# 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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*Senior Scientist-Engineer and Agronomist, International Irrigation Management Institute, Digana Village, Sri Lanka.

## 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:

$$P = Q / [\Sigma \, RIR\ (A)] = Q / [\Sigma\ (RIR_i\, A_i)]$$

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.

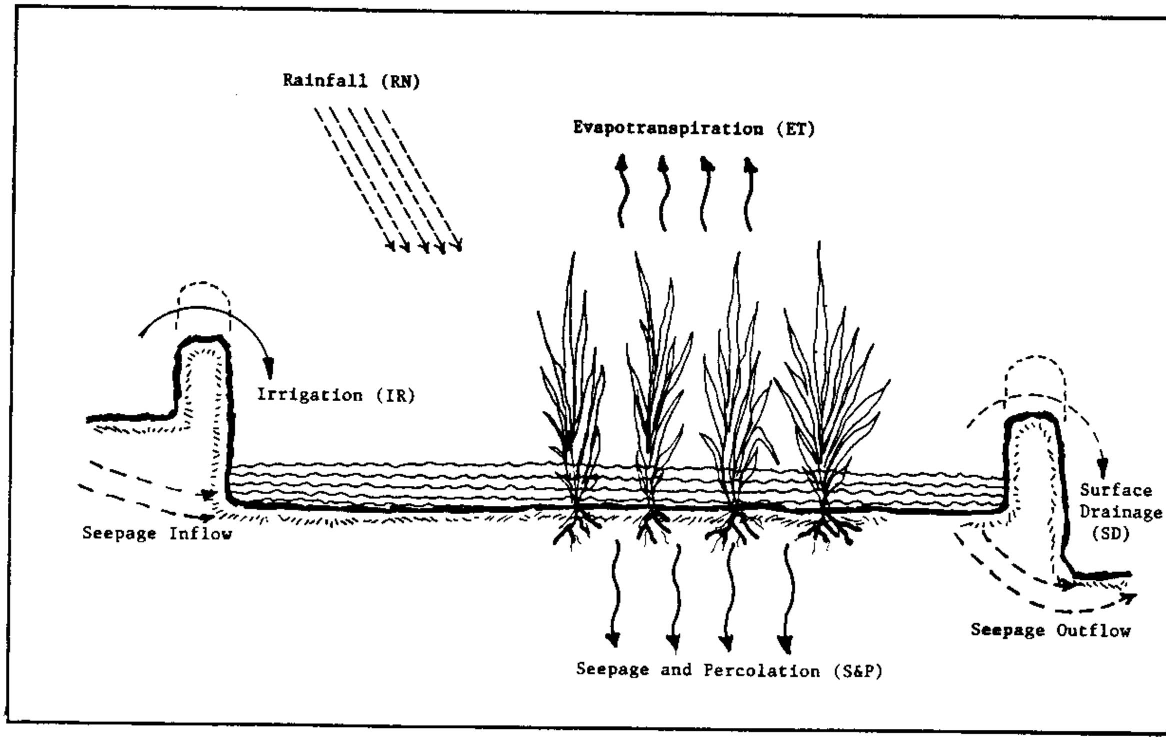
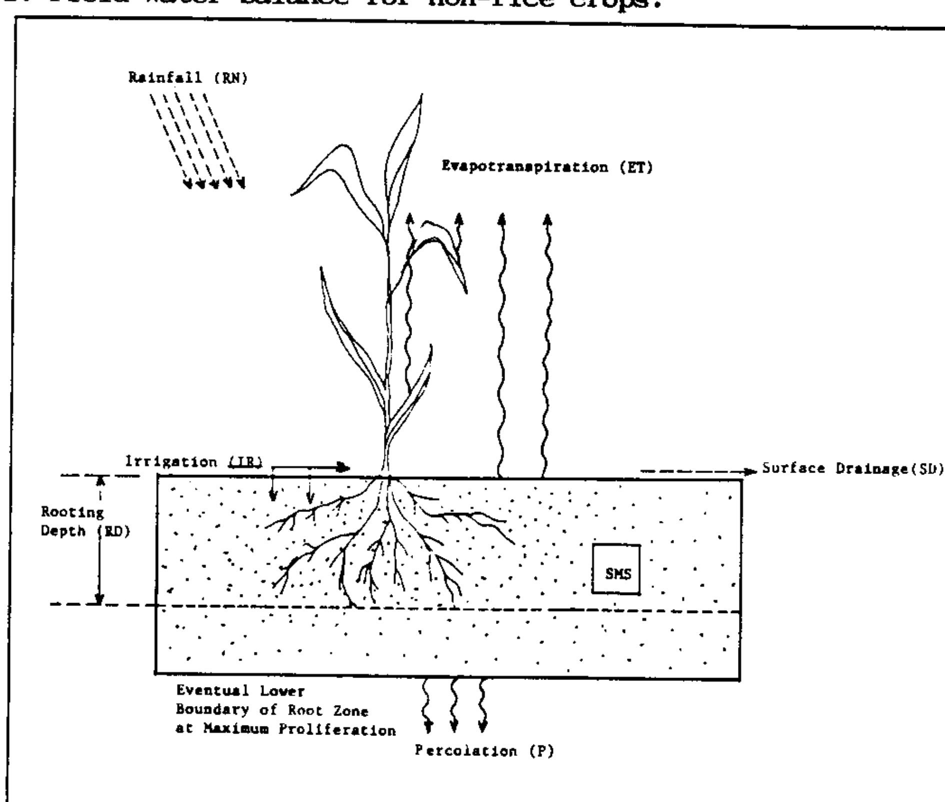



Figure 2. Field water balance for non-rice crops.



## 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.