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IRRIGATION MANAGEMENT NETWORK

IRRIGATION AND WATER MANAGEMENT FOR DIVERSIFIED CROPPING IN RICE IRRIGATION SYSTEMS: MAJOR ISSUES AND CONCERNS

S I Bhuiyan

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S I Bhuiyan

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IRRIGATION AND WATER MANAGEMENT FOR DIVERSIFIED CROPPING IN RICE IRRIGATION SYSTEMS: MAJOR ISSUES AND CONCERNS

S I Bhuiyan

1. INTRODUCTION

1.1 The issue

In recent years there has been a growing concern as to how Asian irrigation systems, which were developed mainly for supporting double-cropping of rice could be effectively utilized for production of irrigated upland crops. The attainment of rice self-sufficiency by a few countries and near self-sufficiency by few others is the major justification for efforts to induce a shift away from rice. The case for such a shift for the Philippines, which is at the threshold of self-sufficiency, has been advanced by Ali(1987). The declining profitability of rice production in recent years is another reason for looking into the production possibilities of irrigated non-rice crops in the dry season. This decline has also spurred a significant slow down of investment in irrigation in the South and Southeast Asian region (Tables 1 and 2), which raises concerns about how future rice production needs of these countries could be satisfactorily met.

Several recent deliberations (for example, Schuh and Barghouti, 1987; Miranda and Panabokke, 1987) have emphasized that the existing irrigation infrastructure is a major constraint to diversification out of rice. Some authors have indicated the importance of rehabilitating or upgrading the irrigation hardware for introducing the flexibility needed to allow large scale crop diversification within the systems.

1.2 Rice irrigation system uniqueness

Rice irrigation systems can be considered unique from a variety of viewpoints: they handle large flows of water per unit of crop land, especially during land preparation periods; their terminal delivery systems are designed for rather a large number of farmers who share one outlet (popularly called turnout or offtake). But perhaps the most unique characteristic common in rice irrigation systems is that they suffer significant design and management inadequacies. Overdesign of the irrigation water supply component and underdesign of the drainage component are the norm, rather than the exception because use of modern high-yielding rice technology evidently requires irrigation water supplies and the rice crop, unlike upland crops, has the inherent capability to withstand limited inundation on the field through the growing season without showing signs of stress. The long-term adverse effects of not adequately draining the soil on soil health and the role of drainage systems in maintaining soil productivity have not been fully recognized.

1.3 Diversified cropping vs farmer's crop choice

As much as it is not desirable to get irrigation systems be technically locked into growing rice only, it is also not desirable that the systems be modified to suit growing one or more upland crop(s) only. Diversified cropping or crop diversification within irrigation systems is often assumed as a necessary goal, but what is important for the farmer is that he is provided with the flexibility of choice to grow a crop or mix of crops that he prefers. Providing the option to grow an alternative crop should therefore be the central focus of irrigation reform of the future. It seems that if the flexibility of farmer's crop choice is given the focus of attention, some of the issues concerning the need for rehabilitation and upgrading of irrigation infrastructure and their management for non-rice crops may appear simpler or at least different.

1.4 Main objective of the paper

This paper represents an effort to examine selected irrigation and water management issues related to farmer's adoption of upland crops in the dry

season within rice irrigation systems. It is assumed that rice will have to be the chosen crop in the wet season for all farmers.

2. RICE IRRIGATION SYSTEMS AND CHOICE OF CROPPING

Stated below are a number of common generalizations concerning the adaptability of rice irrigation systems for production of upland crops in the dry season, which reflect popular notions on the subject. Their validity and possible impacts are examined.

1. Rice irrigation requires continuous flow of water and upland crops require intermittent supplies. Therefore, rice irrigation systems are not suitable for the production of irrigated upland crops in the dry season.

The fact is that ricefields do not require, and should not have, a continuous flow of water. Rice plants grow generally well in shallow ponded water on the field and for that irrigation water is applied to the field intermittently ensuring that the soil maintains at least a saturated condition by the time water is reapplied. Upland crops are also irrigated by intermittent supplies. Thus, farm level irrigation water application systems for rice and non-rice crops are not basically different, although the frequency as well as the in-field water distribution system for the two may vary (for example, basin-flooding for rice but furrow method for corn).

At the main system level, irrigation water may be allowed to flow in the canal network continuously or be rotated in the network canals according to a predetermined schedule for both rice and upland crops. Water supply rotation within the canal network, which is sometimes mentioned as a unique requirement of upland crops, is actually a common practice for rice irrigation in the dry season when availahle water at the source is more limited. There are various forms of such rotation that are found in practice (de la Vina et al, 1986). Therefore, there is no basic difference with respect to the method of canal water flow allocation and delivery for rice and non-rice crops.

However, there are major differences in the manner farmers apply the irrigation water on the farm for rice and upland crops. Fig. 1 exemplifies the various methods used for applying irrigation water to maintain the desired soil-water status for various crops in Indonesia (Johnson and Vermillion, 1987). The water flow differences at the farm level arising from use of different methods can however be supported by the same irrigation system.

2. Rice irrigation systems will need redesigning, upgrading or major rehabilitation to allow widescale adoption of upland crops in the dry season.

If an irrigation system works well for a rice-rice cropping pattern, it can be made to work satisfactorily for a rice-upland crop pattern without major reforms of its facilities. This is because the basic function of the system, which is to deliver controlled amounts of water for needed irrigation and remove the excess water when desired, remains the same regardless of the type of crops grown. Besides, crop-specific modifications are not appropriate when rice must be grown in the wet season. In the dry season farmers may decide to grow several crops within the service area of a single turnout or offtake served by the main irrigation system, and even within the same farm. Therefore the system must remain flexible in terms of its operational method as well as the use of the infrastructure.

A practical way to build-in the desired flexibility in the system's ability to meet the water delivery needs of various crops is to maintain the existing facilities in the main system, and to schedule water deliveries to the turnouts according to a chosen crop (one that is most commonly grown, or recommended by the system authority) in the dry season when mixed cropping is practised. This may require changes in the established practice for water allocation procedures for the selected area. The adjustments of the flow at the farm level for specific crops can be conveniently and effectively done by the farmers, as found in areas where upland crops are grown within canal irrigation systems.

The drainage component of the main irrigation system is one that may require rehabilitation or upgrading to accommodate more upland crop

culture in many rice irrigation systems. Drainage provisions are often neglected from the design to operation stages. The consequence of this is often not dramatic in rice culture because of the inherent ability of the rice plant to cope with certain degree of excess water conditions. But, as stated earlier, the riceland that is not well-drained loses its productivity in course of time. Since upland crops can not tolerate excess water conditions without showing signs of stress or yield losses, many rice irrigation systems may require their drainage systems to be improved for promoting adoption of upland crops. As indicated earlier, such improvements will be to the benefit of both rice and upland crops.

The farm level facilities needed for both irrigation and drainage can be well taken care of by the farmers themselves. Additional on-farm facilities are often required to meet the specific irrigation and drainage needs of the upland crops grown after rice and hence these would be seasonal in nature. For examples, in the Upper Talavera River Irrigation System (UTRIS) in Nueva Ecija, Philippines, in the dry season farmers use 10 to 15 percent of the farm land to provide the on-farm internal ditches for irrigation, drainage, and seepage control required for growing onions. These would be erased from the field at the time of land preparation for the wet season rice and the land saved in the process would be used for rice production in which plot to plot irrigation water flow works effectively (Figs. 2 and 3).

3. In rice irrigation systems, upland crops are not grown on a large scale in the dry season because water deliveries are not precise and reliable.

In most cases, facts do not support this contention. Upland crop culture does not have to wait for the development of capacity to deliver precise amounts of water to each farm or turnout for a group of farms within the irrigation system. There are many examples of average irrigation systems with average structural facilities for water control, in which major areas are grown to upland crops in the dry season.

Precision in water deliveries has rarely been achieved in Asian rice irrigation systems. To operate a system for precise water deliveries may not be economically attractive. But to achieve reliability in water

deliveries is a highly desirable objective regardless of the choice of crop. Rice farming suffers from lack of reliability as much as, if not more than, upland crop farming because farmers resort to low-risk, low input use strategies when water deliveries are unreliable and therefore forego significant rice yield benefits.

Is the lack of reliability in water delivery one of the most important reasons that currently restricts farmers from growing upland crops in the dry season? Maybe it is in some areas, but certainly not in most. This assertion will be borne out by the fact that the vast majority of irrigation water users who are located favourably within the system service area (eg, headend farms) and enjoying the highest degree of reliability that the system can offer, still grow rice in the dry season. We also see that in many areas where water supply is less reliable, farmers decide not to grow rice and try to grow some upland crops. What then decides whether or not farmers will grow an upland crop or not? This question has been discussed later in the paper.

4. Rice self-sufficiency has been recently achieved or nearly achieved in many Asian countries; therefore a strategy to grow more upland crops in the dry season within the rice irrigation systems should be adopted.

The strategy to grow more dry season upland crops in rice irrigation systems without augmenting the water resources would mean converting rice lands into upland crop areas, leading to reduced rice production. The dry season being more productive for rice than the wet season (due to the higher levels of solar radiation), the proportion of rice production loss would be greater than that of the land converted away from rice. If such area reduction is not compensated by equivalent increases in yield potential for remaining areas, rice production shortfall may result. Therefore such a strategy must be carefully weighed against the total agricultural production system and national rice production targets.
For greater adoption of upland crops within rice irrigation systems, a desirable strategy would be to augment the dry season water resources in areas where this is feasible, especially in areas with lighter soils. In parts of many canal irrigation systems where some upland crops are grown, farmers exploit additional water sources such as groundwater or surface water available in inactive canals or depressions. The groundwater

resource is often substantial and economically exploitable for upland crops in the dry season by using shallow tubewells.

5. Because rice self-sufficiency has been achieved in several Asian countries and nearly achieved in many others, investments in new irrigation development should be substituted by investments in upgrading or rehabilitating existing irrigation systems.

Irrigation water is still the most crucial input needed to increase rice production in the Asian rice-growing countries which have limited land resources. Self-sufficiency in rice production achieved recently in a few Asian countries may be a temporary phenomenon. One bad drought in 1987 eliminated most of the reserve food stock of 30 million tons in India. Within India, the major rice-growing eastern Indian states are still rice-deficit areas mostly because of lack of irrigation facilities. Philippines has not yet achieved sustainable self-sufficiency in rice production. Bangladesh, which has less than 25 percent rice area with irrigation facilities, is far from self-sufficiency. So are Nepal, Vietnam, and Kampuchea. Indonesia has recently achieved self-sufficiency in rice, but by high subsidies for inputs. (The Indonesian model can hardly be duplicated by other countries, most of which are also resource-poor.) All the above countries, except India, receive emergency food assistance through the World Food Programme (FAO, 1988).

The late 1960's and the 1970's were periods of considerable growth of irrigated area in the South and Southeast Asian countries. Starting in the early 1980's the growth has slowed down (Tables 1 and 2), a process which may be associated with the declining profitability of rice production. The crucial concern in this regard is that rice-growing countries of Asia are expected to increase rice production at about the same rate between 1985 and 2000 as they did during the past 15 years (FAO, 1987), but with irrigation growth rates which are likely to be much lower than in the past period. Barker and Herdt (1985) estimated that if per capita incomes grow at about the rates they have over the decade of 1970-80, there will be a 58 percent increase in total rice demand by the year 2000 compared to 1980.

How will the demand be met? Will new breakthroughs in rice technology be available in the near future to have higher yields per hectare than those achieved in the early- or mid-1980's? Many experts have their doubts. Brown (1988) describes the situation as a "dwindling backlog of technology", and concludes that there are no identifiable technologies waiting in the wings that will lead to quantum jumps in wheat or rice output in the third world. On the contrary, there is a growing concern that the current levels of rice yields may not be sustainable in the face of continuing environmental degradation. The unprecedented floods in 1988 in various parts of Asia (for example, Bangladesh, China, India (Punjab), and Thailand), which wiped out ricefields of millions of farmers (about 3 million hectares were destroyed in Bangladesh alone), are believed to have been caused by degradation of the environment in the respective catchments. Schuh (1987) emphasized the importance of recognizing the looming environmental problems on agriculture that are brought about by intensive use of fertilizers and pesticides, and shifts of growing farming population to marginal lands.

Will higher yields be achieved through higher levels of chemical inputs use, or other means? These questions deserve most serious examination in formulating strategies to popularize the growth of upland crops replacing rice in the existing rice irrigation systems.

To what extent can rehabilitation or upgrading of the existing irrigation facilities substitute for development of new irrigated area to meet the increasing rice production needs? Undoubtedly, rehabilitation is, and will remain, a continuing necessity in many rice irrigation systems for restoring their deteriorated functions and production capacities. But the benefits from structural upgrading of these systems, that can realistically be achieved and sustained over a period of, say 5 to 10 years, have not been clearly established. A study of recent irrigation systems' rehabilitation in the Philippines indicates that "upgrading" the tertiary facilities (turnout and farm level irrigation and drainage infrastructure) through a rehabilitation program did not meet farmers' needs and, as a result, the upgraded facilities were either left unused, or physically removed by the farmers (Tabbal et al, 1987). Likewise, a study of rehabilitation in Sri Lanka indicated that the physical solutions to water distribution provided through a rehabilitation scheme

did not prove to be effective and did not result in improved management of the irrigation system (Murray-Rust and Rao, 1987). Furthermore, our knowledge of the potential to improve low-performing irrigation systems through improved management to achieve significant, sustainable production benefits is inadequate, and the possible trade-offs between infrastructure and management improvement are not understood sufficiently.

3. FACTORS AFFECTING UPLAND CROP CULTURE IN RICE IRRIGATION SYSTEMS

A growing body of literature on the needs and means for diversifying crop culture in irrigated rice production systems is becoming available. However, many of them have tended to look into the issue from the top, assuming that crop diversification must be pursued, and discussed means to support it. While this approach may be useful in certain situations (eg, where government directives on cropping become binding on the farming community), it seems more important to understand well the farmer's decision-making process regarding the choice of crops. In particular, it is important to clearly identify and analyze the roles of the external forces - socio-institutional and economic - and resident physical features or limitations at the farm level that dominate farmers' decision-making. Few research undertakings have focused integratively on these issues.

Some upland crops are known to give much higher return than rice in the Philippines (Table 3). Yet, rice is the overwhelmingly preferred irrigated crop in the dry season. This implies the complexity of farmer's decision-making process in which his perceptions and experience with risk, market limitations, resource constraints, etc., play vital roles. In some other situations, such as in Indonesia, the profitability of rice is higher than for other food crops (Altemeir et al, 1987) and farmers' choice is mostly guided by the availability of water.
The model in Figure 4 indicates the factors that seem critically important in the farmer's choice of a dry season drop - whether it is rice or an upland crop. The order of priority of these factors will probably vary from farmer to farmer, depending on his knowledge and

perception of how critical a given factor is in relation to the biological performance of and economic returns from the crop under consideration. It can be assumed that as a farmer gathers more experience with the process dealing with a choice among several upland crops, he would have to consider fewer variables. The interactions of these variables, as shown in the figure, render the process quite complicated, and are illustrative of the difficulty faced by farmers in the right choice of crops.

3.1 Farmer's crop choice -- physical factors

The choice of crop between rice and upland crops for the dry season may depend on many factors, but the following are considered most important:

1. *Soil texture and drainability* Heavy clay soils, which are mostly chosen for developing rice irrigation systems, are suitable for rice but largely unsuitable for upland crops. Because of low drainable porosity in these soils, upland crops grown in them may suffer from lack of oxygen, especially when the soil is saturated.

Low internal drainage capacities render heavy clay soils difficult to manage: they become too hard when dry and, in the case of montmorillonitic clay, they crack widely when dry. Proper land preparation becomes more difficult because of these properties. Thus presence of heavy clay soils is a decided physical limitation to growing upland crops. Most of these limitations can be more or less overcome by managing irrigation water very carefully and providing drainage ditches (surface or subsurface) to improve the soil's internal drainage capacity, but these measures are not cost-efficient in most situations.

2. *Irrigation status* There is a minimum supply needed to grow a decent upland crop. If such a supply has been lacking in the past, farmers would be reluctant to try to grow upland crops and risk their investments in land preparation and use of initial inputs in seeds and fertilizers. Strangely, as mentioned earlier, the reliability of water supply may also work in the opposite direction, as seen prevalent in most rice irrigation systems. Farmers may decide to grow rice in areas which have a relatively greater degree of water supply reliability. The influence of

strong interactive roles of some other factors are perhaps responsible for such decisions.

If a farmer has access to a supplementary source of irrigation water, such as a shallow tubewell and a pump set to lift groundwater, his risks of yield loss from water stress is minimized and he is better able to make a crop selection to exploit the market opportunities.

3. *Landscape position and surface drainage capacity* If the farm is located at the bottom of the toposequence and has no natural outlets for removing excess water, it suffers from the risk of getting inundated or temporarily waterlogged from heavy rainfall or excess irrigation in upper farms. Such lands may also be close to the groundwater table at the end of the wet season and remain in excess water conditions too long to be suitable for upland crops.

4. *Influence of neighbours' farming status* A farmer usually feels unsafe to try to grow his small area to upland crops if his neighbours are growing rice. (The same concern is there for rice surrounded by fallow lands.) There is the genuine fear of suffering excess water problems due to inflow of seepage water from adjacent rice plots. Although such excess water can be intercepted and drained away from the crop field if the surface drainage system is effective, such a method involves extra cost. Another reason for feeling unsafe is the possibility of finding the crop field out of phase with neighbouring areas and becoming easy, concentrated targets of insects and disease organisms, and of farm animals of the locality. Fear of major rat infestation in isolated plots is often a dominant reason for deciding to go along with neighbours.

5. *Seasonal rainfall* In many instances high rainfall during critical times badly damage the upland crops. For example, in the Philippines, mungbean farmers are afraid of rainfall at the flowering time and onion farmers wary of excess moisture at the bulb formation period. Late-season rains, i.e. rains in the beginning of the dry season, can damage freshly-sown upland crops, or delay the sowing because of lingering excess moisture condition of the soil and consequent lack of soil tilth for land preparation. This problem is greater in heavy-textured soils. For certain upland crops, for example wheat in Bangladesh, the late-sown

crop is adversely affected by higher temperatures at the reproductive and grain-fill time in the month of March or April. These distractors divert farmers' interests from upland crops to rice, for the sake of lower risks and higher stability of production and income.

3.2 Farmers' Crop Choice - Socio-economic Factors

1. *Family needs for rice* Many farmers grow rice in the dry season to be able to meet the family needs. Growing one's own staple food is often considered a wise strategy and a less risky one, even though more incomes might be possible if other crops are grown. Generally, the smaller the farmer's resources base, greater is the security he seeks with respect to choice of a crop. Therefore, farmers who have already produced adequate amount of rice in the wet season to meet the family needs are likely to be more attracted to growing non-rice crops in the dry season.

2. *Economic incentives* Farmers respond quickly to strong and steady economic incentives offered by crops. In most situations, even if the incentive exists, it is erratic. A successful program of replacement of rice with upland crops in a Taiwanese irrigation system aimed at reducing the national rice surplus level had the following major program of incentives for several years: (a) 1.0 ton of rice to be given to the farmer for each hectare of rice area shifted to corn, sorghum, soybean, or sugar cane; (b) 1.5 tons of rice given for each hectare of rice area shifted to vegetables, fruits, aquaculture, or fallow (Wen, 1977).

Factors that hamper the provision of economic incentives to the farmers are: price fluctuations, inadequate infrastructure for marketing, lack of market information, and lack of proper post-harvest processing and storage facilities. Most upland crops have limited markets and their prices are highly sensitive to production levels. Adriano and Cabezon (1987) showed the pattern of relationship between over-production and price decline for several crops in the Philippines. Producers of upland crops with limited markets have to be lucky to do well in consecutive years, because a season of favourable price is often followed by a season of overproduction and lower price. Such a speculative market may prove to be too much for many small farmers.

3. *Production costs and credit availability* Cash input costs of non-rice crops are usually higher than those of rice. For some high-value crops such as tobacco, garlic, onion, etc , the labour and seed costs are very high. Small farmers have difficulty in mobilizing the needed resources without easily-available credit. In most situations institutional credit is either inadequate, or not available to small farmers, and privately borrowed money is too expensive. These factors discourage resource-poor rice farmers to grow diversified crops and encourage them to stick to rice. In northern Bangladesh, which is the most important irrigated wheat-growing area in the country, many farmers have recently abandoned wheat culture in the dry season (many of them have shifted to rice culture) because of various reasons including the unavailability of institutional credit (which compels the farmers to borrow from private money lenders or sell their wet season rice immediately after harvest when the market price is the lowest in the year) and the low wheat price at harvest time.

4. *Agronomic knowledge* A rice monoculture for many years may create a lack of adequate knowledge and skill among farmers that is needed to grow good upland crops in the irrigated conditions. Such a deficiency may interact strongly with some other problems of upland crop production, resulting in continued disinterest in upland crops.

5. *Land tenure* The farmer's crop choice may be affected by his land tenure status. A tenant farmer usually does not make the choice entirely by himself and he may be directed by the land owner to grow a certain crop. A tenant farmer or a lease-holder is often not eligible for institutional credit, where such credit is available. The output sharing system may also discourage him from trying to grow upland crops which will require more labour and other cash inputs. On the other hand, there are examples in certain areas (eg, certain portions of the Upper Talavera River Irrigation System, Philippines, and of the Manuengteung Irrigation System, West Java, Indonesia) where relatively better-off land owners rent out the farm in the dry season in small parcels to the landless or poor farmers to grow high-value crops such as onion, garlic and chilli which require intensive labour inputs. In the Indonesian case, the land-owners are often found to grow rice in a part of the farm for their own domestic consumption.

6. *Farmer organization* In areas where farmers are better organized to share irrigation water supplies, the adoption of upland crops is potentially higher. This is because without farmers' cooperation water sharing among all needy members is difficult to achieve when irrigation water is in short supply. Mutual cooperation among the water users is especially critical in growing high-value upland crops which require high investments. In the UTRIS case, several farmer groups, each representing the service area of one turnout or offtake served directly by the supply canal, have organized a federated association to establish a fair allocation of water to different turnouts when the canal supply is low.

4. CONCLUDING COMMENTS

Providing options to farmers to grow more upland crops in the dry season within rice irrigation systems should be a major strategy to increase farmers' income and avoid overproduction of rice in countries where rice self-sufficiency has already been achieved. To promote wide adoption of upland crops, it may not be necessary to redesign, upgrade or rehabilitate functional rice irrigation systems, on the untested assumption that they are inflexible and unsuitable for the alternative crops. Drainage improvement however may be required in many such systems because upland crops are highly sensitive to excess water and rice systems are known for their inadequate drainage provisions. Additional irrigation facilities that would often be needed on the farm for most upland crops are seasonal and these can be adequately handled by the farmers themselves.

The oft-made proposition that qualitative improvements through redesign and/or rehabilitation of functional rice irrigation systems would yield significant and sustained rice production increases deserves in-depth assessment. Adequate and convincing evidence of the success of this approach is still lacking. Similarly, our knowledge of the appropriate forms of irrigation system management improvement that will (a) be sustainable, and (b) generate high water use efficiency and crop production benefits, is inadequate. Therefore, irrigation investment strategies based on the assumptions that qualitative improvements made in

existing irrigation systems could substitute for the need to develop new irrigation infrastructure in South and Southeast Asia, where population growth rates and hence, demand for more food production remain high, need careful assessment.

Rehabilitation of irrigation infrastructure in systems which suffer impaired functionality should be carried out to improve their production potential, regardless of whether upland crops should be grown or not. However, the requirements of field level improvements must first be established adequately and the rehabilitation activities designed accordingly to ensure a successful program. Farmers' participation in identifying the field needs is found useful in rehabilitation programs.

In formulating strategies to popularize adoption of upland crops in the dry season, augmentation of irrigation water supplies exploiting groundwater or additional surface storage should be seriously considered. It is recognized that heavy clay soils, which are prevalent in rice irrigation systems, have major physical limitations to growing upland crops and therefore the emphasis of crop diversification should be given to the favourable areas with light-textured soils.

Important factors that influence farmers' decision to switch from irrigated dry season rice to non-rice crops include soil texture and economic incentive. Whereas the soil texture can not be changed and physical manipulations on the farm to improve soil drainability are too expensive for small farmers, economic incentives through effective policies related to post-harvest processing and storage, market infrastructure development, price stabilization, price guarantee, institutional credit, etc., should receive major emphasis. Without improvement of the socio-institutional and economic environments in which farmer communities operate, it is doubtful that physical infrastructural improvements through rehabilitation will achieve the desired goal of crop diversification.

Most rice farming in the developing Asian countries is based on a mixed system of modern and traditional cultivation practices on small land holdings. The prospects of crop diversification on these farms are enhanced when short-duration modern rice varieties are adopted, because

it releases more time for growing non-rice crops as a second or a third crop. In rice-deficit countries, farmers' income enhancement opportunities are likely to be more in growing a third crop (non-rice) than shifting from irrigated dry season rice to non-rice crops. The third crop has to be grown mostly using residual soil moisture and research is needed to explore large-scale use of this option.

If technological breakthroughs are not made in the near future, rice production increases needed to meet the demand from continued population growth rates in the developing countries will have to come from incremental gains possible through further improvements in rice varieties and innovations in resource management techniques. Irrigation water will remain the most critical input for these gains to be practically achieved. There is major concern now how well the rice production gains achieved so far can be sustained over the long run and how rice production systems can be safeguarded from the environmental degradation processes that are unrelated to rice culture as well as those that may be associated with irrigated rice culture. This aspect needs most serious research and development attention. There is a clear need to develop water-conserving rice technologies that would not sacrifice yield potentials. Crop diversification prospects will be brighter if such technologies are available and widely used in irrigation systems.

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Table 1: Compound growth rates of net irrigated area in Asia

	Growth rate (%)				
Period	SE Asia	S Asia	China	Korea	Near East
1965-69	0.9	2.7	2.9	7.3	1.7
1970-74	4.0	1.9	2.9	3.1	0.4
1975-79	3.0	2.2	0	6.2	0.7
1980-84	2.1	1.0	0	0.8	-0.8
1965-84	2.5	2.1	1.2	2.5	-0.3

Source: Levine et al, 1988

Table 2: Average annual lending and assistance for irrigation in South and South East Asia by four major agencies, constant 1980 prices (million $)

	S E Asia					S Asia				
Period	WB	ADB	USAID	OECF	Total	WB	ADB	USAID	OECF	Total
1969-70	-	35	-	6		-	18	-	0	
1971-73	-	61	-	7		-	8	-	0	
1974-76	319	52	-	16		349	32	-	0	
1977-79	467	134	-	29		514	85	-	4	
1980-82	237	153	17	31	438	651	100	54	15	820
1983-85	147	87	5	59	298	533	74	68	10	685
1986-87	88	96	9	18	211	317	48	29	3	397

Source: Levine et al, 1988

Table 3: National average yield (t/ha), actual price (in Philippine pesos* per kg), and relative profitability (pesos/ha) of various crops, Philippines, 1985

Crops	Yield	Price	Total returns	Cost of production	Net returns	Return/ costs**
Sugar cane	533.13	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=$1.00
** Per cent returns to cost of production; Bureau of Agricultural Economics, 1985.

Source: Adriano, M S and Cabezon, V E, 1987

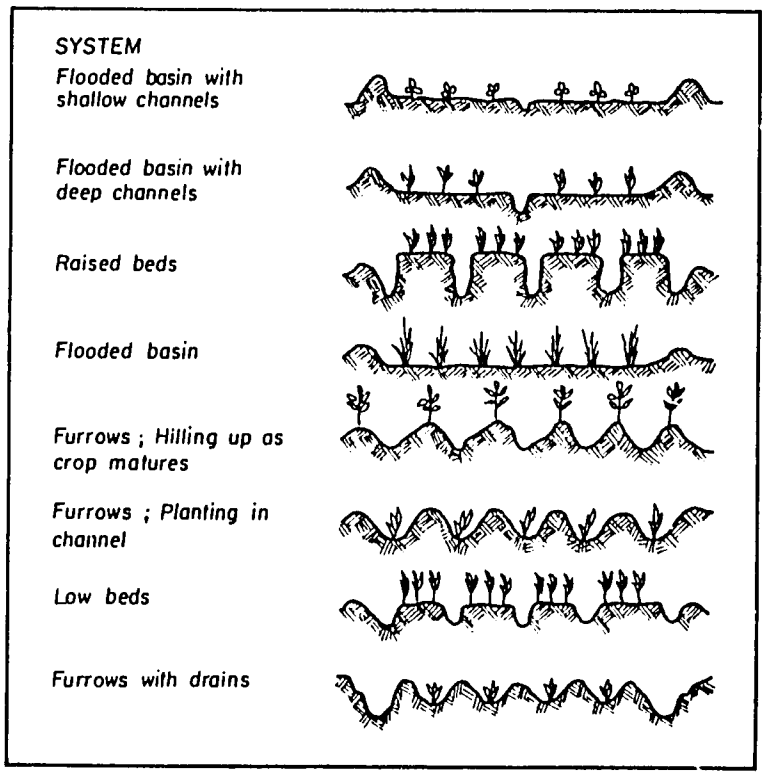

Fig.1. *Methods used to apply and distribute irrigation water for dry season crops (Indonesia)*

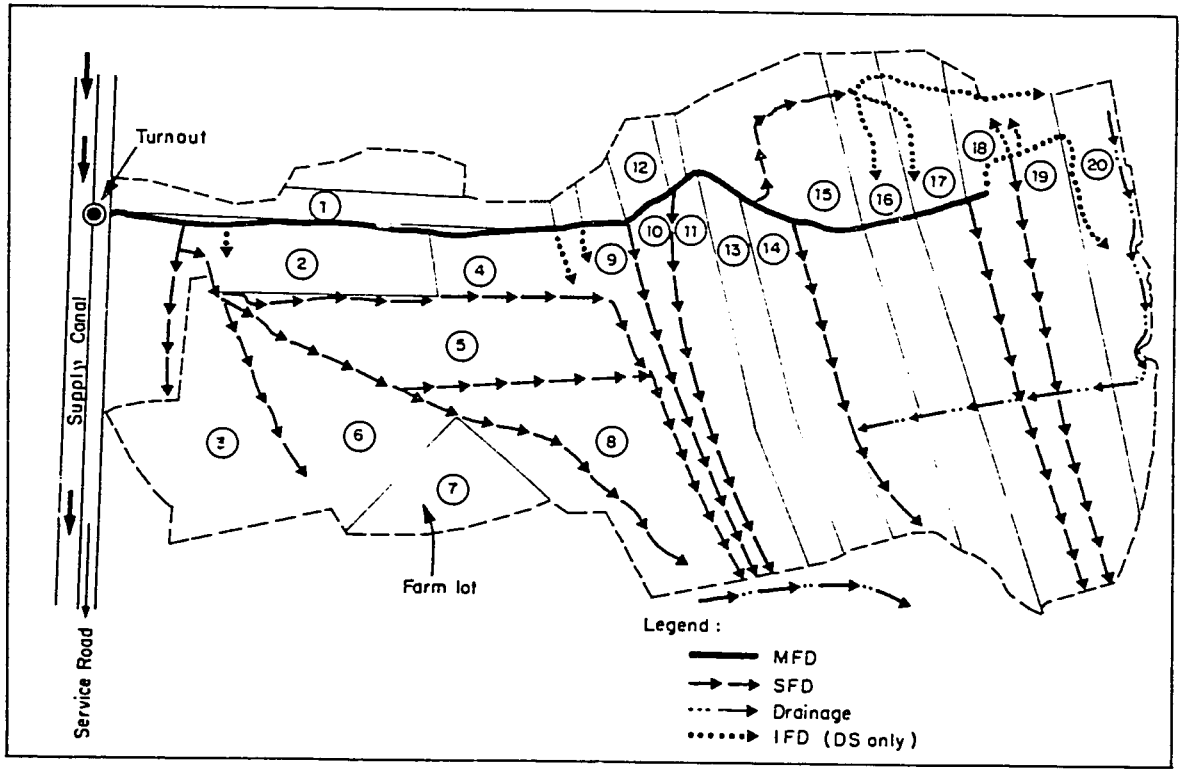

Fig. 2. A typical turnout service area (30-60 ha) in the Upper Talavera River Irrigation System, Philippines, showing water distribution facilities for rice (WS) and onion (DS) Additional seasonal (DS) on-farm facilities are shown in Fig. 4.

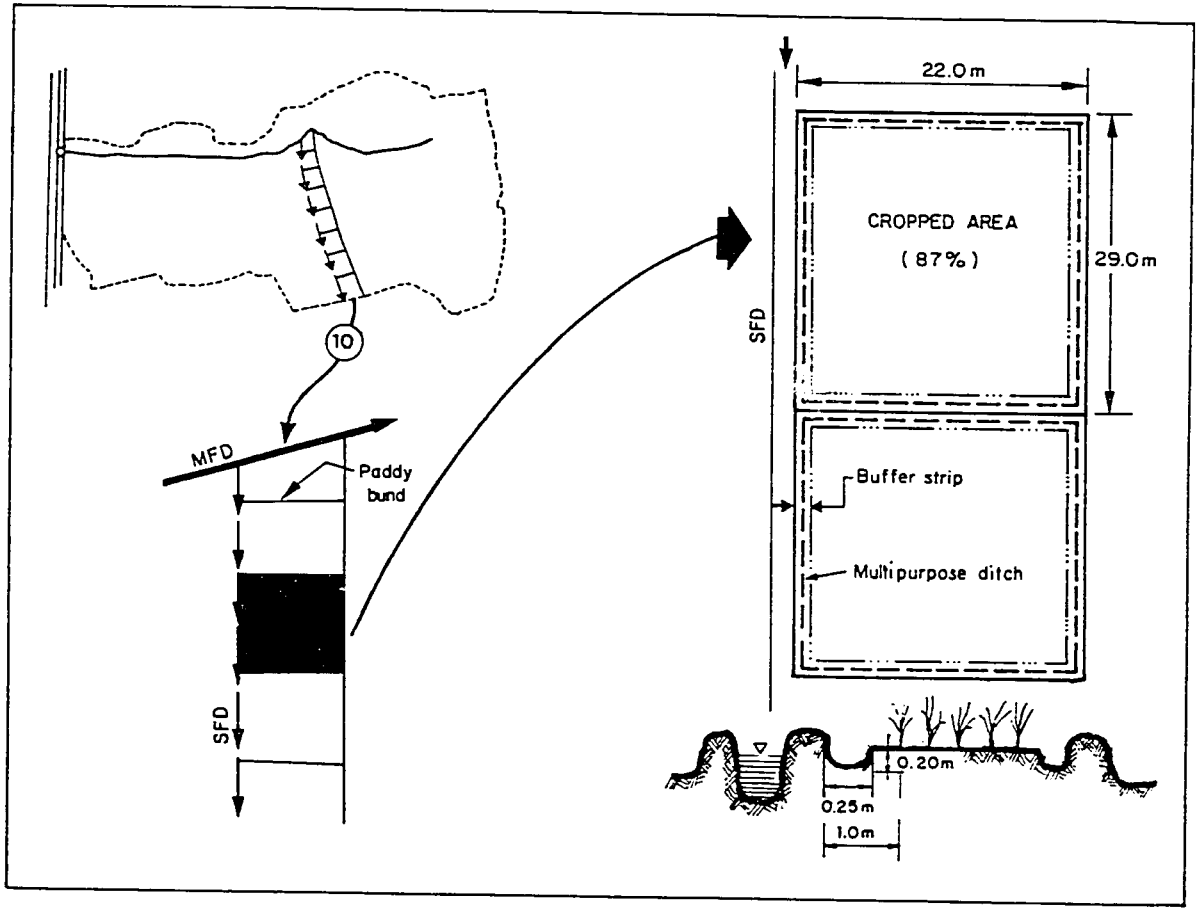

Fig. 3 Typical internal plot - level seasonal facilities developed by farmer for irrigation and drainage control in onion plots

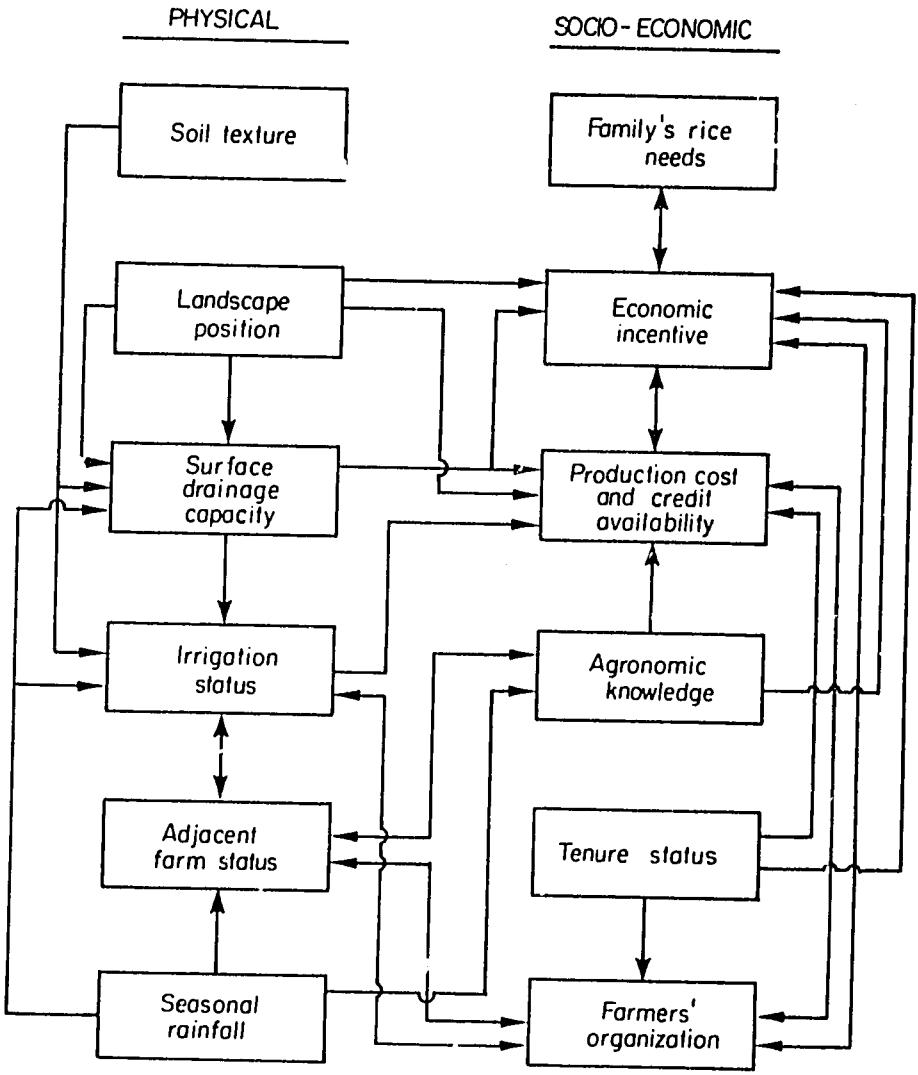

Fig. 4. Model showing different physical and socio-economic factors that affect farmers' choice of crop in dry season, and their interrelationships