Opportunities for the Diversification of Asian Rice Farming Systems: A Deterministic Paradigm

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INTRODUCTION

DECLINING PROFITABILITY OF rice production and the consequent decline in rice farmer income and welfare have increased interest in crop and income diversification. Policy discussions on diversification have often been preceded by farmer initiatives to sustain their incomes by moving at least partially out of monoculture rice production into other crops and/or into other enterprises. Indeed, Thailand, a predominant rice exporter, has exhibited the highest levels of diversification from rice production in the region. A smaller, though significant, shift from rice monoculture has been observed in the Philippines and Indonesia.

This paper views diversification from rice monoculture into a multi-crop/enterprise system as an essential consequence of agricultural development. This process is induced by the changing relative profitability of rice and nonrice enterprises. Diversification from rice to nonrice crops will not always be profitable and will face both physical and economic constraints. This paper attempts to identify and evaluate these constraints for each of the major rice growing environments. Research priorities were assessed for rice and rice-based farming systems keeping in view the relative profitability of rice production by environment.

This paper draws on a variety of data sources both primary and secondary. Panel data sets for the Philippines, Thailand and Indonesia collected by the Social Sciences Division of the International Rice Research Institute for the years 1980 and 1988 are used to examine changes in farmer crop and non-crop enterprise choices over time and to examine the changing profitability of rice versus nonrice enterprises. These data sets were complemented with data from other published sources and from the literature to provide a continent-wide (Asia-wide) perspective for the conclusions reached.

CHANGING PROFITABILITY OF ASIAN RICE PRODUCTION

The long-term profitability of rice production depends on three factors: (a) long-term price of rice; (b) current and potential yields; and (c) input costs. The prospects for sustaining income primarily through rice monocropping are bleak, given low rice prices, stagnant yields and high input costs.

The long-term decline in the real price of rice. Despite the recent increase in world rice prices, several analysts predict a downward trend in real price over the longer run. Figure 1 shows the trends in real world rice prices from 1900 to 1987. This graph was adapted from Mitchell (1987) and used 1964-66 as the base period. It shows that despite frequent and prolonged price fluctuations, the world rice market has been characterized by almost a 50-year declining trend in real rice prices. The major causes of the long-term decline in rice prices are discussed by Mitchell (1987a, 1987b), Mitchell and Duncan (1987), Schuh (1987) and David (1987).

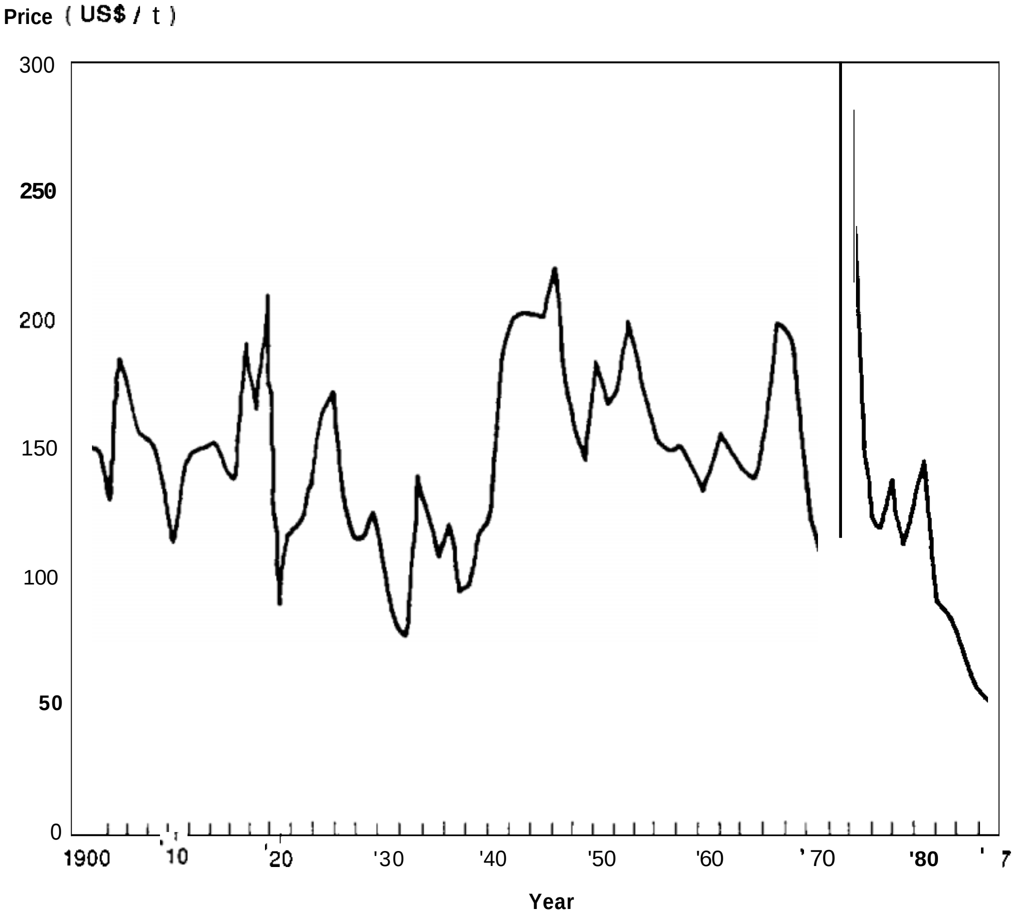
Although, many Asian governments have some form of protection of the domestic producers from the international rice market fluctuations, the long-term trends are passed on to them at least in direction if not in magnitude. If this is the case, other things being equal, the relative profitability of rice production has been declining. Where alternatives to rice production are not easily available, the long-term decline in rice prices leads to a sharp decline in the welfare of rice producers. This downward trend in producer welfare can be arrested if one or both of the following can be achieved: a) a significant reduction in the unit cost of rice production; and b) a reallocation of resources from rice to nonrice enterprises (both crop and non-crop).

Significant reduction in the unit costs of rice production can be achieved either by an increase in farm yields or by an increase in the efficiency of input use.

The diminishing yield gap. During the last two decades, yield increases on farmer fields were obtained by exploiting the gap between the technological yield frontier and actual yields obtained on farmer fields. Recent evidence indicates that the technological yield frontier has stagnated and shows signs of long-term decline (Pingali et al. 1990; Flinn and de Datta 1984). Farm-level evidence indicates that farmer yields are catching up to the yield frontier and that further exploitation of the yield gap is not economical (Pigali et al. 1990). Incremental costs of achieving further yield gains exceed the incremental returns.

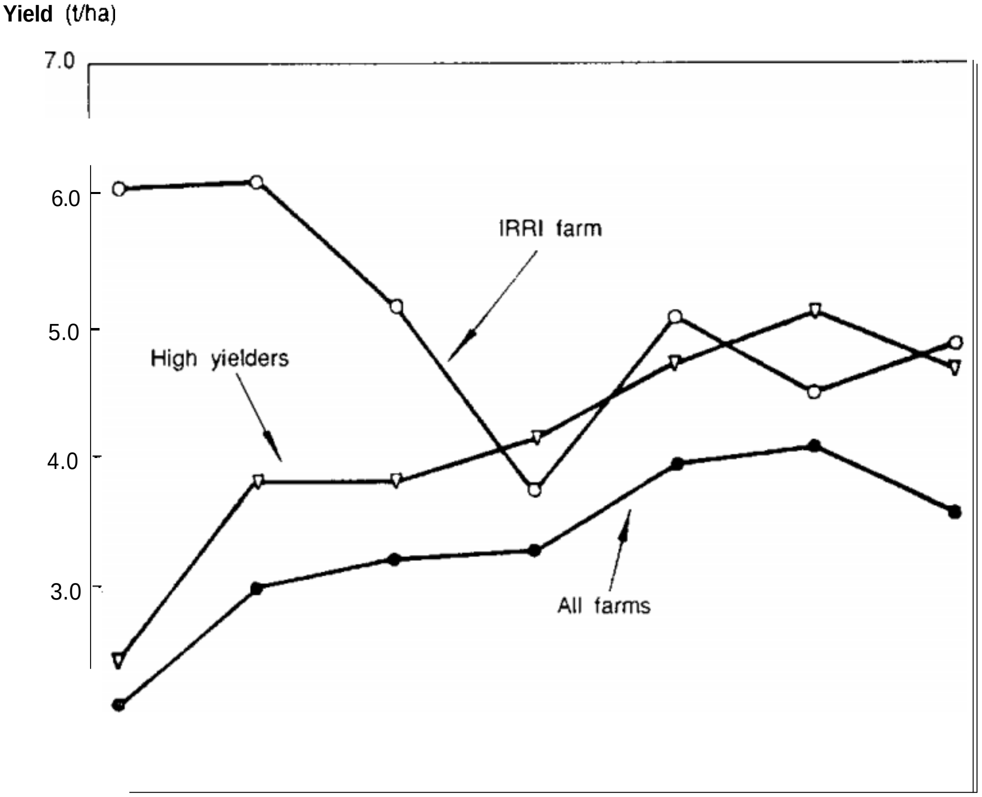
Figures 2 and 3 graphs the highest yielding entries in the maximum yield trials for the wet season at the IRRI farm and at the Maligaya Rice Research and Training Center (MRRTC). These figures show that wet-season rice yields per hectare on the experiment stations have declined from a high of 6.2 tons in 1965-70 to a level of 5.3 tons in 1986-87 h4RRTC and 4.9 tons at IRRI. Similar declining rice yield trends have been observed in other experiment stations in India, Thailand and Indonesia (Nambiar and Ghosh 1984; Gypmantasiri et al. 1989; INSURF 1987).

Figure 1. Trends in *world* rice prices *(1900-1987)*



Source: **Adapt from Mitchell, 1987.**

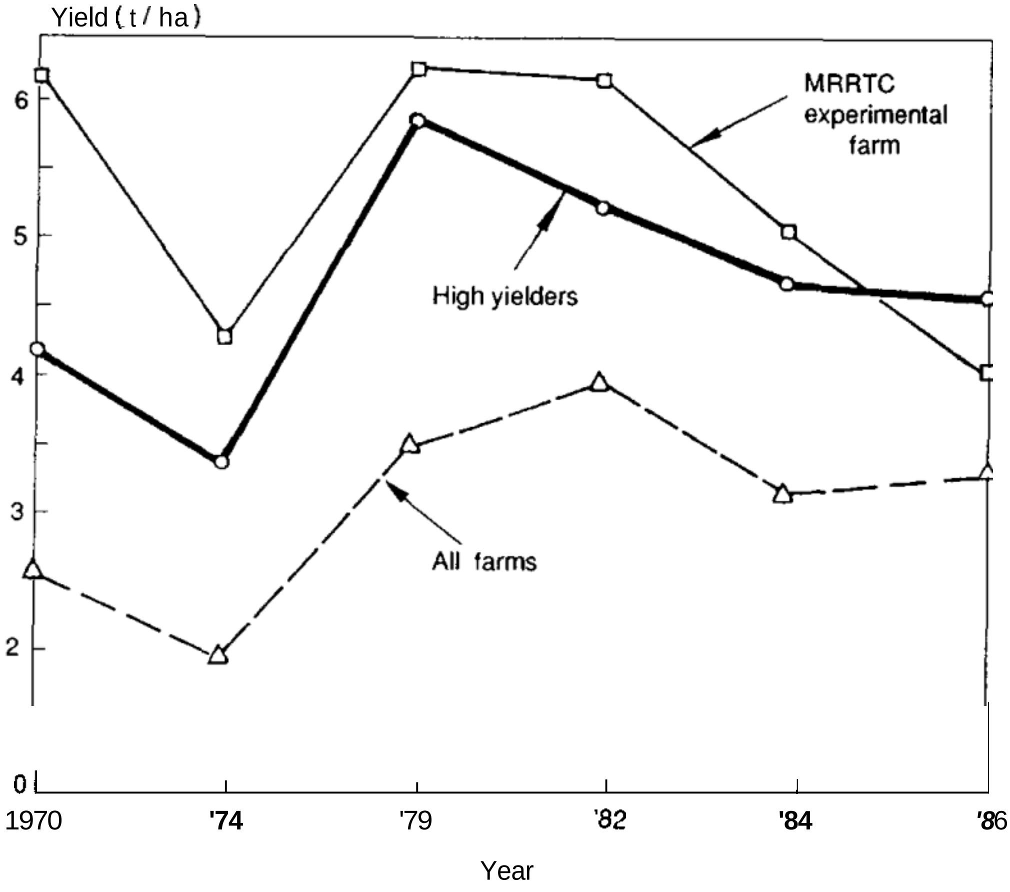
Figure **2.** *IRRI farm data come from the maximum yield trial with N=60 kg/ha. High yielders are the highest yielding 10 farmers out of* **a** *sample of* **35.** *All farms in the sample average.*



Source: **IRRI Agronomy Department and Economics Department.**

**IRRI farm data were from the maximum yield trial with N=60 kg/ha.
High yielders are the highest yielding 10 farmers out of a sample of 35.
All farms in the sample average.**

Figure 3. MRRTC maximum yield trial data with N=60 kg/ha. High yielders are the highest yielding 5 farmers out of 20. All farms in the sample average.



Source: IRRI Agronomy Department and Economics Department

MRRTC maximum yield trial data with N=60 kg/ha. High yielders are the highest yielding 5 farmers out of 20. All farms in the sample average.

The long-term decline in the irrigated-yield frontier under intensive rice monoculture can be attributed to one or more of the following: a) increased pest pressure; b) rapid depletion of soil micronutrients; and c) changes in soil chemistry brought about by intensive cropping and the increased reliance on low quality irrigation water. While the rice research system has been generating varieties with increasingly higher yield potential, the rate of degradation of the rice environment is greater than the rate of increase in the genetic yield potential; hence, a long-term decline in the yield frontier is being observed (Pingali et al. 1990).

Data indicate that the farmers have caught up and that the yield gap with the experiment stations is negligible. The Economics Department of IRRI has been following two groups of randomly selected farmers, the sample in Laguna has been monitored from 1966 to 1988 and the sample in Central Luzon from 1970 to 1988. These samples provide the most accurate information over time of rice-related technical change. For a complete description of the Laguna and Central Luzon samples ***see*** Herdt (1987).

The following information on yields was obtained from each of the samples: a) mean yield per hectare for the sample (adjusted to **14** percent moisture content); b) the average yield of the top third highest yielders for each year. The Central Luzon sample was compared with the experiment station yields from the MRRTC, while the Laguna sample was compared with the maximum yield trial on the **IRRI** farm (Figures 2 and **3).**

Results from Central Luzon showed that in 1970, the gap between the average sample farmer and the experiment station yield was almost 4 t/ha in the wet season. Figure **3** shows a steady reduction in this gap, reaching less than a ton per hectare in 1986. Comparison between the top third of the sample and the experiment station showed a gap of approximately two tons in 1970 which diminished to less than half a ton within a decade. In 1986, the top third outyielded the experiment station by almost half a ton.

Comparison between the highest yielding entries on the IRRI farm and the **Laguna sample farmers shows a** similar pattern. The yield gap between the average sample farmer and the IRRI farm in 1984 was less than half a ton per hectare. The top third in Laguna started off with a 2.5-ton difference in 1965 and outyielded the IRRI farm by 1975. Since then the top third of the Laguna sample have consistently outyielded the IRRI farm.

While the average farm yields have been rising, the top third yields in both Laguna and Central Luzon have peaked and are decliniig. The trend in the top third yields is very similar to the trend in the experiment station yields. One could extrapolate this information onto the average farm yields to predict that a similar peak and decline can be expected on those farms (See Pingali et al. 1990 and Pingali and Moya 1989 for further details).

At least for the irrigated lands in the Philippines, given current technology, the exploitable yield gap between the experiment station and the farmer yields is very small and the long-term prospects are for a stagnation and/or a decline in average irrigated farm yields. Three other implications come out of this analysis:

a. If this trend in stagnant and/or declining yields is widespread, one needs to question the long-run sustainability of intensive irrigated monoculture rice production, as currently practiced in the tropics of Asia. In this context, crop diversification would have to be examined in much greater depth as a mechanism to reverse rice-yield declines in intensive systems.

b. If yield per crop is expected to stagnate, this avenue to greater productivity and profitability is limited. Major attention must be focused on increasing crop production and income per year through intensification or diversification. This may involve fitting in additional rice crops per year, or partially replacing rice with other crops and/or other enterprises, or both.

c. If declining rice productivity becomes a long-term trend in Asia's rice bowls, then rice production and supplies would be affected and projections of a long-term decline in rice prices will no longer be valid.

Degradation of irrigation infrastructure. The degradation of existing irrigation infrastructure in Asia is contributing to an extent to the expansion in areas under nonrice crops. Since the mid-1960s the growth rate of irrigated area in the world has declined by about 60 percent; in Asia, it has declined by 72 percent (Rosegrant and Pingali 1990). This has been due to a sharp reduction in irrigation investments which was caused in part by the relatively favorable food security in Asia and the collapse of the world rice price. The problem is exacerbated by the poor maintenance of existing irrigation infrastructure, despite a relative shift in overall irrigation investment in the 1980s from new construction to rehabilitation and maintenance of existing irrigation infrastructure. An analysis of 92 irrigation systems in the Philippines shows that almost a third of them have declining trends in wet- and dry-season irrigated areas and wet- and dry-season yields (Masicat et al. 1990). Between 1979 and 1989, the absolute wet- and dry-season irrigated areas in Luzon declined by 20,466 ha and 36,175 ha, respectively. Even in areas that continue to be irrigated, the quality of irrigation, in terms of the amounts of water supplied and the reliability of water supplied, has deteriorated over time. Where irrigation water reliability is low, there is a strong case to be made for dry-season crop diversification, both for increasing the efficiency of water use and for sustaining farm incomes.

Increasing input costs. Costs of inputs per hectare could rise due to two reasons: a) holding input levels constant, the unit costs rise; and b) holding unit costs constant, the quantity of inputs used per hectare rises. All inputs like land, labor, all purchased inputs and supervision time are included in the discussion.

Agricultural intensification, measured in the Asian rice context in terms of cropping intensity, leads to an increase in input use per hectare, per crop (Pingali and Binswanger 1987; Herdt 1987). Pingali and Binswanger (1987) discuss the reasons for increasing input use with intercropping intensities. Sustaining yields and soil fertility over time in rice monoculture systems with double and triple cropping requires increasing levels of labor, fertilizers, other chemicals and mechanical power than single crop systems. Farm-level evidence from the Philippines, Thailand and Indonesia provides support for the above proposition.

For the Philippines, a panel of 132 irrigated rice farmers in Nueva Ecija monitored in 1980 and 1988 showed that a 13 percent increase in yield per hectare was achieved with a 21 percent increase in nitrogen fertilizer, a 34-percent increase in seeds and a 24 percent increase in hired labor. For Suphan Buri, Thailand, average irrigated rice yields, for a panel of 146 farmers, increased by 65 percent between 1982 and 1988, while nitrogen fertilizer levels increased by 24 percent, pesticides by 53 percent and seeds by 35 percent. Similarly, for a panel of 71 irrigated rice farms in West Java, Indonesia, average yields increased by 23 percent between 1980 and 1988, while average phosphorus fertilizer use increased by 65 percent and pesticide use increased by 69 percent. Real returns to rice production were stagnant during the periods concerned for each of the three countries (Pingali et al. 1990).

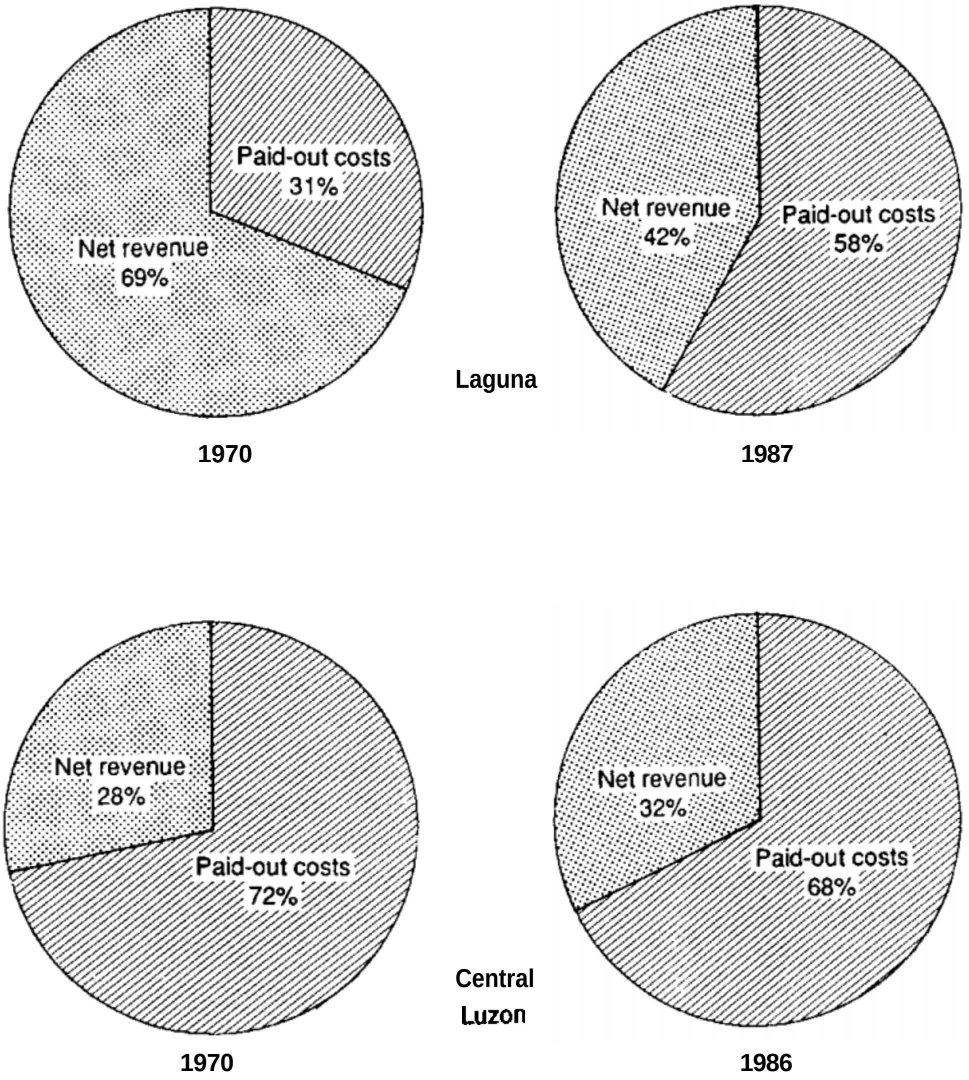
There are several implications of the above on the demand for inputs and the future trends in unit input costs. Land values are positively associated with agricultural intensification (Binswanger and Rosenweig 1986). Given current population growth rates in these countries, the prospects are for relatively higher opportunity costs of land and higher land rental values. Labor costs are also expected to be higher, both for hired and family labor. Hired labor demand during the peak seasons increases as cropping intensities increase. This, coupled with an increase in the opportunity cost of labor due to increased non-farm employment opportunities, necessitates the provision of greater levels of management and supervision.

If rapid efficiency gains in the use of chemical inputs are not achieved, one could also observe a significant increase in the per hectare use of chemical fertilizers and pesticides. Even with these efficiency gains, the long-term prospects are for significant increases in the total demand for chemical inputs.

Declining **long-term** profitability *of rice* ***production.*** Given low rice prices, declining or stagnant yields and increasing input costs, the profitability of rice production has been steadily declining. Figure **4,** shows the Philippine situation. Along with profits, the net income and the welfare of the rice farmer have been declining. The prospects for improvement in this situation are not bright. Improvements in the profitability of rice production depend on either or both of the following factors: a) a substantial increase in experiment station yields that will reverse a twenty-year trend; and b) substantial increase in input use efficiencies.

Sustaining and increasing the incomes of rice farmers will, therefore, depend to a large extent on crop and income diversification. This progression to crop and income diversification has taken place smoothly in countries where product markets operate relatively freely. In Suphan Buri, Thailand, for instance, the

Figure **4.** *Changes in net* **revenues,** *Central Luzon and Laguna* farms.



adoption of nonrice enterprises was closely associated with recent rice price trends. Between 1985 and 1988, 79 percent of **143** households first adopted nonrice enterprises (Table 1). Rice prices in Thailand were on a declining trend between 1980 and 1986, reaching their lowest level during the 1985/1986 period. The nonrice enterprises adopted included: nonrice crops such as vegetables and fruit orchards; non-crop farm enterprises, such as shrimp farming and livestock production; or non-farm activities, **such** as rural industries or urban employment. By 1987, 91 of the 143 households had adopted diversified farming systems. It is interesting to note that a third of these switched back to exclusive rice production in 1988 when rice prices went up again following the drought of 1987. The process of diversification has been slower in the Philippines, Indonesia and Bangladesh where rice profits were buffered to a greater extent by government intervention.

Table 1. ***Number of household adopted nonrice enterprise classified by type of enterprise and the first year of adoption.***

	Year of **first adoption**										**Total house-hold**
Type of **enterprise**	**before 1980**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	
Cattle	2	0	1	0	2	3	2	6	5	13	34
Poultry	4	0	0	3	2	1	2	4	1	2	19
Prawn and fish	0	0	0	0	0	0	0	2	3	0	5
Vegetables	0	0	0	2	1	0	5	10	13	5	36
Fruit trees	0	0	0	2	1	0	1	1	0	1	6
Seasonal crops (short periods)	0	0	0	0	1	1	3	6	8	2	21
Sugarcane E	0	0	0	0	0	0	1	2	7	3	13
Sugarcane C	0	0	0	0	0	0	0	0	5	2	7
Off-farm work (Ag)	0	0	0	1	0	1	0	0	0	0	2
Total	6	0	1	8	7	6	14	31	42	28	143
Price of unhusked rice (baht/ton)	-	-	na	2470	2415	2273	2230	2398	3122	3726	

Source: Srianrunrungreauang, S., **1989.**

OPPORTUNITIES FOR DIVERSIFICATION OUT OF RICE

The opportunities for diversification from rice production depend on both physical and economic factors. A synthesis of the above factors into a predictive framework for the process and magnitude of diversification out of rice is presented.

Flexibility of Crop Choice by Ecosystems, Seasons and Soils

Flexibility is defined in terms of the level of interventions (both physical and human capital) required in switching from rice to nonrice crops and back. For instance, nonrice crops are grown year-round in Indonesia in a Sorjan (ditch and dike) system which involves high levels of investments in drainage control. Flexibility of crop choice is considered to be low in such a system because moving out of monoculture rice to upland crop production on elevated dikes or moving back into monoculture rice production involves high physical investments. On the other hand, upland areas can switch between rice and nonrice crops with minimum additional investments. This system has a high flexibility of crop choice.

Considering different ecosystems and environments, flexibility of crop choice in the wet Season is extremely low in all but the upland environments, because the investment requirements for drainage are high in the lowlands (e.g., sorjan system) (Table 2). Wet-season drainage investments, once made, are not easily reversible. Due to the ease of switching between crops, the uplands have always been extremely diversified in the wet season. Switching between rice, maize and other crops is possible in the uplands because the fields are not bunded and do not require to be puddled before crop establishment.

During the dry-season, crop choice is constrained by two major physical factors: water availability and drainage. The irrigated lowlands have the most reliable water supply. These areas depending on the severity of the drainage constraint have the highest flexibility in dry-season crop choice. Switching from dry-season rice to nonrice crop production will involve a certain amount of investment in temporary drainage structures and in learning nonrice technology, cultivation practices, and irrigation water management. Onion farmers in UTRIS, the Philippines, construct multipurpose ditches and levees in the rice fields for facilitating the drainage of excess water (Tabbal et al. 1990). Other examples of temporary drainage structures can be found for the Philippines (Moya 1990; Alagcan and Bhuiyan 1990; Maglinao and Valdeavilla 1990). The amount of land modification required is related to soil texture: heavy soils require elaborate drainage structures while light sandy soils may not require any drainage structures at all. The returns to these investments are highest for the irrigated lowlands with moderate to well-drained soils and, hence, these areas will tend to diversify more than the other ecosystems as the relative profitability of nonrice crops improves.

Ecosystem	Wet season	Dry season
Irrigated lowland	Low	**Moderate** to high **(a)**
Rainfed lowlands	**Low**	**Low** to **moderate** (b)
Deepwater and tidal wetlands	Low	**Low to moderate**
Uplands	**High**	**Moderate** (b)

(a) This period includes the post-rice period (late wet season) or the pre-rice period (dry-wet transition).
(b) Conditional on rainfall level and distribution.

Irrigated lowland soils can be classified into: well-drained soils, moderately drained soils, and poorly drained soils. Flexibility of crop choice for each of these soils by season is presented in Table 3. For the wet season only the well-drained soils have possibilities for nonrice crop production; investments in a bed and furrow system or a sorjan system are required for successfully growing nonrice crops. On the other hand, for the dry season the flexibility of crop choice in irrigated ricelands is high for all but the poorly drained soils. Only heavy textured waterlogging-prone irrigated rice soils have little option but to specialize in rice production. For this last category the amount of drainage investment that has to be made prior to growing nonrice crops is often prohibitive. Irrigated areas in South and Southeast Asia that have a long history of dry season diversification have all limited their nonrice crop production to well-drained soils while intensive rice production has continued concurrently on poorly drained soils.

The length of the period **of** irrigation water availability is also an important determinant of dry-season diversification. The large partially irrigated areas which cannot support a dry-season rice crop have a natural advantage in diversifying into upland crops during the dry season. But crop choice may again be limited on heavy textured, poorly drained soils, in which water control to avoid waterlogging or drought is difficult.

The relative speed of diversification of rice lands in Suphan Buri, Thailand, for nonrice crop production and for nonrice enterprises has been mentioned in the last section. Diversification of Suphan Buri rice lands took two forms, dry-season diversification and year-round diversification. Dry-season diversification was into vegetables and other seasonal crops, such as, maize and sweet potato; **39** percent **of** the households adopted a dry season nonrice crop. Land investment requirements for establishing these crops is minimal and when the rice price improved in 1988 these lands quickly returned to rice production (Table 1). Year-round diversification was into sugarcane, shrimp and fish farming, and fruit orchards; **14** percent, **3** percent and **4** percent of the households, respectively, adopted these enterprises.

Season	Well-drained soils	Medium drainage	Poorly drained soils
Wet season	Moderate (a)	Low	Low
Dry season	High	High	Low to moderate (b)

Investment requirements for year-round diversification from rice are very high and would only be made if expectations of relative long-term profitability are in favor of the particular nonrice enterprise. For fish and shrimp production, for instance, the initial investment costs are about 110,000 baht per hectare (approximately US$4,400).

Input and labor requirements are also higher for nonrice enterprises, both in the dry season and the year-round enterprises. Table 4 provides data on the relative input requirements and the profitability of rice and nonrice enterprises. Sriarunrungreauang (1989) using the above panel data for Thailand finds that if the rice price drops by 20 percent, dry-season nonrice crops would be relatively more profitable than rice, but year-round diversification would not be a profitable alternative to rice in the irrigated lowlands.

The opportunities for dry-season diversification in the rain-fed lowlands and the deep water areas are limited by water availability for post-rice crop production. In the humid and subhumid zones, rainfall level and distribution are such that a post-rice or pre-rice crop in the rain-fed lowlands is possible. Post-rice cropping of legumes (e.g., mungbean), cereals (wheat, maize) or vegetable crops may be possible on late season rains and residual moisture. This practice has become much more feasible on that portion of rain-fed ricelands which now produces earlier-maturing rice cultivars, which are harvested before the onset of the dry season. In the Cagayan Valley of the Northern Philippines, the replacement of traditional rain-fed rice varieties of six-month duration with early-maturing modem varieties has led to doublecropping of rice in the lower elevations and the introduction of a pre-rice crop of mungbean on the upper elevations (Garrity et al. 1988). Pre-rice crops in the lower elevations are only possible on ridges to prevent waterlogging (Pernito and Garrity 1988). The strategy of increasing cropping intensities in the rain-fed lowland will only be successful if modem rice varieties adapted to these problem hydrologies (i.e., drought-prone, flood-prone and drought- and flood-prone conditions) are available.

In rain-fed environments where there is a sharp and prolonged dry season (especially the semiarid zones) post-rice crops are not possible without supplementary irrigation. In the rain-fed lowlands of South Asia, Northeast Thailand, Cambodia and Laos, dry-season crops on residual moisture would not be possible even if traditional rice varieties were replaced by appropriate short-duration

Table **4.** *Relative input requirements and profitability of rice and nonrice enterprises, Thailand,* 1988 *(baht/year).*

Inputs	**Enterprises**			
	Rice-rice	**Rice-vegetable**	**Sugarcane**	**Prawn**
Fertilizer (B/ha)	2915	27174	995	627
Pesticide (B/ha)	964	19224	280	
Other costs (B/ha)	294	17037	8389	18589
Feeds (B/ha)		42049		
Suh-total	4173	63436	9664	61265
Labor (mds/ha)				
Family	42	595	17	YO
Hired	41	445	60	2
Total	83	1040	77	92
Labor costs (B/ha)	5730	71916	5325	6362
Total costs (B/ha)	9912	135352	14989	67627
Gross returns (B/ha)	28427	160517	32399	104485
Net returns (B/ha)	18515	25165	17410	36858

Source: Srianrunrungreauang, S. *1989.*

modem varieties. There **is** potential, markets permitting, for a short pre-rice crop followed by a short-duration rice crop, suitable candidates being mungbean and green manure crops such as sesbania.

Where supplementary irrigation is available, as with pumps, opportunities exist for a dry-season rice or nonrice crop. In Nueva Ecija, Philippines, where there **is** a six-month dry season, the introduction of deep tubewells has led to the adoption of maize followed by mungbean in the dry season after a rain-fed wet-season rice crop (Gines et al. **1988).** It ought to be emphasized that diversification occurred only on the upper paddies with light textured and easily drained soils ***(turod).*** The lower paddies, on the other hand, with heavy textured soils that are prone to waterlogging (*lungog*), were used for cultivating a dry-season rice crop. While two rice crops are also possible on the turod soils with the dry-season crop being irrigated by pumps, the private and social returns to a diversified cropping system dominate the rice-rice cropping system. This is ***so,*** primarily because the costs of irrigation for rice are high and a significantly smaller area can be irrigated efficiently (Gines et al. **1988).** Engelhardt **(1984)** reports, for the semiarid tropics of India, the emergence of a diversified cropping system with the introduction of deep well pumps. Rain-fed rice in the wet season is followed by either groundnuts, sorghum or vegetables. In Bangladesh, approximately 60 percent of the dry-season cultivated area is imgated by tubewells and pumps (Hakim et al. 1990). Much of this area is planted to a rain-fed wet-season rice crop followed by an imgated dry-season nonrice crop like wheat, potato, gram and onion (Mondal et al. 1990).

Dry-season diversification in the upland areas similarly depends on the level and distribution of rainfall. In areas with a sufficient growing period, a post-rice crop can be grown. Maize, sweet potato, and vegetables are common sequential crops. In Northern Mindanao, the Philippines, for instance, where the average annual rainfall of 2,350 mm is evenly distributed over an eight-month period, double cropping of maize is practiced on a quarter of the upland area (Mandac et al. 1987). On the other hand, in Northern Laos, where the average annual rainfall is 1,400 mm, diversification from one upland rice crop to two nonrice crops is not feasible due to risk of drought stress for the second crop (Fujisaka 1990). For the lower rainfall upland areas in much of the subhumid and semiarid zones, rice production is generally not profitable due to the risk of drought stress. Where irrigation is not available wet-season sorghum, millet and pulses such as pigeon pea and chick pea are commonly grown (Walker and Ryan 1990).

Diversification out of rice production in response to changes in the relative profitability between rice and nonrice crops would be most feasible in the dry season. The rice ecosystems in which it will be most profitable and feasible will be the irrigated lowlands, because of greater reliability of water supply and higher return to diversification investments.

Market Infrastructure Versus Physical Constraints as Determinants of the Profitability of Diversification

Market infrastructure may be divided into two categories, good market access and poor market access. If market access is good, output demand is relatively elastic and hence the returns to investments in land, learning and technology are relatively higher. Physical constraints are represented by drainage problems in the irrigated lowlands and the susceptibility to soil erosion in the uplands.

Table 5 presents, for irrigated lowlands, the physical and market constraints to diversification. The irrigated lowland soils are divided into two categories, well-drained soils and poorly drained soils. In the dry season, in areas with good market access, the profitability of diversification will be high on well-drained soils and moderate to low on poorly drained soils, the latter being dependent on the level of investments required for drainage. In areas with poor market access the profitability of diversification on well-drained soils will be moderate to low, depending on the nature of output demand. If demand is highly inelastic (due perhaps to the high cost of transporting the output to markets) then the profitability of diversification will be low. For poorly drained soils with poor market access the profitability of diversification will be very low.

Table 5. **Market** ***infrastructure uersus physical constraints as determinants of the profitability*** **of** ***diversification.***

Category	Welldrained soils	Poorly drained soils
Good market access	High	Moderate to low (a)
Poor market access	Moderate to low (b)	Very low

Table 6 presents, for the uplands, the physical and market constraints to diversification. The upland soils are divided into two categories: soils that are highly susceptible to erosion (i.e., generally lands on moderate to steep slopes) and soils not highly susceptible to erosion. If market access is good, the profitability of diversified field crop production on soils not highly susceptible to erosion is high. For soils susceptible to erosion, profitability of field crop production is determined by the level of erosion control investments required. Where high levels of erosion control investments are required, tree crops may be a more viable option than field crops, particularly after land degradation has been allowed to occur through field crop production.

In upland areas with poor market access, the returns to diversification out of subsistence rice production are limited in areas with soils that are both susceptible and nonsusceptible to erosion. It is important to note that this argument is only valid if the subsistence crop in the area is rice. There are of course, areas with other subsistence crops (e.g., maize).

Category	Serious soil chemical[a] constraint and/or erosion hazard	Without major soil constraint
Good market access	High input diversified cropping systems or agroforestry systems	Diversified fanning or cash cropping
Poor market access	Shiftiig cultivation systems	Subsistence cropping

[a] Includes highly acid soils with potential aluminum toxicity/P deficiency.

On soils that are susceptible to erosion, the slash-and-bum agricultural system persist as long as population densities are low. **As** population densities, rise, permanent cultivation systems evolve for low-input, low-yield rice production. These systems are often characterized by rudimentary farmer investments for erosion control (Pingali 1987; Pingali and Binswanger 1987). On soils not highly susceptible to erosion, the incentives for diversification out of subsistence rice production are low due to inelastic output demand for rice and nonrice crops.

The relationship between the flexibility of crop choice and erosion control investments becomes very pronounced on the sloping uplands. Sloping lands are extremely susceptible to soil erosion. There are various options for erosion control to maintain permanent cropping on these lands, ranging from grassy strips to stone wall terraces. Farmers' choice of erosion control strategy depends on population pressure on the land, on market access, and on the appropriate erosion control techniques available. Pingali (1990), Fujisaka and Garrity (1988) argue that farmer interest in erosion control measures is directly related to land values and market access and is conditional on suitable technologies being available to them.

Dominant Crop and Non-Crop Options for Sustaining Incomes

Income generating activities are classified as follows: rice production, nonrice crop production, noncrop activities and diversified production systems. Noncrop activities consist of off-farm employment, livestock husbandry, cottage industries, and others. The dominant activity for sustaining income is defined as that activity which provides the major share of income in a particular environment and season. Table 7 provide the dominant income-generating activities for each season and environment. Empirical evidence on the sources of income by rice environments is provided in Tables 8, 9, 10 and 11 for the Philippines, Thailand, Indonesia and Cambodia, respectively.

Table 7. Dominant crop and non-crop option for sustaining incomes by environment

Environment	Wet season	Dry season
Irrigated lowlands	Rice	Rice/nonrice crops
Rain-fed lowlands	Rice	Off-farm employment
Deepwater and tidal wetlands	Rice	Off-farm employment
Uplands	Diversified production systems	

Table 8. Sources of household income, ricefarms classified by environment, Philippines, 1988.

Type of income	Rain-fed farms		Upland farms		Irrigated farms	
	Percent of total income	Number of households	Percent of total income	Number of household!	Percent of total income	Number of households
Rice income	48.1	48	3.0	39	56.7	129
Nonrice income	6.3	41	31.0	39	0.4	1
Noncrop income	9.0	39	16.0	50	6.5	60
Off-farm income	1.0	20	10.0	28	10.2	35
Non-farm income	35.6	53	40.0	15	26.2	95
Total value of (in Pesos) income (in US$)	 22748 1078	 '49	 15777 748	 '54	 33975 1610	 '132

' Total number of samples for each category; some households have two or more sources of income.

Source: Social Sciences Division, IRRI. 1988.

Table 9. Number of villages, number of rural households, sources and levels of net household income by province, Thailand, 1980-81.

Region and province	Number of villages	Number of households	Sources of net household income (baht/percent)				
				Nonfarm			
			Farm	Other sources	Wage	Other	Total
Northeast							
Khon Kaen	8	141	13275 (47.4)	3385 (12.1)	6627 (23.7)	4713 (16.8)	28000 (100)
Roi Et (rain-fed)	5	75	4889 (22.4)	6047 (27.7)	5514 (25.2)	5404 (24.7)	21854 (100)
North							
Chiang Mai (Upland)	9	163	6046 (18.8)	10629 (33.0)	11417 (35.5)	4095 (12.7)	32187 (100)
Center							
Suphand Buri (irrigated)	3	42	29232 (70.8)	-409 (-1.0)	9027 (21.8)	3461 (8.4)	41311 (100)
All provinces	25	421	10643 (35.5)	6284 (21.0)	8544 (28.5)	4481 (15.0)	29952 (100)

Source: Onchan and Chalamwong (Forthcoming). Rural off-farm income and employment in Thailand: Current evidence. future trends and implications.

Table 10. Proportion of total income by source, West Java.

Village	District	Agriculture sector	Nonagriculture sector	Total
Sentul	Serang	33	61	100
Mariuk	Subang	82	18	100
Jati	Cianjvr	52	48	100
Suka Ambit	Sumedang	41	59	100
Balida	Majalengka	63	37	100
Wargabinangun	Cirebon	61	39	100

Source: Wiradi, Gunawan (Landlessness, tenancy and off-farm employment in rural Java: A study of twelve villages).

Table 11. Distribution of farm household by source of income, Cambodia, 1989

Type of income	Rain-fed	Irrigated	Recedinn floodplain
Rice income	99	1	54
Nonrice income	18	0	0
Non-crop income	71	9	2
Off-farm income	11	3	1
Non-farm income	73	11	2
Total number of household	99	15	4

During the wet season, rice will continue to be the dominant source of income in all but upland environments. This is not to imply that rice is not an important source of income for the uplands, but rather to stress the fact that the uplands have always been very diversified. Several different crop and noncrop activities are possible on the uplands during both seasons. Generalizing across upland environments would therefore be difficult.

In the dry season, one observes a mixture of activities for sustaining incomes. In the irrigated lowlands, dry-season rice will continue to be the major source of income. Areas with good market access and those near urban centers will increasingly diversify to nonrice crops and vegetable production. The dominant dry-season activity for the rain-fed lowlands and the deep water areas will essentially be noncrop activities, off-farm employment, livestock production and cottage industries. There is scope for post-rice crops on residual moisture, or pre-rice crops during the early wet season. However, the share of total income from this activity would be lower than that from the other activities. Dry-season cropping activities in the rain-fed areas are limited because of technical problems in timely and effective crop establishment, limited moisture (or excess moisture in some cases), and generally modest yields and high-yield instability. Off-farm activities will often be more dependable income sources, suggesting that dry-season cropping intensities will remain low even if technical problems in crop production are solved.

The above discussions lead to the conclusion that irrigated environments, while having an absolute advantage (relative to the other environments) in a rice-rice cropping pattern, may, at the same time, have a comparative advantage in a rice-nonrice cropping pattern. The extent of comparative advantage for the irrigated lowlands in dry-season diversification depends on the physical constraints and the market opportunities for nonrice crop production. *On* the other hand, during the wet season, the upland environments have both an absolute and a comparative advantage in nonrice crop production.

DYNAMICS OF CROP DIVERSIFICATION

The Dynamics of Farmer Land Preferences

Within an irrigated micro-environment, lands with the greatest preference for rice production are heavy clay soils and lands that have the best access to irrigation water (lands in the head section and fields close to irrigation canals). Yields almost always decline from the head to the tail of the irrigation system (Chambers 1988; l'ingali et al. 1990). Table 12 summarizes data from Sri Lanka on differences in rice yields and incomes by location along the head and tail reaches of an irrigation system. Incomes and net returns to labor decline more sharply than yields (Chambers 1988). The unit cost of rice production would be the lowest on the head lands as compared to that in the tail section, fields far from the irrigation canals and those with more sandy soils (Pingali and Masicat 1990; Wardana et al. 1990). As long as the returns to rice production dominate all alternative crops within the system, the demand for and the price of the head lands will be higher than the others in the system.

Table 12. Average yields, cost and net returns by canal location, Gal Oya Project, Sri Lanka:

	Uhana-Mandur subsystem		Left bank main canal		Gonagolla canal	
	Top	Tail	Top	Tail	Top	Tail
Average yield bushels per acre (four seasons)	53	33	48	33	45	37
Cost per bushel of unhusked rice in rupees	35	53	30	53	29	55
Net returns per family labor day	+27	-48	+28	-11	+44	-8

Source: Chambers 1988.p. 23.

As the relative returns to dry-season nonrice crops rise, one observes an increase in preference for lands normally considered marginal to rice production. Within the irrigated lowlands, the following could be considered marginal to dry-season rice production: upper rice fields that are difficult to irrigate; well-drained soils, sloping lands and stony gravelly land. All these lands would be more suitable for dry-season nonrice crop production due to good drainage characteristics. Investment requirements for drainage are lower on these lands as compared to: low-lying rice fields, heavy clay soils and land with better water access. Wardana et al. (1990) document for the Cikeusik Imgation System in West Java, Indonesia, differences in yields and net returns for rice and nonrice crops (Table 13). They find the relative profitability of nonrice crops to increase on lands further away from the head of the system, to a point where water scarcity could be a problem. Pingali and Masicat (1990) document similar cropping pattern choices for UTRIS in the Philippines. Two crops of rice are grown on the upper portions of the system, while onion, chili and vegetables are common in the midsection. Dry-season crop choices at the tail of the system are conditioned by the reliability of water supply. Where farmers have access to pumps, nonrice crops are grown (Bacayag 1990).

Table 13. *Cost and returns per hectare onion by section, Cikeusik Irrigation System, Cirebon, West Java, Indonesia, 1988 DS I.*

Item	Head n=26	Middle n=29	Tail n=24	All farms n=79
Mean yield per hectare (t/ha)	9.7	10.5	8.4	9.5
Mean price of onion (US$/kg)	0.16	0.17	0.16	0.16
Total value of production (US$/ha)	1676	1822	1332	1590
Costs of production (US$/ha)				
Seeds	494	421	301	396
Fertilizer	137	134	86	116
Insecticide	177	231	143	181
Labor				
Hired labor	556	468	423	477
Family labor	414	215	239	284
Other costs	150	76	168	134
Total paid out costs of production (US$/ha)	1514	1330	1121	1304
Total variable cost of production (US$/ha)	1928	1545	1360	1588
Returns above paid-out costs (US$/ha)	162	492	211	286
Gross margin	(252)	211	(28)	2

US$1.00 = Rp.1,800

Source: Wardana et al. 1990, Table 13.

In the irrigated lowlands, when the dry-season returns to nonrice crop production dominate the returns to rice production, the demand for and the price of land with the least constraints to diversification out of rice will be the highest.

Pingali et al. (1989) examine the changing land preferences in UTRIS in the Philippines. Over the last five years, UTRIS has observed dramatic changes in the preferences for dry-season cultivation of land and consequently changes in land values. The system consisting of areas of heavy clay soils (Lateral A), and areas of sandy loam soils (Lateral B) showed that in the last five years, land preferences have switched from the heavy clay soils to the sandy loam soils. Land values in Lateral A which were once the highest for the entire system are now dominated by Lateral B.

Dealing with Credit, Labor and Risk Constraints to Diversification

The switch from rice monoculture to diversified farming requires substantial start-up investments plus operating expenses. This switch is generally not possible without long-term and seasonal credit arrangements. Where diversification has occurred successfully, farmers have managed to acquire credit through private or public sources. In UTRIS, the main alternative to dry-season rice production is onion. The credit constraint to onion production has been alleviated by arrangements with onion traders. Onion traders from San Jose City provide credit for the purchase of all the required inputs in exchange for a commitment from the farmers that they have the exclusive right to purchase all output at the market price at harvest. No interest is charged for this credit, but the traders benefit substantially from the substantial price increase between the harvest and post-harvest months. This price increase more than offsets the foregone interest charges and the storage costs, Similar credit arrangements from merchants has been observed for vegetable and sugarcane production in Suphan Buri, Thailand where longer-term credit is provided by the government and the agricultural cooperatives.

Relative to rice, the per hectare labor requirements for onion, vegetables and other high-value crops are substantially higher. Providing temporary drainage structures which requires labor is an essential activity immediately following a rice harvest. Planting, weeding, harvesting and post-harvest operations are also extremely labor-intensive for these crops (Table 14). Recent research by IIMI in the Philippines estimated the mean labor demand for rice, mungbean, onion and garlic as 85.7, 68.7, 468.5 and 241.0 man-days per hectare, respectively. Labor requirements for nonrice crops are higher at the head of the system than at the lower portions, presumably because of the greater need for drainage investments in the former (Wardana et al. 1990).

Diversified cropping aggravates labor peaks between the harvest of the rice crop and the planting of the nonrice crop. The land preparation activity for nonrice crops following rice crops would require breaking the rice hard pan (the compact soil surface caused by puddling rice soils). If this hard pan is not broken, there would be problems with root penetration and hence the establishment of a nonrice crop (Zandstra 1990). The power requirement for this soil modification is higher on heavy clay soils than on the lighter soils. Mechanization can, to an extent, alleviate this labor peak. However, the machine power required for upland crops is substantially greater than that required for puddling rice fields. This incompatibility in machines can be overcome by contract hire operations, but these would be profitable only when large areas are grown to nonrice crops. Expansion of nonrice crop area is constrained by, among other things, the nature of the output market, the supply of labor, the prevalence of credit contracts, and farmers’ aversion to production and price risks.

Table 14. ***Relative costs and return (/ha) to palay and onion production, dry season 1988, UTRIS, San Jose, Nueva Ecijn, Philippines.***

Inputs	Palav	Onion
Seeds	644	6086
Fertilizer	1150	2471
Pesticide	433	917
Other costs	2320	5469
Labor costs	3743	7630
Total costs	8290	22634
Gross Income	13863	71751
Net Return	5573	49117

In addition to crop labor requirements, the supervision time required of the farmer is significantly higher. Supervision time rather than the higher labor requirements is suspected to be the dominant labor constraint to high-value nonrice crop production. This would be so, given the highly inelastic nature of management labor available in the farm household, while hired labor supply being augmented by seasonal migrants tends to be relatively more elastic. In UTRIS, the supervision constraint for larger onion producers (greater than 2 hectares) was overcome by dividing their farms into two, cultivating one part and providing the other part to seasonal tenant farmers. Seasonal tenant farmers either come from Lateral A or from neighboring areas to cultivate onion during the dry season. These farmers get land and half of the purchased inputs from the landowner in exchange for 50 percent of the total production.

Unlike in the case of rice, price risks dominate production risks in nonrice crop production. In UTRIS, seasonal tenancy arrangements, could also be a method of diffusing price risks associated with nonrice crop production. The means by which the smaller onion growers do this, is to divide their farms into two, cultivate one part and give the other to a seasonal tenant who pays a fixed rent of pesos 3,000 per hectare plus water charges. This way the landowner gets a certain income from a part of his land and gambles on the remainder. The supply of seasonal tenants has been increasing over the last few years, especially from Lateral A and similar lands with agronomic constraints to diversification.

Collective Action for Water and Land Management

In irrigated environments that have a diversified cropping pattern, collective action is needed, a) to ensure adequate water supply, b) to regulate timing of water supply, and c) to prevent excess water into the nonrice crops. In the Philippines, collective action is achieved through the formation of Irrigators' Associations (Pingali et al. 1988), in Indonesia through Water Users' Associations, in Bangladesh through the Farmer Cooperative Society (Hakim 1990) and in India through the formation of Water Cooperatives (Chambers 1988). These associations have similar operational constraints. The main problem with organizing a viable association is that farmers at the head of the system do not have as much of an incentive to join as farmers at the lower parts of the system since they have a relatively better access to water. Farmers at the lower end of the system find that their access to water improves only marginally by joining the association since the inefficiency of water use or water stealing by the head farmers continues. It is only the mid-section farmers that benefit from the formation of a Water Users' Association. In UTRIS, as reported by Pingali et al. (1989), farmers in Lateral B are well-organized in an Irrigators' Association, while farmers in Lateral A despite several attempts have failed to organize themselves. Lateral A is located in the upper portions of the system and thus has adequate water supply during the dry season. Moreover, the entire lateral grows rice, hence the need for in-season regulation of timing which is minimal but there is no problem of having too much water in the field. Farmers in Lateral B, on the other hand, grow exclusively nonrice crops (onion) during the dry season. The timing of water supply is important. Water flow has to be regulated to prevent excess water flowing into the onion fields. Hence, the need for collective action in B and the success in organizing into an Irrigators' Association.

Collective action although desirable may not always be feasible. Farmers at the tail end of Lateral B organized themselves into an Irrigators' Association but they found that this did not result in any increase in water allocation to their farms. There was not enough dry-season water to service them. After two years, these farmers stopped paying membership fees to the Association and began depending exclusively on pumps for meeting their water needs.

The experience of Bangladesh in the organization of Irrigators' Associations has been similar to the Philippines experience. In the country's largest gravity irrigation system, farmers at the tail end abandoned efforts to secure reliable water supplies through the collective pressure of an Irrigators' Association. But at the head of the system repeated efforts to organize an association failed since these farmers having adequate water had no incentive to join an association (Hakim 1990). Hakim reports that collective management was more successful in the relatively smaller pump irrigated systems than in the large gravity irrigation systems. Chambers (1988) reports on the Indian experience with Water Cooperatives where failures were common despite substantial government encouragement and support. Associations designed to improve efficiency of water use and equity in allocation have generally not worked because their design does not adequately consider: the head farmer-tail farmer conflict; the differential incentives for joining the association; and the high overhead and management costs involved in running the association.

An issue related to collective action is one of efficiency of irrigation fee payment. Experiences reported from Bangladesh and from the Philippines indicate substantial inefficiencies in imgation fee collection. Hakim (1990) reports that there is a wide variation in collection efficiency among the different imgation systems. Collection efficiency was relatively higher in private schemes and in the small tubewell schemes. In large gravity imgation schemes that are publicly managed, the efficiency of fee collection is very low. Fanners at the head of the system can afford to shirk on fee payment since they can resort to 'water stealing,' while farmers at the tail of the system are not assured of adequate water even if they are regular in their irrigation fee payment. Philippines has had similar problems with irrigation fee collection. In UTRIS, farmers close to their irrigation canal are the most delinquent in fee payment while farmers far from the canal had to make regular payments in order to ensure that they get at least some water (Table 15). Farmers far from the irrigation canal, while bearing a higher burden of the irrigation system cost receive a smaller share of the benefits.

In order to increase the farm-level efficiency of water use at the head of the systems and in fields close to the canal, two conditions are required (i) irrigation fees have to be based on the number of applications rather on a fixed rate; and (ii) more involvement is required of Irrigators' Associations in monitoring water use and fee collection.

Table 15. Payment of irrigation fees

Lateral	Distance	Paid	Not Paid
A	Near	1	2
	Far	2	2
B	Near	2	4
	Far	3	2
MC	Near	3	5
	Far	13	1
		24	16

Source: Pingali et al. 1989

Collective action for land management for uplands and the lowlands is equally important. In the uplands, group action for making watershed-level investments for erosion control are essential for developing long-term sustainable cropping systems. Sloping land management systems in the Philippines and terraces in West Java are examples of such collective effort (Fujisaka 1990; Soemarwoto and Soemarwotó 1984). In the irrigated lowlands, crop choice decision making requires collective consensus, on whether the crops are to be grown at the system or the lateral level; without such a consensus the ability of farmers to influence the system management to change water allocation rules for nonrice crops will be limited.

Finally, security of land tenure is crucial for making long-term land investments required for diversification from rice to nonrice crops and nonrice enterprises. Formal landownership as characterized by the possession of titles also helps farmers in acquiring credit for making the necessary investments in the land. Evidence on landownership and investment is provided for Thailand by Feder and Onchan (1987) and Chalamwong and Feder (1986).

IMPLICATIONS FOR RESEARCH PRIORITIES FOR RICE AND RICE-BASED FARMING SYSTEMS

Given current technology, farmer crop-management practices and the long-term decline in real rice prices, the decline in the profitability of rice production is expected to continue. Rice farmers will continue to face pressures to seek alternative income-earning opportunities. Sustaining the profitability of rice production in the face of competing opportunities for resources will require farmer access to technologies that either a) increase yields, b) increase input efficiency, or c) increase cost of rice production per hectare.

Irrigated Lowland

In the short to medium term, understanding the causes of the decline in experiment station rice yields must be a priority. A better understanding of the causes of this decline is essential in arresting and reversing the trend. If the trend toward declining yields is not reversed, the implications for future national production trends and to the economic viability of rice cultivation are serious indeed. Perhaps, this issue, which has not received significant research attention to date, must rank as important as that of increasing the yield ceiling in the future.

Long-term research will, of course, concentrate on breaking the current yield ceiling. But the relevance of a higher yield is conditional on crop husbandry techniques that can sustain the yield gains. Sustaining current yield gains would require the identification of the optimal crop management techniques and understanding the net effects of the interactions of the various component technologies. It is unlikely that there will be one general prescription to achieving incremental yield gains. Rather, one suspects the answer will differ from location to location. This reality highlights the importance of close collaborative research between the national programs and IRRI in sustaining the yield gains already achieved.

Research into appropriate crop management techniques should investigate the comparative long-term productivity of the continuous cropping of rice versus alternative rice-based cropping patterns. Providing break crops in a rice cropping system helps to maintain or regenerate soil fertility, reduces weeds and pest build-up, and provides more diversified options to sustain farm incomes (Westcott and Nikkelson 1988). Grain legume crops such as mungbean or cowpea, leguminous green manures, or vegetable crops may be particularly suitable rotation crops with rice. Wheat and maize are not only popular rotation crops, but nutrient-demanding cereals. There is a concern that yields in rice-wheat rotations are also declining in some areas.

Input-saving technical change like integrated pest management, integrated nutrient management, direct seeding techniques in place of transplanting, and more efficient water use shows the savings in purchased input use with the adoption of these techniques (Table 16 and 17 are examples for direct seeding). Pesticide use in Laguna declined significantly without a consequent reduction in yields per hectare during the period 1984–1987. The average number of applications per season dropped from 3 to 2 and the average dosage per application also declined. These data indicate a more judicious use of chemical pesticides.

Table **16.** ***Distribution-rice farms switching from transplanting** to **direct seeding, dry season 1980-1988, Philippines and Thailand.***

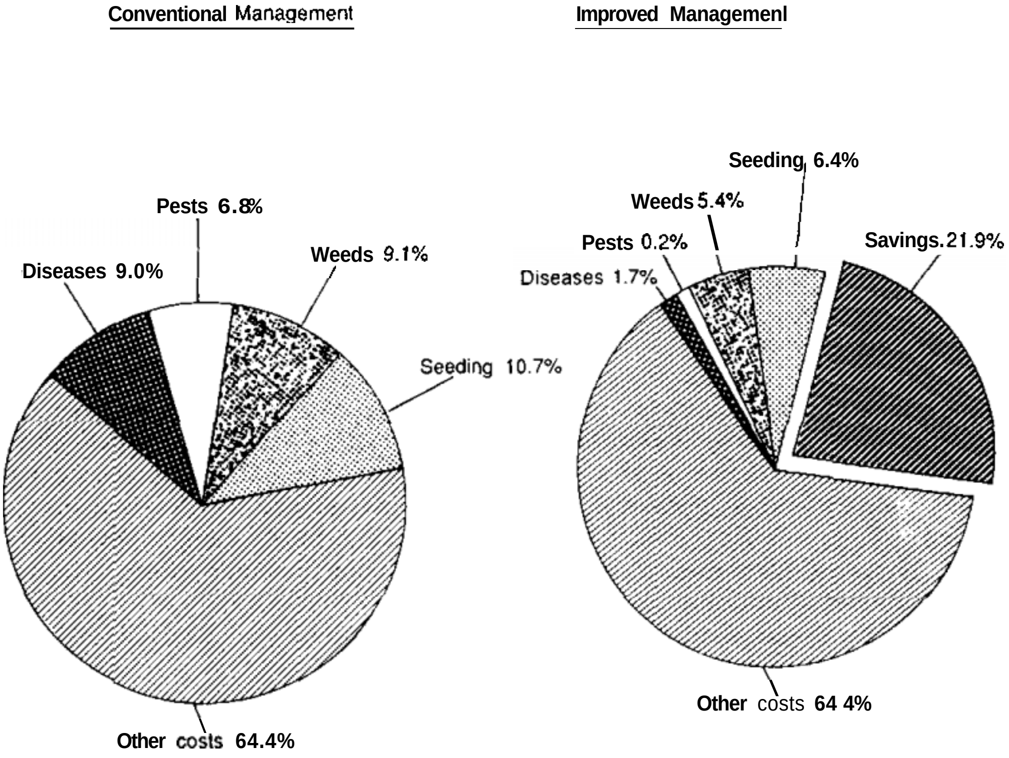
Philippines	**1980**	**1988**	**Percent change**
Transplanting	153	71	-115.49
Direct seeding	14	112	87.50
Thailand	**1982**	**1988**	**Percent change**
Transplanting	75	19	-294.74
Direct seeding	71	127	44.09

Table 17. Comparative input use for transplanted and direct seeded rice, Nueva Ecija, Philippines.

	Dry season, 1988		**Percent change**
	Transplanted	**Direct seeded**	
No. of sample (parcel)	71	112	36.61
N (kg/ha)	95.21	103.2	7.74
P (kg/ha)	27.01	20.06	-34.65
K (kg/ha)	22.03	13.22	-66.64
Seed (kg/ha)	196.04	161.62	-21.30
Pesticide (P/ha)	551.00	708.00	22.18
Yield/ha (kg/ha)	4966.57	4963.83	-0.06
Labor use			
Family	24.74	14.09	-75.59
Hired	70.83	36.02	-96.64
Total	95.57	50.11	-90.72

Integrated management research that critically addresses the contribution of every production factor to the overall cost and productivity can substantially reduce input costs but maintain yields in many cases. Figure 5 shows how production costs were reduced in Columbia by the equivalent of 1.2t/ha without affecting yields. This had dramatic effects on the profitability of rice production. Such work may be essential in counties where there is a real concern that current rice production levels cannot be maintained if the current low profitability of the rice enterprise continues.

Figure 5. Savings in production costs in irrigated rice by changing from conventional to improved crop management, 1986.



Total costs: ₱5162/ha; Average yield: 5234 kg/ha; Total costs: ₱ 3994/ha; Average yield: 5234kg/ha

Source: CIAT. 1987

Given the decline in real rice prices and the stagnant rice yields, there is an incentive for farmers to adopt efficient input use technologies. The increasing importance of off-farm income and other nonrice activities as a result of increasing income diversification make labor-saving technologies very attractive. However, technologies that provide efficiency gains are extremely knowledge-intensive since they require substantially greater levels of farmer judgement and supervision. The generation and adoption of these technologies would require high levels of national program involvement.

Diversified cropping patterns in the irrigated environments can be a definite strategy for increasing the efficiency of input use, the objective being to maximize the residual or carry-over effects of inputs from one crop to the next. The common example is rice legume systems which allow for lower levels of nutrient application for the subsequent rice crop. In wheat-rice systems, the P applied to wheat is efficiently available to rice (since P availability increases in the flooded soil). Also rice-break crop systems are available for reducing pesticide demand for the subsequent rice crop. An issue that has not received sufficient research interest is optimization of input use over the entire cropping pattern rather than on a crop basis (Kundu and de Datta 1988). This ought to be the strategy of a rational farmer in diversified agricultural systems.

Rain-fed Lowlands

The rain-fed lowlands are extremely diverse, but in general, rice yields and further intensification in these environments are constrained by production instability resulting from a highly variable field water regime. Drought, submergence, or prolonged waterlogging seriously affect rain-fed lowland rice in different environments. To raise yields, it is essential to introduce technical innovations which overcome or alleviate these constraints. The development of more stress-resistant cultivars can significantly improve yield stability. For example, the increased submergence tolerance of late generation cultivars is encouraging (Mackill personal communication).

A more holistic diagnostic approach will be required in future research on rain-fed rice to accelerate yield improvement and reduce yield variability. Improved crop and water management practices are essential for achieving and sustaining higher yields. However, input use efficiency in the rain-fed lowlands is very closely related to the reliability of the water regime. Where the reliability of water supply is low, the efficiencies of input use will necessarily be low.

Perhaps, less than 20 percent of the rain-fed rice area is cropped to anything but a single rice crop per year. Increasing the intensity of cultivation on these lands is promising. The demand side constraints to increasing cropping intensity are discussed in detail in Pingali et al. (1987) and Binswanger and Pingali (1988). Intensification of land use is induced by population densities and market demand for the output.

Technically, double cropping of rice on the favorable rain-fed lowland areas is possible with the early maturing varieties and the more determined research on the management constraints. However, the real potential for increasing cropping intensities lies with expanding nonrice crop production. Among the supply side constraints to crop intensification in the rain-fed lowlands the following deserve special attention: a) better crop establishment practices for the pre-rice and post-rice crops, and b) a better qualitative understanding of the competition for labor between crop and non-crop activities during the nonrice growing season. Pingali (1987) provides an example of the latter for Northeast Thailand, where attempts to encourage a pre-rice green manure crop are hampered by the high cost of foregone wages from off-season work in Bangkok.

Uplands

In the Asian uplands, rice is grown primarily as a subsistence crop. Very little upland rice is marketed, which is understandable due to two reasons: a) the upland farmer has a wide range of crops to produce for cash income other than rice; b) the relative profitability of rice production is quite low. These factors provide a backdrop to the unique research imperatives for the upland fanning systems in which rice is grown.

Upland rice yields are highly unstable due to drought, blast disease, weeds, and other stresses. Rice yields are often unsustainable due to production on highly acid, erosive soils which drastically lose their production potential after a few years of cropping. Technology development for upland rice must be directed primarily to stabilizing and sustaining yields, as it attempts to modestly improve them.

The development of ecologically sound and economically attractive crop rotations, within which upland rice is produced, will be a major vehicle for meeting these objectives. Upland rice research in most environments ought to be conducted within a framework of an overall land management strategy, in which appropriate investments in erosion control at the farm level are part of the research strategy. Diversified cropping in the uplands will be an essential part of a viable and sustainable upland farming system.

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