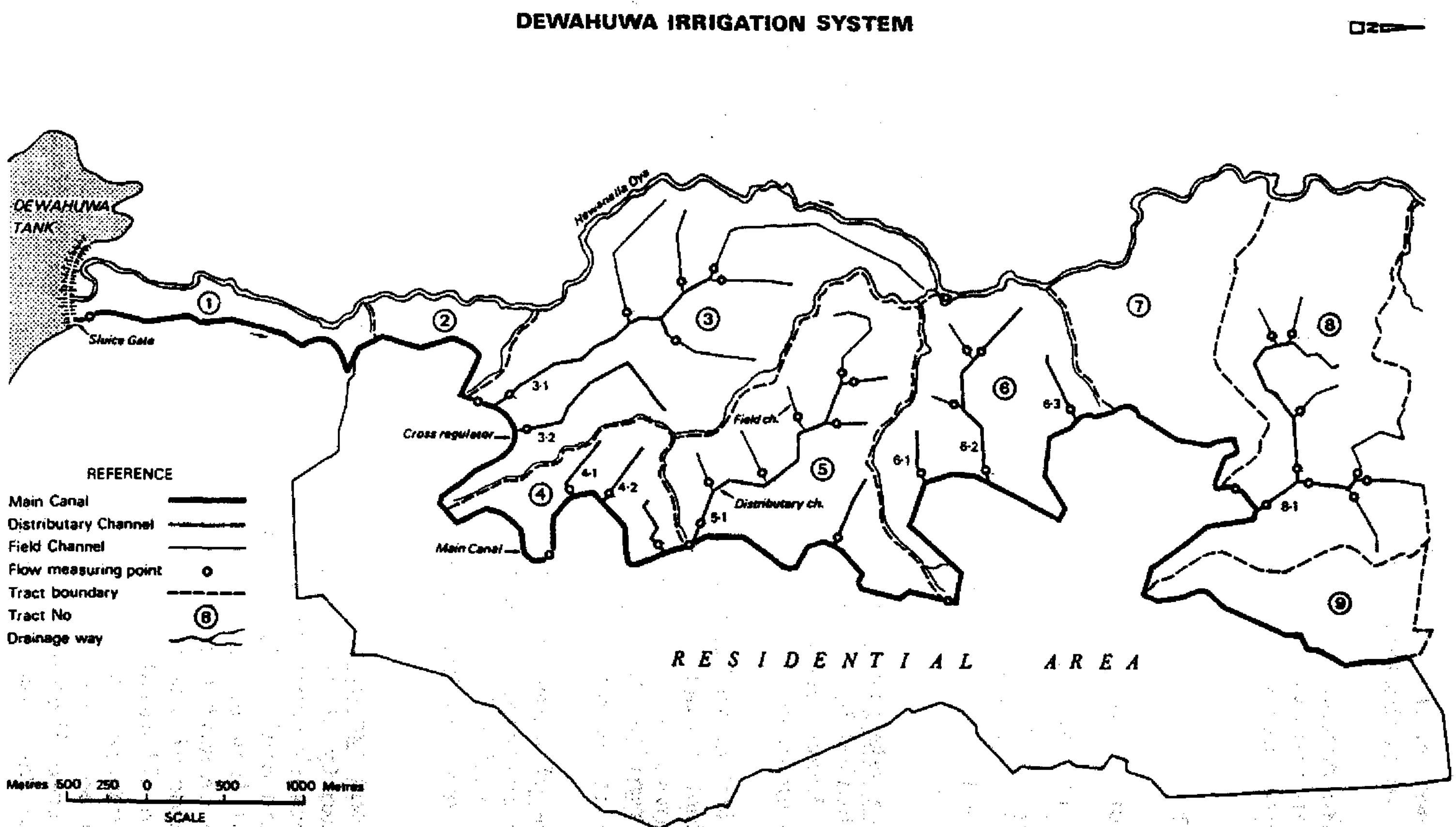
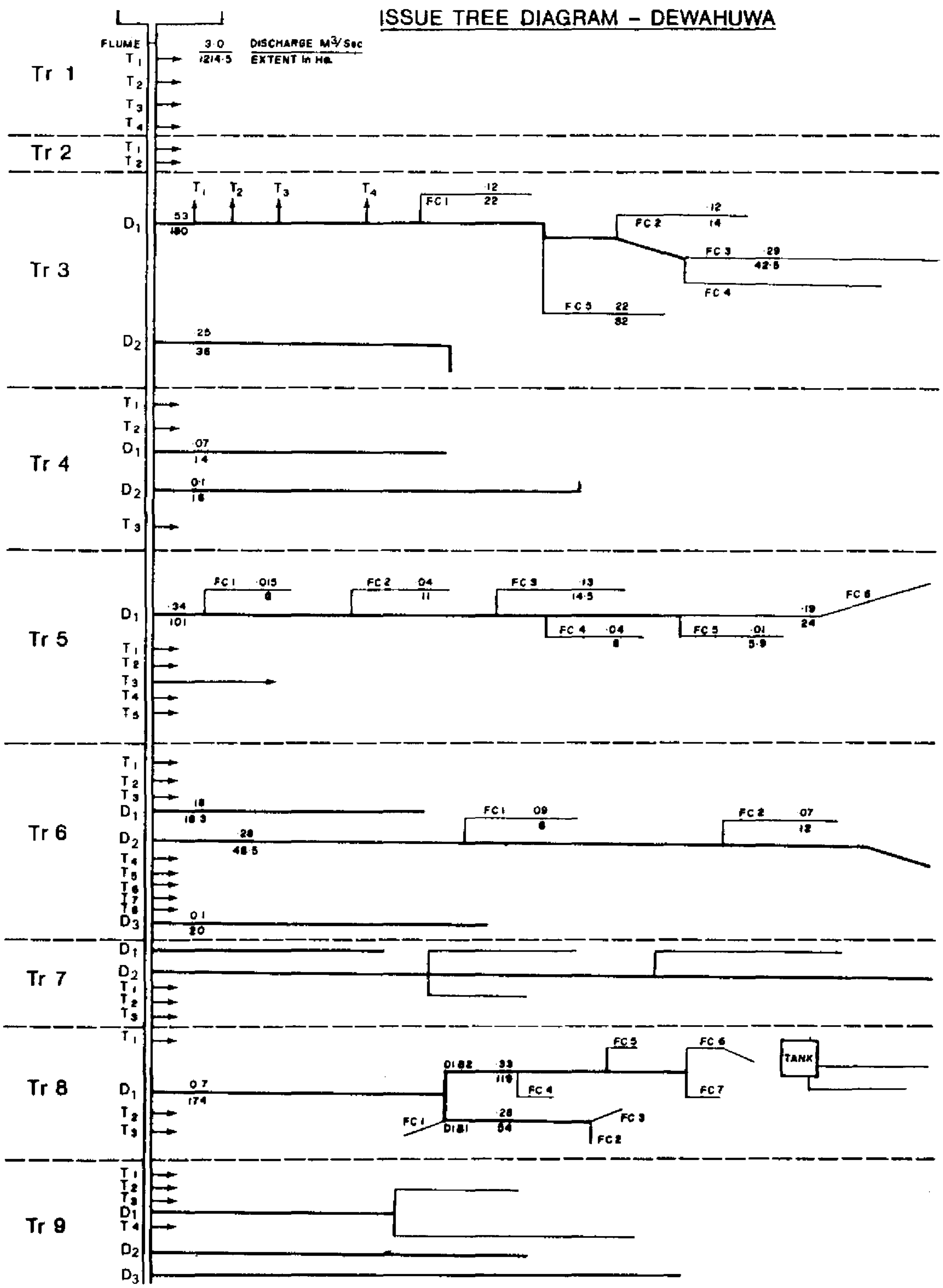


Figure 1. Schematic of Dewahuwa Irrigation System, Sri Lanka.

Figure 2. Issue tree diagram of Dewahuwa Irrigation System, Sri Lanka.



Under a Japanese funded project in the early 1970s, the main canal was desilted, slopes were stabilized, regulating and measurement structures were installed in the main canal, and steel gates and rectangular sharp-crested weirs were installed at the heads of the distributary canals. Most of the canal regulators are in poor condition at present and their gates are either missing or damaged. Similarly, turnout gates, especially in direct turnouts from the main canal and distributaries, are in poor condition.

Table 1. Field research site features, Dewahuwa and Kalankuttiya Irrigation Systems

	Dewahuwa	Kalankuttiya
Type of administration:	Irrigation Dept	Mahaweli Authority
Nature of water source:	Own catchment and occasional diversion from Nalanda Oya Reservoir	Diversion from major river storage system and local storage
Size:	Total command - 1215 ha Irrigation Tracts 1-9 Partial Rehabilitation in 1973	System H - 24,240 ha Kalankuttiya Block in H2 - 2,121 ha
Settlement commenced:	1949	1977

The Kalankuttiya system consists of the Kalankuttiya tank which has a capacity of 1.86 MCM (1,534 acre feet) and which receives supplies from the main Mahaweli system. The water distribution system (Figure 3) consists of a branch canal 11 km long and 20 distributary channels serving a command area of 2,040 ha. The branch canal has a maximum design capacity of 5.65 cumecs (200 cusecs) at the head end area. The distribution system provides irrigation to 5 Irrigation Blocks, numbers 305-309, within the whole of the Kalankuttiya Administrative Block. Duckbill weir cross regulators help to maintain the desired hydraulic head at different sections of the canal thereby ensuring a controlled discharge to the distributaries. The issue tree diagram for this system is shown in Figure 4.

All distributary channel outlets have a measuring weir immediately below the gate. The field channels that take off from the distributary channel have had turnout gates; in some turnouts the gates have been either removed or damaged by farmers. Most of the monitoring devices such as calibrated staff gauges and weirs installed below turnouts have been damaged or removed by farmers, and the control of flow to the field channel has to be done by eye estimation or via past experience. Supply to field allotments of one hectare each is from field channel outlets. Within a field channel it is difficult to find any original outlets in good condition.

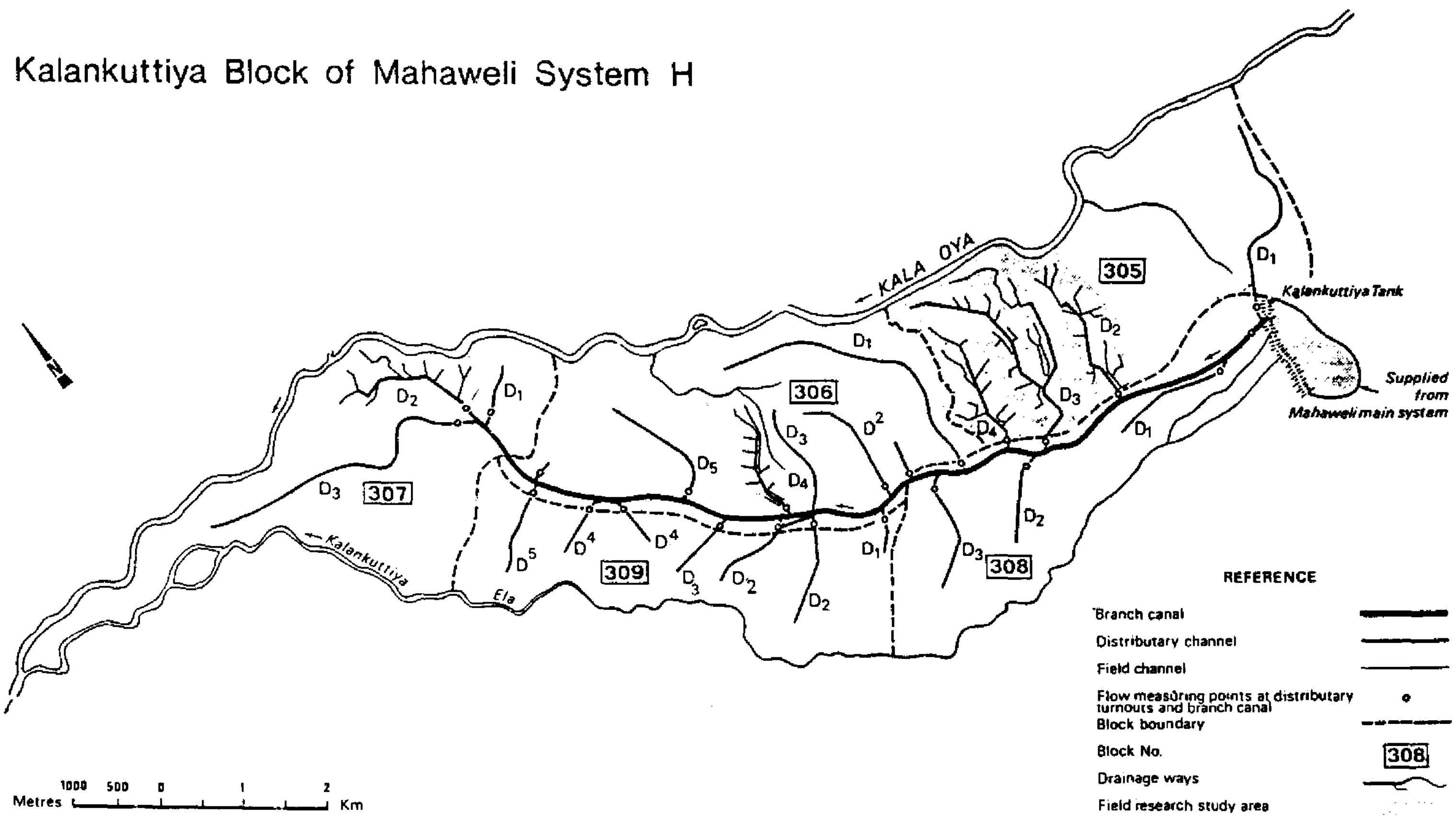


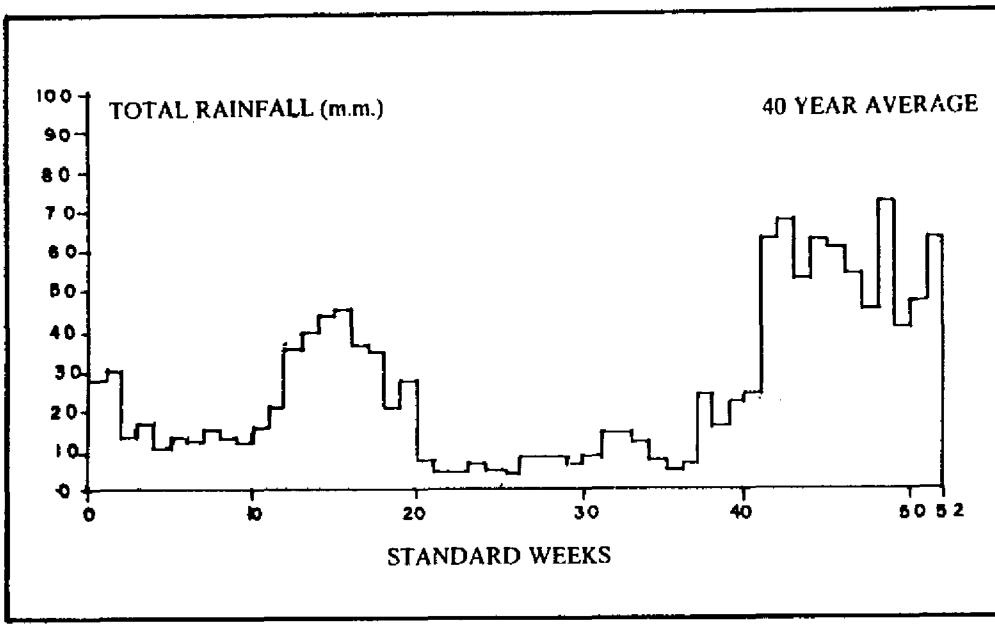
Figure 3. Schematic of Kalankuttiya Block of Mahaweli System H, Sri Lanka.

Figure 4. Issue tree diagram for Kalankuttiya Block of Mahaweli System H, Sri Lanka.

Climate and Soils

This region is characterized by a bimodal distribution pattern for the monthly rainfall with two distinct dry periods, one short and other prolonged (Figure 5).

Figure 5. Total annual rainfall distribution (in millimeters).



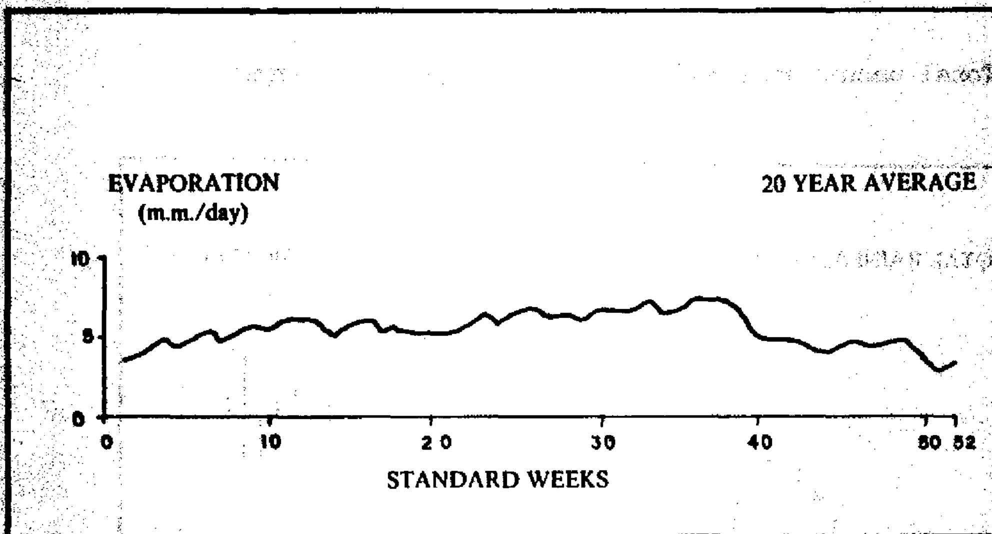
The annual average rainfall is 1,500 millimeters (mm), of which nearly 70 per cent occurs from October to mid-January, the maha season. The remaining rainfall occurs from mid-March to mid May, the yala season. February, June, July, August, and September are relatively rainless. The 75 per cent probability of rainfall expectancy in the maha season is 430 mm and 200 mm in the yala season.

The pan evaporation measured from a class A pan varies from 3.5 mm/day - 7.5 mm/day (Figure 6). From the 1st week of October to the end of January, the pan evaporation is less than 5 mm/day. The pan evaporation from June to the end of September is over 6 mm/day (Figure 6).

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

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

Figure 6. Class A pan evaporation (in millimeters/day).



The soils in the irrigation command areas occur in a catenary sequence in the undulating landscape. The well-drained and imperfectly drained Reddish Brown Earths (RBE) are found in the convex uplands and mid-slopes respectively. Poorly drained Low Humic Gley (LHG) soils occur in the concave valleys and bottom-lands.

In the past the LHG soils were utilized for continuous cultivation of rice both under rainfed and irrigated conditions. With the development of new irrigation schemes, all the soils in the catena were brought under cultivation. Rice was the only crop grown in these lands in the beginning. However, loss of excessive quantities of water was observed due to the high seepage and percolation rates in the well-drained and imperfectly drained lands when standing water was maintained for rice. Other field crops (OFC)* were therefore introduced to overcome the situation. Consideration of groundwater-table behavior and drainage became increasingly important since other field crops proved to be intolerant of excess moisture conditions.

Research Procedures

The main part of the research activity was field observation, including data collection and analysis for the first three research objectives under crop diversification and irrigation systems management. Flow discharge measurements and detailed farm survey data were collected at each site. The following summarize the variables on system management and flow discharge measurements that were included in the study:

1. Decisions reached in cultivators' meetings before each season:
   a) Scheduled first water issues
   b) Planned areas by distributary or tracts to be served with water and for what crops
   c) Schedules of water delivery

2. Actual water delivery:
   a) First water issue
   b) Areas actually planted and served with water under each distributary or tract
   c) Actual dates of water deliveries
   d) Who gives instructions and who actually does the following:
      i) Opening and closing of main sluice?
      ii) Adjusting cross regulator settings?
      iii) Opening and closing of gates to distributaries?
      iv) Opening and closing of turnouts to field channels?
      v) Opening and closing of field outlets?

   e) How is water shared below the field channel turnout and below the field outlet?
   f) How is water applied to the individual basins for diversified crops?

3. Interval, duration, and flow rate of irrigation issues from:
   a) Main canal
   b) Distributary canal
   c) Field channel
   d) Field outlet

Data was collected for the following variables at each site in respect of the Farm Survey:

1. General farm characteristics
2. Cropping patterns
3. Cropping activities
   a) Land preparation
   b) Crop establishment

4. Crop care:
   a) Application of fertilizer - amount, kinds, and cost
   b) Pesticides and herbicides - amount, cost

5. Labor use for all operations - family, hired, and exchange
6. Harvesting - dates, and costs including threshing and transport
7. Production - yields by taking crop cuttings
8. Crop utilization - consumption, marketing, and seed requirements
9. Marketing - private trade, government agencies, prices
10. Credit - banks and private money lenders

Information on other forms of highland rainfed cultivation, and ex-farm employment activities were also documented.

Planning

Dewahuwa. In planning for the season, a Technical Assistant from the Irrigation Department used past available data to determine the area that could be irrigated, crops to be planted, and timing of rotations. The proposals were presented to farmers at the pre-kanna or pre-season meeting.

For yala 1985, agreement was reached to cultivate one third the total command area under a bethma or land sharing basis. Crops were to be chilli, soybean, and green gram on the well-drained soils, and rice on the poorly-drained soils. A 15 day continuous supply of water was to be given for land preparation followed by rotational issue every ten days. For maha 1985 in keeping with the normal practice, it was agreed to cultivate the whole command area with rice. Yala 1986 was handled like yala 1985 except that it was agreed to cultivate half the total command area rather than one third.

Kalankuttiya. For yala 1985, officials of the Kalankuttiya Block office explained to farmers that water was inadequate for a full cultivation of the total area of 2,122 ha. Agreement was reached that a bethma cultivation would be done on half the command area of each distributary. Chilli would be planted on the well-drained soils, and rice on the poorly-drained soils. A 30 day continuous supply of water would be given for land preparation followed by a rotational issue every seven days. For maha 1985, in keeping with the normal practice, it was agreed that the whole command area would be grown to rice. For yala 1986, a bethma was not necessary because the area was provided its full quota of water, and it was agreed that the whole command area under every distributary would be cultivated with chilli on well-drained and rice on the poorly-drained soils.

Results and Discussion: Dewahuwa

Yala 1985. One-third of the total command area, 477 ha from different areas within tracts 1-6, was cultivated. Rice occupied 61 ha and other food crops (OFC), 416 ha. Irrigation issues for land preparation were planned for 15 days but accomplished in 8 days using 174 mm of water. As seen in Table 2, the weighted mean values of delivery for the distributaries in tracts 4-6 amount to 183, 151, and 119 mm, respectively. With 13 per cent of the total irrigated area used for rice, land preparation was mainly for OFC which requires less water than rice for the land preparation methods adopted. Eleven rotational issues of water totalling 881 mm were given over a 120 day crop growth period. The weighted mean value for distributaries in tract 4 is 940 mm compared with 485 mm in tract 6.

When only one-third of the area (477 ha located in the head reaches) was cultivated, about 1.52 cumecs (54 cusecs) was issued in the main canal after land preparation with 3 days on and 7 days off. The issues in the distributaries followed the same schedule. However, in the field channels it was 1.5 days on and 8.5 days off, with the upper half of the turnouts located along distributaries receiving the water first and then the lower half. All the field outlets along the field channels received water simultaneously.

Table 2. Variables involved in land preparation (LP) and crop growth (CG) for three seasons, Dewahuwa, 1985-86.

	Yala 1985		Maha 1985-86		Yala 1986	
	LP	CG	LP	CG	LP	CG
No. of days	8	126	30	123	15	114
Rainfall (mm)	6	145	83	774	34	54
Evaporation (mm)	35	558	78	240	54	497
No. of rotational issues	-	11	-	14	-	13
Total area (ha)	477	-	1214	-	607	-
OFC (ha)	-	416	-	-	-	481
Rice (ha)	-	61	-	1214	-	126
Irrigation Supply (mm):						
Main channel	174	881	536	1174	121	850
Tract 3: Distributary	-	-	746	1233	172	1056
Turnout	-	-	586	1360	132	886
Tract 4: Distributary	183	940	529	883	144	1500
Tract 5: Distributary	151	558	703	1311	123	861
Turnout	155	473	418	817	95	545
Tract 6: Distributary	119	485	726	1105	147	630
Turnout	-	-	589	712	52	339

Maha 1985-86. The whole command area of 1,214 ha was cultivated in wet land rice. Water issues for land preparation were planned for 37 days and accomplished in 30 days using 536 mm. A continuous issue was given during the land preparation period for tracts 1-7. A two-day rotation was given to tracts 8 and 9, during this period because an adequate volume of flow could not be delivered to the tail end of the main canal. The mean delivery values for the distributaries in tracts 3, 5, and 6 exceed 700 mm (Table 2); this is probably due to the run-off water picked up by the single bank main canal (rainfall during this period amounted to 83 mm).

Fourteen rotational issues totalling 1,174 mm were given over a 123-day crop growth period. Flow in the main canal was about 2.74 cumecs (97 cusecs) and was on 4 days and off 3 days during each rotation. Tracts 1, 2, and 7, and parts of tracts 3, 5, 8, and 9 (Figure 1), received water on the first two days and the remainder received water on the second two days. For tracts with long distributaries, both upper and lower halves received water for one day each. The distributaries in tracts 3, 5, and 6 received similar amounts.

Yala 1986. Half the total command area (Figure 1), 607 ha which is located within tracts 1-6 and 10 allotments in tract 7, was irrigated this season with rice occupying 126 ha and OFC, 481 ha. Water issue for land preparation was planned for and accomplished in 15 days using 121 mm. Compared to the previous yala, 20 per cent of the total irrigated area was used for rice. The mean delivery values for distributaries in tracts 3-6 exceeds 121 mm, the value at main canal level (Table 2). While the mean value for distributaries is close to the value of the previous yala season, the mean value for the turnout in Tract 5 is considerably less.

Thirteen rotational issues totalling 850 mm of water were given over a 114-day crop growth period. Although a one-in-ten day rotation was planned, the management had to change to either a one-in-eight or a one-in seven-day rotation from the sixth rotation onwards to cope with the higher demand created by the greater area cultivated. Flow in the main canal was about 2.06 cumecs (73 cusecs) with the flow on for 3 days and off for 4 days during each rotation. The field channels were on for 1.5 days and off for 5.5 days. The long distributaries in both upper and lower halves received supplies for 1.5 days each. The mean delivery values for distributaries and turnouts in the head end tracts 3 and 4 are higher than in the tail end tracts 5 and 6.

On the longer distributary channels (i.e., Tract 5, D1) there is considerable conflict between head end and tail end farmers in sharing water. Monitoring turnouts revealed that tail end farmers had to rely on drawing irrigation supplies mostly during night, and very often had to cope with a larger stream size than they needed. This distributary has used a higher quantity of irrigation water in yala 1986 compared to that in yala 1985.

Discussion. The Dewahuwa irrigation system was originally designed to grow a single crop of rice during the wet maha season. System rehabilitation in the early 1970s with Japanese assistance improved the operational capacity of the system by installing regulating and measurement structures in the main canal, and measuring weirs at heads of distributary channels. Results from the flow measurements made during the last three seasons (two dry and one wet) confirm the feasibility of effectively managing this system for growing non-rice crops during the dry season by rotating water issues.

OFC cultivation using limited supplies of irrigation water has been promoted since 1984 under the sponsorship of the Agriculture, Irrigation, and Land Commissioner's Departments, and more recently the Irrigation Management Division (IMD) of the Ministry of Lands and Land Development. The present management has a good understanding of main system management and is capable of responding to the differential demands within the different sections of the system. However, more effective use of the existing cross regulating and measuring structures, and the provision of additional ones, could help to bring about substantial improvements in the main system management. A modest investment in repairs to regulating structures on the distributary channels will facilitate improved management, minimizing the present variation in supplies at the turnout level. Improved communication between farmers and agency staff is equally essential for improving management at the turnout.

Reported yields by crop cuts on sample allotments show good average yields for OFC during yala and for rice during maha, which generally indicate adequate water supplies. This is further confirmed by the absence of moisture stress for OFC. An important problem is the proper sharing of water between OFC and rice during yala. The supply within the present rotational issue pattern is advantageous for OFC but disadvantageous for rice.

Results and Discussion: Kalankuttiya

Yala 1985. Half the command area (1,100 ha) was cultivated; rice and OFC were both planted on 550 ha each. Irrigation issues for land preparation were planned for 30 days and accomplished in 36 days using 524 mm (Table 3). About 112 mm of rain fell during this period. Thirteen rotational issues totalling 1,002 mm of water were given over a 114-day crop growth period. During each rotation the branch canal and distributaries were open for four days and closed for three. The maximum branch canal issue was about 2.83 cumecs (100 cusecs). At the field channel level each field allotment drew its supply for 6-8 hours, allowing 16 allotments within a turnout area to be irrigated over 4 days (a 1 in 7 day delivery to each allotment). The total delivery for each distributary followed the same order as that during land preparation. The mean values for delivery at turnouts within a distributary ranged from 80-90 per cent of that delivered at the head.

Table 3. Variables involved in land preparation (LP) and crop growth (CG) for three seasons, Kalankuttiya, 1985-86.

	Yala 1985		Maha 1985-86		Yala 1985	
	LP	CG	LP	CG	LP	CG
No. of days	36	114	46	90	63	98
Rainfall (mm)	112	117	490	294	376	10
Evaporation (mm)	174	704	48	213	197	525
No. of rotational issues	-	13	-	10	-	12
Total area (ha)	1100	-	2040	-	2034	-
OFC (ha)	-	550	-	-	-	1040
Rice (ha)	-	550	-	2040	-	994
Irrigation Supply (mm):						
Main channel	524	1002	526	703	520	947
305, D2: Distributary	598	1006	623	728	550	929
Turnout	570	805	559	620	508	824
305, D3: Distributary	380	771	379	656	440	820
Turnout	372	676	358	508	440	633
305, D4: Distributary	418	880	455	513	439	766
Turnout	448	795	396	448	417	669
306, D4: Distributary	-	-	618	748	452	999
Turnout	-	-	405	422	430	946
307, D2: Distributary	-	-	634	797	592	1022
Turnout	-	-	506	612	481	821

Maha 1985-86. The entire command area of 2040 ha was cultivated to wet land rice. Irrigation issues for land preparation was planned for 30 days but was accomplished in 46 days using 526 mm of water. About 490 mm of rain fell during this period. The lengthier period for land preparation was not due to a constraint in water supply, but to a poor response by farmers to the management schedules. The flow measurement data in Table 3 shows that, as in the previous season, the amount delivered to the turnouts in the distributary D3 of Block 305 is less than for all other distributaries.

Ten rotational issues of water totalling 703 mm were given over a 90-day period for crop growth. The sluice was opened continuously with a maximum issue of 4.53 cumecs (160 cusecs); the first 15 distributaries were on for 4 days and off for 3 days. The last five distributaries received water from the fourth to the seventh day. The field channels were served with the same pattern of water issue as the distributaries. The mean values of delivery for field channels within a distributary range from 70-80 per cent of the values of the distributary except in 306 D4, which is closer to 60 percent.

Yala 1986. The entire command area was cultivated; rice was planned on 994 ha and OFC on 1,040 ha. Water issues for land preparation were planned for 30 days but took 63 days and used 520 mm. About 376 mm of rain fell during this period. The lengthy land preparation was again due to farmers not keeping to the scheduled operation plan. The farmers and the agency agreed to begin land preparation one month earlier than yala 1985, mainly to start an early chilli crop. But a delayed harvest of the preceding maha rice crop and the intervention of the Sinhala New Year holiday in mid-April caused a disruption to the proposed plan. Mean values of delivery for turnouts within a distributary are slightly more than 90 per cent of the amount delivered at the head of the distributary except in 307 D2 (Table 3).

Twelve rotational issues of water totalling 947 mm were given over a 98-day crop growth period. The rotational interval of issues to the branch canal varied from 7-12 days (6-7 days on and 1-5 days off) with a maximum issue of 5.09 cumecs (180 cusecs). The total delivery for each distributary follows the same order as in the land preparation period. When compared with yala 1985, a greater degree of variation in the total delivery between turnouts within a distributary occurred during yala 1986. These variations in values of delivery between turnouts within a distributary can be ascribed partly to the ratio of rice to OFC under its command, the position of the turnout either at the head or tail end of the distributary, and to the nature of operations conducted within it.

Discussion. The Kalankuttiya subsystem of the Mahaweli H system was designed for wet land rice during maha; and for OFC on well-drained soils and rice on the imperfectly- and poorly-drained soils during yala. The design and layout of the irrigation network makes a high degree of control and regulation possible up to turnouts leading to field channels. Branch canals, especially, have good regulation from duckbill weirs below each distributary gate. This enables self-management within the branch canal and equitable deliveries to its 20 distributaries. Flow measurement data confirm that this part of the main system can operate efficiently.

Flow measurement data also indicate that control and delivery within the distributary command can also operate satisfactorily. One problem is delivering adequate water to rice during yala within the weekly rotational issues. Rice yields under the present delivery pattern are about 2,500 kg/ha, which barely cover production costs. A shift away from rice at least on the imperfectly-drained soils has already been demonstrated by farmers who raise good crops of OFC, mainly chilli, by ridging and providing rudimentary drainage. This won't be possible on poorly-drained soils which, in any case, are benefitted by substantial seepage and can thus support a good rice crop. Confining rice to poorly-drained soils and promoting OFC on imperfectly-drained soils during yala would be an appropriate strategy that could be tested.

Managing deliveries below the field channel outlet is also a problem. Studies during yala 1986 show that both formal and informal arrangements exist among farmers for sharing water on a rotational basis. Although the original design called for two farmers to share the field channel issue for 12 hours, staff observed that of one farmer took the full flow for 6 hours. As a result, the outlet did not have adequate capacity to accommodate the full flow, encouraging farmers to either bypass or destroy the outlet. The conveyance system at this level is usually in poor shape and maintenance standards are low. Improving the management of water deliveries will therefore require both physical improvements to the conveyance system and closer participation between the managing agency and farmer representatives.

ECONOMICS OF DIVERSIFIED CROPPING UNDER IRRIGATION

To assess the agro-economic constraints to diversified cropping, data on both rice and other field crops (OFC) were collected at Dewahuwa and Kalankuttiya during yala 1985 and 1986. The purpose was to analyze the costs and returns of producing different crops. Some analysis was also made of the reasons for farmers' choice of crops. The managers of both systems promoted the cultivation of OFC during kanna meetings and by scheduling water issues, but many farmers in both systems also grew rice. In Dewahuwa, a significant amount of green gram and soybean were cultivated along with rice and chilli. In Kalankuttiya, chilli was the primary crop grown in addition to rice (other OFC accounted for about 4 per cent of the total irrigated area; Table 4).

Table 4. Crop area and sample size at Dewahuwa and Kalankuttiya, 1985-86.

	Sample farmers		Area Cultivated	
	Number	Per cent	Hectares	Per cent
		Dewahuwa, Yala 1985		
Rice	37	37	13.7	26
Chilli	41	41	19.3	36
Green gram	42	42	15.5	29
Soybean	14	14	5.0	9
		Dewahuwa, Yala 1986		
Rice	30	28	12.3	23
Chilli	35	33	11.9	22
Green gram	49	46	15.2	28
Soybean	35	33	14.4	27
		Kalankuttiya, Yala 1985		
Rice	64	52	22.4	45
Chilli	92	75	26.7	55
		Kalankuttiya, Yala 1986		
Rice	70	65	35.7	49
Chilli	86	80	37.8	51

In Dewahuwa there was little difference in the area planted to rice and green gram in the two seasons, but chilli accounted for 36 per cent of the area in 1985 and 22 per cent in 1986. The area planted to soybean increased from 9 to 27 per cent. This was in part due to the Agricultural Department and the Dewahuwa project manager encouraging soybean cultivation, and the Oil and Fats Corporation guaranteeing a minimum price of Rs 7.00/kg (US$1.00 = Rs 28.00) for soybean. The price actually received by the sample farmers exceeded Rs 9.00/kg on average. Rice accounted for 45 and 49 per cent of the total area of the sample farms in Kalankuttiya in 1985 and 1986, respectively, while chilli accounted for most of the remainder in both seasons. The data reported show the non-rice crops to be more profitable than rice (Tables 5 and 6).

Table 5. Crop costs and returns Dewahuwa, yala 1985 and 1986.

	Rice	Chilli	Green gram	Soybean
1985 yala				
No. of farms	35	41	42	14
Avg. area planted (ha)	0.37	0.47	0.37	0.36
Reported yield (kg/ha)	1300	900	600	1400
Gross returns (Rs/ha)	4968	27351	11772	12177
Production costs (Rs/ha)	3661	8386	3852	3232
Net returns (Rs/ha)	1307	18965	7920	8945
1986 yala				
No. of farms	30	35	49	35
Avg. area planted (ha)	0.41	0.34	0.31	0.41
Reported yield (kg/ha)	2292	1073	751	1853
Gross returns (Rs/ha)	7814	26265	12848	16863
Production costs (Rs/ha)	4339	13010	5682	4098
Net returns (Rs/ha)	3475	13255	7166	12765

US$1.00 = Rs 28.00

Table 6. Crop costs and returns Kalankuttiya, yala season 1985 and 1986.

	1985		1986	
	Rice	Chilli	Rice	Chilli
No. of farms	64	92	70	86
Avg. area planted (ha)	0.35	0.29	0.51	0.44
Reported yield (kg/ha)	2300	1900	3078	968
Gross returns (Rs/ha)	8937	53892	10436	25383
Production costs (Rs/ha)	5217	12820	5139	11505
Net Returns (Rs/ha)	3720	41072	5297	13878

US$ 1 = Rs. 28

This was especially true in 1985 when reported rice yields were very low, 1.3 and 2.3 tons/ha in Dewahuwa and Kalankuttiya, respectively. Rice yields, both as reported by farmers and estimated by crop cut samples, were somewhat higher in both locations in 1986. In Kalankuttiya in 1986, reported chilli yields and return to family resources were only 50 and 33 per cent of 1985 levels, respectively. Several factors may have contributed to the poor performance of chilli in 1986 yala. Heavy rains in April and early water issues saturated the soil, resulting in poor conditions for newly planted chilli. Some farmers who had planted chilli gave up and planted rice instead. Furthermore, disease damaged the chilli crop in 1986 but not in 1985. In 1986 the area planted to chilli was greater than 1985 (0.44 ha versus 0.29 ha) because farmers did not have to share their allotment with a bethma partner as in 1985. Finally, the price received for chilli was lower in 1986 which, along with the lower yields, contributed to much lower returns to farm resources. In 1986 the Cooperative Wholesale Establishment (CWE) graded chilli and rejected sub-standard produce. Many farmers sold their chilli to private traders who paid a lower price but bought all chilli offered.

Given the much greater profitability of non-rice crops (and particularly of chilli), the question arises as to why some farmers chose to produce rice. One answer to this question relates the crop grown to the soil drainage conditions. In Dewahuwa for 1985, OFC were planted on more than 96 per cent of the well-drained soils in both seasons (Table 7).

Table 7. Crops planted under different drainage conditions, yala 1985-86, Dewahuwa.

	Well-drained		Intermediate		Poorly-drained	
	1985	1986	1985	1986	1985	1986
Area of sample farms (ha)	17.2	21.1	28.5	17.0	8.0	15.1
Area planted to rice (%)	1.7	3.7	30.5	28.4	60.0	43.2
Area planted to OFC (%)	98.3	96.3	69.5	71.6	40.0	56.8
Chilli (%)	52.9	28.4	28.1	25.4	26.3	10.0
Green gram (%)	37.3	31.8	30.5	29.4	7.5	23.9
Soybean (%)	8.1	36.2	10.9	16.8	6.2	22.9

In 1985, OFC were planted on 40 per cent of the poorly-drained soils in the sample, and on 56 per cent in 1986. About 70 per cent in the intermediate drainage category were planted to OFC in both years. Rice was grown on a smaller percentage of each drainage category in Dewahuwa than Kalankuttiya, which is likely due to the water delivery schedule. In Dewahuwa, the plan called for farmers to receive water once in ten days; in Kalankuttiya once in seven. The data from Kalankuttiya in 1985 support the conclusion concerning the importance of soil drainage conditions in farmers' cropping decisions, and the correlation of crops with drainage class is more extreme than that in Dewahuwa. Over 90 per cent of the well-drained soils but none of the poorly-drained soils were planted to chilli (Table 8).

Table 8. Crops planted under different drainage conditions, yala 1985-86, Kalankuttiya.

	Well-drained		Intermediate		Poorly-drained	
	1985	1986	1985	1986	1985	1986
Area of sample farms (ha)	22.6	39.1	18.9	31.0	8.1	3.5
Area planted to rice (%)	6.7	28.9	68.8	69.1	100.0	89.7
Area planted to chilli (%)	93.3	71.1	31.2	30.9	0	10.3

Chilli production requires a much higher cash outlay than does rice. Average cash production costs per hectare for chilli are more than twice that for rice (Tables 9 and 10), while the cash production costs of green gram and soybean are approximately the same as for rice.

Table 9. Average cash production costs (in Rupees per hectare) for yala season crops, Dewahuwa, 1985-86.

Item	Rice	Chilli	Ratio[1]	Green gram	Ratio[2]	Soy-beans	Ratio[3]
1985 yala							
Fertilizer	701	1626	2.3	50	0.1	163	0.2
Pest & herb	153	1325	8.7	764	5.0	229	1.5
Seeds	0	158	-	488	-	532	-
Equipment*	1,446	1201	0.8	672	0.5	775	0.5
Labor*	916	3949	4.3	1526	1.7	1153	1.3
Land rent	445	127	0.3	352	0.8	380	0.9
Water cost**	0	2.7	-	0	-	0	-
Totals	3661	8389	2.3	3852	1.1	3232	0.9
1986 yala							
Fertilizer	788	2023	2.6	40	0.05	147	0.2
Pest & herb	181	2580	14.3	1053	5.8	381	2.1
Seeds	57	444	7.8	740	13.0	618	10.8
Equipment*	1234	1125	0.9	1043	0.8	160	0.1
Labor*	1345	6258	4.7	2356	1.8	2462	1.8
Land rent	734	580	0.8	450	0.6	330	0.4
Water cost**	7	78	11.1	0	-	0	-
Totals	4346	13088	3.0	5682	1.3	4098	0.9

US$1.00 = Rs28.00; [1]Chilli to rice, [2]Green gram to rice, [3]Soybean to rice; *Equipment and labor were hired; **includes payment for extra water issue in some cases and cost of pumping from drainage channels. Water costs do not include the O&M fee of Rs 250/ha, which none of the sample farmers reported having paid.

Table 10. Average cash production costs (in Rupees per hectare) for yala season crops, Kalankuttiya, 1985-86.

Item	1985 Rice	1985 Chilli	1985 Ratio	1986 Rice	1986 Chilli	1986 Ratio
Fert & pest	737	2287	3.1	804	2048	2.5
Herbicide	346	2317	6.7	420	2196	5.2
Seeds	219	583	2.7	67	548	8.2
Equipment*	1877	1755	0.9	1856	1358	0.7
Labor*	1139	4917	4.3	1432	4835	3.4
Land rent	899	961	1.1	560	520	0.9
Totals	5217	12820	2.5	5139	11505	2.2

US$1.00 = Rs28.00; Ratio = chilli to rice; *Equipment and labor were hired.

The higher cost of producing chilli is mainly due to greater use of fertilizers, pesticides, and hired labor. Despite this, the average size holding planted to chilli is not significantly different from that planted to other crops. This suggests that soil and related water management constraints were more important in the choice of crop than were credit or risk constraints associated with the higher cost of producing chilli.

The effects of location were analyzed by dividing the distributary units into head and tail sections. In Kalankuttiya in 1985, no differences in chilli yields were observed between farmers served by field channels located at the head of the distributary units as opposed to those located at the tails. For rice, however, significant yield differences were observed in the cases of two of the three distributary units (Tables 11 and 12).

Table 11. Crop yields (in kilograms per hectare) in head and tail portions of distributary channels, yala 1985-86, Kalankuttiya.

	Distributary channel	Head 1985	Head 1986	Tail 1985	Tail 1986
Rice	305 D2	2500	2890	2850	2970
	305 D3	2520*	2840	950	2040
	305 D4	3780*	3100	1720	3320
	305 D4		3720		3420
	305 D2		3570		2060
Chilli	305 D2	1730	1190	2110	970
	305 D3	1740	1120	1530	1200
	305 D4	1820	1200*	1980	340
	306 D4		870		690
	307 D2		810		840

* Row sample means are significantly different at the 0.05 probability level.

Table 12. Water deliveries (in millimeters per hectare) to distributary channels, and rice yields (in kilograms per hectare) in head and tail portions of these channels, yala 1985, Kalankuttiya.

Secondary channel	Water delivery	Rice yield	
		Head	Tail
D2	1604	2500	2850
D3	1151	2520*	950*
D4	1298	3780*	1720*

*Row sample means are significantly different at the 0.05 probability level.

The positive relationship shown in Table 12 between the water deliveries at the head of the distributary channel and rice yields in the tail portions suggests that differences in water supply may have caused these differences. The channel with no significant difference in yields between the head and tail ends (D2) received the largest amount of water due to a leaking headgate. In Dewahuwa, also in 1985, rice yields in head end plots were significantly higher than those in tail end plots (Table 13). There was no significant difference in OFC yields between head and tail plots, however.

Table 13. Yields (in kilograms per hectare) in head and tail portions of the distributary channels in Dewahuwa.

	Head		Tail	
	1985	1986	1985	1986
Rice	1759*	2282	938	2313
Chilli	973	1122	761	946
Green gram	657	794	631	677
Soybean	1518	1848	1188	1859

*Significantly different at 0.05 probability level.

These results suggest that when irrigation water deliveries are scheduled to support the production of upland crops such as chilli, a farmer with poorly-drained soils in the tail end of the secondary may face severe problems. Because of poorly drained soil and generally poor water control, he is unable to successfully grow chilli. At the same time, the amount of water he receives is severely inadequate for rice.

The 1985 data for rice cultivation in Kalankuttiya showed that compared with the rest of the sample farmers, the farmers in the two tail sections where yields were significantly lower used less purchased inputs of fertilizer and pesticides. These same farmers, however, spent more on hired equipment for land preparation (Table 14). These findings are consistent with a strategy of reducing cash outlays in order to reduce the risk of financial losses. The greater amount spent for hired equipment for land preparation

Table 14. Cost and returns (in Rupees per hectare) for rice production on sample farms in the tail portion of distributary channels D3 and D4 compared with all other sample farmers, yala 1985, Kalankuttiya.

	Sample farms	All other farms
Fertilizer	186***	937***
Pesticide and herbicide	54***	451***
Hired equipment	2365***	1701***
Seeds and seedlings	397***	154***
Payments for water	30	46
Hired labor excluding harvest	373	524
Hired labor for harvest	448*	732*
Land rental	1015	859
Total cash costs	4868	5404
Gross returns	5667***	10128***
Net returns to family resources (US$/ha)	799***	4725***
Net returns to family labor (US$/man-day)	9**	80**

US$1.00 = Rs28.00; row sample means are significantly different at the following probability levels: * = 0.1, ** = 0.05, and *** = 0.01.

probably reflects the difficulties that these farmers face in achieving timely land preparation. Delays in water issues may force them either to begin land preparation under somewhat dry conditions (in which case the amount of power needed would be greater) or to complete land preparation in a shorter time than available to farmers with more favorable water conditions.

These findings indicate that because of reduced input levels, the reduction in yield associated with unfavorable water conditions may be considerably greater than the amount that would be attributable to the physiological impact of water stress alone. They also indicate that in spite of reduced chemical input use, a farmer's total cash outlay may not be significantly below that of a farmer with favorable water conditions. The net result of these conditions is very low returns to the farmer's resources (Table 14).

In 1986 yala in Kalankuttiya, there was no significant difference between yields at the head and tail for rice. For one D-channel, chilli yields were significantly different between head and tail end plots. In the same season in Dewahuwa there was no significant difference in yields at the head and for any of the crops. This may be due to the fact that more water was supplied in 1986 than in 1985.

INSTITUTIONAL ASPECTS OF CROP DECISIONS[3]

In both Dewahuwa and Kalankuttiya, farmers prefer to grow a non-rice crop during yala and most commonly chilli. Rice is grown not so much by choice, as by (perceived) necessity. The primary reason that farmers prefer to grow chilli is the high guaranteed commodity price of Rs 26-28/kg. The reasons that some farmers do not grow chilli involve a complex of physical factors (e.g., soil types and water availability) as well as economic and institutional factors, of which the following appear to be important: financing and credit, labor availability, land tenure, and farmers' knowledge of water issues.

Financing

After soil and water, credit appears to be the single most important determinant in farmers' crop decisions. To finance the yala crop, farmers depend upon the sales of their maha rice; otherwise they must seek credit if they have no other source of income. Since yala begins just after the Sinhala New Year (April), farmers are often short of cash. And because a good portion of the maha crop goes for the family's subsistence needs, there is not normally enough left over to finance all the inputs needed for yala. Bank credit is often problematic because so many farmers have defaulted on previous loans. During 1986 yala, additional credit was made available, but generally this happened after crop decisions had been made.

Most farmers must rely on private credit or third party financing for at least some of their inputs. The prohibitive interest rates on private loans (20 per cent/month is typical) induce cash-poor landowners to mortgage their land and/or enter into sharecropping arrangements whereby inputs are paid though a third party. In Dewahuwa, nearly one third of the sample operators were farming mortgaged land; another third were farming under sharecropping (<u>ande</u>) contracts (Bulankulame 1986). Farmers who are using outside financing have extra incentive, as well as the means, to pay for the inputs necessary for chilli cultivation. Farmers who rely upon household resources, on the other hand, may be more likely to opt for rice.[4]

Labor Availability

The fact that chilli cultivation uses 3.4 times as much labor as does rice cultivation indicates the importance of the household labor pool, size of landholding, or adequate financing to hire the labor needed. Many farmers grow chilli on only one part of their holdings because they cannot afford to plant the entire area to such an expensive crop. Where land holdings are small (as in the case of a large family sharing a single 2.5 acre allotment in Mahaweli H), neither labor nor credit is a binding constraint, and there is an incentive to gain maximum profit from a small area. The crop of choice would be chilli.

Labor constraints in Kalankuttiya were more acute during yala 1986 than 1985 because of the alternating bethma practice from year to year. During yala 1985 only half the command area of each distributary channel was irrigated and the land was shared equitably among all farmers with each owner cultivating 50 per cent of his normal area. The labor supply was effectively doubled within each distributary command area as a result. Bethma divisions were not in effect during 1986 yala. That the difference in labor availability between the two yala seasons is not more pronounced in the relative proportions of land cultivated in chilli (55 per cent in 1985 versus 51 per cent in 1986) may be due to mutually compensating factors. The excellent 1985 chilli harvest and high support price may have outweighed the labor shortage in farmers' crop decisions, even at the cost of higher wage rates.

Land Tenure

Farmers who leased-in land during yala paid about 50 per cent/hectare more for well-drained land than for poorly-drained land, reflecting the greater value of non-rice crops. At the same time, having paid a higher rent, the farmer had an incentive to recover his costs through a high income crop such as chilli. The location of the plot can also be important. In Dewahuwa, where bethma divisions are practiced every yala, those farmers who are allocated temporary plots far away from their own fields seem to be more likely to grow rice than are those who cultivate in their usual locations. The reason would be to minimize the need to visit their fields: rice can grow with relatively little attention, while chilli must be looked after closely.

Knowledge of Water Issues

Farmers who anticipate water problems are unlikely to grow either rice or chilli; instead, they would select short-duration varieties of non-rice crops like soybean or green gram. As a result, farmers who normally cultivate in the tail end or who have been given a tail end bethma allotment, are more likely to rent-out their land during yala. Because of the many factors involved in farmers' crop decisions, there is a tendency to wait until the last minute, or even later, to decide. One farmer who was growing six different crops, including chilli and rice, reported that his original intention was to grow only chilli. Due to heavy rains, however, his chilli crop needed replanting. With neither enough time to grow another chilli nursery, nor finances to purchase chilli plants, he planted green gram, cowpea, onion, and vegetables to replace the damaged crop. Another farmer who had decided to grow chilli instead of rice changed his mind after heavy rain waterlogged his fields; he switched back to rice.

One factor with regard to farmers' willingness to grow diversified crops is their level of knowledge about cultivation. In Dewahuwa nearly all farmers are involved in some rain-fed agriculture, either in chena cultivation (usually encroached) or in their 1.2 ha house plots. Their experience in growing non-rice crops in these plots can be readily transferred to irrigated conditions, albeit with some technical advice. The function of extension agents is to provide information about market prices and optimal input use; the basic cultivation practices are already well understood by the majority of farmers. In Mahaweli, most farmers are not engaged in rain-fed farming, and this may help explain why they are more single-minded about chilli as nearly the only non-rice crop; promoting different crops through extension might result in a further expansion of non-rice cultivation.

NOTES

1. Members of the IIMI Crop Diversification Group include S.M. Miranda, E. Martin, and D.G. Groenfeldt. Their assistance is much appreciated.

2. OFC refers to "other field crops," such as chilli, green gram, soybean and black gram.

3. Based on information gathered through unstructured interviews during yala 1986 and through questionnaires administered during maha 1985/86 in Dewahuwa and Mahaweli H-2, Block 305; analysis of questionnaires administered during yala 1986 is currently underway.

4. The relationship between financing and crop selection, as well as other relationships, will be tested as the 1986 yala data are analyzed.

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REFERENCES

Bulankulame, Senarath. 1986. Social aspects of water management during the maha season 1985/86 in Dewahuwa and Mahaweli H-2 Block 305 - Precept and practice. Digana Village: International Irrigation Management Institute, unpublished research report.

Moragoda, Ranjini. 1986. Mahaweli H-2 - Crop decisions. Digana Village: International Irrigation Management Institute, unpublished field report.

Ratnasiri, Ekanayake. 1986. Dewahuwa - Crop decisions. Digana Village: International Irrigation Management Institute, unpublished field report.

Ministry of Finance and Planning. 1984. National agriculture, food and nutrition strategy. Colombo, Sri Lanka.

Somasiri, S. 1981. Land, water and crop management under irrigation in the dry zone of Sri Lanka. Prepared for the Mahaweli Research Committee by Department of Agriculture, Land and Water Use Division.

IRRIGATED DIVERSIFIED CROPPING CONSTRAINTS IN THE PHILIPPINES: A PRELIMINARY STUDY

Danilo Cablayan and Alfredo Valera*

In recent years, developing countries have become increasingly self-sufficient in irrigated rice. As an alternative strategy, many farmers in the Philippines produce non-rice crops under irrigation with highly variable results. The reasons for this are not well understood. Although all public irrigation systems were designed and built for wet season rice, these systems provide only enough water to irrigate a small portion of the full service area in the dry season.

A technological shift to adopt high yielding rice varieties in the past 20 years has increased the value of irrigation in the dry season. The economic viability of farming and of investing in irrigation development is increasingly dependent on dry season production. Competition for limited water in the dry season to produce rice has greatly increased. The need for alternatives has led to growing non-rice crops in suitable irrigated areas. However, the prospects for efficient and profitable production of these crops remain questionable. Agricultural and irrigation technologies, and economic and institutional factors that affect the performance of irrigated non-rice crops are not yet adequately understood.

STUDY OBJECTIVES

The overall objectives of the study were to identify the constraints to successful diversified cropping in irrigated areas and suggest ways to mitigate these constraints.[1] Constraints were grouped into irrigation, agronomic, economic, and institutional aspects of irrigated diversified cropping.

Study Sites

The study was conducted at three locations (Figure 1).

Allah Valley. In southern Mindanao, sites are: 1) the Allah Valley River Irrigation Project (ARIP), specifically the area served by lateral A-extra which is the Pilot Testing and Demonstration Farm Number 2 (PTDF#2) and which covers 277 hectares (ha); 2) the Banga River Irrigation System (BARIS), with an area of 2,300 ha; and 3) the Mani River Communal Irrigation System (MCIS), a farmer-managed system with an area of 732 ha.

Isabela. In northeastern Luzon, sites are part of the service area of the reservoir backed by the Magat River Integrated Irrigation System (MRIIS). Approximately 11,000 ha have soils in dual and diversified land classes. The area is served by lateral A of the Magat River Irrigation Systems (MARIS) --

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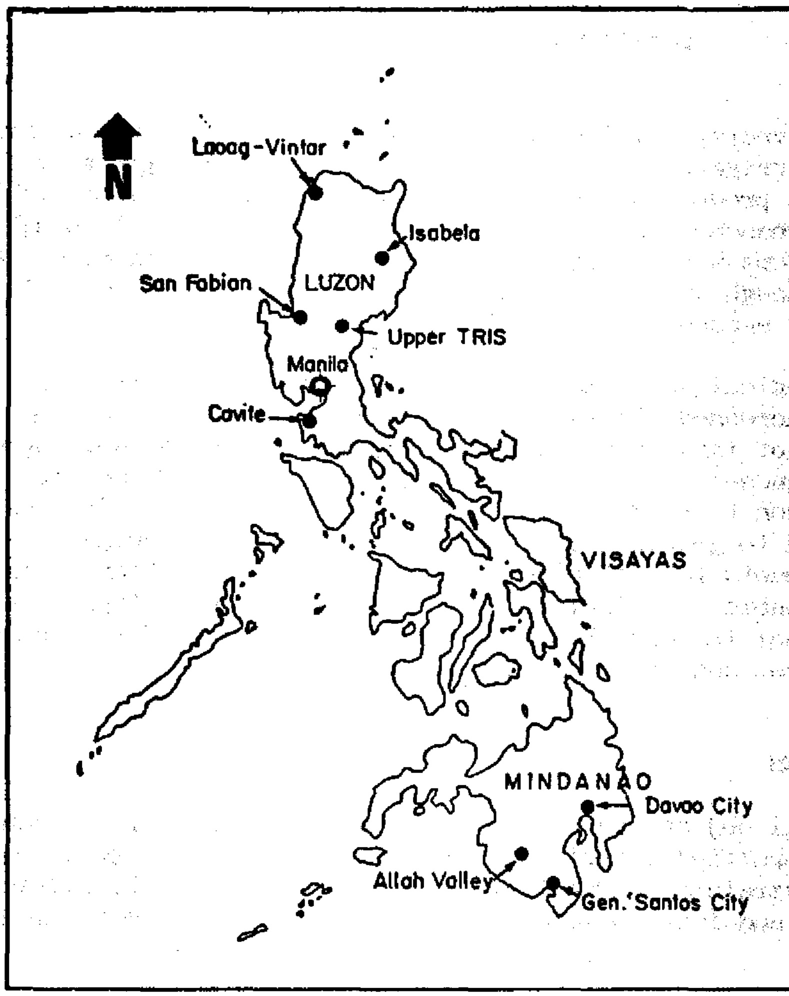
Figure 1. Map of the Philippines showing study sites.

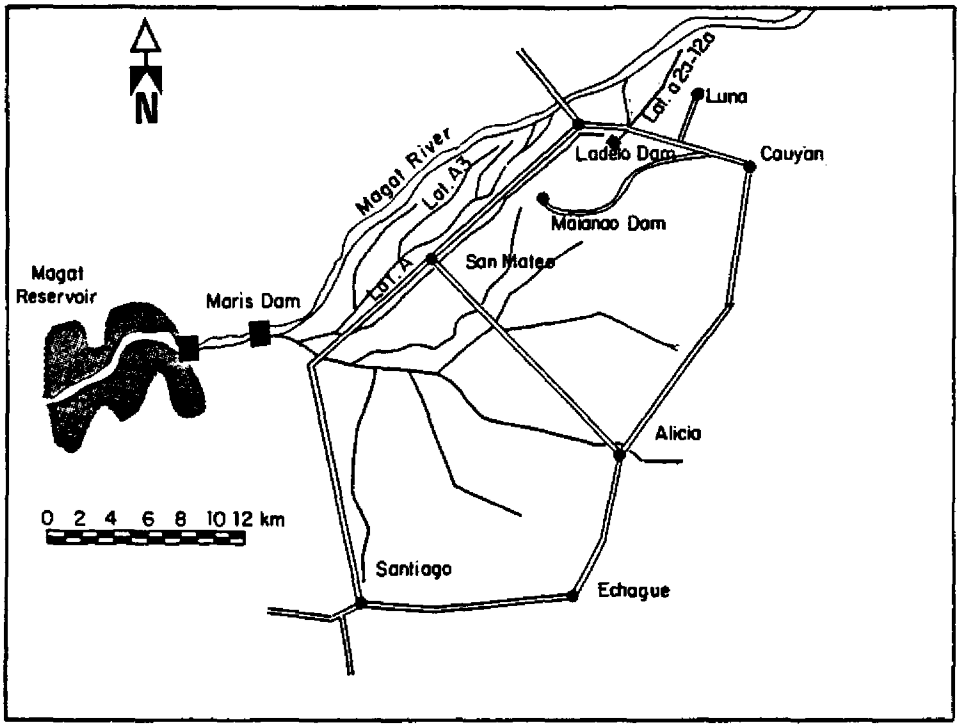


one of the two main systems comprising MRIIS. It is located near the banks of the Magat River and has a very high water duty if planted to lowland rice (Figure 2). It is classified as most adaptable for diversified crops. However with enough water, rice yields more than 5 tons/ha.

Cavite. In Central Luzon, the site is a part of the Second Laguna de Bay Irrigation Project (SLBIP). This project is expected to be completed in 1988 and will irrigate about 13,160 ha in the wet season and 9,600 ha in the dry. Approximately 2,500 ha is programmed for vegetable production in the dry season. Vegetable production is a logical choice for irrigated crop diversification due to the proximity of the project to Metro Manila.

Additional sites. In Luzon, four were added: the Upper Talavera River Irrigation System (Upper TRIS) in Nueva Ecija, the Agno River Irrigation System (Agno RIS) and the San Fabian River Irrigation System (SFRIS) both in Pangasinan, and the Laoag-Vintar Irrigation System (LVRIS) in Ilocos Norte.

Figure 2. Map of Magat River Irrigation System (MRIS) showing laterals.



Climate

Rainfall patterns can be categorized into four types (Hernandez 1975):

Type I. Two pronounced seasons. Dry from November to April and wet during the rest of the year. This type covers study sites in Ilocos Norte and Central Luzon.

Type II. No dry season with very pronounced maximum rainfall from November to January. This covers sites in Cavite.

Type III. Season not pronounced and relatively dry from November to April and wet during the rest of the year. This covers sites in Isabela.

Type IV. Rainfall more or less evenly distributed throughout the year. This covers the Allah Valley sites in southern and southwestern Mindanao.

METHODOLOGY

Study of Constraints to Diversified Cropping

Studies conducted at the main sites were: 1) system management, 2) evaluation of irrigation methods for corn, 3) crop testing of alternative non-rice crops, 4) economic aspects of irrigated/non-irrigated diversification, and 5) the role of irrigators' associations in operations and management.

Study 1. Stations were established in the sites to measure rainfall and evaporation. Canal flows were measured at strategic points to evaluate water availability and distribution equity. Planted areas under irrigation were monitored to estimate water demand.

Study 2. At the Allah Valley sites, furrow irrigation was compared with basin flooding for corn. At Isabela, double furrow and triple furrow methods were compared for corn. At Cavite, single furrow and double furrow irrigation for white beans were compared. In all studies, irrigation was applied when 50 per cent of the available soil moisture was depleted. Cut-throat flumes were used to measure irrigation flow. Duration of application, total water applied, and labor use were compared.

Study 3. Irrigated peanut, mungbean, and corn in Allah Valley were tested for adaptability. Researchers provided inputs and farmers provided land and labor. The farmers received the produce. At Isabela, irrigated peanut was compared with rainfed peanut under arrangements similar to those in the Allah Valley sites. Yields and farmer incomes were compared to those of farmers planting irrigated rice.

Studies 4 and 5. At least 10 per cent of the farmer population in the study areas were interviewed regarding cropping behaviors. At the additional sites, the study focused on the economics of irrigating non-rice crops and on farmer decision making related to irrigated crop diversification. Operations and maintenance procedures were also noted.

Crop Simulation Study

A crop simulation study was done for ARIP lateral A-extra to identify optimum irrigation scheduling for diversified crops. The cropping pattern was irrigated rice followed by irrigated corn. Weekly rainfall data from 1967-86 was used. However pan evaporation data was available only for 1980-85 and this 5-year mean was used for years without data. The flow chart for the simulation study is shown in Figure 3. Two simulations were done using the following:

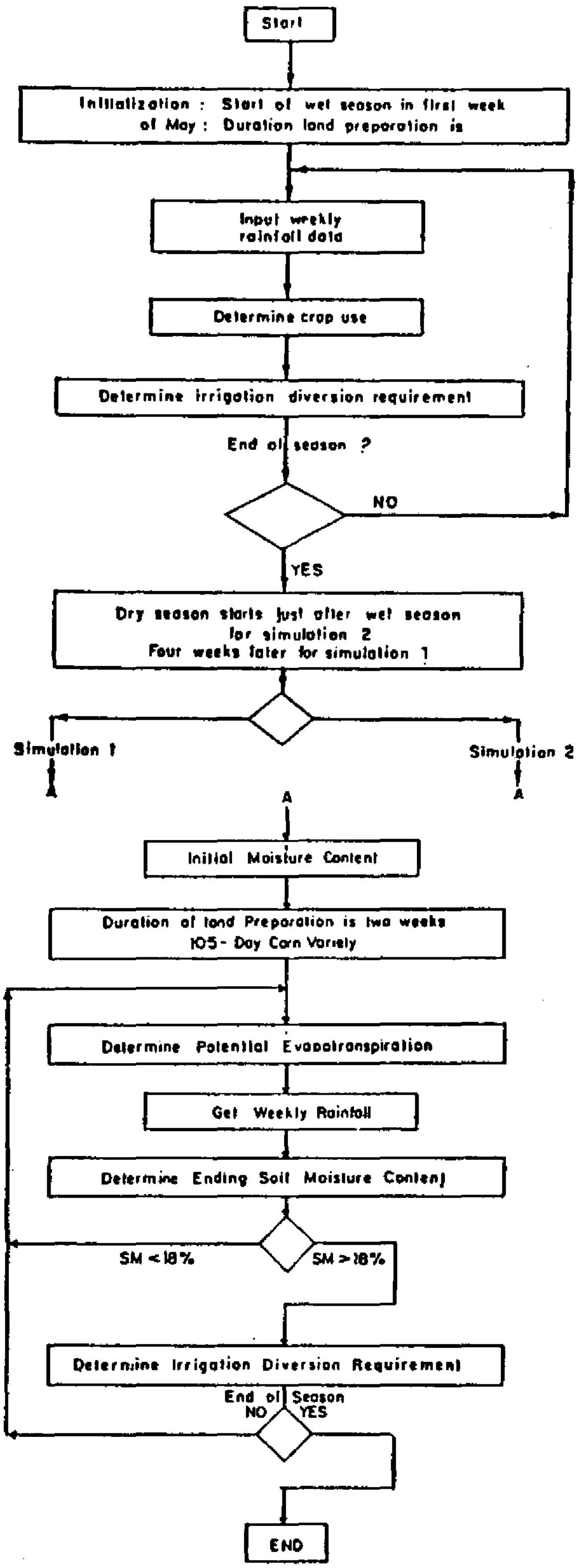
Simulation 1 (wet season):

1. Season started first week of May.
2. Land soaking was staggered to 4 weeks because of limited canal capacity.
3. Three weeks land preparation to coincide with seedling growth of transplanted rice.
4. Rice was 120-day variety.
5. Overall efficiency was 60 per cent.

Simulation 1 (dry season):

1. Season started four weeks after rice harvest. Irrigation began when the available moisture in the upper 60 centimeters (cm) of soil fell below 50 per cent.
2. Corn was 105-day variety.
3. Overall efficiency was 40 per cent.

Figure 3. Flow chart for simulation studies



Simulation 2: All the above hold except that the dry season started immediately after rice harvest. The following were also used:

1. Seepage and percolation = 10 millimeters (mm)/day.
2. Soil moisture saturation = 30 per cent by weight.
3. Apparent soil specific gravity = 1.5.
4. Depth of root zone for corn = 60 cm.
5. Soil field capacity = 15 per cent by weight.
6. Permanent wilting point = 7.5 per cent by weight.

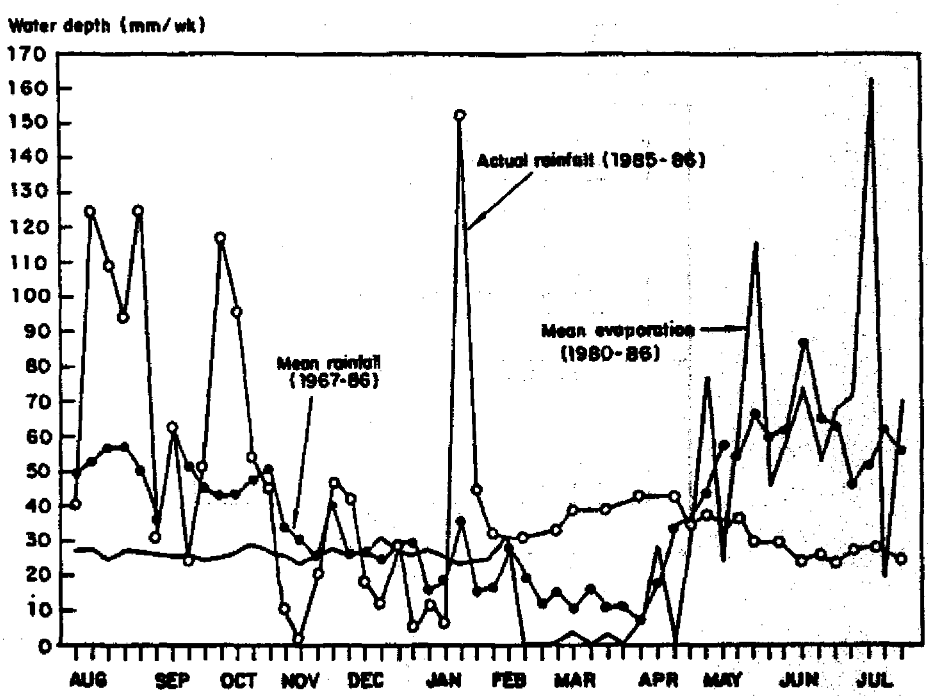
Crop coefficient for corn, which is multiplied by pan evaporation to obtain potential evapotranspiration, ranged from 0.3-1.2 from land preparation to grain formation. Rainfall data was analyzed using the incomplete gamma distribution.

RESULTS AND DISCUSSION

The Allah Valley Sites

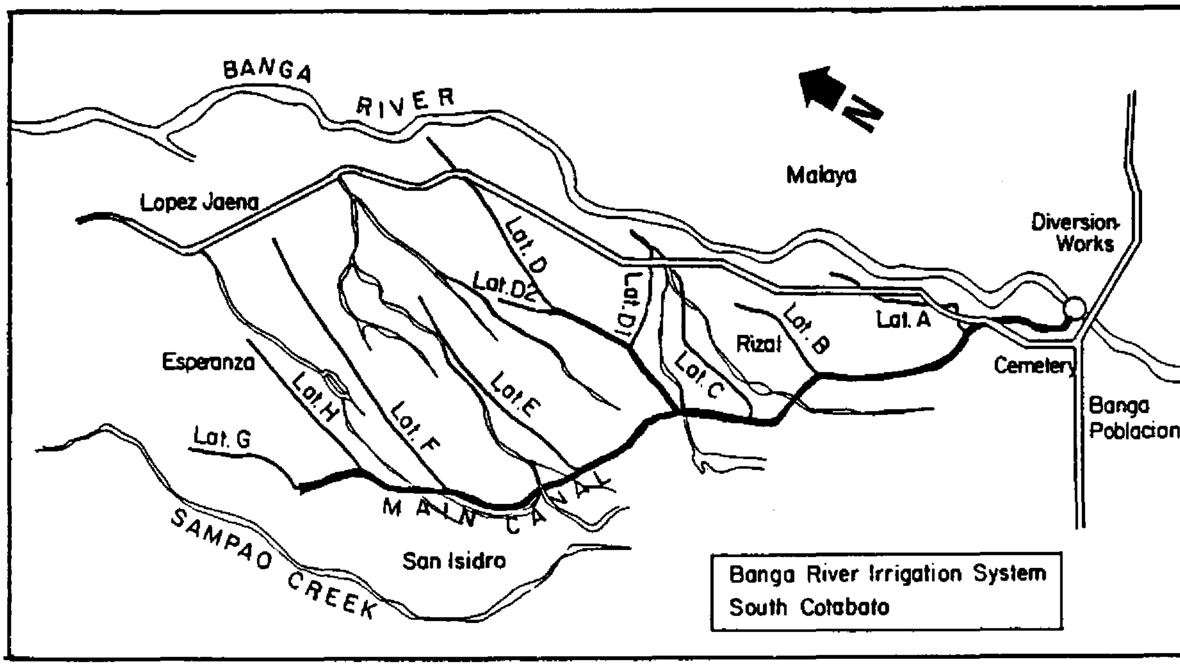
The rainfall pattern is type IV. Evaporation averages 4 mm/day from June to January, and 6 mm/day for the rest of the year (Figure 4). Moisture deficit occurs only from late December to April in an average year. Crop water use averaged 4 mm/day in evapotranspiration and 13 mm/day in seepage and percolation (S&P). The soils are mostly sandy loam. There is a sand-stone-like layer 100-120 cm deep which restricts downward water flow.

Figure 4. Mean weekly rainfall (1976-86), mean evaporation (1980-86), and actual rainfall (1985-86), Surallah, South Cotabato.



Banga River Irrigation System (BARIS). This run-off-the-river system commands 2,300 ha. A major problem is the large amount of silt that limits the amount of water that can be diverted into the canals. The service area, headed by an Assistant Irrigation Superintendent, is divided into three water masters' divisions into six hydrological sectors (Figure 5).

Figure 5. Map of the Banga River Irrigation System (BARIS).



The irrigable area has been reduced to 1,930 ha because of limited water supply. However, when planted to rice, the system can only irrigate 1,600 ha in the wet season and 1,300 ha in the dry. This system has nine irrigators' associations (IA) integrated into one federation. To plan the water delivery schedule, IA, federation, and barangay (smallest political unit in the Philippines) officials meet with representatives of the government and private agencies concerned with agriculture in the area one month before the start of each season. They decide which to irrigate. Farmers are encouraged to plant excluded areas with corn or other diversified crops but the land is not irrigated. However, if there is enough water left after irrigating the programmed rice areas, excluded areas may be given water.

Irrigation is rotated by providing each sector with water for a specified number of days on a weekly schedule. The National Irrigation Administration (NIA) field staff implement the schedule but cannot alter it without consulting farmers. Water supply data is shown in Table 1. Flow measuring devices were installed in August 1985, which was in the middle of the wet season. To prevent unscheduled deliveries, unauthorized checks are removed

Table 1. Irrigation diversion (ID), rainfall, and relative water supply (RWS*, in millimeters per week) by division for BARIS during the wet and dry seasons, 1985-86.

Wk	Season & date		Rain fall	Total		Div A		Div B		Div C	
				ID	RWS	ID	RWS	ID	RWS	ID	RWS
35	Wet	Aug 27-Sep 2	80	46	1.6	60	1.6	29	1.2	52	1.9
36		3-9	140	46	2.3	24	2.0	47	2.1	58	2.7
37		10-16	69	20	1.1	22	1.1	16	1.0	35	1.3
38		17-23	34	59	1.1	37	0.9	15	0.6	67	1.2
39		24-30	38	46	1.0	110	1.8	16	0.6	38	0.9
40		Oct 1-7	34	49	1.0	118	1.8	40	0.9	16	0.5
41		8-14	63	52	1.6	104	2.4	31	1.2	38	1.2
42		15-21	87	47	2.1	178	4.5	17	1.6	24	1.5
43		22-28	38	35	1.2	160	3.8	8	0.8	27	0.9
44		29-Nov 4	16	103	1.5	1735	23.5	41	0.8	76	1.2
45	Dry	Nov 5-11	0	104	1.1	262	2.9	83	0.9	29	0.3
46		12-18	11	74	0.9	187	2.2	59	0.8	22	0.4
47		19-25	30	54	0.9	159	2.1	32	0.7	14	0.5
48		26-Dec 2	3	65	0.7	143	1.6	39	0.8	42	0.5
49		Dec 3-9	28	76	1.1	139	1.8	99	1.4	72	1.1
50		10-16	121	60	2.0	89	2.3	80	2.2	73	2.1
51		17-23	11	65	0.8	45	0.6	73	0.9	84	1.1
52		24-31	10	95	1.1	78	1.0	70	0.9	133	1.6
1		Jan 1-7	2	81	0.9	65	0.7	113	1.3	63	0.7
2		8-14	12	92	1.1	126	1.5	91	1.1	74	0.9
3		15-21	31	101	1.4	148	2.0	136	1.8	85	1.3
4		22-28	36	57	1.0	59	1.0	63	1.1	52	1.0
5		29-Feb 4	23	44	0.7	82	1.2	25	0.5	38	0.7
6		Feb 5-11	5	63	0.8	75	0.9	90	1.1	60	0.7
7		12-18	11	71	0.9	149	1.8	107	1.4	101	1.3
8		19-25	3	85	1.0	250	2.8	217	2.5	152	1.8
9		26-Mar 4	2	139	1.6	784	8.7	475	5.3	213	2.4
10		Mar 5-11	9	95	1.2	0	-	0	-	0	5.0
11		12-18	0	162	1.8	0	-	0	-	0	3.3
12		19-25	0	534	5.7	0	-	0	-	0	11.7
Wet season mean			65	45	1.4	90	2.2	24	1.1	40	1.3
Dry season mean			21		1.0		1.6		1.2		1.0
Overall mean			37		1.2		1.8		1.2		1.1

*RWS = (rainfall + irrigation)/crop water requirement; means do not include weeks 44 and 9-12 due large amounts of water diverted and small areas under irrigation at the end of the season.

by NIA staff. Areas not scheduled have their gates closed. Division A is upstream and laterals are closed when water is not scheduled; checks in the main canals are removed. Division B, served by lateral D, has one supply point. Divisions A, C, and D include many turnouts directly served by the main canal. Division C, the tail end, uses return flows into the main canal, thus receiving more water in the wet season than Division B. Dry season flows were minimal. There were many weeks where the relative water supply (RWS) was less than one. The means show maldistribution: Division A received twice as much water as Division C and three times that of Division B. Crop water stress was not observed.

The large area served by the main canal made it necessary for NIA staff to gather data by division and not by sector; water flows were measured up to the sector level. In order to compare sectors, these flows were converted into values by using a water duty of 1.5 liters per second/ha (lps/ha) or 13 mm/day. As an alternative method of analyzing equity in water distribution, the area in each sector programmed for water deliveries became the basis against which actual irrigation was compared for every rotation. Weeks when the irrigated area is greater than the programmed area are "excess" weeks, while the opposite are "deficit" weeks. Maldistribution is evident with Sector I having fewer deficit weeks (Table 2). Sectors III and IV were not scheduled for irrigation in the dry season; the wet season was extended for 1.5 months for Sector III and 2 months for Sector IV.

More deficit weeks appear in Table 2 than in Table 1 (as shown by an RWS less than one) because actual irrigated area, used in Table 1, exceeds the programmed area, used in Table 2. Although the rotation scheme gave equal opportunity for all farmers to receive a share of water, even during periods of water scarcity thus preventing serious crop damage, there was not enough water to irrigate the system. About 1,500 ha of rice was irrigated in the wet season and 1,200 ha in the dry. Irrigated corn was not included in the program due to farmers' preference for rice.

Including corn in the program would mean a probable loss of revenue for the NIA because of the difficulty in collecting irrigation service fees. Farmer groups scheduled to plant irrigated rice in the wet season tend to request extended water deliveries into their dry season schedule. By doing so, soil moisture may become sufficient to support dry season rice. Such requests are usually granted to compensate farmers for not planting rice in the next wet season. In areas scheduled for rice irrigation, some farmers tend to plant corn adjacent to rice paddies where the corn can be irrigated by seepage. These farmers cannot be billed for irrigation service because the corn is not directly served. Although there is a large area of corn planted adjacent to rice in BARIS, farmers are under the misconception that corn does not normally need irrigation. However, during droughts in 1983 and 1984 dry seasons, farmers requested irrigation for corn and were made to sign promissory notes to pay their irrigation service fees.

<u>Mani Communal Irrigation System (MCIS)</u>. This farmer-managed system serves 732 ha and gets water from a concrete diversion dam across the Mani River at Esperanza, South Cotabato. The system was rehabilitated through a NIA loan which farmers are amortizing. Managed by an Irrigators' Association (IA), the system is divided into five sectors, each having a leader. A hired canal tender oversees water distribution and a hired gate keeper tends the dam's main diversion point. Before each season the IA decides which sectors will be irrigated, and schedules deliveries and cut-off dates. There

Table 2. Water availability and equity by sectors as a function of comparing "Excess" (E) and "Deficit" (D) weeks, BARIS, wet and dry seasons, 1985-86.

Week	Season & date		Total*	Sectors I	II	III	IV	V	VI
35	Wet	Aug 27-Sep 2	E	E	E	D	E	D	E
36		3-9	E	E	E	E	E	E	E
37		10-16	D	D	D	E	E	E	E
38		17-23	D	E	D	D	E	D	E
39		24-30	D	E	D	D	D	D	D
40		Oct 1-7	D	E	D	E	D	D	D
41		8-14	E	E	D	E	E	D	E
42		15-21	E	E	E	E	E	E	E
43		22-28	D	E	D	D	D	D	D
44		29-Nov 4	D	E	D	D	D	D	D
Programmed area (ha)			1930	250	400	360	300	350	270
Excess weeks			4	9	3	5	6	3	6
Deficit weeks			6	1	7	5	4	7	4
45	Dry	Nov 5-11	D	E	D	D	D	D	D
46		12-18	D	E	D	D	D	D	D
47		19-25	D	E	D	D	E	D	D
48		26-Dec 2	D	E	D	D	E	D	D
49		Dec 3-9	D	E	D	D	D	D	D
50		10-16	E	E	E	E	E	E	E
51		17-23	D	D	D		D	D	D
52		24-31	D	D	D		D	E	E
1		Jan 1-7	D	D	D			D	D
2		8-14	E	E	D			D	D
3		15-21	E	E	D			D	E
4		22-28	D	E	D			D	E
5		29-Feb 4	D	E	D			D	D
6		Feb 5-11	D	D	D			D	D
7		12-18	D	D	D			D	D
8		19-25	D	D	D			D	D
9		26-Mar 4	E	E	D			D	E
10		Mar 5-11			D			D	D
11		12-18			D			D	D
12		19-25			D			D	E
Programmed area (ha)			1277	207	509	235	248	309	252
Excess weeks			4	11	1	1	3	2	6
Deficit weeks			13	6	19	5	5	18	14

*Programmed areas were reduced to 150, 36, and 114 ha for the Total, Section A, and lateral B, respectively, from week 1-8.

are monthly meetings in each sector. Instruments to measure canal flows were installed in August; Table 3 shows total water supply. The area was divided into two parts: sector A (300 ha), served by the main canal, and sector B (432 ha), served by lateral B (Figure 6).

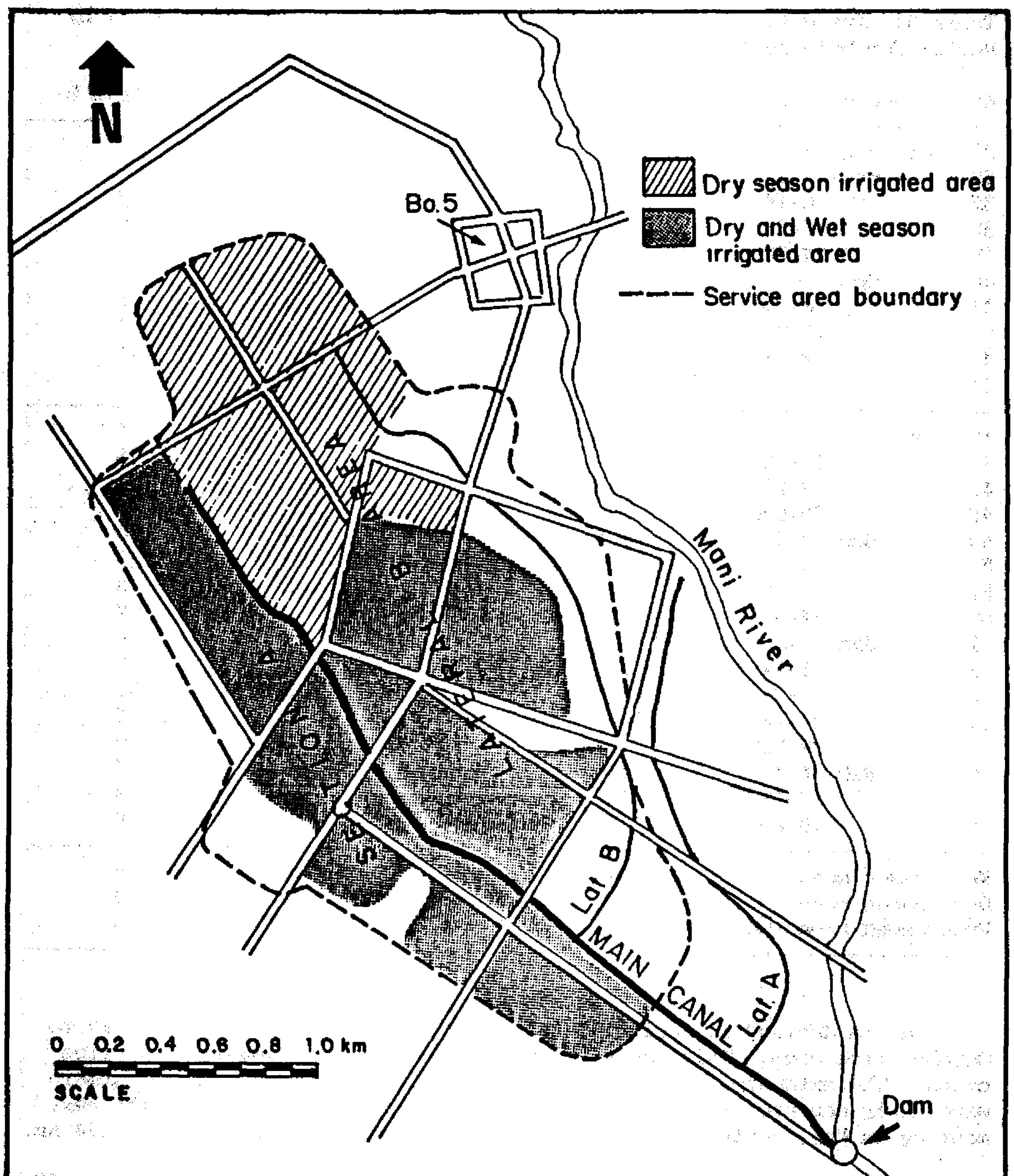
Table 3. Irrigation diversion and rainfall (in millimeters per week) by sector for MCIS during the wet and dry seasons, 1985-86.

Wk	Season & date	Rainfall	Total	Sector A	Lateral B
35	Wet Aug 27-Sep 2	31	59	61	56
36	Sep 3-9	33	71	55	91
37	10-16	31	58	56	59
38	17-23	33	80	83	76
39	24-30	31	68	58	79
40	Oct 1-7	33	81	82	81
41	8-14	31	70	65	75
42	15-21	33	72	84	57
43	22-28	31	63	82	41
44	29-Nov 4	33	54	64	42
45	Dry Nov 5-11	2	75	68	84
46	12-18	1	90	52	135
47	19-25	14	103	102	104
48	26-Dec 2	14	16	29	0
49	Dec 3-9	40	89	56	130
50	10-16	6	85	53	125
51	17-23	36	43	17	73
52	24-31	5	96	79	117
1	Jan 1-7	3	65	48	84
2	8-14	27	73	21	136
3	15-21	29	21	9	35
4	22-28	148	0	0	0
5	29-Feb 4	7	0	0	0
6	Feb 5-11	15	80	56	67
7	12-18	11	97	28	88
8	19-25	11	65	8	118
Wet season mean		32	67	69	66
Dry season mean		20	63	51	80
Programmed area (ha)			240	132	108

The IA decided in April 1985 to program the area for a single May to October rice crop. This was extended to January to accommodate two rice crops. The extension helped the tail end area of lateral B whose farmers were newly accepted members of the IA. From February 1986 until the next meeting in May, sector A was programmed for 36 ha and lateral B for 114 ha.

For the main season, the mean irrigation supply for the system was 62 mm/week. Sector A had 53 and lateral B had 73 mm/week. This shows maldistribution in favor of lateral B. Most areas served by sector A got their

Figure 6. Map of the Mani Communal Irrigation System (MCIS).



water after the head gate of lateral B. The IA president has a farm served by this lateral and the ditch tender responsible for water distribution is his son. In the extra cropping season, the mean water supply for the whole system was 72 mm/week (sector A had 69 mm/week and lateral B, 82 mm/week). The data shows maldistribution favoring the upstream farmers.

Farmers in MCIS irrigate a smaller rice area in the dry season and take advantage of seepage for adjacent corn. Farmers don't directly irrigate corn, even during drought periods unless corn planted away from the rice fields exhibit moisture stress. However, these corn fields are located far from water sources in higher elevations. As in BARIS, the area not planted to rice is rotated to give equal opportunity to all farmers.

Institutional Observations at BARIS and MCIS. Members of the IAs formally organized by NIA in ARIP and BARIS, and members of the communal irrigation association at MCIS, were interviewed in order to compare the NIA and communal systems.

The results in Table 4 show a discrepancy between the farmers' perceptions of their responsibilities for operations and maintenance and actual practice. This discrepancy is also apparent in the system level management studies at BARIS and MCIS. At BARIS and MCIS, water delivery schedules agreed to between NIA and IAs were seldom adhered to, particularly by the upstream farmers, which resulted in maldistribution. Seasonal decisions were ignored, which made it hard to implemcnt regular rotations and cropping schedules. In order to reduce farmers' uncertainty, the IAs need to communicate to farmers the dates of deliberate suspensions of delivery due to activities such as dam desilting and repair of main canals. Poor communication and implementation of policies appear to be the major constraints that limit effective operation of IAs in BARIS and MCIS. Responses showed that sufficient water and increased income were the dominant benefits perceived by farmers. This implies that an IA's viability is dependent on the irrigation needs of the farmers. The results also indicate that the communal system does no better than the NIA system in terms of actual operational effectiveness.

The responses of the farmers indicate ambivalence in their willingness to shift from rice to non-rice crops (Table 5). However, the popular choice of non-rice crops are corn and mungbean. Particularly at BARIS and MCIS, the testing of alternative non-rice crops might have convinced farmers of the profitability of mungbean production at these two sites.

Isabela Site

The Magat River Integrated Irrigation Systems (MRIIS) service area has a Type III rainfall pattern. Average evaporation is 4 mm/day in cold months, and 6 mm/day in hot months (March-July). Moisture deficits occur from December to April (Figure 7). Corn and tobacco, usually planted October to November, were the main dry season crops before irrigation was introduced. The mean 10-year weekly rainfall shows that such deep-rooted crops may not need irrigation in the early growth stages. This is why farmers believe that such crops do not need irrigation.

Table 4. Percentage responses to questions about perceived problems affecting the Irrigators' Association (IA), responsibilities of the IA members, actual activities of IA members, and perceived benefits of IA membership at ARIP, BARIS, and MCIS, 1985-86.

	ARIP	BARIS	MCIS
<u>Perceived problems affecting IAs</u>			
Members lack interest in IA activities	22.0	25.5	16.4
Inadequate supply, unequal distribution	23.7	25.5	61.8
Poor Irrigation fee collection	1.7	0.0	1.8
Poor management, weak leadership	1.7	0.0	7.3
Marketing problems lack of drainage, no funding	3.4	4.3	1.8
Insufficient & bad farm roads, poor drainage	25.4	0.0	0.0
Did not answer	22.4	44.7	10.9
Total responses	59	47	55
<u>Responsibilities of IA members</u>			
Attending meetings	41.5	7.9	23.4
Maintaining and repairing canals	5.7	14.3	11.7
Paying irrigation fees and financing the IA	40.2	25.4	46.8
Cooperating with IA policies and plans	12.6	49.2	16.9
Helping plan, decide, and solve IA problems	0.0	3.2	1.2
Total responses	51	56	54
<u>Actual activities of IA members</u>			
Maintaining and repairing canals	98.0	64.3	98.1
Cooperating with IA policies and plans	0.0	16.1	0.0
Helping in building IA center	0.0	17.9	0.0
Did not answer	2.0	1.7	1.9
Total responses	51	56	54
<u>Perceived benefits of IA membership</u>			
Increased income and production	35.3	27.7	34.9
Improved standard of living	6.8	1.1	22.1
Sufficient water	54.5	27.6	39.5
Personality development, human relations	0.0	18.4	0.0
Facilitated farm operation	0.0	5.7	0.0
Additional knowledge and technology	1.1	18.4	0.0
Others (request is easier, inputs/financing aid)	0.0	1.1	0.0
Did not answer	2.3	0.0	2.3
Total responses	88	87	86

Note: Respondents gave more than one answer.

Table 5. Percentage responses to questions asking if farmers would consider planting alternative crops to rice during the dry season at ARIP, BARIS, and MCIS, 1985-86.

	ARIP	BARIS	MCIS
1. Are you willing to plant alternative crops to rice during the dry season?			
Yes	84.3	50.0	85.2
No	15.7	50.0	14.8
Total responses	51	46	54
2. If yes, which crop would you prefer?			
Corn	63.6	32.7	44.4
Mungbean	19.7	23.6	30.3
Peanut	4.5	0.0	4.0
Cotton	0.0	0.0	7.1
Eggplant, watermelon, sweet potato, cassava	12.2	41.9	8.1
Total responses	66	55	99
3. If no, what are your reasons?			
Used to planting rice and its our staple	0.0	6.3	0.0
Farm is not suitable for upland crops	13.7	25.4	3.7
Poor drainage	2.0	12.7	11.1
Limited water during the dry season	0.0	1.6	0.0
Not applicable	84.3	38.0	85.2
Total responses	51	63	54

Note: Respondents gave more than one answer.

The Magat River Integrated Irrigation System (MRIIS). This is a 97,400 ha reservoir-supported system that covers the Magat River Irrigation System (MRIS) and the Siffu River Irrigation System (SFRIS). MRIS includes 11,000 ha classified as diversified crop land which is served by lateral A. These areas have light soils and very high water requirements if rice is grown in the dry season. The mean water duties in lateral A areas are: 59 mm/day for land soaking, 27 mm/day for land preparation, 29 mm/day for vegetative stage, and 30 mm/day for reproductive stage.

Two sub-laterals in lateral A were used for growing irrigated diversified crops in past years, specifically corn. Sub-lateral 3a is under the SIBESTER irrigators' association, and sub-lateral A2-a12-a1 is under the CPPL irrigators' association. These two IAs are active and assist NIA with water distribution in their respective areas. NIA has contracted them to clean the canals and participate in irrigation service fee collection.

Figure 7. Mean weekly rainfall (1975-85), evaporation (1985-86) and actual rainfall (1985-86) in millimeters per week for Luna, Isabela.

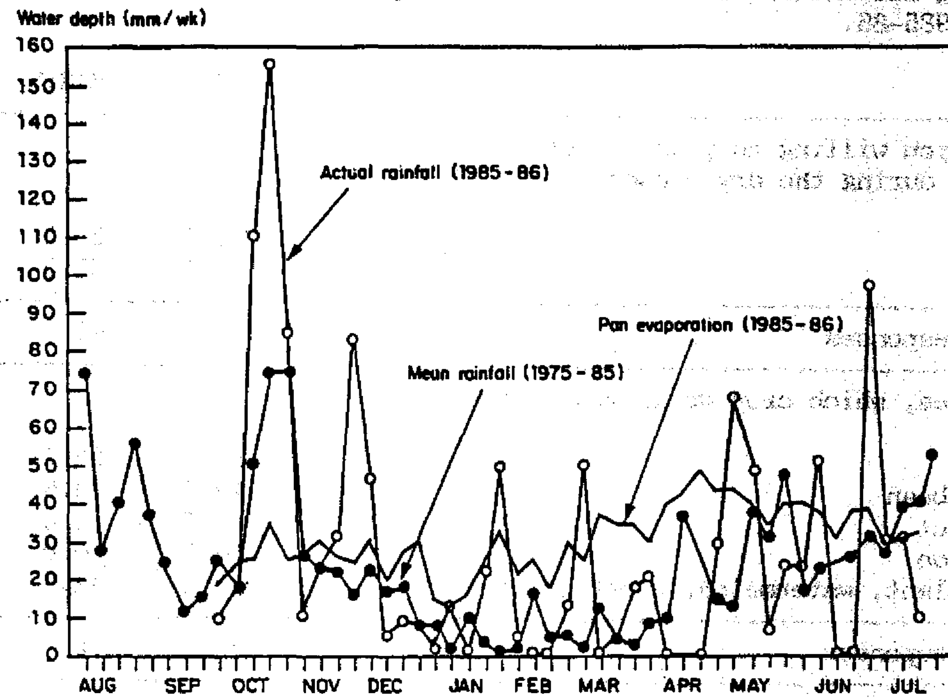
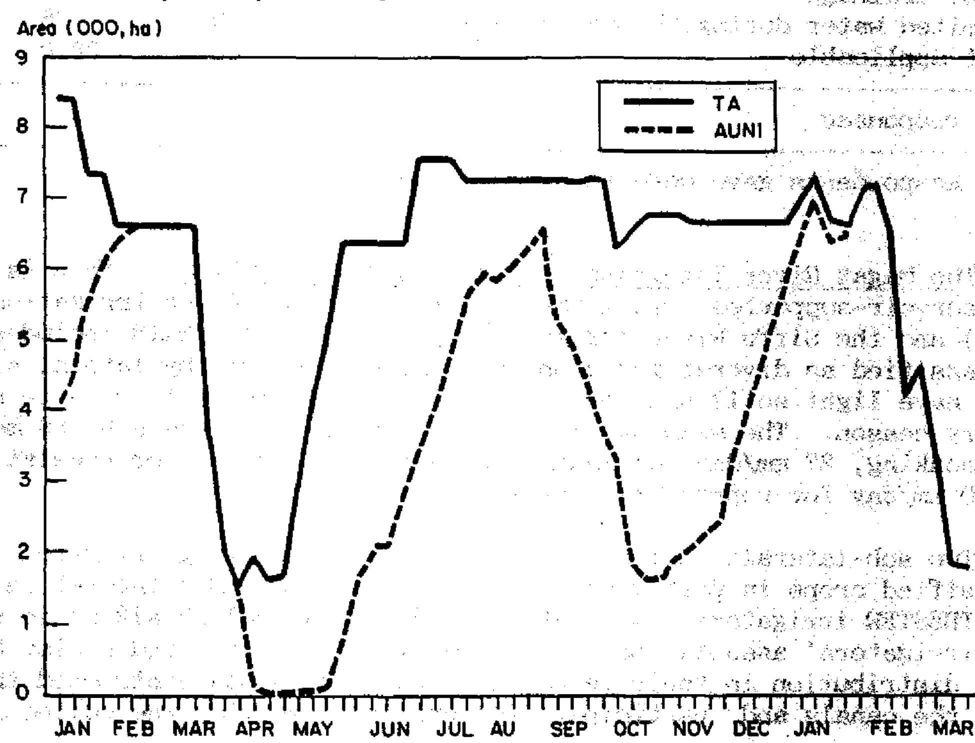


Figure 8. Weekly irrigated areas under normal irrigation (AUNI - covering the period between transplanting and terminal drainage), and total irrigated area (TA = AUNI plus other areas under land soaking and land preparation), for rice, lateral A, MRIS, January 1985 to March 1986.



Although in MRIS there is continuous cropping in lateral A (Figure 8), water is cut-off in April. Rainfall enables some farmers to start farming activities earlier. Some have a standing crop by the start of water delivery in early June. They can often grow three crops during the two-crop season specified by the irrigation plan for MRIS. The cropping schedule planned for the area is not followed by some farmers.

The start and end of each cropping season is not distinct. Usually beginning in November, in some areas dry season begins in mid-October when land preparation has already started. Farmers try to grow three crops of rice in a year if they are located nearer the water source and served by the main lateral or upstream sub-laterals. Planting activities in the tail end sub-laterals are delayed for a month longer, causing maldistribution favoring those who plant early. This practice is not conducive to introducing crop diversification. Although these tail end areas are more adaptable to diversified crops, farmers can hardly grow two crops of irrigated rice.

Figure 9 shows that the total water supplied in MRIS (rainfall plus irrigation) is greater than the irrigation diversion requirement (IDR) during most weeks. The resulting relative water supply averaged 1.5 for the whole duration of the observation (Table 6). There is sufficient water in the system to support lowland rice even in areas where the water duty is high. Farmers feel no need to change crops for efficient use of water. When the MRIIS service area is fully developed, it will serve a large area and there will be a need to efficiently use the available water to irrigated all areas.

Figure 9. Actual irrigation supplied (IS), irrigation diversion requirement (IDR), and rainfall (RF), lateral A, MRIS, October 1985 to March 1986.

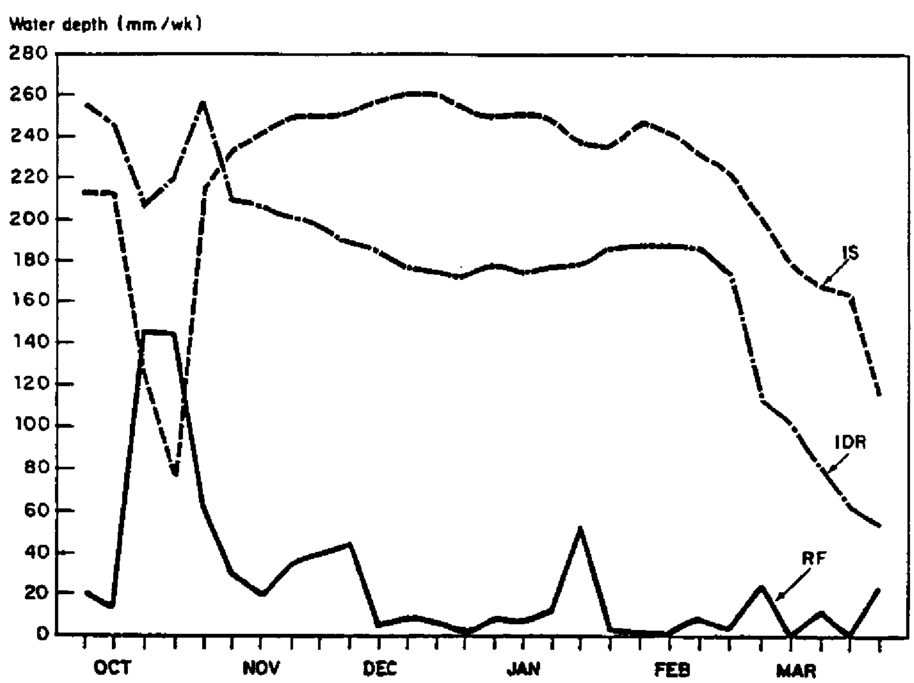


Table 6. Weekly irrigation diversion requirement (IDR), actual irrigation water supplied (IR), and rainfall (RF) in millimeters per week, and relative water supply (RWS), MRIS, District II, lateral A, dry season 1985-86.

Wk	Date	IDR	IR	RF	RWS*
40	Oct 1-6	256	213	21	0.9
41	7-13	244	213	13	0.9
42	14-20	206	124	146	1.3
43	21-27	220	75	145	1.0
44	28-Nov 3	257	214	63	1.1
45	Nov 4-10	209	234	30	1.3
46	11-17	207	244	20	1.3
47	18-24	201	251	34	1.4
48	25-Dec 1	198	249	41	1.5
49	Dec 2-8	188	250	44	1.6
50	9-15	185	257	5	1.4
51	16-22	176	260	9	1.5
52	23-29	174	261	7	1.5
1	30-Jan 5	172	255	1	1.5
2	Jan 6-12	179	248	8	1.4
3	13-19	173	252	7	1.5
4	20-26	178	249	12	1.5
5	77-Feb 2	178	236	52	1.6
6	Feb 3-9	186	234	3	1.3
7	10-16	187	248	2	1.3
8	17-23	187	243	0	1.3
9	24-Mar 2	187	231	3	1.3
10	Mar 3-9	173	223	3	1.3
11	10-16	114	201	24	2.0
12	17-23	102	177	0	1.7
13	24-30	79	167	12	2.3
14	31-Apr 6	60	163	0	2.7
15	Apr 7-13	52	116	23	2.7
Mean		175	217	26	1.5

*RWS = (IR + RF)/IDR

Flow measurements were neglected in MRIS. However, inflows equivalent to 10,000 ha sections were measured. Flows into and within each water master's division (750 ha) should be measured to improve distribution. Because flows are not measured, upstream farmers cannot be detected getting more than their share, which causes shortages downstream while excess water upstream goes to the drains. Some downstream farmers reuse the drainage water.

<u>Institutional observations at the Isabela site</u>. Two IAs were studied: SIBESTER and CPPL. The former had more active participation in meetings and group work (maintaining or cleaning canals). The latter was beset with problems caused mainly by ineffective leadership. Other causes included dependence on NIA and structural defects in the irrigation facilities.

Crop diversification at the Isabela site was unanimously perceived as feasible at both IAs if the market price of corn and other non-rice crops were attractive and stable enough to warrant a shift from rice. The abundance of irrigation water for rice exacerbates the economic constraints as reflected in the unfavorable market price of corn.

Additional Sites

Ilocos Norte and Nueva Ecija belong to rainfall Type I. In the wet season, rainfall peaks at a mean of 500 mm/month in August. This enables farmers to grow rainfed lowland rice. There is very minimal rainfall in the dry season and diversified crops cannot grow unless provided with irrigation (Figure 10 & 11). Farmers adopt irrigated diversified crops which need less water. Although irrigation systems in Northern and Central Luzon have areas planted to irrigated diversified crops in the dry season, in Ilocos, it is necessary to grow crops all-year round because of the small land holdings (less than a hectare) if the farmer is to survive financially. When water is available, the preferred crop is lowland rice (Layaoen 1982).

Figure 10. Rainfall pattern (1965-1976) and cropping seasons. Ilocos Norte, Philippines (taken from Ilocos Agriculture, Vol.1, No.1, January to March 1982.

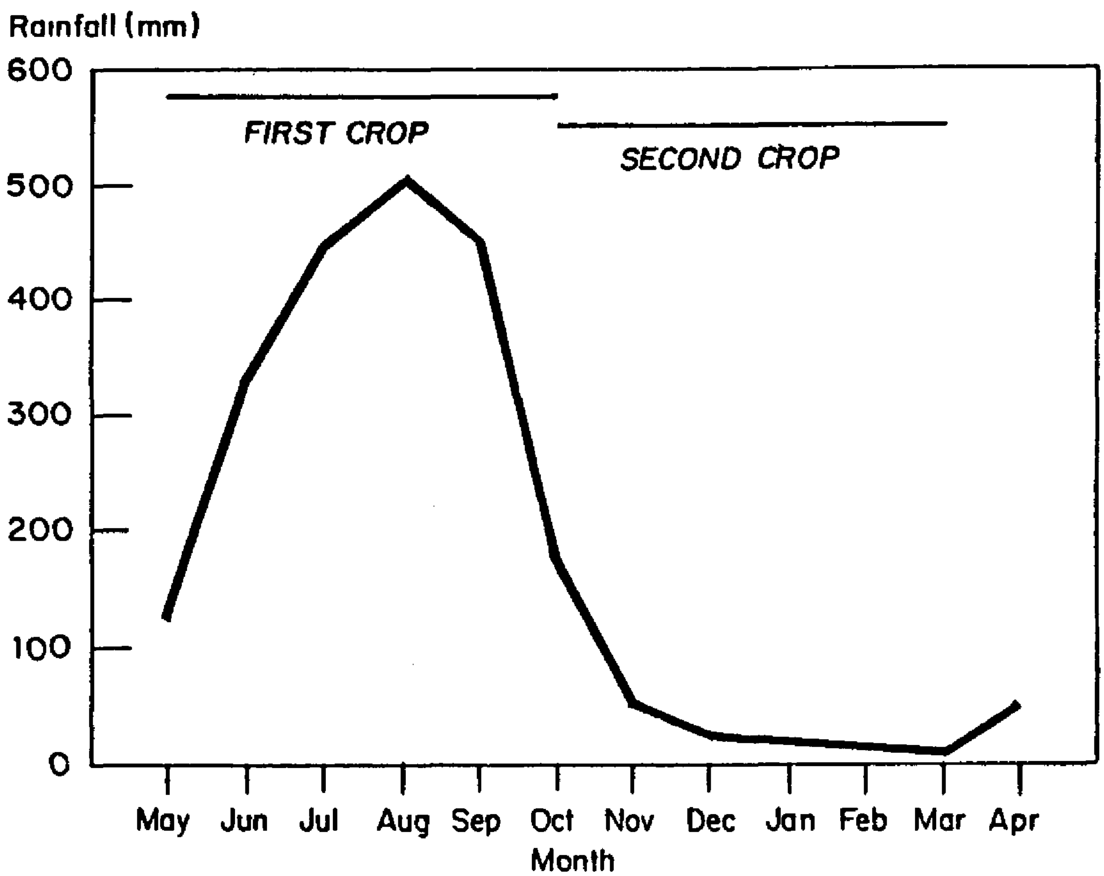
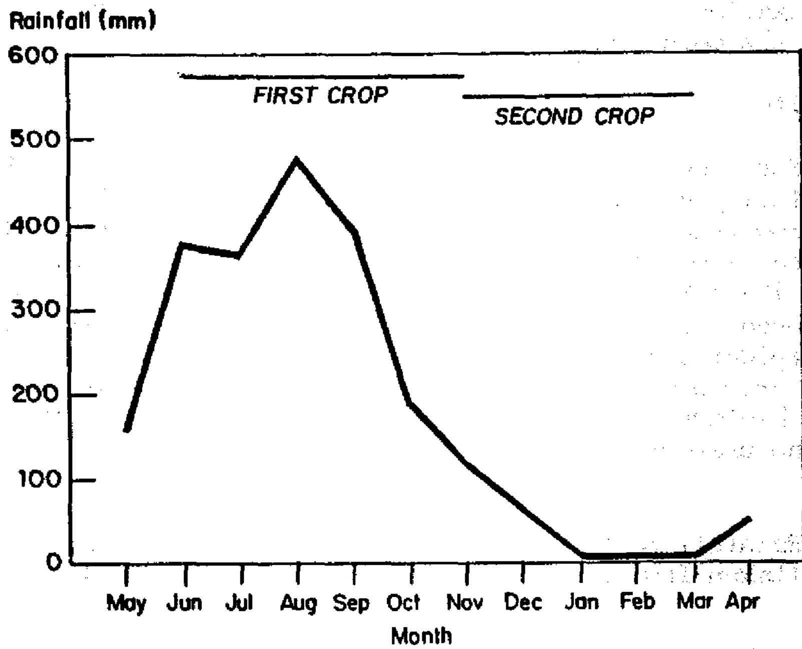


Figure 11. Rainfall pattern (1948-1970) and cropping seasons. San Jose, Nueva Ecija (ECI-EDCOP 1975).



Upper Talavera River Irrigation System (Upper TRIS). Although the entire dry season service area (500 ha) was scheduled for irrigated diversified crops, some farmers persisted with rice in the upstream and low areas. In most years, only 50-60 per cent (about 200-300 ha) of the programmed area was actually planted. Continuous irrigation is generally practiced but, during water shortages, non-rice crops receive priority on a rotational schedule. Because there are few control structures and few guidelines to operate the system for diversified crops, farmers have evolved a basin-flush-flooding method. The paddy dikes are retained from the previous rice crop to impound the water which is later drained into the next paddy in a form of paddy-to-paddy irrigation. Onion and garlic are grown in either mulched plots or raised beds. For the former, ditches are constructed on the inside edges of the paddies, and used as perimeter ditches for flooding and draining. For the raised beds (1.0-1.5 meters wide), ditches are made between beds for both flooding and draining. NIA provides water to the turnouts and enforces rotational schedules when water is scarce.

Agno River Irrigation System (Agno RIS). Only 20 per cent of the service area is programmed for crops, such as mungbean, cotton, tomato, and tobacco. The latter two are contracted with commercial firms which are assured water because they guarantee payment of irrigation fees. Crops are planted in upstream areas. Tobacco and corn are planted sparingly in elevated portions adjacent to rice, while mungbean (about 200 ha) is located at the tail end of the system. When water is short, rotations are by sections of the main and lateral canals. Because the canals have no control gates, farmers provide their own checks to raise water elevation. The mungbean area is dependent on additional water being diverted into the Agno River from the hydroelectric dams at Ambuklao and Binga. Because there is no reliable schedule for water releases, farmers use the basin method to irrigate mungbean.

San Fabian River Irrigation System (SFRIS). Here the yearly dry season water supply determines the actual irrigated area. NIA staff schedule irrigation and inform the farmers when collecting fees. For heavy soils, water duty is computed at 1.5 lps/ha; for coarser soils at 2.5 lps/ha. Of 1,383 ha in the dry season, about 884 ha was planted to tobacco and the rest to rice. Continuous irrigation is practiced in the wet season. However, a rotational schedule by laterals or sections of the main canal is implemented in the dry season due to limited water. The measurement gauges at the main canal and lateral head gates are rarely calibrated, and flow duration proportional to the area and crop grown is estimated by the NIA staff for a weekly rotation. As in other systems, control gates in the main and lateral canals are absent. Checking is done ad hoc by farmers using debris. Tobacco is irrigated using the basin-flush-flooding method. In flatter areas and in larger paddies, additional farm ditches are constructed and openings are made in the paddy dikes to hasten irrigation delivery and drain excess water to other paddies.

Laoag-Vintar Irrigation System (LVIS). This system is divided into an upstream portion serving the Vintar area with irrigated rice during both seasons, and a downstream portion serving the Laoag-Bacarra-Sarrat (LABASA) area with irrigated rice in the wet season and irrigated diversified crops in the dry. Only 1,800 ha is irrigated in the dry season due to limited water; of this, about 700 ha is planted to diversified crops and the rest to rice.

The Vintar IA is not functional. The LABASA IA is active because farmers need to cooperate to effectively use the scarce water. The LABASA area is divided into two zones, each managed by one water master, and each zone is sub-divided into districts. Irrigation is planned jointly by the LABASA IA and NIA staff two weeks before the start of the season. In the dry season, areas for irrigated rice and diversified crops are based on land classification. About 90 per cent of the land is planted to garlic, mungbean, and other vegetables. Weekly irrigation water is supplied for coarse soils and every other week for clay. When there is acute water shortage, priorities are decided by the district officers in cooperation with the NIA field staff. Gauges at major canal points are rarely calibrated and farmers have evolved ad hoc irrigation practices. For diversified crops, water is impounded in paddies and basin flooding is practiced. The mean farm ditch density is 108 meters/ha. The undulating topography (mean slope of one per cent) allows water to flow from paddy to paddy. The small farm size (0.5 ha) enables, in some cases, a 300 per cent cropping intensity.

Simulation Studies

Allah Valley River Irrigation Project Pilot Testing and Demonstration Farm No. 2 (ARIP PTDF#2). Results of the simulation showed that the seasonal water requirement for the rice crop would be 1,700-2,300 mm. After considering rainfall, the seasonal irrigation diversion requirement (IDR) ranges from 900-1,800 mm, with a mean of 1,300 mm. In an average year, the daily IDR will not exceed the 2 lps/ha design of the system. Table 7 shows results of the simulation studies.

Table 7. Total evapotranspiration (ET), water requirement (WR), and irrigation diversion requirement (IDR) in millimeters from crop simulation studies for an irrigated rice-corn cropping pattern in South Cotabato, 1968-85.

	Total	ET	WR	IDR
<u>Irrigated rice, planted 1st week of May</u>				
Mean	1274	612	2498	1363
Probable rainfall - 20%	550	717	2619	2069
- 50%	1051	717	2619	1568
- 80%	1766	717	2619	856
<u>Irrigated corn, early planting (early November)</u>				
Mean	514	631	514	100
Probable rainfall - 20%	150	595	493	165
- 50%	398	595	493	93
- 80%	697	595	493	44
<u>Irrigated corn, late planting (early December)</u>				
Mean	457	672	560	134
Probable rainfall - 20%	100	633	534	228
- 50%	319	633	534	107
- 80%	571	633	534	82

With probable rainfall of 20 per cent, the IDR would be 2,069 mm (2.5 lps/ha), which is higher than ARIP's design capacity (Table 7). At 50 and 80 per cent probable rainfall, IDRs are 1.9 and 1.1 lps/ha, respectively. For irrigated corn planted in late December and assuming land preparation starts 4 weeks after rice harvest, the mean seasonal IDR is 134 mm. The minimum is 73 mm in 2 applications, and the maximum is 231 mm divided among 6 applications. For 20 per cent probable rainfall, the IDR is 228 mm, divided into 6 applications with one made every 2 weeks (Figure 12). For the 50 per cent probable rainfall, 3 applications are needed, totalling 107 mm (Figure 13). For the 80 per cent probable rainfall, two applications are needed with a total of 82 mm (Figure 14). Simulation 1 shows that throughout the year irrigation is needed for a corn crop planted in early November to maintain the soil moisture above stress levels.

For simulation 2 (assuming land preparation for early planting starts first week of November, just after rice harvest), the mean seasonal IDR is 100 mm, with a maximum of 183 mm over 5 applications and a minimum of 46 mm in one. There is no year where irrigation is not needed. For 20 per cent probable rainfall, the seasonal IDR is 165 mm distributed in 4 applications (Figure 12); 50 per cent, 2 applications totalling 93 mm (Figure 13); and 80 per cent, 1 application of 44 mm (Figure 14). Earlier planting thus reduces the amount of irrigation needed for corn because of rainfall.

Figure 12. Results of simulation study 2 with probable weekly rainfall (PR) at 20 per cent giving potential evapotranspiration (PET) and weekly irrigation water requirement (IWR) for irrigated corn planted early (e) and late (l) in the dry season, South Cotabato.

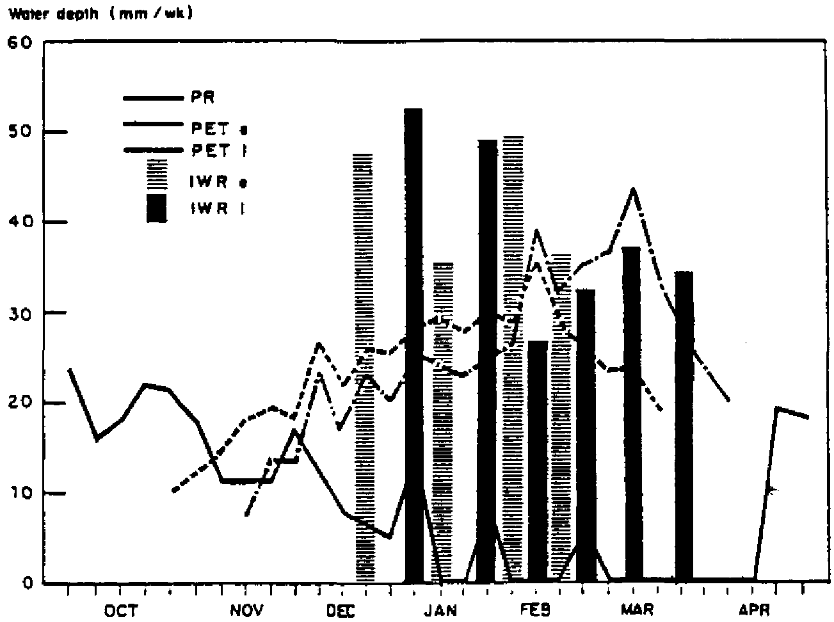


Figure 13. Results of simulation study 2 with probable weekly rainfall (PR) at 50 per cent giving potential evapotranspiration (PET) and weekly irrigation water requirement (IWR) for irrigated corn planted early (e) and late (l) in the dry season, South Cotabato.

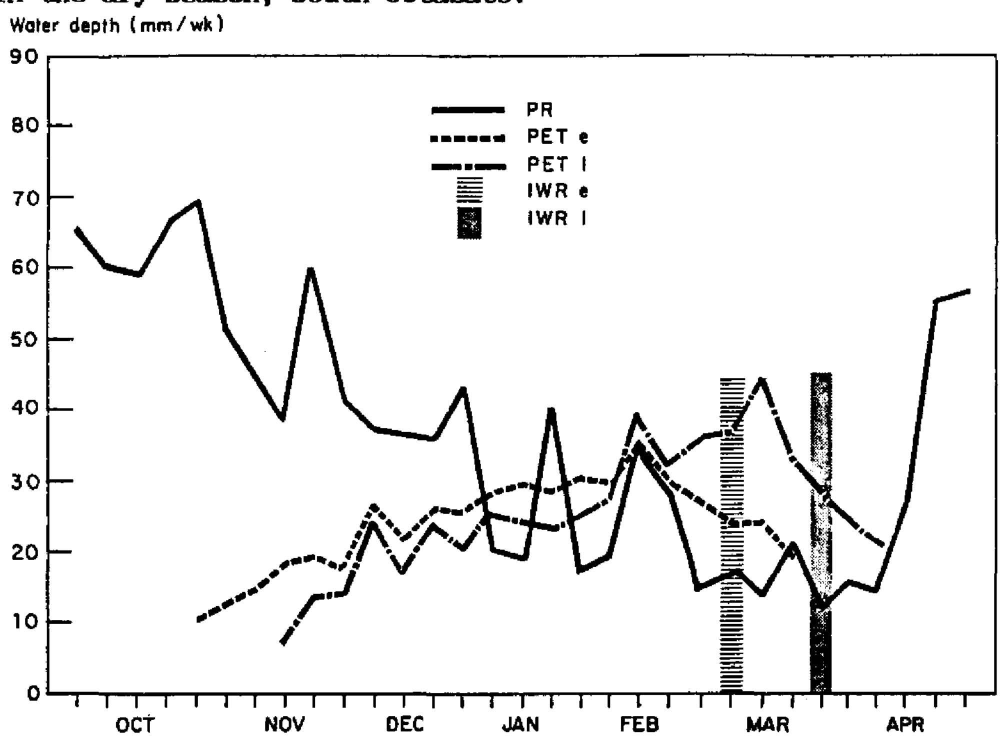
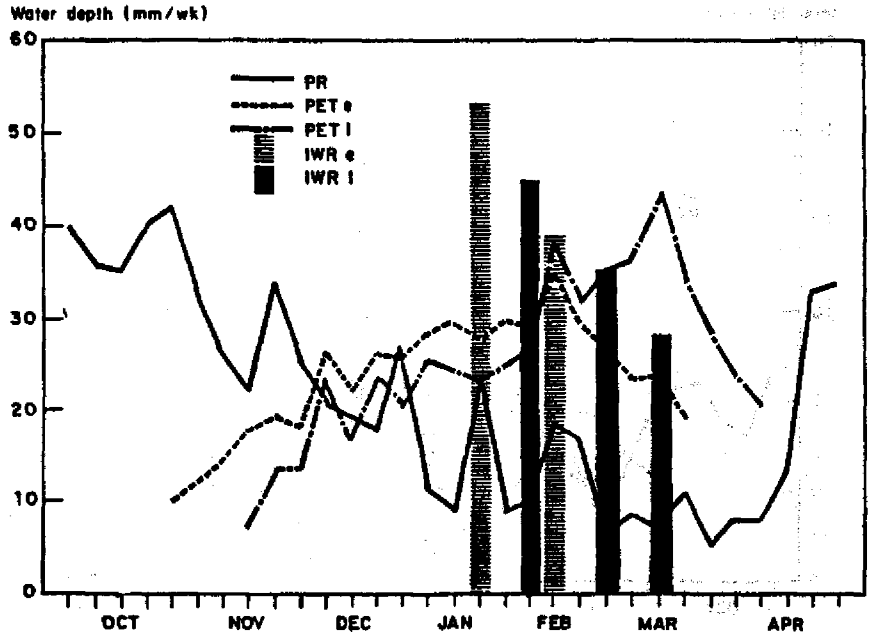


Figure 14. Results of simulation study 2 with probable weekly rainfall (PR) at 80 per cent giving potential evapotranspiration (PET) and weekly irrigation water requirement (IWR) for irrigated corn planted early (e) and late (l) in the dry season, South Cotabato.



The simulation shows that irrigated corn will need less water than lowland rice seasonally. Such volume should be delivered in a short time at a high discharge rate. If irrigation is to be applied at 50 per cent available soil moisture, the actual irrigation required could be computed as :

$$IR = [0.5\ (FC - PWP) \times SG \times RZD] / 100$$

IR = irrigation water required to bring soil moisture to field capacity (mm)
FC = field capacity (%)
PWP = permanent wilting point (%)
SG = specific gravity of the soil
RZD = root zone depth (mm)

Using the data from PTDF#2 and a RZD of 600 mm, IR will be 67.5 mm. If a field application efficiency of 60 per cent is assumed, the required depth will be 112.5 mm. At the turnout, the daily demand will be 22.5 mm for 5 days. Assuming 10 hours of operation, the design capacities of facilities would be 6.25 lps/ha; for 7-days at 10 hrs/day, 4.5 lps/ha. The design capacity on the main canals and laterals will be less. Even if there is no rainfall, diversified crops will only need irrigation once every 2 weeks and every week only 50 per cent of the service area will need to be irrigated. For a 5-day operation, main system canal capacities should be designed at 3.13 lps/ha; for 7-days, design capacity should be 2.25 lps/ha.

A simulation on ARIP PTDF#2, lateral A-extra, dam 1 was made to find out if a system designed for rice could accommodate diversified crops. Because canal capacity did not allow crops to be planted simultaneously in all areas, the tail enders planted their corn the first week of November. The upstream group planted the first week of December. The 50 per cent probable rainfall was used to calculate the IWR. Assumed efficiencies for field application was 60 per cent and for conveyance was 75 per cent due to unlined main farm ditches. The overall efficiency was 40 per cent. The irrigation delivery schedule was adjusted to conform to a turnout capacity of 75 lps/ha. The capacity of the lateral was the design value of 390 lps. The lateral would only operate for 38 days for the entire dry season. The maximum delivery was to 383 lps and the minimum was 208 lps (Table 8).

The simulation shows that for an average year a rice-based system can accommodate irrigated diversified crops by adjusting water schedules. In dry years, this may not be the case because the flows are already near the design capacity. In this system, capacity can be increased by lining the main farm ditches. If this were done and capacity increased to 150 lps, the conveyance efficiency could be assumed to be 100 per cent and the overall efficiency, 60 per cent. With these adjustments, the lateral would operate in the dry season for 18 days at an average of 3 days/week with mean flows of 340 lps. The system could then accommodate diversified crops even in a dry year.

Table 8. Irrigation requirements (IR, in liters per second) at 40 and 60 per cent efficiency and schedule given rainfall (RF) and evapotranspiration (ET) in millimeters per week: simulation study 2 for corn on ARIP lateral A-extra, dam 1, South Cotabato.

Wk	Season and date	RF	ET	IR (40%)	Days	IR (60%)	Days
42	dry Oct 15-21	35	27				
43	22-28	40	29				
44	29-Nov 4	42	33				
45	5-11	32	25				
46	12-18	26	24				
47	Nov 19-25	22	26				
48	26-Dec 2	34	28				
49	Dec 3-9	25	22				
50	10-16	21	33				
51	17-23	19	24	340	7	344	3
52	24-31	18	29	289	7	381	5
1	Jan 1-7	27	25				
2	8-14	11	28	244	7		
3	15-21	11	27	231	6	344	4
4	22-28	24	23	208	4	343	3
5	29-Feb 4	9	25	383	7	293	3
6	Feb 5-11	10	24				
7	12-18	19	32				
8	19-25	17	27				
9	26-Mar 4	6	29				
10	Mar 5-11	9	33				
11	12-18	7	40				
12	19-25	11	40				

Farm-Level Study Results

Table 9 compares corn irrigation practices at the Allah Valley sites. Farmers at BARIS irrigate one hectare fields for three days using the basin method due to the low volume water flows necessary to prevent farm ditch erosion and the minimal field slopes. The corresponding furrow slopes range from 0.8-1.0 per cent. By comparison, the double and triple row irrigation methods at Isabela showed no significant differences in yield, total water, or labor (Table 10). However, there was a significant difference in labor at CPPL, where more was required to irrigate double row furrows. Differences between sites were to some extent due to differences in soil characteristics.

Table 9. Irrigation method, soil type, flow (in liters per second), total water applied (in millimeters), and mean duration of flow (in hours) at ARIP-PTDF#2, BARIS, and MCIS, dry season 1986.

Site	Irrigation method	Soil type	Critical flow	Total water	Duration of flow*	Difference
ARIP	Basin	Sandy	10	380	3.2	0.8
PTDF#2	Furrow			242	2.4	
BARIS	Basin	Sandy	15	520	6.2	1.8
	Furrow	Clay loam		384	4.4	
MCIS	Basin	Sandy loam	15	381	6.1	2.1**
	Furrow			242	4	

*Mean duration to irrigate 0.25 ha of corn; **significant at 10 per cent.

Table 10. Mean yield (in tons/hectare), water use (in millimeters), and labor use (man-days/hectare) for double-row and triple-row furrow irrigation methods for corn at CPPL and SIBESTER sites, Isabela, dry season 1986.

Site	Method	Yield	Water use	Labor use
SIBESTER	Double-row	4.79	43	3.47
	Triple-row	4.61	39	2.00
CPPL	Double-row	4.84	131	2.15
	Triple-row	4.46	120	1.23

Furrow and basin methods for irrigating white beans were compared at the Cavite site. Labor use was much higher for the furrow method (Table 11) due to the labor needed to direct water into the furrows. Furthermore, with basin flooding, pre-planting irrigation is applied prior to seeding in order to suppress weed growth. For the furrow method, the first irrigation is applied after planting and fields require weeding.

Table 11. Total water supplied and stored (in millimeters), water application efficiency (EFF, in per cent), mean yield (in tons/hectare), labor use (in man-days/hectare), and field slope (in per cent) for for basin and furrow methods to irrigate white beans, SLBIP, Cavite, dry season 1986.

Irrigation method	Supply*	Stored	EFF	Yield	Labor	Slope
Basin flooding	161.8	152.3	94.1	0.99	0.5	0.00
Single-furrow	132.6	109.0	82.2	0.89	4.5	0.25
Double-furrow	94.3	77.1	81.8	1.18	4.0	0.25

*For basin method, 7 mm of rainfall was stored; none for the other methods. EFF = (Stored/supplied) x 100; does not account for losses from percolation.

Although the furrow method requires more frequent applications, this can be an advantage at bean formation when pods touch the ground and may rot in contact with water from the basin method. Most diversified crops need hilling up for weed control. The furrow constructed by such operations can serve as a water conveyance to prevent water logging. All the irrigation methods need ditches within the field plots to drain excess water. The additional labor needed for land preparation can be reduced by double or triple furrows.

Agronomic Study Results

A preliminary assessment of agronomic constraints for alternative crops to irrigated rice was conducted at the study sites to determine actual field production potential and adaptability in an irrigated environment.

Allah Valley sites. At these sites early maturing improved open-pollinated yellow corn, mungbean, and peanut were planted at PTDF#2 lateral A-extra, BARIS, and MCIS. Each crop was planted on a 0.25 ha plot to simulate actual field conditions. Table 12 shows yields and profitability.

BARIS had the lowest yields (excluding PTDF#2 where excess water was inadvertently applied by the farmer and, due to water logging which induced disease, low or no yield was obtained for corn and mungbean). Late planting at all sites contributed to pest and disease infestation. Thus, corn yields were not impressive. The open-pollinated corn was relatively unresponsive to irrigation. Low soil fertility did not affect the peanut crop much but proper timing of planting made a big difference in yield. Both peanut and mungbean encountered marketing problems. Problems with farmer cooperation at BARIS resulted in a delay in planting the test crops.

Isabela site. Comparative testing between irrigated and rainfed peanut production used two methods: raised bed and furrow. The sites were at San Mateo and Luna. Four field plots were planted at San Mateo: one rainfed plot with sandy loam soil was planted in November 1985; and three irrigated plots with soils ranging from clay loam to loamy sand were planted in January 1986. Three plots were planted at Luna: two rainfed field plots, one with sandy loam soil and the other with clay loam soil, were planted in December 1985; and one irrigated plot with silty clay loam soil was planted in January 1986.

Table 12. Summary of yields (kilograms per hectare) and costs and returns (in Philippine pesos) of selected diversified crops at the Allah Valley sites, dry season, 1985-86.

Crop	Site	Yield	Gross returns	Costs[1]	Net returns
Corn	PTDF#2	588[2]	1586	2924	-1338
(shelled)	BARIS	2240	6048	3596	2452
	MCIS	2660	7182	3728	3454
Peanut	PTDF#2	1988	14200	5708	8492
	BARIS	1120	8000	4933	3067
	MCIS	1400	10000	5183	5817
Mungbean	PTDF#2	0[3]	0	1249	-1249
(shelled)	BARIS	1320	6600	4979	1621
	MCIS	1742	8710	5330	3380

Pesos 20.00 = US$1.00; [1]production costs do not include land rent; [2]low yield due to pest and disease infestation, and low organic content of soil; and [3]no yield due to water-logging inducing nematode and virus infestation.

Table 13 shows that the mean yields for the irrigated plots were consistently higher than those for the rainfed plots, and irrigated plots at San Mateo were higher than those at Luna. These differences in yield can be attributed to soil moisture availability and earlier planting of the irrigated plots. Results indicate that irrigated peanut should be planted in January, and preferably in sandy loam and clay loam soil.

Table 13. Mean yields of bean and pod yields of peanut (in tons per hectare) planted at San Mateo and Luna, Isabela, dry season 1986.

	Bean yield		Pod yield, peanut		Number of pods/plant	
Site	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed
San Mateo	1.52	1.08	2.28	1.65	20	10
Luna	1.00	0.70	1.52	0.90	18	16

Cavite site. Irrigated white bean production was introduced with NIA MAF credit incentives to encourage production, and marketing was assured by a commercial company. Only 21 ha were planted out of 100 ha targeted. However, not all farmers who joined the program made a profit (Table 14). The reluctance of farmers to join can be attributed to unfamiliarity with the production technology despite the training provided. This was exacerbated by the limited credit for inputs finally provided. Farmers who did not strictly follow the planting, fertilizer and pesticide schedule obtained low yields. White bean is sensitive to high temperature especially during pod formation. The recommended planting period is from early November to mid-December so pod

Table 14. Sample area (in hectares), yields (in kilograms), and costs of production and net returns (in Philippine pesos) to produce white beans in 13 sample farms in Cavite, dry season, 1985-86.

Farm	area	Yield	Gross returns	Costs	Net returns
1.	0.4	686	8924	3071	5853
2.	0.5	506	6578	3445	3133
3.	0.4	404	5252	2774	2478
4.	0.3	296	3835	2735	1100
5.	0.2	181	2353	1688	665
6.	0.2	157	2041	1512	529
7.	0.2	127	1651	1151	500
8.	0.4	228	2957	2523	434
9.	0.3	73	949	1703	-754
10.	0.2	106	1372	2306	-935
11.	0.5	225	2925	3904	-979
12.	0.3	25	325	1613	-1288
13.	0.5	148	1924	3341	-1417

Pesos 20.00 = US$1.00

formation will occur in the cooler periods of January and February. Proper applications of fertilizers and pesticides to control bean fly and root rot are necessary for optimum production of the white bean. Successful farmers were from the area where white bean had been pilot tested the year before and this experience, and the continued incentives, contributed to the farmers' adoption of white bean in the following year. Irrigated crop diversification can succeed where the farmer is familiar with the cropping technology.

Economic Study Results

At the Allah Valley and Isabela sites a study was undertaken of economic aspects of cultivating rainfed crops and irrigated rice and non-rice crops.

Allah Valley site. Particularly at BARIS and MCIS, profitability and labor use were assessed across rice-rice, rice-rice/corn, and rice-corn irrigated cropping patterns. The results showed that irrigated rice-rice gave the highest profitability. A further analysis of irrigated and rainfed hybrid and open-pollinated corn showed significant differences between irrigated rice and irrigated hybrid corn (Table 15). Except for fertilizer, seeds, and returns to family labor, all other items were higher for irrigated rice. The non-significant difference in returns to family resources can be attributed to the significantly higher production costs of irrigated rice. The study also showed that the higher costs of seeds and fertilizer for hybrid corn inhibit farmers from growing corn. This is consistent with the farmers' responses on production problems encountered (high input cash costs) as indicated in the survey at BARIS.

Differences between irrigated and rainfed hybrid yellow corn were not statistically significant (Table 165). The non-significant difference in

Table 16. Comparison of yields and costs of production of irrigated rice and hybrid corn at BARIS, dry season 1985-1986.

	Rice	Corn	Difference
Number of samples	77	15	
Average farm area (ha)	1.41	1.13	
Yield (kg/ha)	4199.41	3673.93	525.48 ns
Price (Pesos)	2.52	2.26	0.26
Output value (P/ha)	10585.73	8234.12	2351.61 **
Inputs: Fertilizer (P/ha)	843.77	1369.56	-525.79 **
Pesticides	359.21	35.38	323.83 **
Seeds	516.08	773.34	-257.26 **
Equipment rental	1045.20	631.84	413.36 **
Other cash outlay	27.78	10.72	17.06 ns
Total farm inputs	3002.52	2802.84	181.68 ns
Hired labor cost	1396.87	964.37	432.50 **
Land rental payments	1208.93	463.38	470.63 ns
Irrigation fee	540.09	0.00	540.09 **
Total family labor	1561.50	1090.87	470.63 ns
Total production cost	7709.93	5339.75	2370.18 **
Return to family resources (P/ha)	2875.81	2894.37	-18.56 ns
Return before labor (P/ha)	4437.31	3985.24	452.07 ns

Pesos 20.00 = US$1.00; ** = significant at 1 per cent, ns = not significant.

Table 16. Comparison of yields and production costs of irrigated hybrid and open-pollinated (OP) and rainfed hybrid corn at BARIS, dry season 1985-86.

	Irrigated hybrid	Rainfed hybrid	Irrigated OP
Number of samples	15	13	10
Average farm area (ha)	1.13	1.38	1.05
Yield (kg/ha)	3673.93	2926.23	2122.00
Price (Pesos)	2.36	2.32	2.18
Output value (P/ha)	8234.12	6765.13	605.48
Inputs: Fertilizer (P/ha)	1369.56	1412.18	493.45
Pesticides	35.38	30.77	8.68
Seeds	773.34	766.67	61.78
Equipment rental	631.84	599.34	220.12
Other cash outlay	10.72	15.38	75.00
Total farm inputs	2820.84	2824.34	859.02
Hired labor cost	964.37	973.62	596.74
Land rental payments	463.38	853.36	466.51
Irrigation fee	0.00	0.00	0.00
Total family labor	1090.87	932.77	1324.10
Total production cost	5339.75	5584.09	3246.37
Returns to family resources (P/ha)	2894.37	1181.04	1359.10
Return before labor (P/ha)	3985.24	2113.81	2683.20

yield can be attributed to rainfall in the dry season which masked the effects of irrigation on hybrid corn yield.

Another factor is the higher costs of corn production relative to gross income or yield compared to irrigated rice production (Table 17). Despite lower total labor costs of irrigated upland crop production, the study also showed higher profitability of irrigated rice production, which in turn explains farmers' preference for irrigated rice over corn in the dry season.

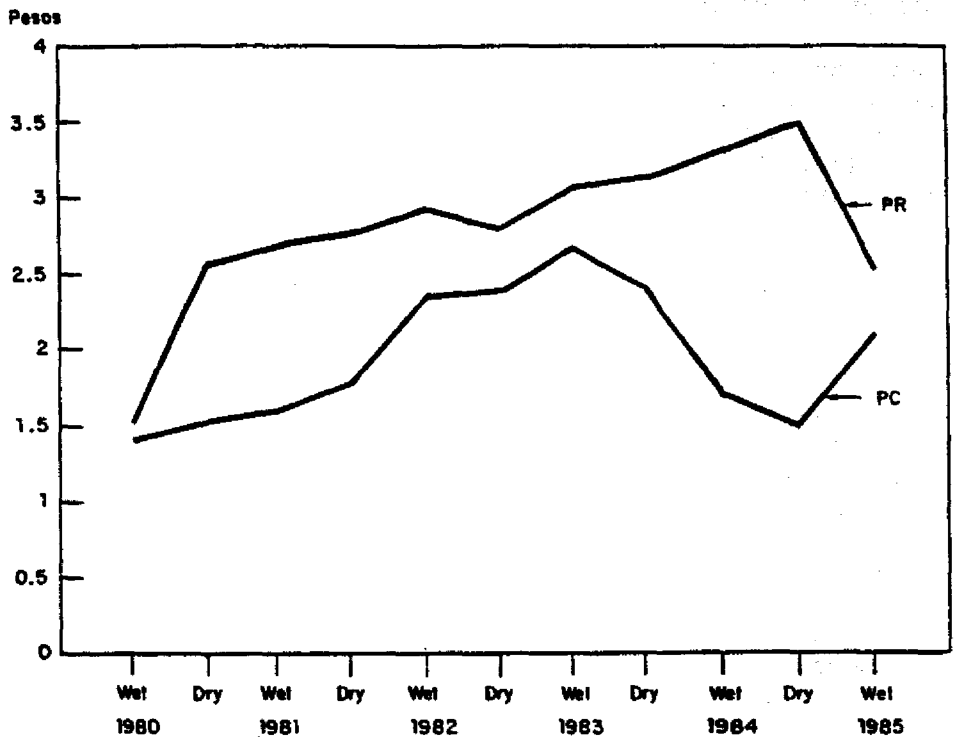
Table 17. Comparison of yields and costs of production of irrigated rice and corn at SIBESTER Irrigators' Association area, Isabela, dry season 1985-86.

	Rice	Corn
Number of samples	11	5
Average farm area (ha)	0.69	0.6
Average yield (kg/ha)	5015	10826 (unshelled)
Total receipts (P/ha)	12689	12018
Total cash inputs (P/ha)	4400	3767
Fertilizer	1175	1338
Pesticides	473	715
Seeds	445	740
Hired labor	2307	974
Land rental payments	1246	-
Irrigation fee	572	-
H/T share	963	-
Creditor's share	1474	-
Others	655	751
Family labor	1072	344
Exchange labor	386	-
Total production cost	10769	4862
Returns to family resources (P/ha)	1920	7150

Isabela site. Results, particularly for the SIBESTER IA, showed that irrigated corn production was more profitable than rice (Table 16) due to the optimum yields and high market price. However, only a few farmers planted corn, and practically none at the CPPL IA, which can be attributed to the low market price of corn compared to rice (Figure 15). This low market price at the start of the dry season discouraged farmers.

Moreover, production costs for irrigated corn were lower than rice, no irrigation fee was charged for corn as long as the previous fee was paid for rice, and there were no land rental charges for corn. Landowners do not normally charge land rental for corn due to its low income as long as the income from rice is shared. The responsiveness of farmers to market price for non-rice crops indicate the fragmented market structure existing at Isabela. Incentives which reduce irrigation fees and land rental help promote irrigated crop diversification.

Figure 15. Seasonal price of rice (PR), and corn (PC), Isabela, 1980-85.



Farmer's Decision Making Processes

Six case studies were conducted to identify conditions that are conducive to the successful adoption of diversified cropping in the dry season. Tobacco, cotton, mungbean, tomato, onion, and garlic were selected as alternative non-rice crops. The sites for this study were at SFRIS for tobacco; Agno RIS for cotton, tomato, and mungbean; Upper TRIS for onion; and LVRIS for garlic. Forty respondents for each crop were interviewed. The results revealed the following conditions that promote crop diversification:

1. Water is limited for rice.

2. Other sources provide low income opportunities.

3. Farmer observes profitability of neighboring diversified farm.

4. Family's rice consumption requirement has been met for the year from the wet season cropping.

5. The crop is perceived as technically feasible to grow (suitable soil, topography, familiarity with crop technology, and water availability).

6. Seeds are available.

7. The crop is perceived as economically feasible (availability of market, sources of credit if needed, and labor).

8. The farmer is convinced that the crop will significantly provide higher returns than rice, and the market price is assured or relatively stable.

9. The persistence of diversified cropping at these sites can be attributed to the trend of positive net returns.

Table 18 shows that higher cash outlays were required for diversified crops compared to rice. The labor demands, particularly family labor, were significantly higher than rice. Net farm incomes after deducting family labor indicated low returns. The implications are that diversified cropping is more viable for small farms, and that there is no "real opportunity cost" for family labor, at least not in the sites for this study.

Table 18. Mean of rice production costs and returns, and input-output ratios for non-rice/rice patterns.

	Rice*	Tob/R	C/R	Tom/R	M/R	O/R	G/R
Total cash costs	7507	1.22	1.39	1.26	0.39	3.22	1.94
Hired labor	2842	0.60	0.78	0.53	0.22	2.56	1.39
Seeds	435	0.00	0.00	1.15	1.79	9.84	29.17
Fertilizer	1243	1.82	1.51	1.95	.00	.00	1.25
Pesticides	290	5.60	8.57	9.15	2.00	3.72	1.78
Labor & non-cash costs	1911	4.80	2.58	3.07	0.37	7.08	11.78
Gross return	11035	1.86	1.89	0.62	0.25	3.70	2.19
Net return	3528	3.48	2.59	-	-	4.77	2.69
Net farm income	1617	-	2.59	-	-	3.75	-

* mean values in Philippine pesos/ha for all sites P20.00 = US$1.00; R = rice; Tob = tobacco, C = cotton, Tom = tomato, M = mungbean, O = onion, G = garlic; - = negative return for non-rice crop.

CONCLUSIONS

These results are preliminary due to only one dry season observation. A second phase is being developed to capitalize on the following:

Irrigation Factors

Four constraints to crop diversification were identified: dry season rainfall, availability of irrigation water for rice, limited irrigation management, and inappropriate on-farm irrigation and drainage facilities.

At Allah Valley, and to some extent at Isabela, rain was sufficiently frequent to grow upland crops without irrigation. Irrigation under rainfall conditions discourages non-rice cropping because of water logging. There is little or no dry season rainfall in Pangasinan, Nueva Ecija, and Ilocos Norte where crop diversification has been successful. However, there were years in which rainfall was not sufficient to sustain dry season corn. Further study is necessary to demonstrate optimum production and profitability levels.

In the Allah Valley and Isabela sites, crop diversification was to a large extent discouraged by the continuous supply of irrigation water. In Isabela, water is currently delivered at two to three times the design rates, encouraging farmers to grow rice rather than other crops. This is prevalent where seepage affects corn planted adjacent to rice fields. Results from all sites show that irrigation is continuous in the main system, and management techniques have not yet been developed to allow precise control of flows. Design capacities of lateral canals should be increased in order to accommodate large and intermittent flows. Results at PTDF#2 and surveys of existing canal capacities show that a design capacity of 2.25 lps/ha can be accommodated provided appropriate control and scheduling are undertaken.

On-farm irrigation facilities, especially where continuous flows on heavy soils result in water logging, require modifications to provide optimal water conditions for diversified crops. Turnout capacities should be raised to 3.0 lps/ha and deliveries rescheduled to speed up irrigation from three days to one day per hectare. This will require additional research to determine the optimal ditch density and to develop less erodible channels. Farmers should consider adopting furrow rather than basin irrigation to speed up and provide more uniform water applications to their crops.

Agronomic Factors

Farmers are unfamiliar with producing non-rice crops under irrigation. In Allah Valley and Isabela, most non-rice crops are grown under rainfed conditions or by utilizing seepage water from adjacent rice fields. Where dry season rainfall is adequate farmers are unwilling to risk water logging non-rice crops with excess irrigation. Thus yields do not reach their full potential. In drier areas, acceptance of crop diversification and improved agronomic practices are evident. In areas where rainfall is prevalent in the dry season, the correct timing of irrigation relative to crop growth stages should be demonstrated. The results from Cavite demonstrate that agronomic constraints to crop diversification can be overcome.

Economic Factors

For diversified crops, prices are generally unfavorable compared with rice, and costs are higher. Where market prices are stable compared to rice, there is evidence that crop diversification can be achieved. The results at Cavite show that most farmers who have grown white beans successfully once will grow them again. At Isabela, farmers cite the unstable farm gate price of corn as a constrainst to diversifying in the dry season. Markets and post-harvest facilities should be investigated, incentives should be considered for stable pricing of non-rice crops, and indirect incentives, such as reduction of irrigation fees for non-rice crops, should be further studied.

At all sites, the cash input costs before harvest for non-rice crops are higher than for rice and labor requirements are less. Removing the agronomic constraints would raise the profitability of diversified cropping. Support for input costs, as in the Cavite case, would reduce risks and encourage farmers to shift away from rice in the dry season. This was undertaken at Cavite to guarantee supplies to the bean processing industry.

Institutional Factors

Irrigation schedules need to be better communicated between the IAs and NIA to reduce uncertainty over water scheduling. At sites with continuous irrigation for rice, ways to improve water delivery schedules are needed if diversified crops are to be grown. The intermittent and large volume flows needed for diversified crops require better communication between farmers and system operators. The preliminary study indicated that the viability of the IAs depends on the benefits derived by the farmer members and the foremost benefit identified is adequate irrigation water supply. Studies to improve joint management of irrigation facilities by IAs and NIA are needed.

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NOTES

1. This study was conducted in support of the International Food Policy Research Institute and the International Rice Research Institute (IFPRI-IRRI) joint study. The objective among others was to assess the potential of irrigated crop diversification in the Philippines. The Asian Development Bank (ADB) in collaboration with the International Irrigation Management Institute (IIMI) financed the study to assess technical and socio-economic constraints to irrigated crop diversification. Component studies were jointly conducted with the University of Southern Mindanao, Isabela State University, and the University of the Philippines at Los Banos. These universities are under the research consortia of the Philippine Council for Agriculture and Resources Research and Development (PCARRD). The lead agency collaborating with IIMI in the study was the National Irrigation Administration (NIA).

REFERENCES

ECI-EDCOP. 1975. Upper Pampanga River Project irrigation agriculture study. Manila: National Irrigation Administration.

Hernandez. 1975. Rainfall type based on ratios of dry month and wet month. Manila: PAGASA, Climatological Division.

Layaoen, H. 1982. Merits/limitations of some cropping patterns in Ilocos Norte and Ilocos Sur. Part I. Cropping patterns. In Ilocos Agriculture. Batac, Ilocos Norte: Mariano Marcos State University.

National Irrigation Administration. 1985. Operations manual for the Magat River Integrated Irrigation System. Manila, Philippines.

IIMI-INDONESIA CROP DIVERSIFICATION RESEARCH

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CROP DIVERSIFICATION IN INDONESIA

Indonesia, one of the largest rice consuming countries in the world, has a per capita consumption close to 150 kilograms (kg)/year, up from 99 kg/year in 1975. Indonesia has been self-sufficient in rice production since 1984, and now produces a small surplus. This transformation from the world's largest rice importer in the 1970s has been achieved through a combination of irrigation development and agricultural improvements.

Rice is the most important irrigated crop. Indonesia has about 5.1 million hectares (ha) of irrigated land; 4.1 million ha are under government systems and the remainder are under village systems. In the November-March wet season, almost all the cultivated land is planted to rice, while in the first dry season (March-July), depending on reliability of irrigation, rice is planted on 30-100 per cent of the irrigated land. But, in the second dry season (August-November), almost all this land is planted to non-rice crops.

According to the Department of Public Works, in 1984 about 88 per cent of the irrigated land served by government was planted to rice in the wet season. Of the remainder, 171,000 ha went to grow irrigated non-rice crops and 136,000 ha to irrigated sugarcane. In the two dry seasons, about 58 per cent of the area was planted to rice, but more than 1 million ha were planted to irrigated non-rice crops and 180,000 ha to irrigated sugarcane. Unfortunately, available statistics do not differentiate between the two dry seasons, so it is difficult to identify the mix of rice and non-rice crops. However, if the data from East Java (where the areas in non-rice crops are reported separately for each dry season) are used, it appears as if the areas in dry season rice and first dry season non-rice crops are almost equal, around 40 per cent of the available irrigated land. In the second dry season, again about 40 per cent of the irrigated land is in non-rice crops but, due to water shortages and pest control measures, the land in rice is very small.

INTERNATIONAL IRRIGATION MANAGEMENT INSTITUTE CROP DIVERSIFICATION STUDY

Study Purpose

The purpose is to identify the physical, managerial, and institutional changes in irrigation management that must be made before non-rice crops can be more intensively cultivated in irrigation systems developed primarily for rice cultivation. The study also examines the technical and socioeconomic factors constraining more intensive <u>palawija</u> (non-rice) cropping during those crop seasons when water is insufficient to grow rice.

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The crop diversification component of IIMI's Indonesia research has broader implications than irrigation management alone. Clearly, physical, biological, institutional, and economic factors also play an important role in determining the farmer's decision to grow palawija crops. However, as much as possible, IIMI's study is limited to the critical role of irrigation management in the diversification process.[1] To date, very little comparative irrigation research in Asia has concentrated on field irrigation practices for non-rice crops. This study collects data on the varying crops and labor requirements associated with the different irrigation practices used, with the assumption that these are key aspects of the diversification process.

Water Management Practices

When rice paddies are flooded, it is fairly simple to determine if they have sufficient moisture, but with non-rice crops moisture adequacy is much more difficult to determine but equally critical. One proven measure of system performance is to track field level soil moisture adequacy throughout the entire season. This variable is directly linked to irrigation management practices, in particular, irrigation rotation schedules. The study monitors available soil moisture in a set of "intensive" plots, where water balance is tracked, and in "extensive" plots, where both soil moisture and plant growth are tracked. The intensive and extensive plots are aggregated into research blocks. Irrigation management practices are also monitored in order to relate soil moisture status to particular management decisions.

Irrigation Practices for Palawija Crops

Farmers generally grow irrigated, lowland rice using flooded basins with continuous water flows, if possible. For irrigated palawija crops, they use a variety of bed arrangements and irrigation methods, the choice of which is influenced by physical considerations, including water and labor availability, soil type, depth to groundwater, drainage, pest prevalence, and climate. In addition, socio-economic considerations, such as local knowledge and acceptance, secure markets, transportation, price stability, off-farm employment alternatives, and timely availability of chemical inputs and seed are all important determinants of which palawija crop to plant.

In each research block, four to six irrigated palawija plots were selected. Every irrigation application into these plots is being measured, and weekly soil samples and farmer interviews are being made. In addition to the weekly field data, observers also collect daily rainfall and pan evaporation data for each block. Thus it is possible for a water input-output model to be developed for each intensive irrigated palawija plot. This data will help answer questions about farmers' actual field irrigation practices for palawija crops across much of Java. Table 1 presents a sample of the data from the intensive plots for the second dry season (July-November) 1986, and shows that there is not much over-irrigation, when the amount of irrigation water actually applied is compared to the evapotranspiration requirements. The data for Central Java from Table 2 show that the fields in Pemali Comal are, in general, continuously wet. This condition is not good for many palawija crops, particularly soybeans, and may well explain the extremely low yields for palawija crops in the research areas.

Table 1. Field irrigation rates (in millimeters) and yield (in kilograms per hectare) for selected non-rice crops, July-November 1986.

Location/code	Device	Crop	TI	Amount	ET	RF	Yield
Nganjuk - East Java							
EJWJ00099030	Tho	Soybean	3	85.1	382	0	828
00099008	Tho	Maize	3	211.1	453	0	2946
29208011	Tho	Soybean	1	81.1	404	0	380
00099060	Tho	Soybean	2	52.6	363	0	780
Gung - Central Java							
CJGUJT00578	Tho	Maize	1	31.7	281	66	3478
00290	Cip*	Maize	3	127.1	332	93	na
002139	Cip*	Maize	3	246.3	316	75	na
002021	Cip*	Soybean	1	14.2	344	0	625
005115A		Peanut	3	121.0	234	69	2446
CJPSCK007032	Cut	Maize	2	133.7	253	91	1100
Cirebon - West Java							
WJCWMT001033	Cut	Long bean	6	166.7	226	28	1869
001033	Tho	Mungbean	4	86.7	223	32	176
001026	Cut	Peanut	2	172.9	250	36	1297
001026	Tho	Long bean	5	151.5**	158	23	1463
002061	Cip*	Peanut	4	120.2	255	65	1216
001027	Cip	Maize	7	232.8	299	40	na

Measuring device: Tho = Thomson, Cip = Cipolletti, Cut = Cutthroat; TI = number of times irrigated; Amount = amount of water applied; ET = estimated evapotranspiration; RF = effective rainfall. *Some water readings were above the acceptable level for this type of measuring device; data for these fields are indicative only. **After rechecking the exact area for this field.

In many cases there was very little need to irrigate. In fact, in some of the intensive plots for the July-November 1986 dry season, the farmers were able to harvest a crop without applying any additional water. Further research will explore alternative irrigation practices and obtain better information on depth to groundwater during the two dry seasons.

Because of the small sample from the intensive plots, three additional data sets are being collected. The first contains extensive data on a larger sample of plots, generally 20-25, in each block. This data set monitors soil moisture conditions and crop development but does not measure actual irrigation flows into the fields. A second set represents a 50 per cent sample of all the plots in each block. This sample provides additional data on planting dates, yield levels, and farmers' irrigation practices for palawija crops in every research block. Based on this data, irrigation practices for non-rice crops can be classified. Figure 1 shows the initial classification of

Table 2. Dates of irrigation and soil samples, and soil moisture status of research plots, Central Java, July-November 1986.

Plot code and crop	Irrigation date	Soil sample date	Average of three samples 10 cm	20 cm	30 cm
CJGUJT002139 - maize planted 01 Aug 86					
		30 Aug	M	M	M
		05 Sep	M	M	M
		12	M	M	M
	22 Aug	19	W	W	W
		26	M	M	M
		03 Oct	D	M	M
	09 Sep	10	W	W	W
		17	M	M	M
	21	24	W	W	W
		01 Nov	W	W	W
		08 Nov	*****	harvest	*****
CJGUJT005115A - peanut planted 29 Jul 86					
		18 Aug	M	W	W
		26	M	M	W
		02 Sep	M	M	W
		08	M	M	W
	12 Sep	17	M	W	W
		24	M	W	W
		01 Oct	M	M	M
		08	D	M	M
		14	D	M	M
	15 Oct	21	M	M	M
		28	*****	harvest	*****
CJPSCK007032 - maize planted 09 Sep 86					
	08 Sep*	18 Sep	W	W	W
		25	M	W	W
	31-9	02 Oct	W	W	W
		09	W	W	W
		16	M	M	M
		23	M	M	M
		30	M	M	M
		06 Nov	W	W	W
		13	*****	harvest	*****

*Received 42mm of rain; W = wet, M = medium, D = dry.

some of these systems with both their local Indonesian names and the nearest English equivalent. Table 3 draws from the 50 per cent sample studies to relate type of crop grown to field irrigation land shapes.

Figure 1. Irrigated land shapes for various crops, Java, 1986.

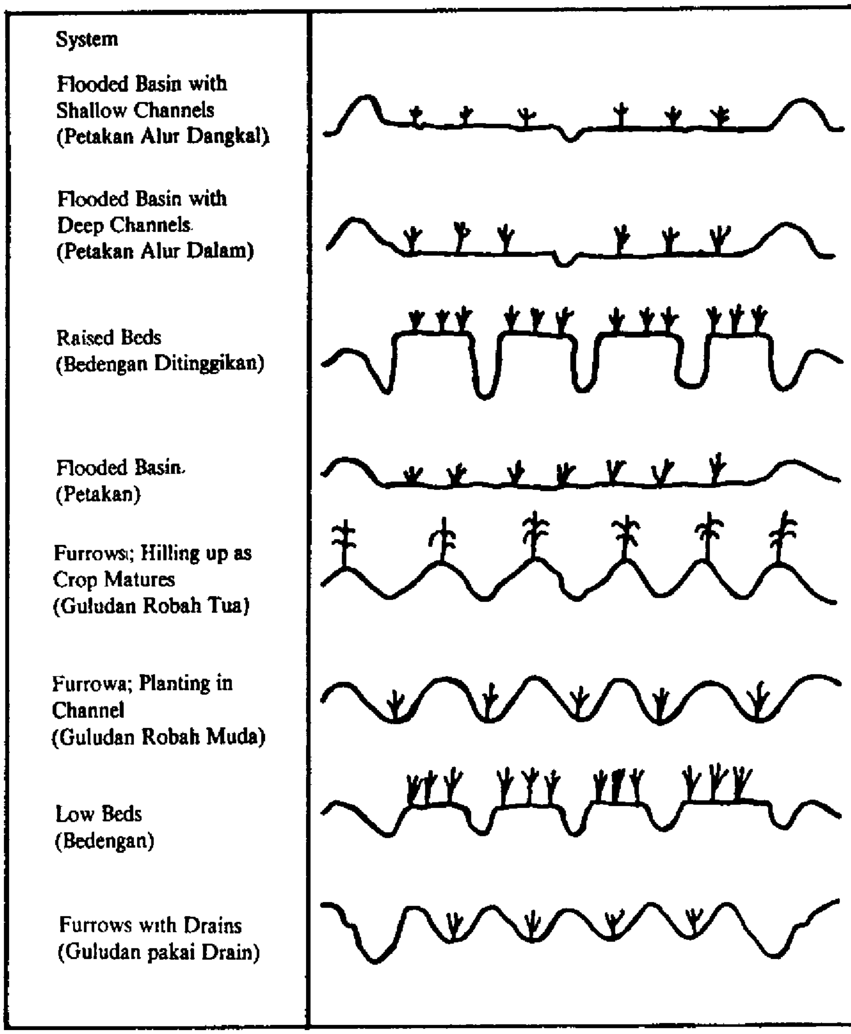


Table 3. Field irrigation land shapes for non-rice crops at IIMI research sites, dry season 1986.

Crop	Irrigation Practice
Corn	Furrows; hilling up as plant matures
Soybean	Flooded basins with shallow channels
Cassava	Furrows; hilling up as plant matures
Peanut	Flooded basins with shallow channels
Mungbean	Flooded basins with shallow channels
Rice	Flooded basins
Sugarcane	Furrows; hilling up and sugarcane beds
Long bean	Flooded basins with shallow channels
Cucumber	Low and raised beds
Shallot (red onion)	Raised beds

The third data set, which has just been completed, attempts to better understand how farmers decide to plant palawija crops. Additional data were collected to define the costs of converting land to the different irrigation land shapes. Preliminary estimates of these costs are presented in Table 4.

Table 4. Average labor inputs (in hours per hectare) for preparing different irrigated land shapes, Java, 1986.

Application method	Wet season	1st dry	2nd dry
<u>West Java</u>			
Flooded basin	392.1 (n=16)	360.2 (n=13)	
Flooded basin, shallow channel	333.5 (n=12)	385.3 (n=6)	
Flooded basin, deep channel			
Fixed furrows			
Hilling up from furrows (early)			
Hilling up from furrows (late)			
Low beds			345.1 (n=14)
Raised beds		528.1 (n=6)	757.9 (n=8)
<u>Central Java</u>			
Flooded basin	383.6 (n=34)	416.4 (n=25)	417.0 (n=9)
Flooded basin, shallow channel	511.0 (n=5)	188.8 (n=8)	308.5 (n=15)
Flooded basin, deep channel			
Fixed furrows	603.0 (n=10)	544.7 (n=10)	
Hilling up from furrows (early)			179.5 (n=8)
Hilling up from furrows (late)	917.6 (n=5)	917.6 (n=5)	
Low beds			
Raised beds			
<u>East Java</u>			
Flooded Basin	226.1 (n=65)	212.7 (n=54)	240.1 (n=12)
Flooded Basin, shallow channel		118.8 (n=5)	99.1 (n=15)
Flooded Basin, deep channel			
Fixed furrows			
Hilling up from furrows (early)			503.5 (n=5)
Hilling up from furrows (late)			234.2 (n=30)
Low beds			
Raised beds			

n = size of sample.

Table 4 shows that costs vary by location as well as by season. Assuming that labor works 7-hour/day and that the average wage rate is US$1.81/day (US$1.00 = Indonesian rupiahs 1,514), land preparation costs for conversion from rice to palawija crops would range from US$25-238. Averaging is difficult because of the wide variation in practices by location, but for all the provinces a good first estimate is US$77-91/ha for land conversion from rice to a palawija crop and back to a rice crop.

Irrigated Palawija Crops

The results of IIMI's literature and research review is that only limited information exists on irrigated non-rice crops. Most research on secondary crops is focused on non-irrigated land at higher topography, consequently the results are only partially relevant to the present study. In order to address this problem, a two-round agro-economic field survey was implemented. However, the research schedule, which is dependent on cropping schedules, did not fit well with the times fixed for project reporting, and additional data on crop location and crop production calendars were collected from the research blocks. From this data it is possible to establish yield levels and up-to-date crop budgets and, thereby, examine the relative profitability of the various palawija crops. The returns in turn can be compared to returns from rice production during the same season to identify one set of possible "incentives/constraints" to crop diversification. Appendix I contains a set of "representative" crop budgets[2] from the three provinces. These budgets are representative in that they represent the usual situation in the provinces but, due to the small sample sizes, do not purport to be average.

What is not apparent from the crop budgets is the variation in yields and rates of return that exist for the various crops, particularly the palawija crops. Table 5 shows that non-rice crops generally have lower mean returns and higher standard deviations than rice. This implies that palawija crops are currently more variable in terms of production returns and, therefore, more risky. This risk, if proven to be representative of irrigated non-rice crops in Indonesia, is a major constraint to expanding diversified crops. Given that the data comes from some of the best irrigated areas in Indonesia, uncertainty must be even greater for more marginal areas.

Table 5. Comparison of average yields (in tons per hectare) and standard deviations (SD) for irrigated non-rice crops in Central Java research blocks, wet season, 1985-86.

Crop		Jarot 5	Jarot 2	Ck 7 kn	Ck 3
Maize	Avg	5.04	3.14		
	SD	2.57	0.39		
Soybean	Avg	0.83	1.33		
	SD	0.57	0.26		
Peanut	Avg	1.65	2.52		
	SD	0.99	0.22		
Mungbean	Avg	5.53			
	SD	3.14			
Sweet potato	Avg	3.17		5.87	9.13
	SD	2.13		3.26	5.17
Rice	Avg	3.14	4.32	4.04	2.32
	SD	2.15	1.04	1.20	1.55

From Table 5, it seems that growing irrigated palawija crops is an unstable enterprise in the wet season. Except for soybean, yields for palawija crops were about the same in the wet season as in the dry. But this is not unexpected as rice is clearly the dominant crop during the wet season at the research sites in East and West Java. However, the relatively high variation in yields of wet season rice in Central Java is surprising, particularly given the skills of the Javanese farmers and the availability of irrigation. Table 6 shows that the high variability in rice production appears to be the norm at almost all sites. Given that the production technologies, including rice varieties and level of inputs, are generally the same across sites, the significantly lower rice yields in West Java suggest further study is needed.

Table 6. Comparison of average yields (in tons per hectare) and standard deviations for irrigated in the research blocks, wet season, 1986.

East Java	Central Java	West Java
3.829 (0.765) Blocks - 206/207/208	3.135 (2.150) Block - Jarot 5	2.587 (0.936) Block - Jasem 2
6.088 (0.645) Block - a99	4.322 (1.04) Block - Jarot 2	3.151 (1.016) Block - Jasem 7
5.700 (1.93) Blocks - 74/a73/58	2.32 (1.55) Block - Ck 3	2.755 (1.267) Block - Wln I
	4.039 (1.199) Block - Ck 7 km	2.850 (0.968) Block - Mirat I ki

Constraints to Palawija Cropping

In order to understand the potential for irrigation in the process of expanding and intensifying palawija crop production, it is necessary to identify the full range of constraints and incentives, both those directly related to irrigation (such as system design or water rotation procedures), and those which are not (such as pests or prices). It is also necessary to identify the constraints or incentives which can be directly influenced by management or policy changes. However, the limits of this research preclude such an intensive analysis. Instead, short-term methods are employed for at least identifying constraints and incentives in the research sites, in addition to examining comparative factors such as prices, land tenure, marketing, soils, and decision making criteria from the farmer perspective.

Hierarchical decision models[3] can be used to identify and test the criteria actually used by farmers in deciding whether to plant rice, palawija crops, or fallow their fields. Through group and individual interviews, decision making criteria have been identified, and simple models constructed. These models have been partially tested and will soon be validated by interviewing larger numbers of farmers about actual decisions made.

Such decision models may enable researchers to identify the range of factors effecting planting decisions within a locality and understand the relative importance of the factors, both those related to irrigation and those which are not (by tracking how many farmers follow particular decision paths and choose particular outcomes in a model). The researcher can then compare across localities to see how local decision criteria vary in order to develop a broader perspective on constraints and incentives at the main irrigation system, or at national or regional levels. Only after identifying the relative importance of irrigation and non-irrigation related factors is it possible to estimate the likely effect of irrigation management or policy changes on the expansion or intensification of palawija crop production.

In the decision models, questions are posed to reflect the same level of abstraction expressed by farmers and then listed in order of frequency of relevance, determinacy, or logical relatedness. Questions evoke "yes" or "no" responses and determine which decision paths will be followed. In the model shown in Appendix II, the number of responses which were "explained" correctly (C) by the model and those which were in error (E) are noted below the respective decision outcomes.

Because the model has not yet been fully tested, only a few tentative inferences should be made at this time. In general, the timely availability and drainage of water figure prominently in the farmers' decisions to plant rice or palawija crops. Not surprisingly, in all three provinces there is a marked tendency to plant rice during the November-March rainy season (Musim Rendeng) and palawija crops during the August-November dry season (Musim Gadu II), except in a few cases specified in the model.

The March-July dry season (Musim Gadu I) is more problematic. Farmers often identify the availability of water at the desired time for land preparation as a key factor in deciding to plant rice. If experience tells farmers that there is usually enough irrigation and/or rain water for rice during Gadu I, they use the availability of water at the desired time as a seasonal decision criteria and begin land preparation (with a range of two weeks generally being the maximum waiting period to see if there will be sufficient water). During Gadu II, inadequately drained soils are sometimes a primary constraint to planting palawija.

At the West and East Java sites, almost no palawija crops are planted in the rainy season. During Gadu I, farmers prefer to plant rice, even if their fields are dry enough for palawija crops. However, there are additional influential factors, such as lateness in planting and harvesting the prior rainy season crop (which may cause farmers to plant palawija crops to "catch up") and the threat of pest attack. In Central Java, a significant number of farmers will plant palawija crops during the rainy season, apparently because of soil characteristics, late planting, and palawija crop price speculation.

The research sites in West Java have an established pattern of planting rice twice a year, except in fields at high topography or at the bottom-end of secondary canals or tertiary blocks where they cannot obtain adequate water supplies. Historically, during Gadu II, in three of the four research tertiary blocks, rainfall and irrigation water are insecure even for palawija crops. The relative insecurity of water supplies, the prevalence of off-farm work, and the high risk of crop damage by rats (which has been frequent and severe in recent years) prompt many farmers to leave their fields fallow or to permit landless villagers to cultivate free of charge.

In the research sites in Central Java, there is considerable variation in cropping patterns and planting dates between individual fields within tertiary blocks. Generally speaking, farmers have long experience cultivating palawija crops, such as soybean, corn, groundnut, mungbean, long bean, red onion, cucumber, tomato, sweet potato, red pepper, and cassava. Planting decisions are more individual than group oriented. Generally, pest damage has not been high in recent years. Soils are lighter and more well-drained than those in West and East Java.

In two of the research tertiary blocks in East Java (a99 and a206-8, Desa Barong) there are usually abundant water supplies in both the wet and first dry seasons. Farmers generally plant only soybean, corn, or groundnut. In recent years, soybean has required weekly spraying with pesticides. The availability of land for rice seed beds permits relay cropping (2 rice crops in 7 months) so that renters, who typically rent for 12 months, can plant rice twice and palawija twice (3 months for soybean and 2 for corn). Farmers in this area are more oriented towards group-level planting decisions based on discussions among individual farmers. Soils in many areas are not well-drained between November and June.

In one research site in East Java (a73, Desa Mojokendil) farmers are experienced in planting and marketing a variety of palawija crops. There have been no serious pest attacks against palawija crops in recent years. There is a prevalence of sandy, permeable soils which require frequent applications of water for rice during the dry season. This leads farmers to prefer planting palawija, as reflected in the model for Desa Mojokendil.

Spatial Distribution of Palawija

Variation in palawija cropping patterns and planting dates can be seen between irrigation systems, between secondary canals of the same system, between tertiary blocks on the same canal, and within the same block. In many cases soil chemical properties and associated drainage are a major determinant. In others, variation is due to water availability (including irrigation and rainfall) and water holding capacity of the soils. The rotation, pests, prices, seed availability, and labor all play a role in determining selection and spatial variability of crops and planting dates.

Detailed maps, such as Figures 2 and 3, made of every land holding within a research block allows the research staff direct observation of crops to identify their exact location and area by season. Data from farmer interviews can then be cross-checked and areas needing further study can be identified. The maps can be linked with irrigation rotation schedules and maps to see the relationship between water allocation practices and crop diversification. In conjunction with the decision models, maps help the researchers identify critical variables and confirm the relationship of the variables to planting decisions made by the farmers.

Figure 2. Map showing first dry season crop in Jarot 2, Central Java, 1986.

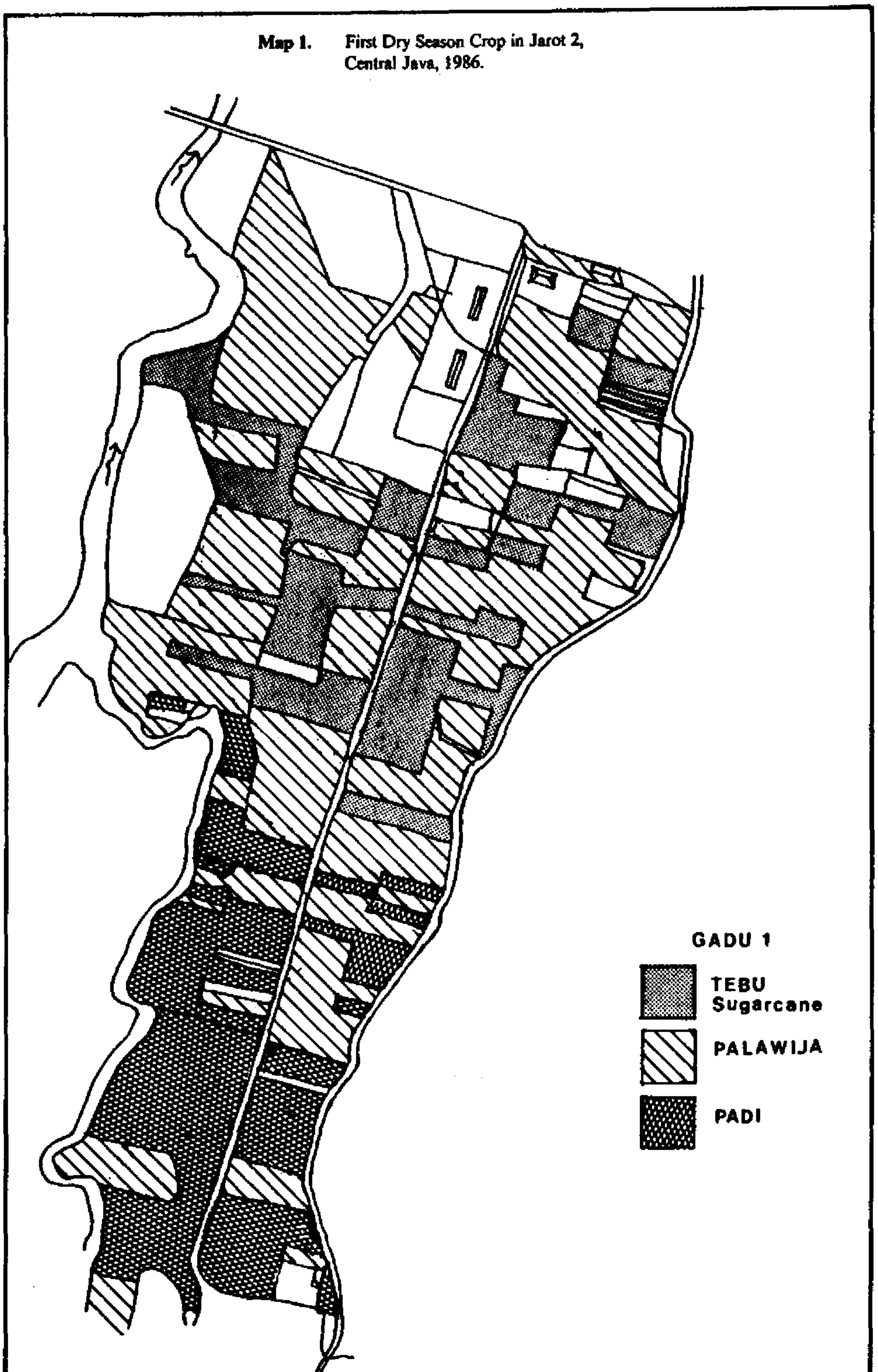
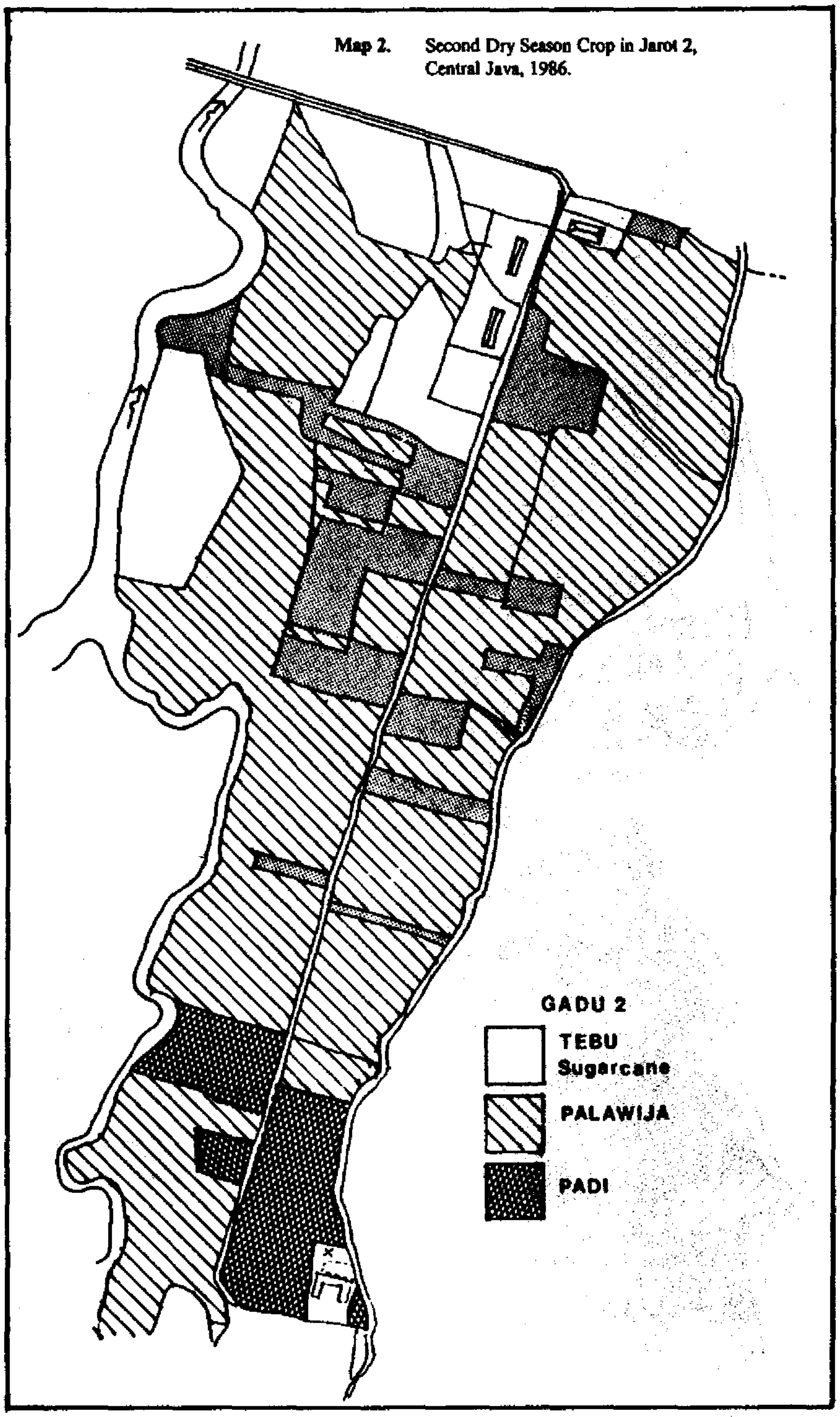


Figure 3. Map showing second dry season crop in Jarot 2, Central Java, 1986.



IRRIGATION MANAGEMENT FOR DIVERSIFIED CROPPING

Due to the high levels of cropping intensity found in Indonesia, particularly in Java, unique irrigation management techniques have been developed. Three major methods are used for water distribution: 1) pasten, 2) Faktor-K, and 3) Factor Palawija Relative (FPR). These methods are differentiated by the way each uses relative versus actual water requirements, and the method used to account for distribution and tertiary losses.

The relative water requirement (RWR)[4] assumes that fields are provided with their full water needs which, for rice, means flooded throughout crop growth. RWR values have been developed from past experience for different stages of rice and sugarcane relative to values for secondary crops (Table 7). Accordingly, rice fields are assumed to require about 4 times as much water as those of secondary crops, while sugarcane requires about 1.5 times as much. In addition, there is often a distinction between palawija crops that use large amounts of water and those that only use limited amounts.

Table 7. The relative water requirement (RWR) for selected crops and their stages of production, East Java, 1985.

Crop	Production stage	RWR*
Rice:	Seed bed	20.0
	Land preparation	6.0
	Transplanting and vegetative growth	4.0
	Ripening	2.5
Sugarcane:	Young cane	1.5
	Mature cane	0.0
Secondary crops		1.0
Unauthorized rice**		1.0

*Water requirements in lps/ha relative to an index value of 1, which is the requirement for secondary crops such as maize, soybeans, and tobacco.
**Rice that was not included in the cropping system plan.

The Direktorat of Irigasi I has recently recommended using the Faktor-K method for water allocation. This method was developed to incorporate distribution system losses into the original pasten method and to reduce the need to use the RWR concept. Other than East Java where the FPR is used extensively, the Faktor-K method is now used widely in the country. Mathematically, the Faktor-K method may be expressed similarly to that of the pasten method; the main difference is that the former uses the actual water requirement values (Table 8) rather than the RWR values. This is felt to reflect crop water requirements more accurately, and to be easier to calculate because the values from agronomic research can be substituted directly.

The equation for Faktor-K is as follows:

$$K_k = \sum_{i=1} \frac{Q}{(A_i * q_i) * (1 + t_1) * (1 + s_1) * (1 + p_1)}$$

where: K_k = Faktor-K for irrigation system (k)
i = 1st to nth crop
Q = actual discharge of water in liters per second (lps) at intake taken from a discharge curve or from flow discharge data
A_i = crop area in hectares
q_i = crop water need by growth stage for crops (i) in lps/ha
t_1 = tertiary canal losses
s_1 = secondary canal losses
p_1 = primary canal losses

Table 8. Full water requirements (in liters per second/hectare) for selected crops and their production stages, Faktor K method, Central Java, 1985.

Crop	Production stage	Water requirement
Rice:	Seed bed	1.20
	Land preparation	1.20
	Tillering	0.73
	Flowering	0.79
	Ripening	0.52
Sugarcane:	Land preparation	0.45
	Young cane	0.36
	Mature cane	0.00
Secondary crops:	Much water	0.30
	Less water	0.15
Unauthorized rice*		0.30

*Rice that was not included in the cropping system plan.

Faktor-K, like the pasten method, is used in operational decisions on water allocation. Twice each month (on the 9th and 24th), the ulu-ulu (village water masters) assess and report to their respective juru pengairan (irrigation inspectors) the area and growth stage for each crop expected during the next two weeks in the area for which they are responsible. The juru calculates the field water requirement (lps/ha) for each crop and growth stage, and the total in-field water requirement (liters per second) for the area covered by his tertiary block(s). This total is multiplied by a constant that varies from 1.2-1.3 to account for distribution system losses. The result is taken to represent the "normal" water requirement at the inlet.

The quantity of water to be diverted in a specific 10-14 day period is calculated when the juru pengairan submit their forms to their respective pengamat (water masters), who aggregate the data for all tertiary blocks served by each diversion point (bendung). The total water requirement is adjusted for losses in the intake (induk) and secondary channels, and for water reallocation (supplemental), if available. The adjusted total (call it "D") represents the total "normal" demand for irrigation water at the diversion headworks.

The penjaga pintu/bendung (gate keeper) responsible for each diversion point records the quantities which have entered the system(s) served by his diversion point, and the amounts which have passed over the diversion point each day during the prior two weeks. The average daily total (call it "S") represents the best estimate of water availability (supply) over the forthcoming two weeks. The quotient, S/D, represents the expected value of Faktor-K (call it K_e). The diversion point gate keeper then notifies the appropriate water masters of the value of K_e. The water masters, in turn, notify their respective irrigation inspectors who then notify their respective village water masters. At each level, gates are adjusted to reflect the new value of K_e. The new value is also posted on the sign-boards adjacent to each respective control structure.

At one, two, or three day intervals during the two-week period, the gate keeper recalculates Faktor-K -- taking into account that day's actual flow discharge. If the recalculated value of Faktor-K is equal to or greater than K_e, no further action is taken; if it is less than K_e, the chain of communication just described is set in motion. As long as the value of K remains above roughly 0.6-0.7, water is distributed continuously through all intended water control structures. However, if the value of K falls below a certain level, a rotational (giliran) system is usually introduced.

IIMI has developed a computer model that compares estimated water requirements (including distribution losses) with scheduled water deliveries. Figures 4a and b show that the method used now in Indonesia is fairly accurate in meeting field water requirements for the dry season, but for some critical periods it falls short. Further research will focus on this issue.

Figure 4a. Comparison of estimated water needs and scheduled deliveries.

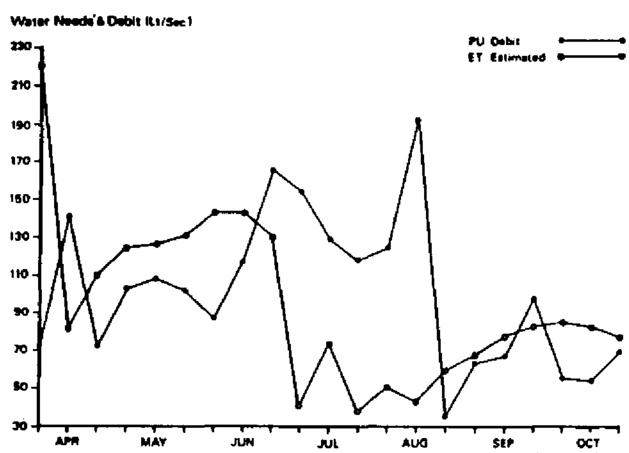
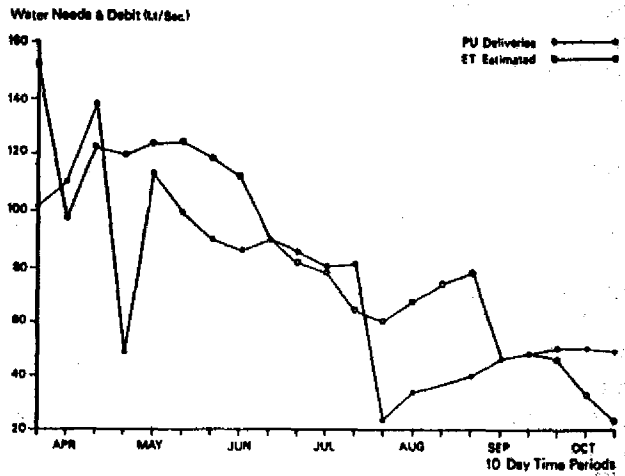


Figure 4b. Comparison of estimated water needs and scheduled deliveries.



CONCLUSION

IIMI's research program in Indonesia has the task of analyzing the implications of irrigation management for expanding and intensifying crop diversification. In this paper, two basic questions are addressed: what are the incentives and constraints to crop diversification in irrigated areas designed primarily for rice cultivation, and what are the appropriate irrigation management practices in areas where diversified cropping already exists?

Until recently more attention has been given to the first question. In the future more attention will be directed toward the second question, which will involve comparing the performance of different irrigation management practices for diversified cropping.

NOTES

1. Interested readers are encouraged to see the July 1986 document by the World Bank Projects Department, "Indonesia: Agricultural assessment," for a discussion of many of the non-irrigation aspects of crop diversification. Also, the recent studies by Stanford Food Research Institute on corn and cassava present a wealth of information on non-rice crop production and marketing in Indonesia.

2. The budgets provide information on economic returns to capital, management, and land when it is not rented.

3. See Christina Gladwin. 1980. A theory of real-life choice: Applications to agricultural decisions. In P. Barlett (ed.), Agricultural decision making: Anthropological contributions to rural development. New York: Academic Press. Also see Human organization (Fall 1984).

4. RWR is the estimated water requirement for all the crops, where an index value of 1.0 is taken as the requirement for secondary crops.

APPENDIX I: REPRESENTATIVE CROP BUDGETS, JAVA, INDONESIA, 1986

Summary of Production Costs for Soybean, Dry Season I, Gung Section, Central Java, 1986

Item		Quantity (kg or hr)	Cost/value (Rp/unit)	Total (Rp/ha)
Land rent:	Share			
	Cash			
Inputs:	Seed	42	900	37800
	Urea	60	125	7500
	Organic fertilizer	100	125	12500
	Pesticide	6 6 24 24	2800 3200 450 450	57600
	Herbicide			
	Tractor			
	Well water			
	Other: KCl	60	125	7500
Labor use:	Seed bed			
	Family			
	Hired			
	Land preparation			
	Family			
	Hired	35	1500	52500
	Planting			
	Family			
	Hired	20F 7M 2M	600 750 1500	19500
	Cultivation			
	Family			
	Hired			
	Irrigation			
	Family			
	Hired			
	Harvesting			
	Family			
	Hired	14M 8F	1500 600	25800
	Processing			
	Family			
	Hired			
Taxes				4000
Marketing				10000
Credit				
Water fees				5000
Total costs				285300
Gross returns (yield and price)				888000
Net returns				602700

Note: Family and hired labor charged at same rate. Rp. 1514.00 = US$1.00.

Summary of Production Costs for Rice, Wet Season, Nganjuk Section, East Java, 1986

Item		Quantity (kg or hr)	Cost/value (Rp/unit)	Total (Rp/ha)
Land rent:	Share			44000
	Cash			
Inputs:	Seed	55	300	16500
	Urea	600	110	29370
	TSP	204	110	22400
	Organic fertilizer			
	Pesticide			
	Herbicide			
	Tractor			
	Well water			
	Other: animal power	14	2500	35000
Labor use:	Seed bed			
	Family			
	Hired	10	1200	12000
	Land preparation			
	Family			
	Hired	26	1000	26000
	Planting			
	Family			
	Hired	50	800	40000
	Cultivation			
	Family			
	Hired	58	800	46400
	Irrigation			
	Family			
	Hired			
	Harvesting			
	Family			
	Hired		1.8 share	86072
	Processing			
	Family			
	Hired	28	1000	28000
Taxes				8800
Marketing				
Credit				
Water fees				10838
Total costs				404700
Gross returns (yield and price)		5.43	126810	688578
Net returns				283878

Note: Family and hired labor charged at same rate. Rp. 1514.00 = US$1.00.

Summary of Production Costs for Chilli, Wet Season, Cerebon Section, West Java, 1986

Item		Quantity (kg or hr)	Cost/value (Rp/unit)	Total (Rp/ha)
Land rent:	Share			
	Cash			
Inputs:	Seed	3	4000	12000
	Urea	90	125	11250
	TSP			
	Organic fertilizer			35000
	Pesticide	7 35	1500 500	28000
	Herbicide			
	Tractor			
	Well water			
	Other			
Labor use:	Seed bed			
	Family			
	Hired			
	Land preparation			
	Family			
	Hired	77	1500	115500
	Planting			
	Family			
	Hired	20F 37M	1000 1500	75500
	Cultivation			
	Family			
	Hired	17 56	1000 1500	101000
	Irrigation			
	Family			
	Hired			
	Harvesting			
	Family			
	Hired	64	1000	64000
	Processing			
	Family			
	Hired			
Taxes				
Marketing				
Credit				
Water fees				
Total costs				442250
Gross returns (yield and price)		4800	400	1920000
Net returns				147750

Note: Family and hired labor charged at same rate. Rp. 1514.00 = US$1.00.

Summary of Production Costs for Maize, Dry Season I, Nganjuk Section, East Java, 1986

Item		Quantity (kg or hr)	Cost/value (Rp/unit)	Total (Rp/ha)
Land rent:	Share		1 season	44000
	Cash			
Inputs:	Seed	34	550	18700
	Urea	622	100	62200
	TSP			
	Organic fertilizer			
	Pesticide			
	Herbicide	6.5	1000	6500
	Tractor			
	Well water			12650
	Other			
Labor use:	Seed bed			
	Family			
	Hired			
	Land preparation			
	Family			
	Hired	12	2500	30000
	Planting			
	Family			
	Hired	40	1000	40000
	Cultivation			
	Family			
	Hired	34	1000	34000
	Irrigation			
	Family			
	Hired	21	1250	26250
	Harvesting			
	Family			
	Hired	24	1000	24000
	Processing			
	Family			
	Hired	50	1000	50000
Taxes				4500
Marketing				
Credit				
Water fees				
Total costs				352800
Gross returns (yield and price)		3.842	139370	535647
Net returns				182847

Note: Family and hired labor charged at same rate. Rp. 1514.00 = US$1.00.

Summary of Production Costs for Peanut, Dry Season I, Nganjuk Section, East Java, 1986

Item		Quantity (kg or hr)	Cost/value (Rp/unit)	Total (Rp/ha)
Land rent:	Share		1 season	44000
	Cash			
Inputs:	Seed	112.97	1033.07	16670
	Urea			
	TSP	58.72	102.21	6022
	Organic fertilizer			
	Pesticide	18.72	928.63	17226
	Herbicide			
	Tractor			
	Well water			
	Other			
Labor use:	Seed bed			
	Family			
	Hired			
	Land preparation			
	Family			
	Hired	31	1500	46500
	Planting			
	Family			
	Hired	57F	600	34200
	Cultivation			
	Family			
	Hired	80	1000	80000
	Irrigation			
	Family			
	Hired			
	Harvesting			
	Family			
	Hired	30	1000	30000
	Processing			
	Family			
	Hired	40	1000	40000
Taxes				2400
Marketing				
Credit				
Water fees				6500
Total costs				318498
Gross returns (yield and price)		1.328	46265	614400
Net returns				295902

Note: Family and hired labor charged at same rate. Rp. 1514.00 = US$1.00.

Summary of Production Costs for Shallot, Wet Season, Gung Section, Central Java, 1986

Item		Quantity (kg or hr)	Cost/value (Rp/unit)	Total (Rp/ha)
Land rent:	Share		1 season	25000
	Cash			
Inputs:	Seed	1100	200	220000
	Urea	200	120	24000
	TSP	380	120	45600
	Organic fertilizer			
	Pesticide	1.5 0.1 0.5	300 1100 4900	7060
	Herbicide			
	Well water			
	Other: NPK	80	400	32000
	ZA	280	120	24000
	KCl	80	120	9600
Labor use:	Seed bed			
	Family			
	Hired			
	Land preparation			
	Family			
	Hired	155M	1500	232500
	Planting			
	Family			
	Hired	40F	800	32000
	Cultivation			
	Family			
	Hired	70M	1500	105000
	Irrigation			
	Family			
	Hired	155	1000	155000
	Harvesting			
	Family			
	Hired	120F	800	96000
	Processing			
	Family			
	Hired			
Taxes				2000
Marketing				
Credit				
Water fees				4000
Total costs				1013760
Gross returns (yield and price)		55	45000	2475000
Net returns				1461240

Note: Family and hired labor charged at same rate. Rp. 1514.00 = US$1.00.

Summary of Production Costs for Cucumber, Dry Season I, Cirebon Section, West Java, 1986

Item		Quantity (kg or hr)	Cost/value (Rp/unit)	Total (Rp/ha)
Land rent:	Share			100000
	Cash			
Inputs:	Seed	3	10500	31500
	Urea	280	120	33600
	TSP	280	120	33600
	Organic fertilizer			
	Pesticide	10 7.5	1500 1500	26250
	Herbicide			
	Tractor			
	Well water			
	Other: bamboo			50000
Labor use:	Seed bed			
	Family			
	Hired			
	Land preparation			
	Family			
	Hired	86	1500	129000
	Planting			
	Family			
	Hired	21	750	15750
	Cultivation			
	Family			
	Hired	24 10 21 42 100	1500 x 3 750 x 2	189000
	Irrigation			
	Family			
	Hired	84	1500	126000
	Harvesting			
	Family			
	Hired	96	1500	144000
	Processing			
	Family			
	Hired			
Taxes				
Marketing				
Credit				
Water fees				
Total costs				878700
Gross returns (yield and price)		199	10000	1990000
Net returns				1111300

Note: Family and hired labor charged at same rate. Rp. 1514.00 = US$1.00.

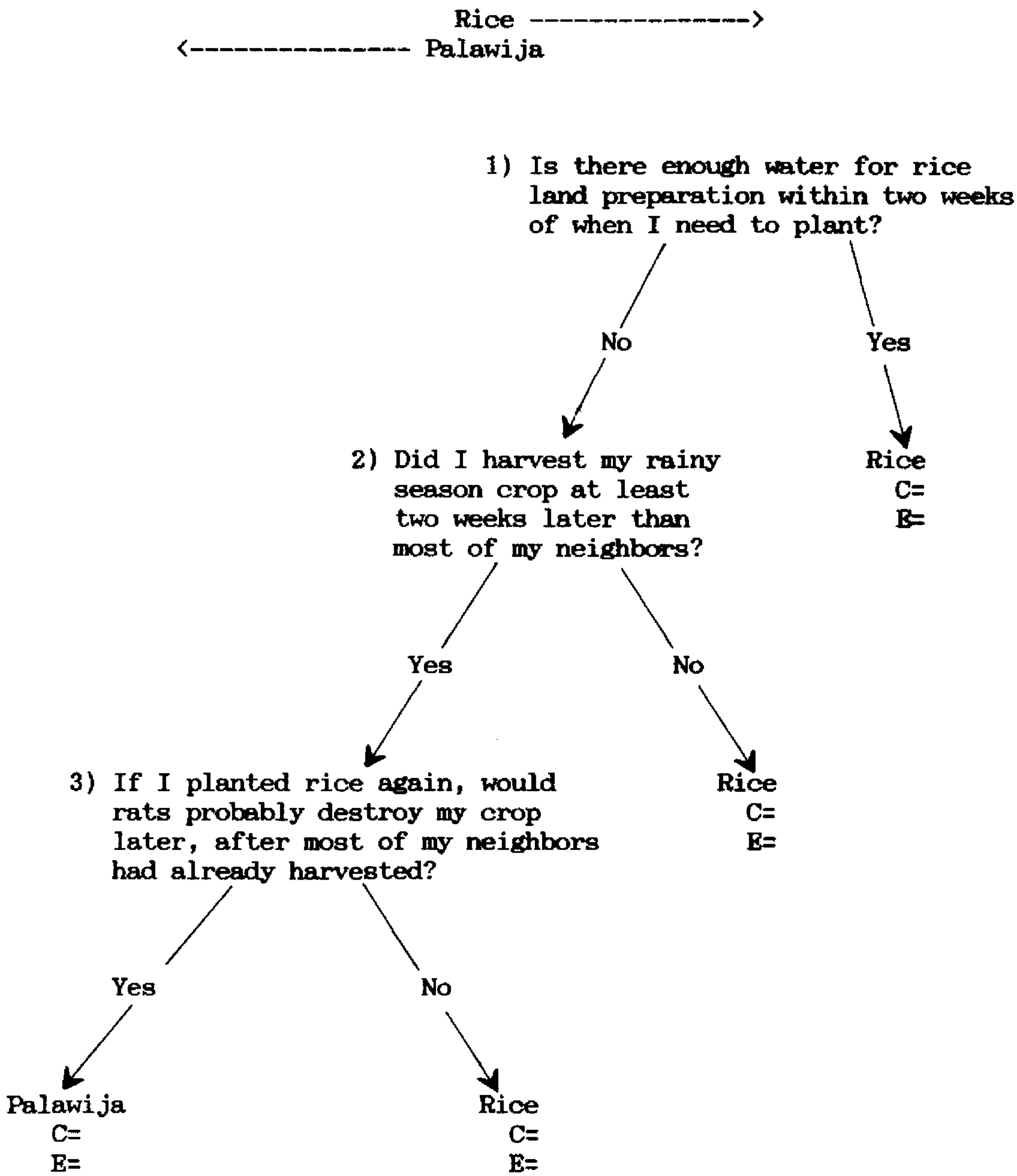
Summary of Production Costs for Mungbean, Wet Season, [illegible], Central Java, 1986

Items		Quantity (kg or hr)	Cost/value (Rp/unit)	Total (Rp/ha)
Land rent:	Share	1 season		30000
	Cash			
Inputs:	Seed	15	850	12750
	Urea			
	TSP			
	Organic fertilizer			
	Pesticide	1.5 1.5 8.0	950 1400 100	4087
	Herbicide			
	Tractor			
	Well water			
	Other			
Labor use:	Seed bed			
	Family			
	Hired			
	Land preparation			
	Family			
	Hired	22M	1500	33000
	Planting			
	Family			
	Hired	17MF	800	13600
	Cultivation			
	Family			
	Hired	20F	800	16000
	Irrigation			
	Family			
	Hired			
	Harvesting			
	Family			
	Hired	14M	1500	21000
	Processing			
	Family			
	Hired			
Taxes				1000
Marketing				
Credit				
Water fees				1500
Total costs				132937
Gross returns (yield and price)		290	650	188500
Net returns				55563

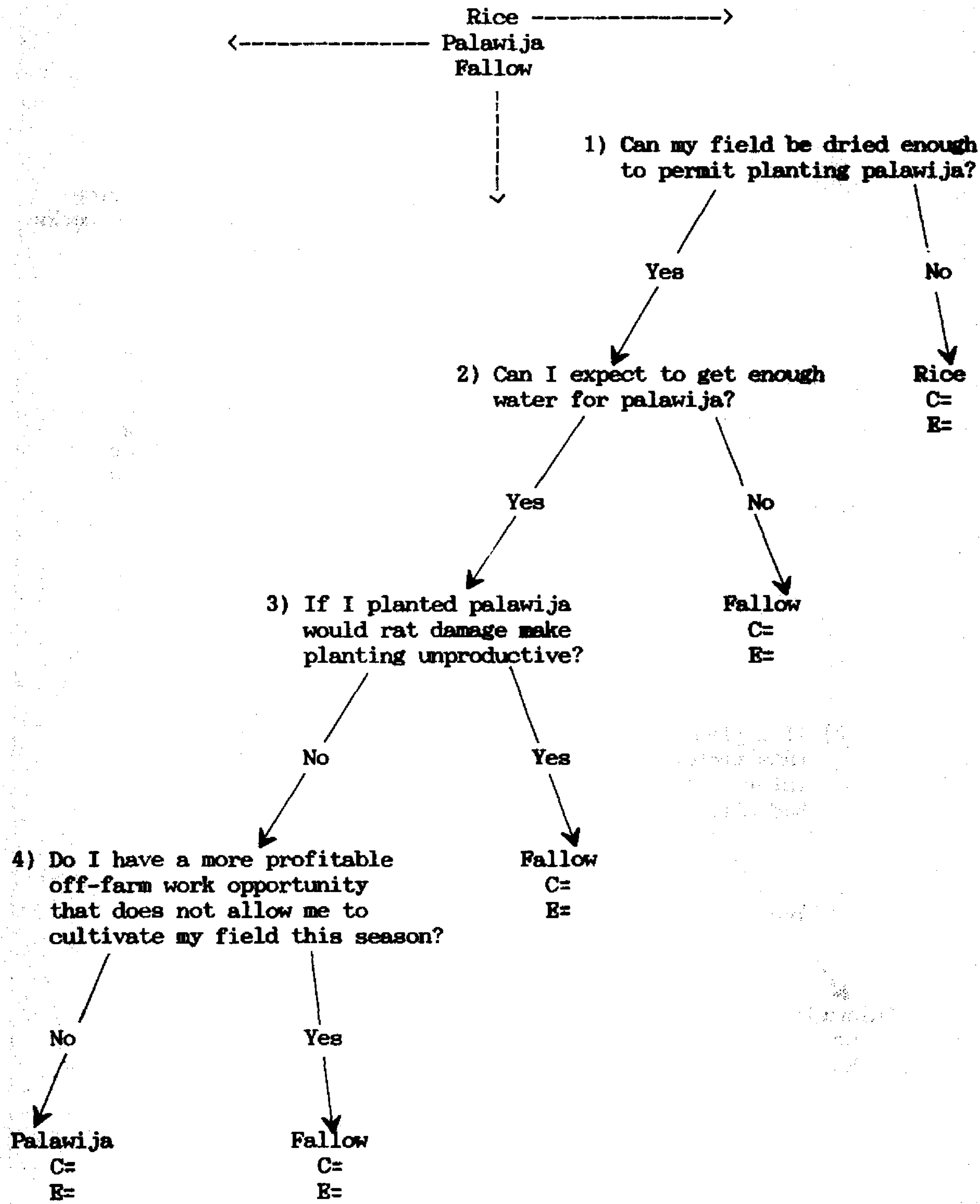
Note: Family and hired labor charged at same rate. Rp. 1614.00 = US$1.00.

APPENDIX II: FARMER DECISION MODELS

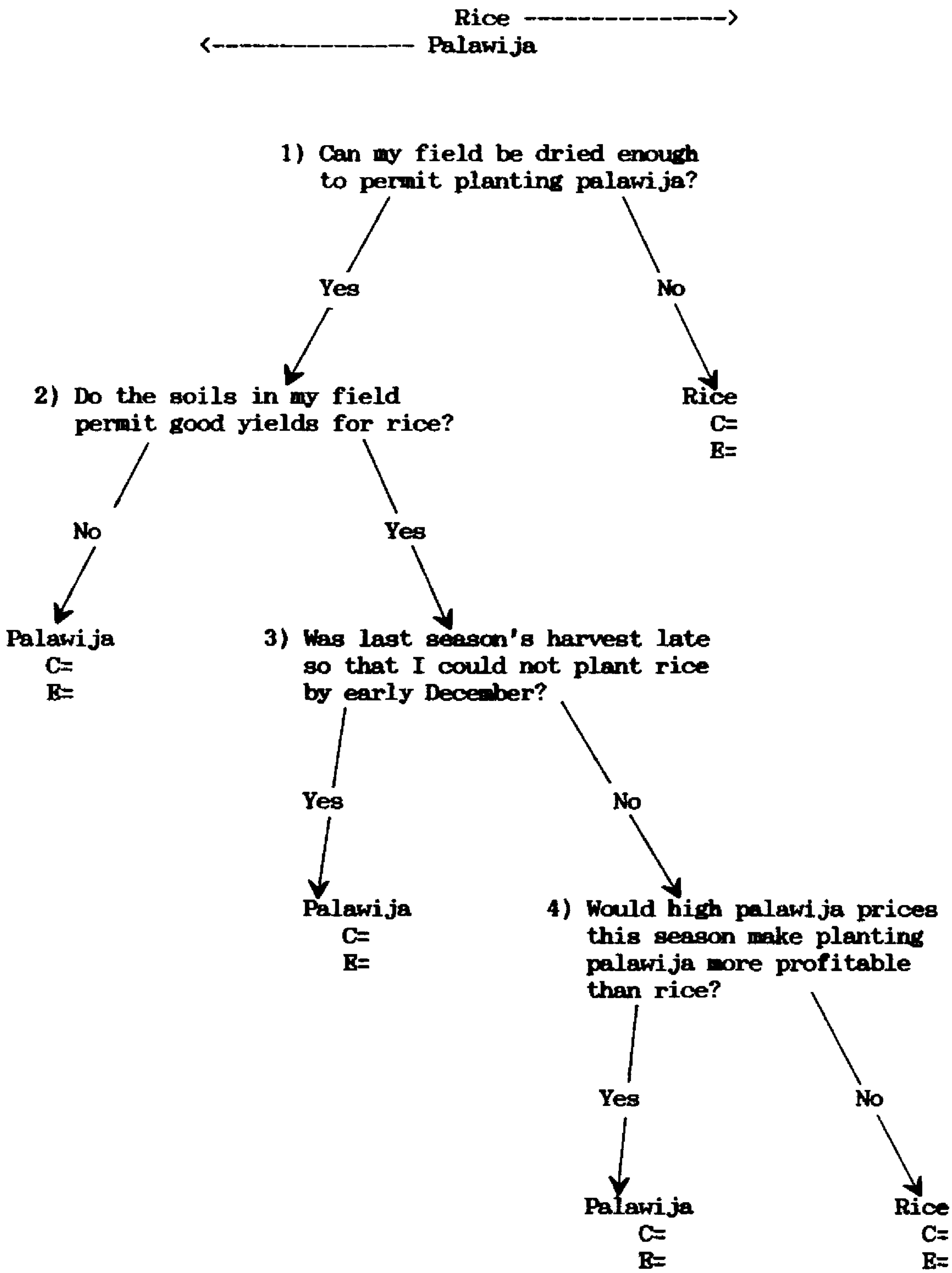
Farmer Decision Model For Planting Rice or Non-rice Crops (Palawija), Cirebon-Kuningan Section, West Java: First Planting Period, Dry Season (Gadu I)



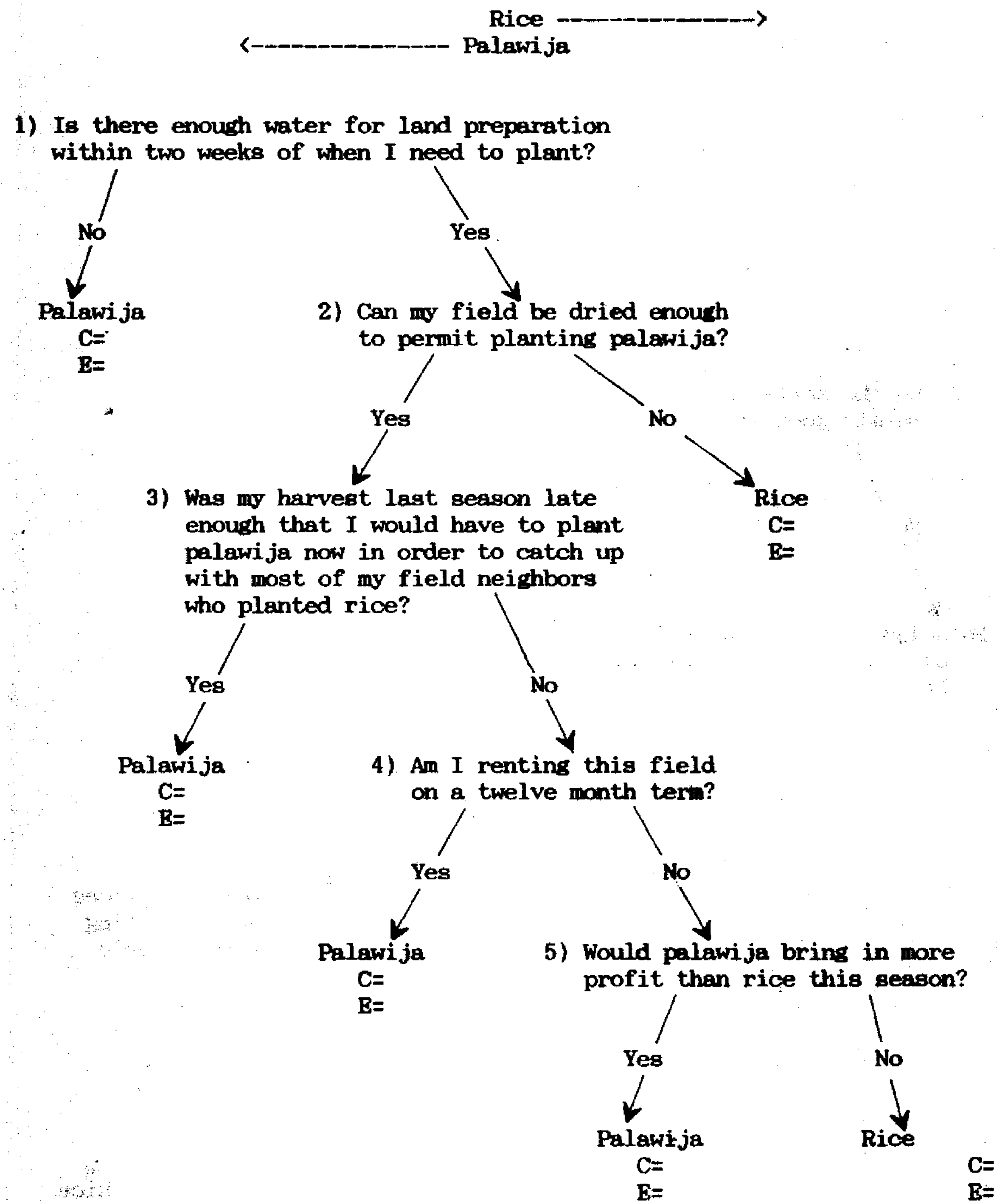
Farmer Decision Model For Planting Rice, Palawija or Leaving Fallow Cirebon-Kuningan Section, West Java: Second Planting Period, Dry Season (Gadu II)



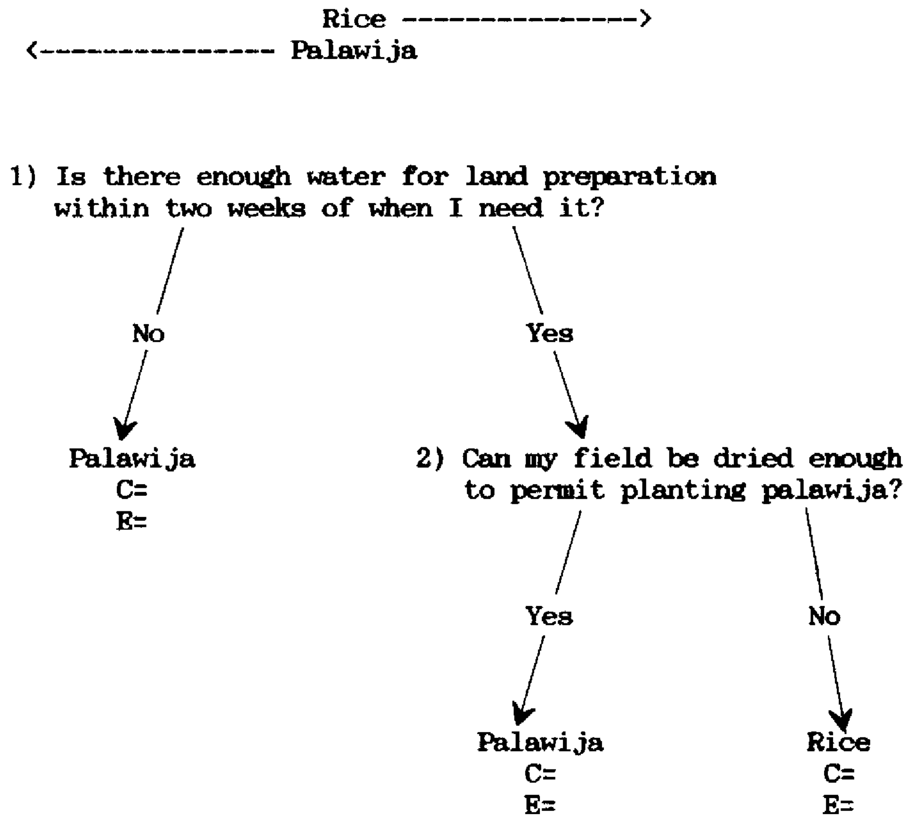
Farmer Decision Model For Planting Rice or Palawija, Gung Section, Central Java: Rainy Season



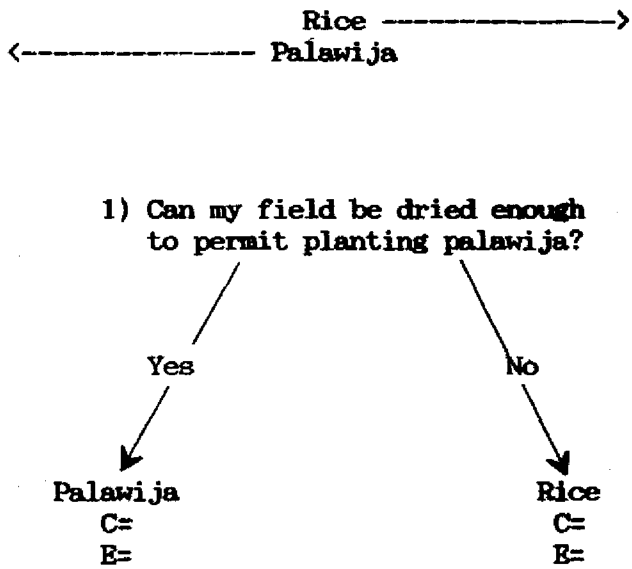
Farmer Decision Model For Planting Rice or Palawija, Gung Section, Central Java: First Planting Period, Dry Season (Gadu I)



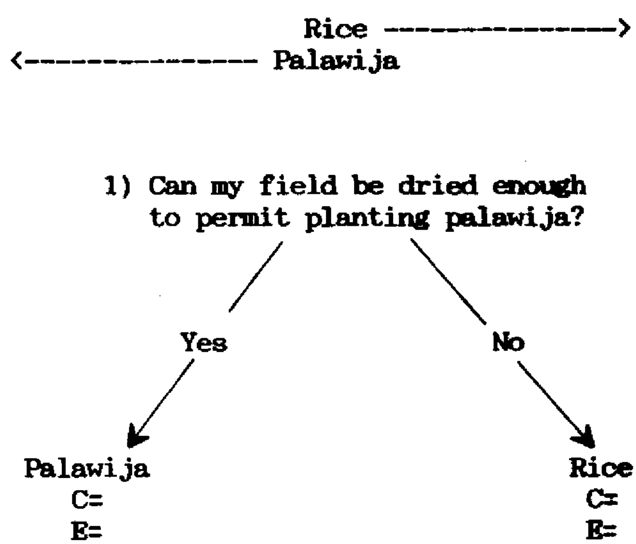
Farmer Decision Model For Planting Rice or Palawija, Gung Section, Central Java: Second Planting Period, Dry Season (Gadu II)



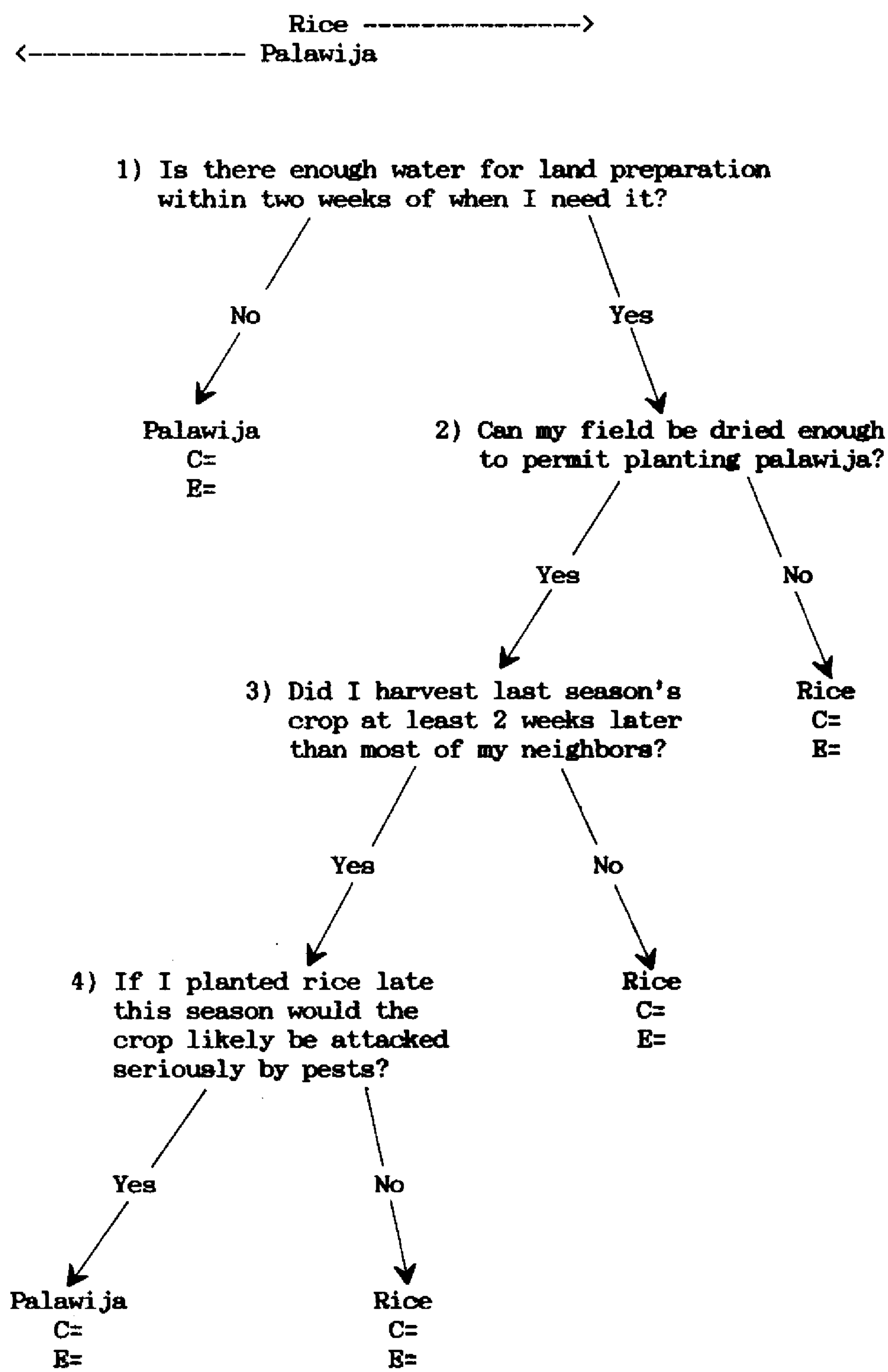
Farmer Decision Model For Planting Rice Palawija, Desa Mojokendil, Nganjuk Section, East Java: First Planting Period, Dry Season



Farmer Decision Model For Planting Rice or Palawija, Nganjuk Section, East Java: Second Planting Period, Dry Season



Farmer Decision Model For Planting Rice or Palawija, Desa Barong, Nganjuk Section, East Java: First Planting Period of Dry Season (Gadu I)



DISCUSSION: RESULTS OF ON-GOING RESEARCH

M.R. Biswas wondered why the price of corn was lower than that of rice, as shown in Figure 15 in the Cablayan and Valera paper. **Alfredo Valera** explained that the figure reflected actual farm gate prices in Isabela which were determined by the forces of supply and demand. But in certain parts of Isabela, the corn prices were higher than rice prices, suggesting the lack of an established market. He cautioned, however, that this price difference did not reflect the overall country situation.

Sunil Dimantha was confused by the term "land shaping." In the Sri Lanka Country Paper and the Concept Paper by IIMI, the term indicated on-farm activities to prepare the land for irrigated agriculture. This involved forming bench terraces, graded terraces, or basins, which was generally a one-time operation. However, the Indonesia paper referred to "land shaping" raised beds, ridges, furrows, or basins at the beginning of every season. This was referred to as "on-farm irrigation layout" in the Sri Lanka paper. **Douglas Vermillion** said that "irrigation layout" meant the network of channels in the main system. On-farm land preparation for planting was referred to as "land shaping." **Dimantha** contended that the channel network in the main system should be called the "system irrigation layout." The furrows and basins that distribute water within the farm would then be the "on-farm irrigation layout," and would not pertain to land shaping. **Senen Miranda** agreed with **Dimantha** that "land shaping" should refer to the initial operations when the original surface features of the land are changed to create uniform surfaces at pre-determined grades.

Kapila Gunasekera pointed out that Table 9 from the IIMI Status Research Report showed that Dewahuwa labor requirements in 1986 were much higher than in 1985, and he wondered why. **Edward Martin** replied that exact ratios relating to rice were presented in Table 9 and showed no significant difference between the two years. Although 1985 was the first year of IIMI's field research, data collection actually began after the season started. He felt that some data may have been lost, accounting for the lower values. Furthermore, farmers' responses were less consistent in 1985. In 1986, farmers were more confident of increased water supplies, and records of farmer responses were more consistent and covered the full season from planting to harvest.

1977 studies showed, according to **Gunasekera**, that chilli gave the highest net returns per unit of water and this resulted in widespread chilli cultivation. Since 1977, production costs increased, especially labor. Farmers who diversify must be aware of increased labor requirements. Although weeds in rice can be controlled by flooding, weeding needs labor for other crops. Irrigation management for diversification should emphasize soil moisture conservation; after all, he observed, soil is in reality a huge reservoir.

R.D. Wanigaratne, referring to Table 5 of the Sri Lanka paper, wished to know the basis for listing soil and water as constraints, and minimizing the importance of costs and risks. The basis, according to **Martin**, was a strong correlation between other food crops (OFC) and well-drained areas, and rice and poorly-drained soils. The average area planted by individual farmers to input-intensive OFCs was not significantly different from the average area planted to rice, which requires less cash input, suggesting that costs were not as constraining to cultivation of OFCs as poor soil conditions.

Shawki Barghouti wondered how the data and study results should be used to improve crop diversification. Without a framework within which variables can be tested, research simply accumulates unfocused data from diverse situations. According to Thomas Wickham, this should be treated as two issues: to develop a strategy of overall purpose, and, within it, to produce a separate framework for each study. Although IIMI had hoped to do this at all its research sites, financing and other problems forced a variety of strategies. Nevertheless, IIMI's goal is to identify, document, and field test management techniques that make diversification profitable. Thus, the common theme at all sites is to search for innovative irrigation management technologies and practices. Barghouti asked if IIMI was applying new irrigation management practices developed by the Institute. Wickham replied that they did not feel they could add new ones but would borrow from one area and apply to another. Miranda commented that all disciplines generally manifest their biases, and thus, although this was reflected in the presentation of the respective progress reports, it should be noted that they had common objectives. The workshop was trying to learn if these objectives were still viable. Similarly, IIMI is trying to develop methodologies that would be common across sites. Roberto Lenton emphasized that commonalty should be the guide for the working groups.

David Groenfeldt pointed out that researchers had to address a variety of information all under the rubric of "crop diversification." To do so, they had to approach the research in a new way to demonstrate the interrelationships between constraints and diversified agriculture. For example, the complexity of institutional constraints had to be recongized.

There was consensus that it was important to develop a consistent framework for research in diverse settings to synthesize data generated. The participants concluded that IIMI should focus on:

1. Conducting studies with common objectives and methodologies.

2. Conducting research in relatively similar environments, especially similar market conditions.

3. Systematically applying proven agricultural technology and irrigation practices, rather than developing new technology.

4. Emphasizing an interdisciplinary framework that recognizes interrelationships and the complexity of constraints to diversified cropping.

IIMI's work should be more in the realm of farmers' decision making than in that of national policy making. There was scope, everyone felt, for further research within the farmer environment by an international institute like IIMI. Research still required a socio-economic perspective on crop diversification that takes into account, among others, consumers' acceptance of OFCs and the per capita consumption of non-rice crops.

SECTION IV: GROUP DISCUSSIONS

GROUP DISCUSSIONS

INTRODUCTION

Participants were convened into five groups and requested to address themselves to the following topics:

1. Constraints in production of diversified crops under irrigation.

2. Applicable and promising irrigation management practices for relaxing constraints.

3. Research issues in irrigation management for diversified cropping.

4. Formation of a research network.

5. Issues with policy implications.

The outcome of the group discussions, rather than the discussions themselves, are presented in the form of recommendations. Because of its special importance, discussion on topic 4 is included with the recommendations under Session 5.

GROUP 1: CONSTRAINTS IN PRODUCTION OF DIVERSIFIED CROPS UNDER IRRIGATION

Identification of Constraints

The group listed constraints under the broad headings of: 1) agronomic; 2) irrigation at both the farm and main system levels; 3) institutional/ social; 4) economic; and 5) policy and other constraints.

The relevant agency, institution, or process that would be instrumental in relaxing constraints includes: 1) farmers, 2) government, 3) irrigation management, 4) research and technology (R&T), and 5) economic development. Constraints and their relaxing agencies were interrelated.

Agronomic Constraints

R&T can help develop techniques to compensate for poor and unsuitable soils (e.g., heavy clay), as well as develop appropriate crop varieties. Along with R&T, better irrigation management can reduce susceptibility to pests and disease, and to heavy rains at critical periods. Improved irrigation management can also reduce water logging.

Irrigation Constraints

<u>Farm level</u>. With help from R&T, farmers can take steps to relax the constraints of small plot size, inadequate field drains, lack of or inadequate size of field channels, and problems of field-to-field irrigation. Research and technology and government could work with farmers to improve

irrigation management. Improving methods of land preparation and irrigation also fall within the purview of farmers and R&T.

Main system level. The constraints of accurately identifying system demand for water and of preparing operational schedules can be remedied by R&T and improved irrigation management. These two, along with the government, can also help relax the constraints of insufficient drainage and the lack of appropriate control structures. Farmers too could help improve control structures. The government alone could solve the problem of inadequate canal capacity by increasing the size of canals. Farmer participation is necessary for system maintenance; and farmers, along with the government, could solve the problem of encroachment into drainage channels.

Institutional/social Constraints

R&T and government can work together to overcome farmer and agency inexperience with non-rice crops. Economic development through the government is the only means of solving the inadequate credit, inputs, and services such as marketing facilities. Farmers, the government, and better irrigation management are required to relax constraints brought about by land tenure arrangements such as bethma. Agency constraints, especially those related to timely and reliable water deliveries, could be resolved through improved irrigation management. Farmer organizations could be set up with government support. Government, with support from R&T, could improve extension services. Coordination among government agencies is a constraint that can be relaxed through improved irrigation management.

Economic Constraints

The government could provide market access and thereby better prices for produce, but only improved irrigation management can relax the constraint of risk-high cash inputs. Farmers and the state together could make mechanization viable for small scale cultivation. Crop insurance and access to land outside the irrigated area can only be provided by the government. Economic development would create more off-farm employment. Better irrigation management techniques and farmer involvement could resolve the problem of small stream size resulting in time-consuming irrigation.

Policy Constraints

Policy constraints can only be relaxed by the government. These include produce (including input subsidies and output price guarantees) and irrigation water pricing, import and research policies, formation of agro-industries, and changing irrigation policy that favor a pro-rice bias.

Conclusions

Farmer involvement through both extension and farmer associations is essential for developing and adopting improved irrigation management. Although in many cases, direct government intervention or enlightened support policies have been shown to relax constraints, governments must be convinced of the need and the probable resolution of problems through such action.

GROUP 2: APPLICABLE AND PROMISING IRRIGATION MANAGEMENT PRACTICES FOR RELAXING CONSTRAINTS

Hypotheses

1. Irrigation systems were originally conceived and designed for rice cultivation. Diversified cropping was not originally envisaged.

2. Diversified cropping takes place only during the dry season (i.e., with a shift of cultivation from rice to upland crops).

3. Systems are open-channel gravity types and not closed pipe systems.

Constraints Considered

The group decided to first identify constraints to crop diversification, and then to only discuss constraints occurring at the following levels:

Farm level. a) Waterlogging (poor drainage and canal seepage; b) costs of seasonal shifts in land preparation; c) inflexible supply; d) fluctuating manpower needs; e) unsuitable soils; and f) mixed cropping (with rice).

Distributary level. a) Inflexibility of supply; b) inappropriate organizational structures to control and distribute water; and c) inappropriate or lack of control structures.

Main canal level (to changes in delivery system). a) Main canal operation incapable of responding to fluctuating demands of water (flows); b) inappropriate organizational structures to control and distribute water; c) inappropriate/lack of control structures on the main canal.

Promising Irrigation Management Practices to Relax the Constraints

Farm level.

a) Preventing waterlogging and improving water use efficiency by providing farm drainage ditches, using raised beds for cultivation, providing properly graded furrows to minimize losses, and providing smaller crop basins to cut costs (while increasing the productive area taken up by bunds).

b) Identifying areas in systems suitable for diversified cropping by: zoning according to soil and water conditions; preventing mixed cropping, particularly with rice; and gradually establishing permanent areas for upland crops.

c) Increasing flexibility and reliability of water supplies by using supplementary water sources (i.e., conjunctive use) through shallow wells, and by pumping and storing drainage water on farms.

d) Encouraging more flexible timing for cultivation activities by staggering.

e) Using soil modification techniques where necessary (e.g., where seasonal shifts in crops are needed but where soil suitability is doubtful).

Distributary system level.

a) Changing the operating principles of the distributary system to make it more responsive to user needs by: changing the organization, and the principles of control and operation of the distributary canals; and decentralizing management and operation of the distribution system (within limits), thereby enabling adjustment of schedules and operations to meet fluctuating demands.

b) Improving manageability of the distribution system by improving efficiency and manageability of the distribution facilities.

c) Improving water availability in the distributary system by increasing buffer capacity through secondary storage, and recycling drainage water.

Main canal level.

a) Improving control structure efficiency by improving effectiveness of water-level control structures in the main canal.

b) Introducing a control system for operating the main canal by improving the information feedback mechanism for managing the main canal system so that it can respond to fluctuating demands at the heads of secondary canals, arising out of a more flexible operation at the distributary level; and providing means for communication, transportation, and telecommunication, and a capacity to process information.

Effective Ways of Introducing Irrigation Practices For the Benefit of Users

Changes in irrigation management practices have implications at all levels of the system, producing another set of needs.

a) Introducing innovative practices at the farm level would entail: extension and demonstration; pricing, credit, and service incentives to farmers if they adopt these practices; and improved water supply at the farm level which is itself dependent on the management of the system at other levels.

b) Introducing innovative practices at the institutional level would entail: revising the processes of planning and allocating land for diversified cropping; providing information about available alternatives and techniques to manage systems more efficiently; and testing the feasibility of control techniques for canal operations through simulation models prior to installation.

GROUP 3: RESEARCH ISSUES IN IRRIGATION MANAGEMENT FOR CROP DIVERSIFICATION

Identifying Issues

After considering IIMI's objectives for research on irrigation management for crop diversification, the group unanimously agreed that they were adequate provided a fifth objective was included: developing suitable extension methodologies for wider application of field tested and viable alternatives. The following issues raised in the IIMI concept paper were discussed:

1. If greater management control over limited water is necessary for irrigated non-rice cropping, how can this control be effected? Would designing and field-testing operating procedures in publicly-managed portions of irrigation systems be the right approach in effecting the desired control? Cost effective management methods at farm level should be evolved and field tested as alternatives (e.g., soil moisture conservation and management techniques). Farmer participation at all stages of such a procedure should be considered.

2. Practical guidelines on irrigation methods for successful non-rice cropping are apparently not yet available to farmers, extension agents, and irrigation/agricultural officers. How can this gap be bridged? The group felt that introducing the fifth objective would resolve the problem.

3. Identifying parts of irrigated commands with comparative advantage for selected non-rice crops is important for optimal limited water use. Is current knowledge on this subject adequate for a conceptual methodology to identify such areas for field testing in selected research sites? The group decided that such methodology already existed for selected non-rice crops.

4. Given that relaxing constraints to irrigated diversified cropping includes policy interventions by governments, what are these options and is it appropriate to study them? The consensus was that important study options related to: a) institutional organizations (both farmer and bureaucratic); b) land tenure; c) privatization; d) legislation; e) land improvement, land shaping, and drainage; and f) subsidies. However, research should be restricted to those options where irrigation management methods are responsive to the cropping decisions of the farmers.

Other Research Issues

1. Commonalties among research methodologies adopted in different countries. Also research methodologies for specific country situations and areas.

2. The extent to which the change from rice to non-rice crops would affect irrigation management in relation to changes in the properties of the soil.

3. Analysis of successful and unsuccessful cases of crop diversification to further understand the critical requirements for diversification in specific situations.

4. Learning from experienced and successful farmers and managers the requirements of crop diversification.

5. Identifying the causes of failure of particular physical control structures in different irrigation schemes.

Research Issues Raised in Different Country Papers

Sri Lanka and the Philippines. On-farm irrigation layouts, irrigation procedures, and timing for easy adoption of diversified cropping patterns.

Indonesia. a) Evaluating incentive and disincentive mechanisms for stimulating effective demand for irrigation water; b) assessing the extent to which the demand side approach prevails in diversified cropping, since this would either encourage or discourage the introduction of water fees for individual crops; and c) assessing comparative advantage of irrigation water application on various traditional crops cultivated in the locality.

Taiwan. a) Preventing land subsidence due to over-pumping ground water; b) air and water pollution control; and c) low cost management and farming practices.

GROUP 4: FORMATION OF A RESEARCH NETWORK

Thomas Wickham asked how different countries would visualize a research network on irrigation management for diversified cropping (IMDC). Were there alternative suggestions for a network name? **Edward Martin** suggested "Irrigation Management for the Dry Season in Rice-based Systems," so as not to preclude rice. **Senen Miranda** proposed "Dry Season Irrigation Management."

Wickham referred to two modes for implementing the network: intensive and extensive. **David Groenfeldt** felt that the intensive mode would be too expensive, referring to IIMI's de facto networks in Sri Lanka, Philippines, and Indonesia. He preferred a weaker mode. **Wickham** replied that although the intensive mode was demanding in terms of resources, it was necessary to find out what the national irrigation agencies would prefer, and wondered if there should not be two levels of participation by member countries. **Ernst Schulze** said that the different levels would depend on the objectives of the research. It would be necessary to differentiate between the farm, the system, and the government. He outlined three objectives for the network: 1) Ensuring efficiency in research through the cross-fertilization of country research results and the exchange of information and research methodologies; 2) promoting country research e.g. identification of research areas; and 3) informing policy makers of the problems of crop diversification.

M.R. Biswas noted that IIMI had a comparative advantage in carrying out network type research. He felt that a weak mode might permit individual countries to link up with IIMI even without a deep commitment to diversified cropping. The description of IIMI's research program, according to **Wickham**, showed clearly that the Institute believed strongly in the network concept. IMDC fitted IIMI's Irrigation System Management Program area (i.e., how to improve the performance of existing systems through better management). He added that, because IIMI had a decentralized structure, it was difficult to generate research from headquarters aimed at issues differing from country to country. Because IIMI worked through the national agencies in various countries, two collaboration models -- information dissemination and active research -- might be considered for the network. The International Rice Research Institute's experience in the 1970s for adopting new rice technologies and the international rice testing program (IRTP) were cited as examples.

Shawki Barghouti observed that the interest expressed in the network from South and Southeast Asia, Africa, and Latin America, signified acceptance of the concepts. A good starting point, according to **Manuel Vergel**, was the utilization of national resources. IIMI could intervene, he felt, by helping to collate the different national experiences. The present workshop exemplified such collaboration. **Miranda** observed that a preference had been shown for a broad-based network. He suggested that it might be better to start off by focusing on crop diversification, and later allowing the network to be subsumed by a more broad-based network. **Groenfeldt** commented that it was beyond IIMI's scope to influence national policies on economics. But wherever crop diversification had been identified as being important, IIMI could help address the more limited issues of irrigation management. **Wickham** felt that the time was right to address procedural questions, such as a mechanism to establish the network's steering committee. **Honorio Bautista** stressed the immediate need to set up even a simple network. **Cheong Chup Lim** suggested that country representatives should decide on procedural matters.

Rationale and Form of Research Network

The involvement of member countries in the IMDC network would vary from information exchange to active research, depending on levels of interest. The network would be organized within a multidisciplinary and multi-institutional framework through appropriate national government agencies, universities, and research institutes. A steering committee would coordinate and provide overall guidance to the network. IIMI volunteered to serve as secretariat.

Operationalizing the Research Network

Participants from Bangladesh, India, Korea, Malaysia, Nepal, Philippines, Taiwan, and Thailand, outlined some preparatory steps. Strong network activity was advocated for Bangladesh, India, Indonesia, Madagascar, Malaysia, Nepal, Philippines, and Thailand. Information exchange and visits were indicated for Korea and Taiwan.

IIMI undertook to communicate about the objectives and formation of the network to each country. In Bangladesh, this would include the Bangladesh Agricultural Research Council, the Ministries of Irrigation and Agriculture, the Planning Commission, and various universities. In India, IIMI would communicate with the Ministry of Water Resources in states where rice irrigation was important, as well as explore using the research and development programs of WALMIS, the Irrigation Department, and the World Bank as channels. IIMI would work through its Resident Scientist in Nepal, and through the Ministry of Scientific and Technological Research in Madagascar. In Malaysia, the Department of Irrigation and Drainage and the Ministry of Agriculture would be contacted. IIMI would communicate with the National Irrigation Administration (NIA) in the Philippines, and keep its Resident Scientist informed and involved. NIA would then interact with the National Economic Development Authority, whose endorsement would make the arrangement official. IIMI would inform Thailand through the Royal Irrigation Department (RID). RID would submit it to the secretary of the Integrated Agriculture Committee as well as to its chairman who is also the Minister of Agriculture. It was also decided to contact the NESDB and the Ministry of Agriculture directly. Korea would be contacted through the President of the Agricultural Development Cooperation and the executive Director of Overseas Projects. IIMI would also communicate with the Council of Agriculture of the Taiwan.

To operationalize the network, it was felt that:

1. IIMI could set up its own coordinating mechanism at IIMI Headquarters to attend to network activity. A working group with a leader could be officially recognized for the purpose. The group's initial task would be to prepare a draft proposal for the research network, indicating its rationale, objectives, structure, mode of operation, and activities.

2. IIMI could circulate the draft proposal initially among the country participants of the workshop for comments and suggestions, and use the final consolidated proposal as the basic document to communicate the intention of organizing the network.

3. Country representatives could convene a planning meeting once agreement was reached, to discuss implementing the network. IIMI could request and obtain seed money for this meeting.

4. IIMI could help identify possible sources of country funding for the bulk of the work to be undertaken by each country.

5. IIMI could organize at least one annual meeting to review activities and results, to be attended by network participants and donors. The venue, to be decided at each meeting, would rotate among network countries, giving participants an opportunity to visit and observe activities in each country.

6. IIMI could try to build the network onto research activities in Indonesia, Philippines, and Sri Lanka, which together form the closest approximation to a research activity network.

Research Objectives of the Network

1. Determine existing and potential irrigation management practices for non-rice crops at the main system, tertiary, and farm-field levels.

2. Identify constraints to diversified cropping under irrigated conditions, and identify ways to relax such constraints.

3. Determine and field test feasible practices which make the irrigation of selected non-rice crops more effective and profitable.

4. Develop suitable extension methodologies for wider application of field tested viable alternatives.

The Group agreed that country-specific interests would be addressed before location-specific research objectives and corresponding studies.

GROUP 5: ISSUES WITH POLICY IMPLICATIONS

The group addressed the following issues that required government policy intervention, identified feasible policy options, and to visualized the role of research in guiding such policies.

277- 278 missing

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