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CROPPING SYSTEMS IN ASIA

ON-FARM RESEARCH AND MANAGEMENT

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FOREWORD

This publication presents the highlights of on-farm cropping systems research and development by the member country programs in the Asian Cropping Systems Network (ACSN) coordinated by the International Rice Research Institute (IRRI). It includes detailed data-based presentations and discussion of farmers' existing cropping systems and testing of improved cropping patterns and component technologies in eight well-defined agroecological environments. Also briefly described are the concepts, approaches, and methodologies developed and used by the ACSN scientists. The use of site-specific on-farm research findings in target area development is discussed with specific ACSN examples.

This monograph highlights the impact cropping systems research and development have had on the agricultural research and production on small Asian farms and illustrates how ACSN scientists have used cropping systems research and development methodologies to improve existing cropping systems.

Dr. M. Zahidul Hoque prepared the manuscript during his stay as a postdoctoral fellow at IRRI. Gene P. Hettel, assisted by Corazon Mendoza, edited the publication.

M. S. Swaminathan
Director General

Chapter 1

INTENSIVE MULTIPLE CROPPING: THE FOOD FORMULA FOR HUNGRY ASIA

In December 1974, the General Assembly of the United Nations endorsed the Declaration adopted by the World Food Conference that "Every man, woman, and child has the inalienable right to be free from hunger and malnutrition in order to develop fully and maintain their physical and mental faculties. Society today already possesses sufficient resources, organizational ability, technology, and hence the competence to achieve this objective" (Hannah 1976). While this Declaration must be considered as a landmark in the history of mankind, Hannah emphasized that not only must food production increase to solve the problems of hunger and malnutrition, but food must reach the people who need it. However, the first challenge is still to produce more food in the developing countries, particularly in Asia.

POPULATION AND FOOD PROBLEMS IN ASIA

In 1980, the population in Asia was estimated at 2.55 billion, which constitutes about 58% of the total world population (FAO 1981). The average annual population growth rate in Asia dramatically rose from 1.6% in the 1950s to 2.6% in the 1970s (Banta 1980). While the annual birth rate remained more or less constant, around 40 per 1,000, the large-scale introduction of modern medical technology and health programs in Asia after World War II reduced the mortality rate from approximately 25 per 1,000 in the 1930s to half of this figure in the 1970s. In 1971-75 the food production in the Far Eastern countries as a whole increased faster than population (Table 1.1). But relative growth rates of population and food production vary widely. An examination of annual growth rates in several countries between 1952 and 1972 showed that population grew more rapidly than food production in Nepal, Bangladesh, Afghanistan, and Indonesia (Herdt and Barker 1979). While this situation reduced cereal exports from Nepal, the other three countries had to increase their food imports. In Pakistan, India, Burma, and the Philippines, production grew faster than population, but slower than demand. In Thailand and Malaysia, on the other hand, the rates of output growth exceeded the growth rates of demand, resulting in increased exports from Thailand and decreased imports in Malaysia.

During the past few decades, the average per capita food supply in Asia has remained relatively constant at about 2,000 calories/d. The daily per capita protein supply also remained constant at 49 g. Mensah (1976) reported that the average per capita daily energy intake in the Far East has been 6 to 8% lower than the required level of energy intake (Table 1.1). However, considering the recommended daily levels per capita of 2,130 calories and 47 g protein for East and

Southeast Asia (Sukhatme 1972, cited by Chong 1979), the present levels appear to be adequate. Unfortunately, millions of men, women, and children in the Far East actually consume amounts of calories and protein per day much lower than those average per capita supply values. As a result, these people have fallen victim of chronic hunger and malnutrition.

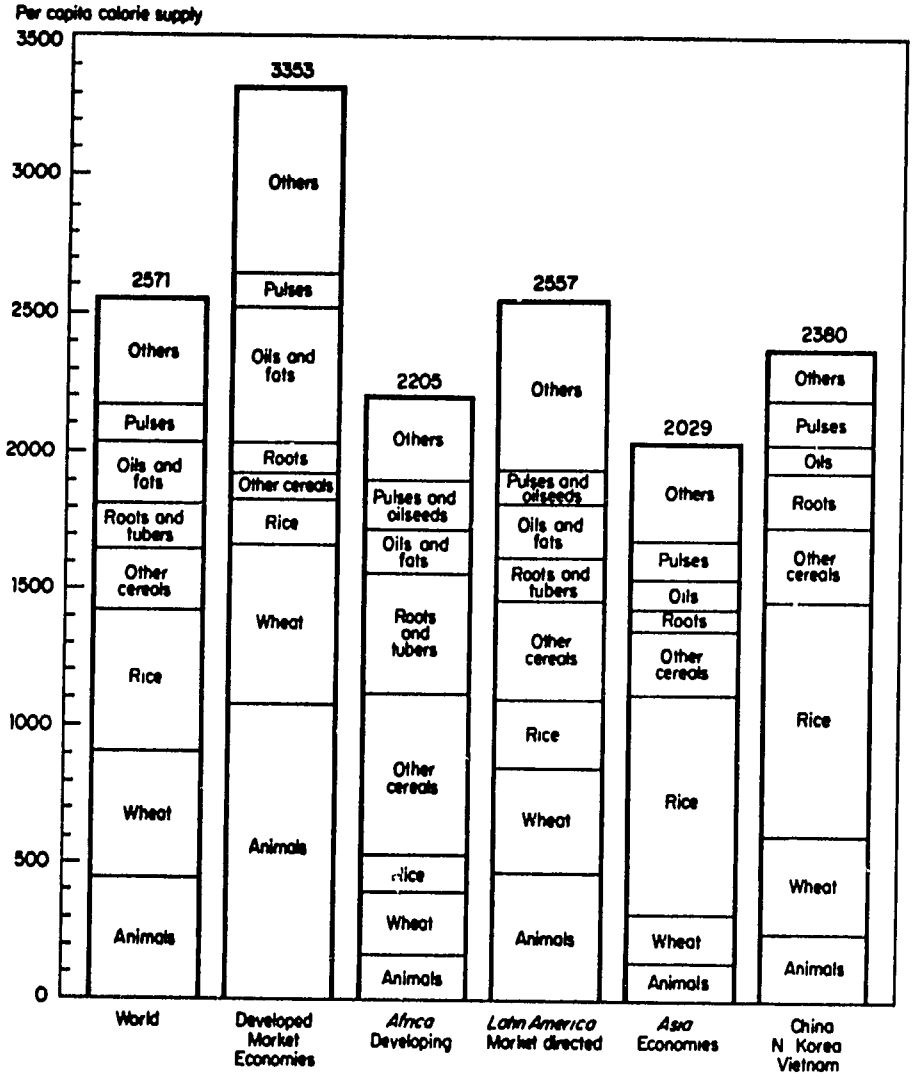
Of the world's estimated 462 million severely malnourished people, 434 million live in developing areas and the remaining 28 million in the developed countries (Knight and Wilcox 1976, cited by Brady 1977). About 69% of the malnourished of the less developed countries are in the Far East, and they constitute about 30% of the region's total population. Ironically, most of these victims of chronic malnutrition are the innocent children and their mothers — the architects of tomorrow's world and their caretakers and teachers.

The major nutritional problem in Southeast Asia is the protein-energy malnutrition that covers a wide range of syndromes from severe and fatal forms of kwashiorkor and nutritional marasmus to moderate forms manifested by retarded physical growth, apathy, and an impaired learning capacity (Chong 1979). This malnutrition is basically the result of protein and calorie deficiencies and is often aggravated by parasite infections. In the highly populated Java-Madura areas in Indonesia, severe deficiencies of both protein and calories have been demonstrated. The urban poor in Java-Madura consumed only 49% of their calorie requirements and 47% of their protein requirements. For the rural poor, these figures were 53% and 51%, respectively. Nutritional surveys by the Food and Nutrition Research Center of the Philippines showed that arrested growth in children becomes serious at weaning time (Bradfield 1972). The average weight of 9- to 66-month-old children was about 75% of normal. It takes 8 years for a Filipino child to reach the normal weight of a 6-year-old. The surveys also revealed that 25% of all deaths occur among infants under 1 year and 20% among children between 1 and 4 years old. Many surviving children become handicapped for life because of malnutrition during childhood. Bradfield (1972) challenged and

Table 1.1 Growth rates of human population and food production, and level of energy intake in different regions of the world.

Region	Past and projected population growth rate[a] (%/year)		Growth rate of food production[b] (%/year)		Energy intake[a] (% of requirement)	
	1960-70	1970-85	1962-70	1971-75	1961	1969-71
North America	1.3	1.0	2.2	1.7	118	126
Western Europe	0.8	0.6	2.2	2.0	118	123
Eastern Europe and USSR	1.0	0.9	4.3	2.3	116	127
Oceania	1.9	1.8	2.9	2.9	121	123
Latin America	2.8	2.8	3.1	2.5	100	105
Africa	2.5	2.9	2.5	0.7	91	94
Near East	2.7	2.9	3.2	3.8	89	102
Far East	2.5	2.6	2.8	2.8	92	94
Asian centrally planned economies	1.8	1.6	2.7	2.4	86	92
World	1.9	2.0	2.9	2.2	100	104

[a]Mensah (1976). [b]Aziz (1976).



1.1. Relative contribution of different food items to the per capita calorie supplies in different regions of the world (FAO 1980).

then opined, "Would that some economist, with the necessary skill and imagination, make an estimate of the costs to a developing country of these inroads on the health and efficiency of its most valuable resource. Lacking more precise information, I think it is highly probable that the cost of providing adequate nutrition at the start would be cheaper than the cost of malnutrition to society in later years."

In 1969-71, the gross cereal deficit in Asia was estimated at 11.5 million t and rose to 18.3 million t in 1974-75. The gross deficit is expected to reach 46.3 million t in 1985-86 (IFPRI 1976). Almost 75% of the people in low-income, food-deficient, developing market economies that form the core of the world's food problem are in Bangladesh, Burma, India, Indonesia, Nepal, Philippines, and Sri

Lanka (Banta 1980). While the gross deficit in the production of major food crops in these countries was almost 6 million t in 1975, the projected deficit may reach 36 million t by 1990, depending on growth of population and per capita income. Cereals are the major food in Asia, with rice being the single most important food crop (Fig. 1.1). Therefore, maintaining a steady growth rate of rice production is the key to improving Asia's food problem. At the same time, increased production of high-protein nonrice food crops such as legumes is of paramount importance for reducing malnutrition.

The food problem in Asia worsens daily and time is running out. Asian countries must seriously attempt to arrest population growth and to boost agricultural production. High investment requiring large-scale overall agricultural development programs is unlikely to happen in Asia unless there is a radical change in the actions of the developed countries (Banta 1980). The 608 million people economically active in Asian agriculture (FAO 1981) must decide and develop their own agricultural fate. The role of the educated people, particularly the professionals, must be outstanding in the battle against hunger.

THE UNTAPPED TROPICAL PRODUCTION RESERVOIR

The food-deficit countries of the Far East are in the tropical and subtropical rice belt. This is a paradox because, considering the soil and climatic potentials, the tropics should be the breadbasket of the world (Chandler 1976). Year-round crop production is possible in the tropics. Ample solar radiation is available during the 12 months for satisfactory crop yields. Bradfield (1971) showed that the cumulative degree-days are over four times higher at a tropical location (Los Baños, Philippines) than at a location in the temperate zone (Ithaca, New York). He also claimed that the dry matter produced per year in a tropical rain forest is about four times that in a deciduous forest in the temperate zone. On the basis of the similarity of these ratios for cumulative degree days and the growth of perennial forests in the tropical and temperate zones, Bradfield suggested that the farmer in the tropics could produce, per unit area, about four times as much dry matter as his counterpart in the temperate zone, if a few layers of green leaves are kept between the soil and the sun throughout the year.

The developing tropical and subtropical countries are in the areas where modern science and technology have not been widely applied. As a result, the food production potentials in these countries have not been realized. Many people are short of food because they have not yet learned to use their available food production resources efficiently (Bradfield 1972). If they take full advantage of the production potentials through intensive multiple cropping, the problems of hunger and malnutrition can be solved. To achieve this, more trained manpower, scientific research, and infrastructural development are needed.

AGRICULTURAL PRODUCTION RESOURCES IN ASIA

The arable land area in Asia is estimated to be 428.2 million ha, excluding the 26.5 million ha of permanent crop area (FAO 1981). These areas of arable lands and

permanent crops constitute 31.59% and 28.35%, respectively, of the total areas of these categories in the world. Of the 206.5 million ha of irrigated arable land area of the world, about 65% (134.4 million ha) is in Asia. While about 58% of the total human population lives in Asia, about 73% of the world agricultural population lives there, indicating the significance of agriculture as a means of livelihood.

Only about 16% of the total land area in Asia is considered arable, with another 1% under permanent crops. On an average, about 31% of the cultivated area is irrigated (FAO 1981). Of the 2.6 billion people in Asia, about 58% are agricultural. Interestingly, about 58% of the 1.05 million economically active people in Asia are also engaged in agriculture. At present, about 1.4 persons/ha of arable land work to support an average population pressure of about six persons/ha (FAO 1981).

Wide variations in arable land and irrigation water resources exist among the Asian countries (Table 1.2). Bangladesh and India have relatively much higher percentages of cultivated land area. Although China has a vast land area (930.5 million ha), only about 10.6% can be used for crop production. Similarly, Indonesia has a smaller proportion of cultivated land. Malaysia has only 3% of its land area under field crop production. It is important, though, to note that some Far Eastern countries have considerable areas under permanent crops such as cocoa, coffee, tea, rubber, and fruit trees, which provide a livelihood for millions. Among the South and Southeast Asian countries, Indonesia has the largest area (5.25 million ha) under permanent crops, which constitutes about 3% of its land area (FAO 1981), followed by India (4.05 million ha), Malaysia (3.3 million ha), and the Philippines (2.85 million ha). Among the other countries, the areas under permanent crops in Thailand, Sri Lanka, China, and Burma are 1.7 million ha; 1.1 million ha; 760,000 ha; and 449,000 ha, respectively. Bangladesh (212,000 ha), South Korea (138,000 ha), and Nepal (14,000 ha) have relatively smaller areas under permanent crops. Sri Lanka has the highest percentage of land area under permanent crops (17.33%), followed by Malaysia (10.06%), the Philippines (9.55%), and Thailand (3.32%). The permanent-crop area in India constitutes only 1.36% of its land area. In Indonesia, Malaysia, Philippines, Thailand, India, Sri Lanka, and Bangladesh, a large number of seasonal and annual crops are grown under permanent crops and, in some cases, under the forest trees, using intensive mixed cropping systems.

About 69% of the arable land in Asia is cultivated under rainfed conditions. Fortunately, the monsoon rains are adequate to grow one or two crops in most South and Southeast Asian countries. In many places, where moisture-holding capacity of the soil is good, a short-duration, relatively drought-resistant third crop is also grown with residual soil moisture. In addition, the monsoon rains often provide ample water for surface and groundwater irrigation during the dry season. However, the economic condition of a region determines its capacity to use such water resources for agriculture. For example, Japan and Pakistan have brought 75.6% and 72.6% of their arable land under irrigation (Table 1.2). South Korea, Sri Lanka, and China have made remarkable progress in developing large-scale irrigation facilities. Indonesia and Malaysia have also brought considerable areas under irrigation. Other countries still need to develop more extensive irrigation systems to attain significant and immediate increases in agricultural production.

Table 1.2. Total arable land resource and extent of irrigation development in several Asian countries (1979 data).[a]

Country	Arable land		
	Total[b] (thousand ha)	% of total area	Under irrigation (%)
Bangladesh	8 918	66.6	17.0
Burma	9 579	14.6	10.9
China	98 550	10.6	49.9
India	165 500	55.7	23.6
Indonesia	14 168	7.8	37.8
Japan	4 315	11.6	75.6
Malaysia	995	3.0	36.2
Nepal	2 305	16.9	9.5
Pakistan	19 900	25.6	72.6
Philippines	7 050	23.6	18.0
South Korea	2 069	21.1	55.1
Sri Lanka	1 019	15.7	54.0
Thailand	16 250	31.8	16.2
Vietnam	5 430	16.7	31.0

[a]Adapted from FAO (1981). [b] Excluding permanent-crop area.

Table 1.3. Population pressure and number of available agricultural workers per hectare of arable land in several Asian countries (1979 data).[a]

Country	Av no.[b]	
	Persons/ha arable land	Active agricultural workers/ha arable land
Bangladesh	9.95	2.84
Burma	3.68	0.76
China	9.71	2.70
India	4.19	1.02
Indonesia	10.72	2.16
Japan	27.06	1.53
Malaysia	13.71	2.23
Nepal	6.18	2.72
Pakistan	4.14	0.60
Philippines	7.23	1.15
South Korea	18.36	2.71
Sri Lanka	14.60	2.70
Thailand	2.93	0.99
Vietnam	9.63	3.10

[a]Adapted from FAO (1981). [b]Excluding permanent-crop area.

Meanwhile, more efficient rainfed cropping systems technologies must be developed.

The population pressure on arable land is increasing in most of the Far Eastern countries, except Thailand and Burma. The pressure is particularly high in Japan, South Korea, Sri Lanka, Malaysia, Indonesia, Bangladesh, China, and Vietnam (Table 1.3). Pakistan, Burma, Thailand, India, Philippines, and Japan have very low labor availability. Developers of future cropping systems technologies must

take this factor into account or consider introducing appropriate mechanization.

The countries in the tropical and subtropical rice belt have a wide and diverse crop base. A large number of plant species, including cereals, fiber crops, legumes, oil seeds, roots and tubers, narcotics and beverages, fruits and vegetables, and spices and condiments, are grown throughout the year as commercial crops. Wheat, barley, and mustard have also been widely adapted in subtropical Asia. Agricultural scientists are making significant advances to improve the region's varieties of major crops. The existing diverse crop base provides enormous opportunities for further crop improvement and a more intensive agriculture.

INCREASED PRODUCTION PATHWAYS

The three suggested solutions to the world food problem include population control, restructuring of the world socioeconomic order to the advantage of the food-deficit countries, and development and use of improved food production technology (Knight and Wilcox 1976, cited by Brady 1977). Success in population control depends on many factors and will take time. Development of a more equitable world socioeconomic order to benefit poor countries depends on the policies of the developed countries. Therefore, increased food production is the only immediate course that can save millions from hunger, starvation, and premature death.

Historically, there are three general methods to increase food production: expanding cultivated land area, increasing the yields of individual crops, and increasing the cropping intensity. The first alternative connotes the so-called horizontal revolution in agriculture; the second and third methods provide avenues for the vertical revolution in agriculture.

Unlike Africa and Latin America, where only 22 and 11% of the potentially arable lands are cultivated, the prospect for new agricultural land in Asia is limited. Brady (1977) reported that 83% of potentially arable land is already being used in Asia. Considering the high population pressure in the developing countries, total or partial use of the remaining 17% for crop production would be very beneficial. But much of this land is considered poor for agriculture and is difficult to bring under cultivation. Usually these lands are located where the population is low and where it is hard to transmigrate people from other areas. Moreover, large economic investments are needed for reclamation, which most of the countries cannot afford. However, some countries, such as Indonesia and Malaysia, are making considerable progress in extending their arable lands. In most of the South and Southeast Asian countries, the intensity of arable land use is usually less than 100% because of the persistence every year of fallow lands. This is due to various physical and socioeconomic constraints.

Considerable increase in food production in the Far East during the last 15 years have come from the higher yields from cultivated land. These higher yields are attributed mainly to the application of scientific principles and new technologies. For example, the introduction of modern varieties of rice and wheat, and the associated improved cultural practices have increased yields throughout tropical and subtropical Asia. However, the national average crop yields in most of these

Table 1.4. Actual and potential rice yields in several South and Southeast Asian countries.

Country	Actual yield[a] (t/ha)	Potential yield[b] (t/ha)				
		Dry season	Wet season	Upland	Rainfed	Weighted av
South Asia						
Bangladesh	2.0	6.6	4.9	2.0	3.7	3.3
India	2.0	6.8	5.4	2.0	4.0	4.4
Nepal	1.9	6.0	4.8	2.0	3.6	3.7
Sri Lanka	2.3	5.7	5.3	2.0	4.0	4.8
Southeast Asia						
Burma	2.6	6.0	4.8	2.0	3.6	3.8
Indonesia	3.1	5.9	4.8	2.0	3.6	4.0
Malaysia	2.6	6.0	4.8	2 0	3.6	4.5
Philippines	2.1	5.9	4.6	2.0	3.5	4.1
Thailand	1.9	4.4	3.7	2.0	2.5	2.7

[a]FAO (1981). [b]Herdt and Barker (1979).

Table 1.5. Cropping intensity in several countries of Asia.

Country	Period	Cropping intensity (%)	Source
Bangladesh	1976-77	148.89	Bangladesh Bureau of Statistics (1978)
Burma	1974-75	117	Saing et al (1978)
China	1958	145	Kuo (1976)
India	1976-77	119	Sharma (1981)
Indonesia	1978	161	Oldeman and Frere (1982)
Japan	1974	102	Sanderson (1978)
Malaysia	1973	157.94[a]	Van (1975)
Nepal	1970-71	112.67	Ministry of Food and Agriculture, Nepal (1972)
Pakistan	1967-68	108	Dalrymple (1973)
Philippines	1960	136	Dalrymple (1973)
South Korea	1979	130.9	Kim (1980)
Sri Lanka	1979-80	120	Ranaweera (1981)
Taiwan	1973	175	Chao (1975)
Thailand	1968	129	Seetisarn (1975)

[a]Cropping intensity on riceland in Peninsular Malaysia.

countries are far below those obtainable with proper management. The national average rice yields in eight South and Southeast Asian countries ranged from 1.9 to 3.1 t/ha in 1980 (FAO 1981). Herdt and Barker (1979) showed that these yields are much below the potential rice yields that have already been obtained in these countries (Table 1.4). Bradfield (1971) claimed evidence that the low yields are not inherent in the tropical regions, but are due to failure to make appropriate investments in research and technology development. In many places in the tropics, however, production technology needed for increased yields is now

available. So, these places need efficient extension services coupled with reliable input delivery systems and sound marketing policies.

In the tropics the potential for increasing cropping intensity is tremendous. Farmers can grow three to five crops per year on the same land, depending on crop growth duration and water availability. Bradfield considered it fortunate that most of the ill-nourished people live in the tropics where food can be produced year-round. But he also observed that intensive techniques for increased food production have not been extensively developed in the tropics. This observation is correct because, although intensive cropping patterns have been adopted in several areas, the national average cropping intensity in the Asian countries is not very high (Table 1.5). The cropping intensity is highest in Taiwan, China, followed by Indonesia, Bangladesh, and the People's Republic of China.

Considering the limited opportunity for expanding arable land area, increased food production must come from land being cultivated. Massive extension efforts are needed to ensure adoption of more intensive cropping systems. Agricultural scientists can make an important contribution by developing suitable year-round farming systems for the tropics (Chandler 1976).

CROP INTENSIFICATION PROSPECTS IN ASIA

The four important factors that favor crop intensification are the scarce arable land resource (0.17 ha/person), adequate farm labor, presence of most of the low-income group in rural areas, and the subsistence nature of most farms. While intensive and productive cropping patterns are necessary to maximize food production from limited land area, crop intensification also increases farm employment. The benefits from intensive land use do not discriminate against and may even favor the small farmers (Gomez 1974). Labor-intensive improved multiple cropping has such bright prospects that it has been considered a means to bring most subsistence farmers into the stream of a market-oriented economy. While crop intensification can improve the bargaining capacity of the small landowners, it will definitely improve the nutrition of the rural poor.

Growing more than one crop on the same land in a year is not new in Asia. It is age old in Java, Bangladesh, India, and Nepal. The Chinese have done it for centuries in a primitive way and in the early 1900s, the Japanese began to update multiple cropping in their country and Taiwan (Streeter 1972). After the Nationalist Chinese took refuge in Taiwan, they carried the process much further to make it one of the world's most intensive agricultures.

Aside from traditional social barriers, the rather low national average cropping intensities (Table 1.5) have been attributed to difficulties in the transfer of technology and lack of socioeconomic structures to support the technology (Gomez 1974). However, while the magnitude of these constraints must be reduced, attention must be focused on the scientific research that can generate appropriate technologies for intensive farming. Research must also ensure productivity of the proferred technology package under farmers' conditions and with enough profit incentives.

AGRICULTURAL RESEARCH IN ASIA

The basic aspects of poverty, hunger, and unemployment are inseparable. Because most of the developing Asian nations are agrarian, their leaders naturally look to the agricultural sector to provide food and employment (Sadikin 1982). As a result, in recent years the major thrusts have been on agricultural development.

Research is the foundation of development. Although, in some cases, there has been not enough appreciation of nor adequate support for agricultural research in Asia, a number of institutions are now trying to assist farmers through research. Each country has a ministry or department of agriculture with an objective of increasing agricultural production. It has a research component managed by specific research projects or institutes. Also, most of the agricultural universities in Asia have some research programs although these are much narrower in scope than those of the national departments of agriculture (Banta 1980). The agricultural development projects supported by different donor or outside agencies may also have a small research component. These organizations include the World Bank, the Asian Development Bank (ADB), the United States Agency for International Development (USAID), the British Overseas Development Authority (ODA), the Australian Government, and the Canadian International Development Agency (CIDA). The international agricultural research centers located in Asia are the International Rice Research Institute (IRRI) in the Philippines, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India, and the Asian Vegetable Research and Development Center (AVRDC) in Taiwan.

Although the payoff on research investment in the less-developed countries has been extraordinarily high (Evenson et al 1979, cited by BARC 1979), the amount of investment in agricultural research in these countries has unfortunately been very insignificant. For example the research expenditures as percentages of the value of agricultural production are only 0.023% in Bangladesh, 0.097% in India, 0.044% in Pakistan, 0.275% in the Philippines, and 0.207% in Thailand (BARC 1979). These figures are 1.34% for Japan, 1.48% for the United Kingdom, and 1.73% for the United States. The per capita expenditures on agricultural research are only $0.03 in Bangladesh, $0.05 in India, $0.02 in Pakistan, $0.02 in the Philippines, and $0.15 in Thailand compared with $2.66 in Japan, $1.16 in the United Kingdom, and $3.00 in the United States.

Until recently, most of the agricultural research programs implemented by the national research organizations in Asia were crop or commodity oriented. The primary role of IRRI, since its inception, has also been to increase rice yields. Although the commodity-based research and development programs such as those on rice and wheat brought about the so-called green revolution in many Asian countries, most of the poor farmers in these countries remained untouched by the benefits (Harwood 1974) because they could not adopt the advanced technologies. Although the yield potential of the modern rice varieties was demonstrated, their adoption by farmers has been disappointing. For example in 1974-75, the percentages of total rice area planted to modern rice varieties were 28.5% in India, 14.9% in Bangladesh, 18.0% in Nepal, 39.3% in Pakistan, and

51.7% in Sri Lanka (Palacpac 1982). During the same period, the percentages were 6.3% in Burma, 39.7% in Indonesia, 35.7% in Malaysia, 61.5% in the Philippines, 5.5% in Thailand, and 25.5% in South Korea. Aside from the high inputs and management requirements for the modern variety cultivation in many places, the modern varieties have created conflicts in the farmers' cropping patterns. For example, in India and Bangladesh, where transplanted rice is grown after jute under rainfed conditions, many modern varieties are not suitable for cultivation because of delayed availability of land for transplanting. Similarly, in many places, modern wheat varieties cannot be grown after long-duration modern rice varieties, particularly under rainfed conditions. Because most of the varietal improvement work emphasized the performance of the varieties within a given season rather than in the context of the farmers' cropping patterns, the new varieties were misfits.

Starting in the late 1960s, IRRI scientists realized that they could not look at rice production in isolation and they started a multiple cropping research program to increase the productivity of rice-based cropping systems. Although rice is the main crop in tropical and subtropical Asia, farmers also grow other crops, often in rotation with rice. These nonrice crops are of great value to subsistence farmers. Therefore, IRRI recognized the importance of improving the traditional rice-based cropping patterns. Bradfield (1967) observed that the first goal of agriculturists in the Asian rice belt is to produce enough rice to feed the huge populations. As self-sufficiency in rice is attained, attention should be focused on the increased production of other crops, mainly grown in rotation with rice, that will supply the proteins and vitamins that are deficient in a diet largely made of polished rice.

Research based on the systems approach is not new in agriculture. The Roman farmers who practiced rotation cropping grew richer. The Rothamstead Agricultural Station has shown that crop rotation was superior to monocropping for the last 200 years (Banta 1980).

According to Dillon (1976), the systems approach differs from traditional research in three major ways. First, it is holistic, that is, the problem is looked at in the context of the specific situation. The immediate objective is not to reduce the magnitude of the problem, but to determine interactions of the various components of the system. Second, the research problem is selected on a systems basis and, with the use of a matrix or flow diagram, gaps in the data base are identified. Third, systems research is likely to be more efficient than traditional research. Banta (1980) maintains that the systems approach is efficient because its overall goal is defined and each piece of research is evaluated on the basis of reaching that goal.

The concept of rice-based cropping systems research developed and proposed by IRRI was accepted by its Asian cooperators and, in 1975, IRRI organized and formulated the Asian Cropping Systems Network (ACSN) that now addresses the rice-based cropping systems development on small farms. This approach has gained prominence in Asia and the payoff from it has already started to benefit thousands of poor farmers.

Chapter 2

THE ASIAN CROPPING SYSTEMS NETWORK

During its first decade, IRRI, with an annual budget less than that of a modest-sized state agricultural experiment station in the U.S., revolutionized the world's understanding of rice production in the tropics. But perhaps more importantly, it showed how science can be applied in solving agricultural problems in the less-developed areas of the world. IRRI's early accomplishments with the stiff-strawed modern dwarf rice varieties have shown man's potential capacity to feed himself (Brady et al 1973). However, after the first remarkable progress with modern rice varieties in increasing yields and improving rice quality, IRRI recognized that the development of rice-based cropping systems in the tropics should be focused on next. Such future cropping systems must utilize to the limit the favorable tropical environments for food production and minimize the effects of insect pests, plant diseases, and other constraints (Brady et al 1973). Other considerations were that the cropping systems must optimize biological output and include high-protein crops and vegetables to provide better human nutrition. Most importantly, the new improved cropping systems must be oriented toward the environmental, institutional, and socioeconomic constraints that the farmer confronts.

EARLY MULTIPLE CROPPING RESEARCH IN ASIA

Although farmers in some areas of the humid tropics have practiced multiple cropping for a long time, research done on such cropping systems generally had been insignificant until the 1960s. After World War II, remarkable progress in crop intensification took place in Taiwan, China. Taiwan has led in multiple cropping research and development. Taiwanese farmers harvest as many as five crops per year from the same field, using intercropping and relay cropping methods. However, the intensive cropping systems have been developed mainly for the irrigated lands. Moreover, Taiwan has a subtropical climate and the intensive multiple cropping systems developed there cannot be wholly transferred to the humid tropics.

Intensive cropping systems for use in irrigated wetland typical of humid Southeast Asia have been studied at IRRI since 1964 (Brady et al 1973). The initial objective of the IRRI multiple cropping project was to develop crop rotations in which rice, the principal rainy season crop, is followed in quick succession by other food crops (Bradfield 1967). The early work at IRRI demonstrated that intensive diversified multiple cropping can quickly and substantially increase food production and income in the tropical rice belt. Bradfield (1972) showed that, with proper water management and efficient land preparation techniques, an intensive cropping pattern of rice - sweet potato - soybean (dry seed) - sweet maize - soybean (vegetable) could be grown on the same land in a year with very high yields and a gross return of a little over $3,000/ha (Table 2.1). Production from a

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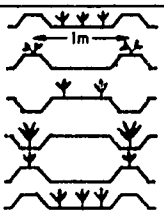
Table 2.1. Description of a typical intensive cropping pattern grown at the IRRI experimental farm during the early 1970s.[a]

Crop in the pattern	Date		Field days (no.)	Tillage operation and planting method (ridge/furrow)	Yield (t/ha)	
	Planting	Harvest			Crop	By-product
Rice	1 Jun	30 Sep	120		5.0	5.0
Sweet potato	1 Sep	24 Dec	114		25.0	20.0
Soybean (dry seed)	27 Dec	17 Mar	85		2.5	–
Sweet maize	1 Mar	5 May	66		40 000 ears	15.0
Soybean (vegetable)	1 May	1 Jul	60		6.0 (green pods)	6.0
Rice	1 Jun	30 Sep	(next cycle)			

[a]Bradfield (1972).

hectare of this cropping pattern was considered enough to feed 72 persons year-round with 2,600 calories and 55 g protein/day, plus considerable forage residues for livestock. During the following years, the IRRI program focused on selecting the most suitable crops, varieties, and production practices for different rice-based cropping patterns as well as on the evaluation of these intensive systems at the research stations and in farmers' fields.

Considerable multiple cropping research has been done on the Indian subcontinent (Brady et al 1973). Farmers there use numerous multiple cropping patterns, even under rainfed conditions. Research programs have identified cropping systems more suitable for drier areas typical of the subcontinent. Also, numerous studies have been conducted on the long-term effect of different intensive cropping patterns on productivity level and soil fertility.

The Ford Foundation supported multiple cropping research at Chiangmai University in northern Thailand. With assistance from the Colombo Plan, the Thai Royal Irrigation Department also started a cropping systems program for the Central Plain.

The United States, France, Taiwan, and Israel supported some multiple cropping work in Laos, Kampuchea, and Vietnam (Brady et al 1973). Crop diversification and extension of multiple cropping became priorities in Sri Lanka. Under a USAID contract, Indonesia began a major multiple cropping research project with assistance from IRRI. The Philippines also started several research and extension projects on multiple cropping with support from USAID, International Development Research Centre of Canada (IDRC), and other agencies. The Bangladesh Rice Research Institute (BRRI) initiated a cropping systems project with IDRC and IRRI support. By the early 1970s, most of the countries in South and Southeast Asia realized the importance of cropping systems research and started organizing research and development projects. However, there was no coordinated effort to address developmental issues on a regional or international basis.

THE FORMATION OF AN ASIAN CROPPING SYSTEMS NETWORK

In March 1975, IRRI organized a workshop to determine the status of rice-based cropping systems in the region and to explore the scope and possibilities for future

collaborative development. Eighty-two scientists from 19 countries listened to the deliberations at the workshop. Committees reviewed all materials presented and then recommended plans for action. A cropping systems network and a working group consisting of national program leaders, an IRRI cropping systems program leader, a network coordinator from IRRI, and several resource persons were formed. IRRI was given the mandate to develop ideas, principles, and methodologies, and to serve as a coordinating agency. The proposed roles of the network working group were to serve as a focal point for ideas; to coordinate activities and plan meetings; to deliver ideas and information to national programs; to formulate directions and methodologies for cropping systems improvement; and to design collaborative studies. For regionwide collaborative cropping systems testing, three sites in the Philippines and two sites in Indonesia were selected and it was suggested that similar sites be started immediately in Bangladesh, Sri Lanka, Thailand, Vietnam, and other countries. The working group was to meet twice a year in conjunction with field tours or a workshop. Between then and November 1981, 12 working group meetings have taken place.

Objectives of the network

The Asian Cropping Systems Network (ACSN) scheme provides opportunities for IRRI and national programs to jointly develop rice-based cropping systems in major rice environments of Asia. The specific objectives (Carangal 1978a, Carangal and Jayasuriya 1982) are

- To develop cropping systems technology for the major rice-growing regions in Asia;
- To enable IRRI to extend relevant technology and research methodology into national programs;
- To establish and develop strong national cropping systems programs;
- To provide a series of data points on the Asian agroclimatic grid, for determining the cropping systems potential in major rice areas, for utilization by the policymakers and development planners for agricultural development in the region;
- To provide a mechanism for joint program planning and review between the national programs and IRRI; and
- To help organize international and regional meetings, workshops, conferences, and symposiums on cropping systems research and development.

The network members

The ACSN now encompasses 11 national programs and the IRRI Cropping Systems Program. The countries and organizations represented include

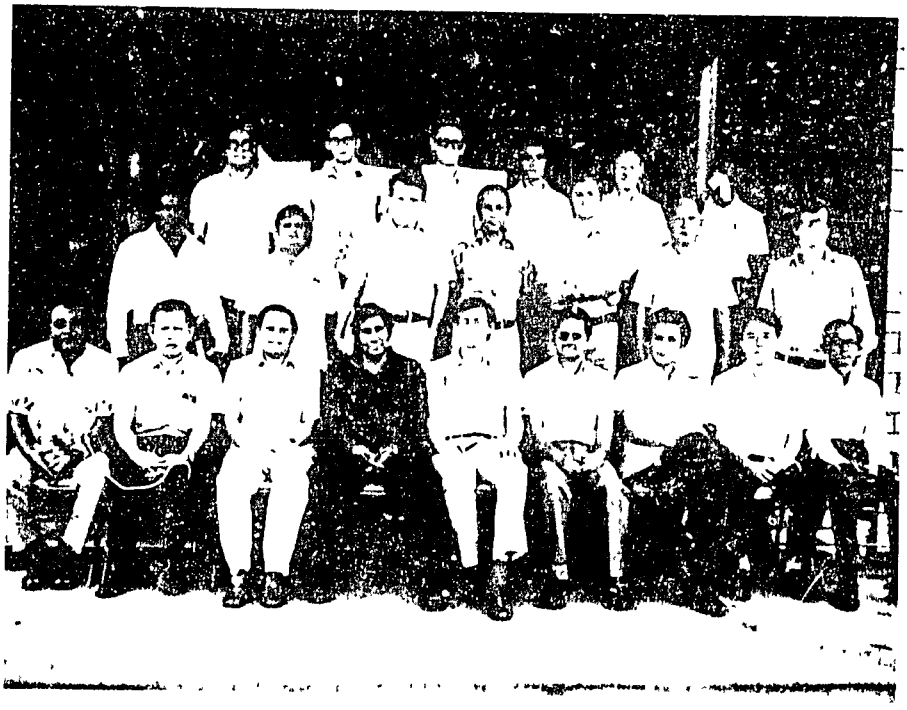
- Bangladesh: Bangladesh Rice Research Institute (BRRI)
- Burma: Agricultural Research Institute (ARI)
- China: Chinese Academy of Agricultural Sciences (CAAS)
- India: The Indian Council of Agricultural Research (ICAR)
- Indonesia: The Central Research Institute for Food Crops (CRIFC)
- Malaysia: Malaysian Agricultural Research and Development Institute (MARDI)
- Nepal: The Department of Agriculture

- Philippines: The National Food and Agriculture Council (NFAC)
- South Korea: The Office of Rural Development (ORD)
- Sri Lanka: The Department of Agriculture
- Thailand: The Department of Agriculture and Kasetsart University
- International Rice Research Institute, Philippines

Recently, the Ministry of Food and Agriculture (MFA) in Pakistan and the Vietnamese Institute of Agricultural Sciences (VIAS), Hanoi, Vietnam, have expressed interest in joining the network (Pendleton 1981).

Working group functions

The working group provides the ACSN leadership (Pendleton et al 1981) and is composed of only those directly responsible for the research. The members are the program leaders from countries involved in the network plus three IRRI staff: the cropping systems program leader, an economist, and the network coordinator. Usually, several resource persons working in different programs under the network are invited to assist the working group. Presently, the group is composed of 14 working scientists, most of them with a wide background in Asian agriculture. Figure 2.1 shows working group members and resource persons at the Seventh Working Group Meeting. An open and very clear line of communication has been maintained by keeping the group small and the members regularly interacting.



2.1. Working group members and resource persons, the Seventh Working Group Meeting, Asian Cropping Systems Network, 2-5 Oct 1978, The International Rice Research Institute, Los Baños, Philippines.

The primary functions of the working group are to review research data from the network sites, plan and design collaborative research, develop research approaches and methodologies, standardize methods and measurements, help IRRI develop its research programs, and facilitate exchange of ideas, problems, and research information (Carangal 1978a, Carangal and Jayasuriya 1982). The meetings are scheduled once or twice a year and rotated among member countries, enabling the group to see firsthand the problems and prospects in each country. A regular part of the meeting is a tour of several cropping systems research sites. The proceedings of the working group meetings are published and made available to the scientists working in the network as well as to interested outside scientists or organizations. Through November 1981, 12 proceedings have been distributed. The outcomes of the working group meetings have had a very significant effect on the direction of IRRI's research and the methodology used in the national programs (Banta 1980).

The topics for the early working group meetings were general in nature, but after the third workshop, specific methodological problems were addressed, committees formed, experiences shared, and solutions proposed (Zandstra 1980a). These proposed solutions have been tested, refined, and, at times, abandoned for better ones. With each succeeding meeting, better definitions of research methods were developed. Reporting of data on site descriptions and on-farm cropping pattern testing became uniform by the fifth meeting in Bangladesh and the methodological issues discussed became very specific. The sixth meeting in Sri Lanka more elaborately addressed the issues of economics data collection, cropping pattern monitoring, and varietal testing. During the seventh meeting, at IRRI, the working group made suggestions for IRRI's cropping systems research and network support activities. Providing feedback from the network to IRRI continues to be an important function of the working group. The eighth meeting, in Nepal, emphasized the importance of component technology research and of methodology to better compare experimental or introduced cropping patterns with farmers' existing patterns. Previously, the network economists held a special meeting and developed procedures for economic analysis of cropping systems. Starting with the tenth meeting, in South Korea, the working group placed a high priority on the utilization of site-specific research in multilocation testing of cropping systems technology and pilot production programs. During the eleventh meeting, in Indonesia, the emphasis continued to be on pilot production programs and technology transfer. In addition, long-term studies on cropping patterns and improvement in the training of young network scientists were seriously considered. Before that meeting, the network entomologists reported to the working group on the methodology development for entomological research. The twelfth meeting, in Burma, reviewed the status of pilot production programs and cropping pattern monitoring results from network sites, and considered issues of small-scale mechanization, and alternative methods of moving cropping systems technology to farmers.

The major accomplishments of the ACSN working group are the development of the conceptual framework for cropping systems research and development in Asia, the development and subsequent refinement of a set of on-farm research

methodologies, the monitoring and review of work progress at each network site, the establishment of collaborative research in problem areas of mutual interest, the assembly of information on Asian cropping systems and experimental work, and the motivation of fellow agricultural scientists to work in the context of farmers' cropping systems.

The priority areas for the future include: long-term cropping pattern trials, fertilizer efficiency in cropping systems, the development and identification of more suitable varieties of upland crops to be grown before and after rice, the development and identification of simple farm implements for intensive cropping, the monitoring and evaluation of pilot production programs, and an assessment of the impact of cropping systems research in a region or a country.

CROPPING SYSTEMS CONCEPTS AND APPROACHES

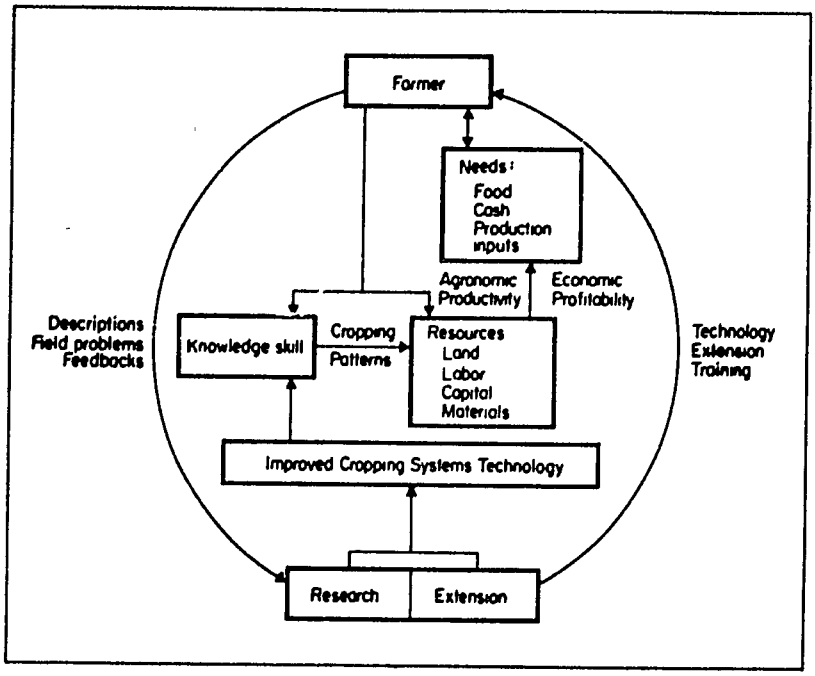
The farmer is the ultimate integrator of technology components. He makes the ultimate decisions that determine the success or failure of any agricultural research program. Therefore, the scientists must present alternatives that expand the farmer's options (Izuno 1980).

The systems approach to multiple cropping is based on the utilization of a farmer's resources to provide for the family (Harwood 1973). A farmer's well-being is largely determined by how efficiently he uses available resources. Scientists can influence his well-being by showing him how to effectively use his resources or how to increase those resources. Increasing farm resources can often increase farm productivity to meet the needs of the society. However, to help the farmers, the scientists must first understand resource utilization patterns and how particular cropping systems influence them. Therefore, scientists must understand the intricacies of the farmers' present cropping systems before introducing changes.

The cropping systems concepts

During the March 1975 cropping systems workshop at IRRI, the new ACSN developed a conceptual model that integrated physical, biological, and socio-economic determinants of cropping systems (IRRI 1975). In the subsequent years, the network members followed, with modifications and refinements when needed, the model illustrated in Figure 2.2. Researchers first recognize that the farmer has knowledge and skills that he learned from his forefathers. He also has land, labor, capital, and other production input resources. Above all, the farmer needs food for his family; and then cash for housing, health, children's education, and production inputs. Major emphasis is placed on food crops that will make the grower self-sufficient. The cropping systems approach emphasizes research and extension work, preferably under one administrative umbrella. The improved cropping systems technologies coming from research through extension are then combined with the farmers' skill to give alternative choices.

In designing these cropping patterns, two important considerations are made. First, the patterns should allow available farm resources to be used efficiently. Second, they should be designed so that the available farm resources are adequate



2.2. The cropping systems conceptual model.

for satisfactory production to meet family needs. The most important criteria for determining the performance of the introduced cropping patterns are agronomic productivity and economic profitability.

Until recently, most agricultural research in Asia was crop or commodity oriented. Attention was mainly focused on the improvement of individual crops. Since a farmer had to fit the individual crop recommendations into his existing cropping patterns and because these crop-oriented advanced technologies were not developed in the context of his cropping patterns, there were major conflicts. In many cases, adoption of crop-oriented technologies has been minimal, slow, or at the expense of other components in the system. The systems approach adopted by the ACSN, on the other hand, emphasized the improvement of a cropping pattern or the sequence of crops rather than only that of a single crop in the sequence The ACSN recognizes that a vast majority of the small Asian farmers cannot afford to adopt the high inputs required by many advanced crop-oriented technologies and puts priorities on the development of appropriate technologies for them.

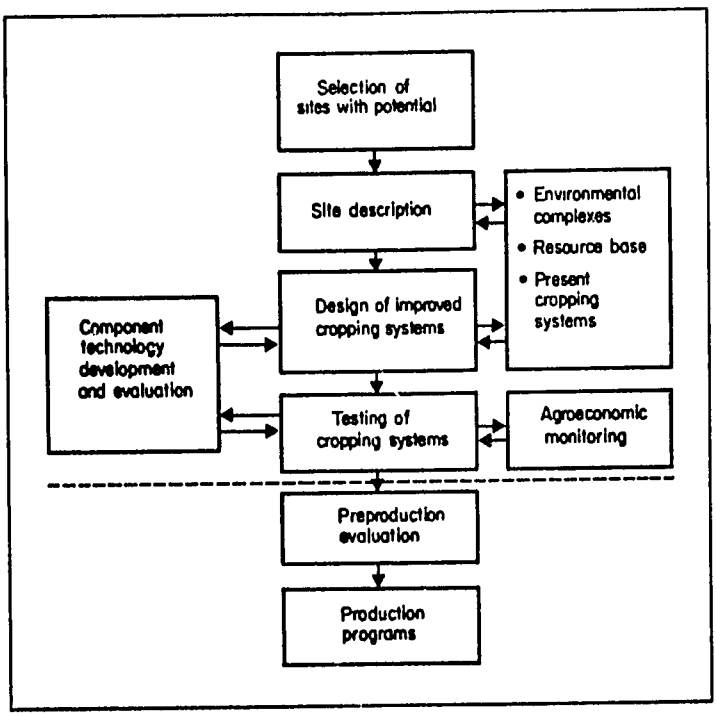
Farmers in most of the developing South and Southeast Asian countries usually consume what they produce. These subsistence farmers do not always consider the economic criteria in evaluating crop performance because their first concern is food for their families. Agriculture in developed countries may be considered as a rural factory for producing carbohydrates, proteins, etc, and the entire farming system is mainly evaluated from a strictly economic viewpoint. However, with high population pressure in the developing countries, the quantity of food produced and the kind of crops grown count the most. Even so, most of the

national cropping systems programs in the network are now placing more emphasis on economic profitability and nutrient yields.

The unique concept of the farmer actively participating in the research was adopted in the network from the beginning. The network scientists have successfully developed ways and mechanisms to work with the farmers, not merely to advise but mainly to understand and help them.

The cropping systems approach

The ACSN on-farm cropping systems research program is based on a scientific approach that recognizes several well-defined domains. First, the target area is placed in agroclimatic classification to explain the performance and stability of the existing cropping patterns. This helps determine the feasibility of growing new crops and cropping patterns and the potential for agricultural development, and to extrapolate from research results at one site hypotheses at a similar one. Second, farmers' characteristics, needs, and available resources are conceptualized. Utilization of the biophysical potential of a certain area is largely dependent on the socioeconomic conditions there. The actual needs, capabilities, and characteristics of the farmers must be clearly understood first. Then the new improved cropping systems technologies are designed, tested, and recommended in accordance with the existing resource base and adoption capability. Third, a scientific model is used to determine the fit of the designed cropping systems with the farmers' resource base and socioeconomic background. The model should be practical and



2.3. Components of the on-farm cropping systems research methodology.

efficient so that components of the production complexes and farming systems can be integrated. Fourth, the process must have a built-in mechanism through which research and extension can jointly operate and contribute to technology generation, verification, and use. Recently, it has also been a policy in the ACSN for scientists to delineate the domain of adoption of the recommended technologies.

METHODOLOGY DEVELOPMENT

Zandstra et al (1981) documented the research methodology developed and used by IRRI and national cropping systems programs. The cropping systems research process involves a series of on-farm activities outlined in Figure 2.3 and briefly discussed here.

Site selection

First a site for on-farm research is selected. A site is a contiguous area or several selected areas that represent one or more land types in production environments that occur over an extensive area. Scientists address themselves to specific sites because cropping systems are site specific. Criteria for site selection include the potential for crop intensification or increased production, or both; representation of the wider target areas; accessibility; and farmer cooperation. It is wise to select a site in a government priority development area so that when increased production potential is demonstrated, production programs are easily started.

Site description

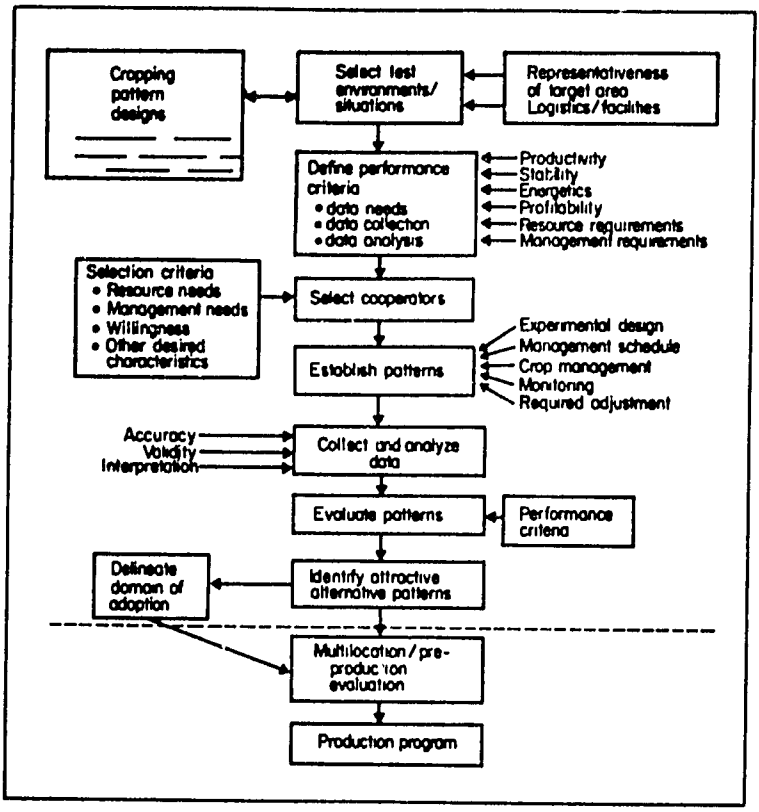
The site description characterizes existing cropping systems, physical, socio-economic conditions, etc. Sites could be described through benchmark-type surveys, crop-cut studies, farmer interviews, and farm management studies.

Cropping system designs

Cropping patterns are designed on the basis of site characteristics to achieve greater productivity. The site determinants and characteristics must be carefully used in the design so that the designed patterns stand more chances of developing into stable, productive, and profitable systems.

Cropping systems testing

Designed cropping systems are tested in farmers' fields to determine their suitability and stability. Usually an individual cropping pattern is tested in a 1,000-m^2 area with replications in several fields. Test criteria used to determine cropping pattern performance include agronomic productivity, biological stability, land-use efficiency, resource requirements, and economic profitability (Hoque 1976). The test environments include research stations, a research station simulating a farmer's conditions, a farmer's field managed by the researcher, and a field managed by the farmer. The cropping pattern trials could be replicated small plot trials, replicated large plot trials, or production plot trials with replicates in different fields. The steps are illustrated in Figure 2.4.



2.4. The sequence of events in the on-farm cropping pattern testing process.

Preproduction evaluation

The productive and profitable cropping patterns are identified on the basis of testing results and then entered into a preproduction evaluation. The purpose of preproduction research, consisting of multilocation cropping pattern testing and pilot production programs, is to evaluate the technology in an applied research situation as well as to delineate the final production program area. Preproduction research indicates the technology performance and the institutional support requirements for adoption on a wider scale. It also helps in planning and structuring large-scale production programs.

Production programs

After the most promising cropping patterns are identified and the associated technologies specified, a regional or national production program is started. Extension organizations with support from other relevant institutions implement the program. The researchers are involved in planning, training the extension workers, and monitoring certain aspects of the production programs.

Based on the experience of the ASCN member countries, the cropping systems methodologies, applied to both research and extension, have offered the most effective means of identifying appropriate technologies for the small farmers (Freeman 1980).

A productive commodity technology is not rejected in favor of some more nebulous cropping systems technology. Rather, the commodity technology becomes pattern specific. The commodity programs with feedback from cropping systems research need to develop technologies with specifities that make the commodity technologies more acceptable to the small-scale farmers.

IRRI'S ROLE IN THE NETWORK

Cropping systems research is one of IRRI's major programs, second only to the Genetic Evaluation and Utilization (GEU) program (CGIAR 1978). More than 20% of IRRI's budget is allotted to the Cropping Systems Program. The general purpose of the program is to develop a cropping systems technology to increase cropping intensity on rice farms.

Objectives of IRRI Cropping Systems Program

The general objective of the IRRI Cropping Systems Program is to generate technology to increase food production in the South and Southeast Asian rice-growing countries through the identification of more productive rice-based cropping systems acceptable to the small farmers (Carangal 1977a). The three specific objectives of the program are

- To develop appropriate cropping systems technologies for the farmers in the major agroecological zones. Considerations are given to increased food production, improved nutrition for farm families, increased farm employment, and improved bargaining capacity and general economic welfare of small farmers.
- To develop cropping systems research methodologies that can be used by IRRI and other scientists working in the national programs and in agronomic and socioeconomic research.
- To help initiate, develop, and support national cropping systems programs by providing expert technical consultants, training facilities, and materials; and through collaborative research and development activities.

Components of the IRRI program

The whole range of cropping systems activities at IRRI falls under research and the cropping systems network.

The research component. The objective of the research component is to conduct research aimed at the following major areas:

- Environmental classification. IRRI has published a report, "An agroclimatic classification for evaluating cropping systems potentials in Southeast Asian rice-growing regions" (IRRI 1974). In cooperation with the Bangladesh Rice Research Institute, a detailed agroclimatic survey has been completed in Bangladesh. Similar work in other countries such as Indonesia and Thailand is in progress. These projects will help the IRRI program in extrapolating from results at one site the potentials of similar ones in the region.
- Site-specific cropping systems research. IRRI has completed on-farm cropping systems research at Batangas, Iloilo, and Pangasinan in the

Philippines. The research results are being used in large-scale production programs by Philippine national agricultural agencies. The IRRI program now has an on-farm research site at Tuguegarao in Cagayan Province. In cooperation with the Philippine Ministry of Agriculture and the Cagayan Integrated Agricultural Development Project (CIADP), IRRI researchers are trying to improve the existing cropping patterns as well as to develop new potential cropping patterns and management systems for increased production at this site.

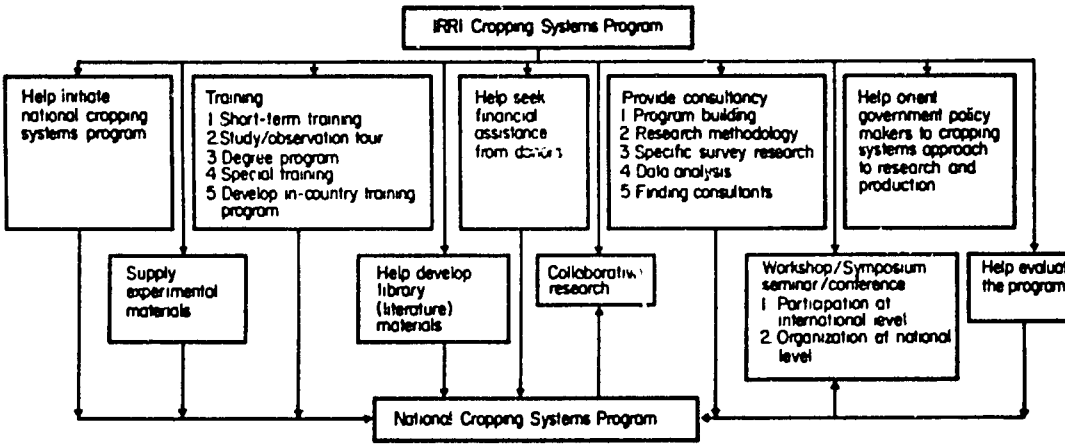
- Development of research methodologies. The most important contribution of IRRI site-specific research has been the development of methodologies for agronomic and socioeconomic research. The IRRI program continues to emphasize the development of simple and more appropriate methodologies that can be easily adopted and used by the national programs.
- Component technology development. The IRRI cropping systems program has emphasized the development of suitable component technologies for intensive cropping patterns for the selected sites. Component technology research such as establishment of upland crops before and after rice has been useful in several network sites.

The network component. The most important contribution of the IRRI program to the development of cropping systems has been through the ACSN. Because of the importance IRRI assigns to the network, more than 40% of the IRRI Cropping Systems Program budget is destined for the network support activities (Zandstra 1980a). In addition to the network coordinator, IRRI has also now made the services of a network economist available to the country programs. The network component is so important that the success or failure of the IRRI Cropping Systems Program depends to a great extent on the success of the cropping systems research activities in the national programs (Zandstra 1980a, Pendleton 1981).

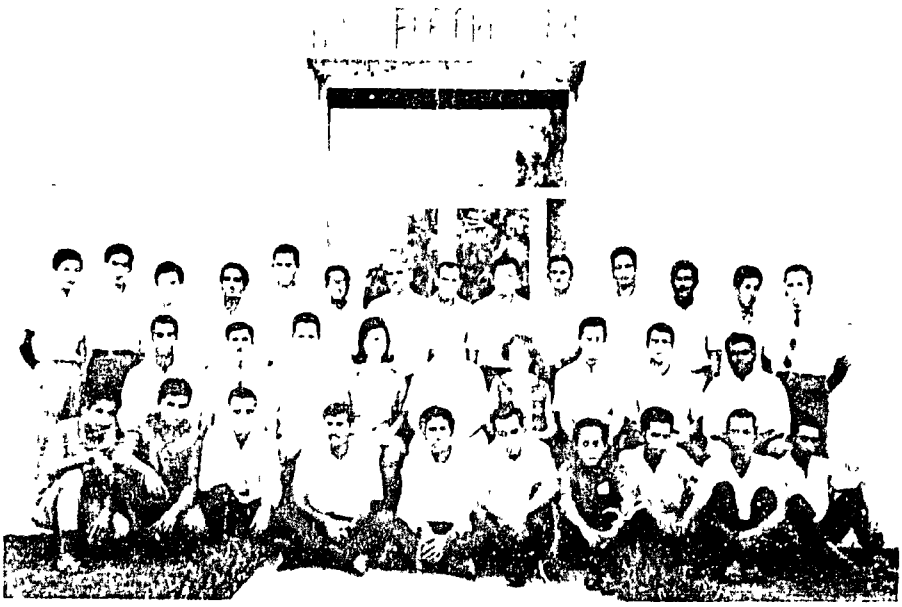
IRRI support areas

IRRI, with assistance from the International Development Research Centre (IDRC) of Canada and the International Funds for Agricultural Development (IFAD), provides the necessary services to the national programs (Pendleton 1981). A committee composed of national program leaders (Hoque et al 1978) at the Seventh Cropping Systems Working Group Meeting at IRRI in 1978 clearly identified areas where IRRI could help the national programs (Fig. 2.5). The IRRI program has already made significant contributions in most of these support areas and continues to provide these vital services to develop and strengthen the national programs.

Catalytic and consultative services. Because of the high capability and credibility of the IRRI scientists, their encouragements, suggestions, and direction have been well accepted by the national research programs and ministries in the governments in initiating and developing cropping systems programs. The consultative services provided by IRRI at the initial stages of most of the national programs were critical to the overall development of cropping systems programs. The IRRI program continues to help initiate new national programs and provide expert technical consultative services and assistance in obtaining and administering financial support from donor agencies.



2.5. Areas for IRRI contribution to national cropping systems programs through the Asian Cropping Systems Network



2.6. Twenty-one participants from eight countries of Asia and Latin America in 1970 IRRI Multiple Cropping Training Program with Dr. and Mrs Richard Bradfield and Multiple Cropping Department staff Several of these trainees later became national cropping systems program leaders in their countries

Training and orientation. The IRRI Cropping Systems Training Program has made a tremendous impact on the dissemination and adoption of the cropping systems concepts and approaches. It has worked as a prerequisite to the development of the extensive and vigorous on-farm cropping systems research program that now exists. The present cropping systems training program is the product of a multiple cropping course that began in 1969, with 14 Filipino trainees and 1 Pakistani, under the direction of Dr. Richard Bradfield, then the Head of

IRRI's Multiple Cropping Department (Pendleton et al 1981). The objective of the first multiple cropping course was ". . . to demonstrate the food production potential of a tropical environment under scientific management and to equip the trainees with knowledge and skills necessary to operate successful multiple cropping systems involving rice and some other food crops" (IRRI 1969). In 1970, Dr. Bradfield personally coordinated the training of another 21 young research and extension workers from Asia and Latin America (Fig. 2.6). In the following years, several of these trainees became the national cropping systems program leaders in their countries. Up to 1981, 348 young scientists have been trained in the IRRI cropping systems training course, which also includes a 2-week short course on modern rice cultivation. The course content and strategy of the present Cropping Systems Training Program at IRRI are mostly based on the on-farm research methodology developed by the ACSN working group.

The senior scientists in the IRRI Cropping Systems Program have served as graduate advisers for 16 MS and 7 Ph Ds in cropping systems up to 1981. These graduate students came from different countries and enrolled at the University of the Philippines at Los Baños (UPLB).

Depending on the needs of and requests from the national programs, IRRI also arranges for special on-the-job short training courses for scientists working in the country programs. In the past, such training courses have been organized in cropping systems economics, weed science, entomology, and varietal testing.

Table 2.2. Number of participants from different countries in the IRRI cropping systems training programs and study tours (1969-81).[a]

Country	Participants (no.)					
	Cropping systems short course (4-6 mo)	MS program	Ph D program	Special short training course	Study tours	Total
Bangladesh	43	7	–	4	13	67
Burma	14	2	–	1	4	21
Colombia	2	–	–	–	–	2
England	–	–	1	–	–	1
India	21	–	–	–	1	22
Indonesia	85	1	2	6	17	111
Israel	1	–	–	–	–	1
Japan	1	–	–	–	–	1
Laos	2	–	–	–	–	2
Malaysia	19	–	–	–	2	21
Nepal	12	–	–	1	13	26
Pakistan	4	1	–	–	–	5
Philippines	56	1	–	10	19	86
Senegal	–	–	–	1	–	1
South Korea	4	–	2	–	–	6
Sri Lanka	28	–	–	3	14	45
Thailand	51	4	1	6	25	87
U.S.A.	–	–	1	–	–	1
Vietnam	4	–	–	–	–	4
West Indies	1	–	–	–	–	1
Total	348	16	7	32	108	511

[a]Multiple Cropping Department, IRRI.

Since 1978, the network coordinator has been arranging, in cooperation with the national programs, cropping systems monitoring tours almost on an annual basis. These tours are meant primarily for the scientists who are directly involved in cropping systems research and production programs and are not members of the working group. These working scientists thereby get an opportunity to see other

Table 2.3. Cropping systems working group meetings, workshops, symposiums, and conferences, 1975-1981.

Meeting	Institute/organization and sponsoring country	Participants (no.)	Observers (no.)	Copies of proceedings	
				Printed	Circulated
First Cropping Systems Working Group Meeting together with Workshop on Cropping Systems, 18-20 Mar 1975, IRRI, Philippines	IRRI	55	27	500	490
Second Working Group Meeting, 3-8 Nov 1975, Indonesia	CRIA, Department of Agriculture, Indonesia/IRRI	18	–	300	295
Third Working Group Meeting, 16-18 Feb 1976, Thailand	Department of Agriculture, Thailand/IRRI	24	12	300	295
Cropping Systems Symposium 21-24, Sep 1976, IRRI, Philippines	IRRI	66	23	500	450
Fourth Working Group Meeting, 20, 24, 25 Sep 1976, IRRI, Philippines	IRRI	12	18	300	285
Fifth Working Group Meeting, 15-22 Feb 1977, Bangladesh	BRRI, Bangladesh/IRRI	11	17	300	225
Sixth Working Group Meeting, 13-17 Dec 1977, Sri Lanka	Department of Agriculture, Sri Lanka/IRRI	12	18	400	303
Seventh Working Group Meeting, 2-5 Oct 1978, IRRI, Philippines	IRRI	12	13	450	368
Eighth Working Group Meeting, 28-31 May 1979, Nepal	Department of Agriculture, Nepal/IRRI	12	25	400	250
Cropping Systems Research in Asia, 3-7 Mar 1980, IRRI, Philippines	IRRI	76	30	5,000	
Ninth Working Group Meeting, 7 Mar 1980, IRRI	IRRI	12	12	No proceedings	
Tenth Working Group Meeting, 15-19 Sep 1980, South Korea	ORD, South Korea/IRRI	11	10	400	240
Eleventh Working Group Meeting, 18-22 May 1981, Indonesia	Department of Agriculture, Indonesia/IRRI	11	27	500	420
Twelfth Working Group Meeting, 8-13 Dec 1981, Burma	Ministry of Agriculture and Forests, Burma/IRRI	12	15	550	500

research programs and problems, and exchange ideas and information. From 1978 to 1981, 108 Asian scientists participated in the program. Table 2.2 presents the number of participants from countries in the training courses, degree programs, and study tours offered and coordinated by IRRI. In January 1976, IRRI organized, in addition to training and study tours for the scientists, an orientation program on cropping systems research and development for the agricultural leaders, research administrators, and senior officials of agriculture departments from Sri Lanka, Bangladesh, Indonesia, Thailand, South Korea, Philippines, India, Malaysia, and Nepal. Senior IRRI scientists briefed 18 high-ranking key officials from these countries on the cropping systems concepts, approaches and methodologies and, particularly, requirements of government institutional support.

Distribution of plant materials. In most cases, the national programs need better varieties particularly of nonrice upland crops to fit into intensive rice-based cropping patterns. Considering this, the network coordinator has collected plant materials from different national and international sources and redistributed them among the network members depending on the individual country's needs. Several varieties of maize, sorghum, and peanut with better yield potentials than local varieties have been increased and distributed on a large scale in the national programs. This support of the network in varietal testing has been a close cooperative effort between the Institute of Plant Breeding (IPB) of UPLB and IRRI. Future plans are to strengthen this collaboration in close cooperation with institutes that have breeding programs on tropical upland crops such as ICRISAT, Institute of Tropical Agriculture (IITA), AVRDC, and national programs in the region.

Collaborative research. The IRRI program is collaborating with the national programs in the network on agroclimatic classification, cropping pattern monitoring and testing, cropping systems economics studies, and other areas. Future collaborative work will include long-term cropping pattern testing, fertility management, small-scale machinery development and use, and pilot production programs.

Information sharing. IRRI sponsors and cosponsors workshops, working group meetings, seminars, symposiums, and conferences on cropping systems research and development. The proceedings of these meetings have been widely distributed. Table 2.3 presents the chronological records on the cropping systems workshops, symposiums, and conferences organized by IRRI and national programs. Within 7 years, 14 major meetings contributed much to the dissemination of cropping systems ideas and information.

FUTURE PLANS FOR THE NETWORK

The future plans for the ACSN include establishment of more research sites in India and China and extension of the network to Pakistan and Vietnam (Carangal and Jayasuriya 1982). On-farm research will be continued at the network sites. More emphasis will be placed on the pooling and interpretation of the generated information. More collaborative studies between IRRI and the country programs

will be conducted. The economic components of the cropping systems programs will be strengthened. IRRI will provide strong assistance to the country programs for developing in-country training facilities, data processing, and organizing and implementing multilocation and pilot production testing. The network working group will refine the methodology on delineation of technology extrapolation zones and multilocation testing. Emphasis will continue on the use of site-specific research results in large-scale production programs and structuring of broader farming systems research and development projects in the target areas.

The IRRI Cropping Systems Program is the first of its kind at an international agricultural research center. It has pioneered many aspects of farming systems research and has been a leader in developing concepts and methodologies for multidisciplinary research, notably for on-farm studies (CGIAR 1978). The ACSN has provided a vital framework for international cooperative research and delivery of IRRI technology to the cooperating countries. It has also provided a mechanism for exchange of research information and feedback from farmers.

Chapter 3

THE SETTING OF CROPPING SYSTEMS RESEARCH IN ASIA

The ACSN encompasses a vast and diverse physical area from Indonesia to China and from Sri Lanka to South Korea. Eleven countries and many government and other agencies are actively engaged in cropping systems research and development. These agencies are using cropping systems research approaches and methodologies developed by the ACSN working group.

THE ASIAN CROPPING SYSTEMS NETWORK RESEARCH SITES

In 1975, there were only six research sites in the Philippines, Indonesia, and Bangladesh (Carangal and Jayasuriya 1982). By 1982, there were 43 sites (Fig. 3.1). Research at 11 of these sites has been phased out. Currently, the network has 32 operational sites in Bangladesh, Burma, China, India, Indonesia, Nepal, Philippines, South Korea, Sri Lanka, and Thailand. In the near future, sites should be operational in Pakistan, Vietnam, and Malaysia. In addition to the ACSN sites, most of the country programs have opened up additional ones, bringing the number to 137. ACSN and national research sites can be located in Appendix Figures 1-9.

Description of network research sites

The network research sites represent a broad range of climatic zones, soil types, and socioeconomic conditions.

Pumdi Bhumdi, Nepal. The site lies in the Pumdi Bhumdi *panchayat* of Kaski district in the midhills of the Western Development Region. It is 8 km west of Pokhara airport and is adjacent to the Pokhara-Bhairawa road. Elevation ranges from 750 to 1,270 m above sea level (CSP, Nepal 1979). The site has a unimodal rainfall pattern with an annual average of 4,000 mm.

Rice and maize receive about 95% of the available rainfall; the winter crops receive the rest. Hail damage, generally occurring from mid-September to Mid-November and from mid-February to mid-March and occasionally in May-June, is a serious problem for the farmers.

The farmers have built an intricate water diversion system that catches nearly all runoff water and diverts it to the ricefields as supplemental irrigation. This system not only helps hold soil erosion to a minimum and efficiently uses available water for crop production but also brings nutrients from animal and human wastes dropped in walkways and public areas.

The land at Pumdi Bhumdi ranges from wetland (*Khet*) to dryland (*bari*). The soil textures include sandy loam, silty loam, and silty clay. The wetland and dryland categories are further divided into subclasses that determine the cropping patterns and performance. These are dryland with high production potential; dryland with low production potential; wetland with high production potential;

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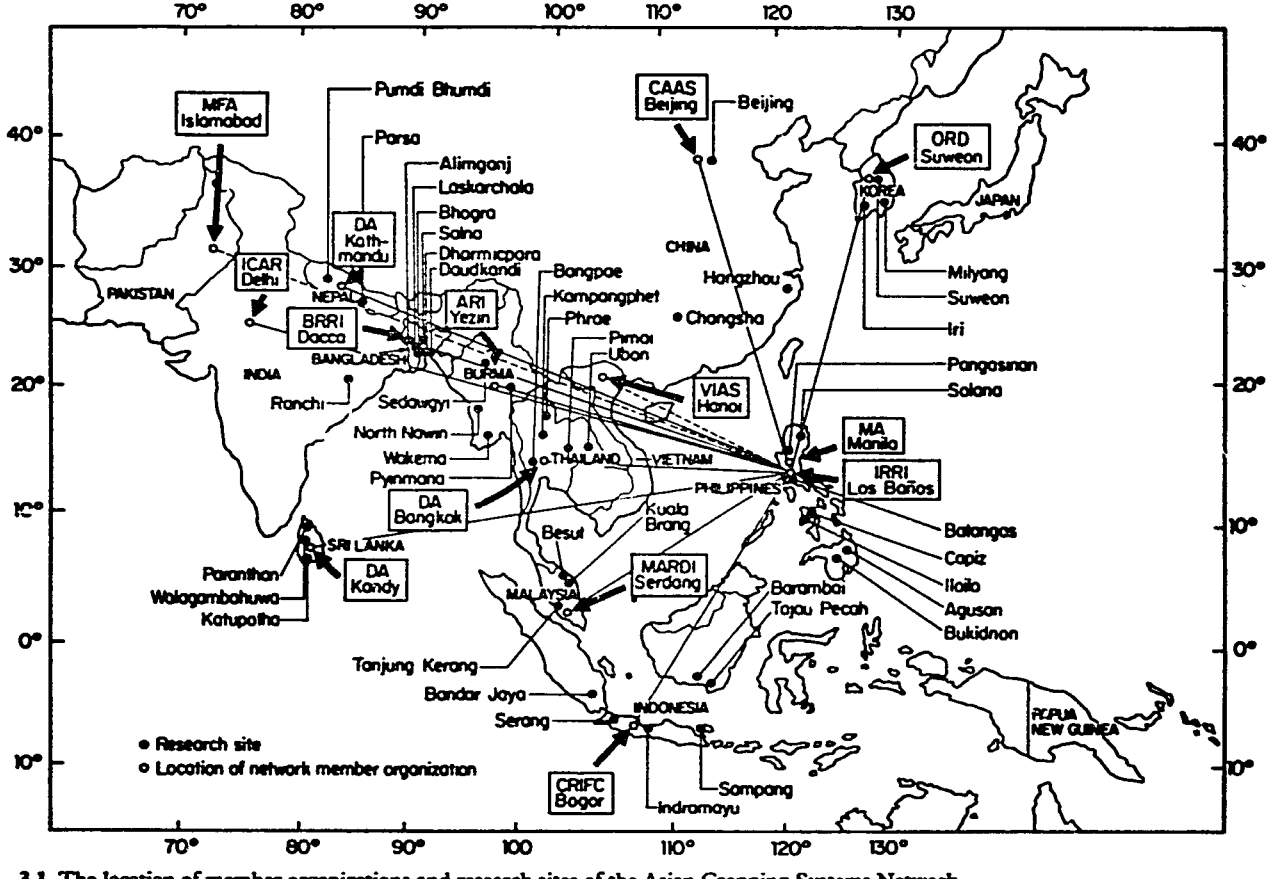


3.1. The location of member organizations and research sites of the Asian Cropping Systems Network.

and wetland with low production potential. These classifications are mainly based on water availability and soil fertility, which is related to soil type, intensity of erosion, and compost use. Farms at Pumdi Bhumdi are small, ranging from 0.45 to 0.75 ha.

Parsa, Nepal. Research is done at Dhobini and Langari under irrigated conditions and at Sukchaina under partially irrigated and rainfed conditions. Recently, work on irrigated cropping systems was also started in the Bauhari area.

The Dhobini-Langari area is located about 30 km west of Birgunj of Parsa district in the Terai Belt of Nepal. The land is relatively flat and irrigated from the Gandak Canal of the Narayani Zone Irrigation Development Project (CSP, Nepal 1979). The soil texture includes loams, silty loams, and sandy loams with a pH of about 7. The site has a unimodal rainfall pattern with an annual average of 1,500 mm. June, July, August, and September are the wet months with more than 200 mm rainfall monthly. Farms range from 0.5 to 1.2 ha.

The research on rainfed and partially irrigated cropping systems is done in Sukchaina Village of Bhawanipur panchayat of Parsa District and is about 6 km from Birgunj town and close to the Parwanipur Agriculture Station. The altitude is 100 m above sea level and the mean annual rainfall is about 1,200 mm. Most of the land is rainfed lowland. Some fields are irrigated by lift irrigation or by surface canal, but availability of irrigation water is uncertain. The average farm is 1.92 ha. The soil texture is silty loam or loam with a pH of about 7. In the rainy season, rice occupies 95% of the lands and the remainder is devoted to finger millet. During the dry winter season, wheat is grown on about 25% and legumes occupy another 15%.

Ranchi, India. The rainfed site selected by ICAR is near Ranchi in the Bihar State. It is characterized by a short rainy season and the soils have low water retention capacity (Pendleton et al 1981). The area is divided into high-, intermediate-, and low-elevation land types. The research program involves the participation of staff from the Ranchi Agricultural College, affiliated with the Rajendra Agricultural University. The cropping patterns include rice - wheat, rice - barley, rice - maize, rice - chickpea/lentil, rice - mustard/linseed, and other mixed and intercropping combinations.

Bhogra, Bangladesh. Bhogra is a rainfed site in Joydebpur thana in Dhaka District. It has a unimodal rainfall pattern with an annual average of about 1,668 mm. The total annual rainfall between 1976 and 1981 ranged from 1,601 to 2,329 mm. The soils belong to the Madhupur tract. The Madhupur clay is a weathered unconsolidated alluvial sediment probably of marine deposit. The clay minerals are mainly Illite and Kaolinite. The soil is a grey terrace soil (Aeric Haplaquept) with a grey compact clay substratum and a silty clay surface. It is shallowly flooded in the monsoon season, is slowly permeable, and has poor moisture retention capacity in the dry season. Cation exchange capacity is low and pH is about 6.9. The land is usually planted to two rainfed rice crops per year with a fallow dry season.

Forty-two percent of the farmers cultivate less than 1 ha. There is large variability in the number of livestock; 26% of the farmers have less than a pair of bullocks, but 50% have a pair. Larger holdings have more manpower and draft power than the smaller farms (Hoque et al 1982a). Family size is large and averages

more than eight persons per farm. The major constraints to higher crop yields include lack of irrigation facilities, droughts in the premonsoon and postmonsoon period, and unavailability of adequate production inputs and credit.

Salna, Bangladesh. Salna is an irrigated rice area in Dhaka District. It is a tubewell-irrigated area that has flood-free medium highland and narrow depressed valleys. All lands fall under irrigated lowland category. The annual rainfall ranged from about 1,600 mm to 2,330 mm during 1976 to 1981. The soils are similar to those of Bhogra and belong to the Chhiata soil series (Aeric Haplaquept). The soil is clay loam with pH values from 6.1 to 7. Farmers grow either single, double, or triple rice cropping patterns under irrigated conditions. The average farm is about 1.47 ha. The family has about eight to nine persons of which three or four are farm laborers. Farmers use bullocks for draft power. Fifteen percent of the farmers enjoy government credit facilities. In general, Salna is a developed area. It is connected with Dhaka, the national capital, and other areas with good communication systems. Farmers have good access to markets. Salna has also been an area selected for other government development projects on self-reliance and family planning.

Laskarchala, Bangladesh. Laskarchala is a partially irrigated site located in the Savar thana of Dhaka District. It has a unimodal rainfall pattern with an annual average of about 1,668 mm. The soils are moderately well-drained yellowish to brown clay loams (Typic Paleudults) on level upland and poorly drained grey silty clay loams (Aeric Haplaquept) in the narrow valleys that dissect the highland area. The soil pH values range between 5.8 and 6.7. Deep tubewell irrigation is available for dry season cropping. Traditionally, farmers grow a crop of direct-seeded rice or mesta fiber (*Hibiscus sabdarifa*), followed by a pulse or oilseed on the highland and double rice cropping on the narrow valley lands. Availability of irrigation facilities brought about changes in land-use pattern. The average farm is 0.91 ha, ranging from 0.34 to 2.43 ha. Most of the farmers own their land; 37% rent extra land. Seventy-four percent of the farmers own two draft animals, although the larger farms have more animals.

Dharmicpara, Bangladesh. Dharmicpara is a collaborative site of the Directorate of Land and Water Use of the Bangladesh Water Development Board (BWDB) and BRRI. It is located in the Dhaka-Narayanganj-Demra (DND) Irrigation Project of BWDB, about 7 km southeast of Dhaka. The site is deep lowland, flooded to a depth of 3-5 m from June to October. Canal irrigation is available during the dry season (December-April) for the cultivation of winter (boro) rice. The average annual rainfall is about 1,700 mm. The soil texture is clay loam to clay and the soil pH is about 7.4. This flood-affected site was selected mainly to grow a deepwater rice crop after the boro rice.

Daudkandi, Bangladesh. Daudkandi is a deepwater rice site in Comilla district. It has an average annual rainfall of about 2,000 mm. It is low-lying and the annual hydrology pattern determines the cropping patterns. Farmers seed their deepwater rice (locally known as broadcast aman) in April-May under dry-seeding conditions. The site is flooded starting June and reaches the flooding peak (5-6 m) in August, after which the floodwater subsides. The deepwater rice grows along with floodwater and is harvested in October-December when water is gone. At

this time the fields are completely drained of floodwater and farmers prepare their lands for different dryland winter crops such as wheat, sesame, potato, etc. The soil has a silty clay or clay loam texture and the residual soil moisture is usually enough for short-duration, dry-season crops (locally called rabi crops). The average farm is 1 ha. The average family has about seven persons, of whom only one is engaged in farm labor. The site was selected to study the deepwater rice-based cropping systems and to devise possible improvements.

Alimganj, Bangladesh. Alimganj is a rainfed site situated on the bank of river Ganges under Paba thana in Rajshahi District. Its annual average rainfall is 1,438 mm. There are only 3-4 wet months (more than 200 mm rainfall/month) and more than 6 dry months (less than 100 mm rainfall/month). The alluvial soil is clay loam to silty clay in texture and possesses good moisture retention. Two selected land types include a flood-free upland area and a flood-prone wetland area. Soil pH ranges from 6.5 to 6.9. Farmers grow traditional rice varieties in double or triple cropping patterns. Barley, chickpea, and wheat are the most important winter season dryland crops. Farm size is somewhat larger than the Bangladesh average of about 1.5 ha, and ranges from 4 to 20 ha. An average farm family has about 13 members. The research emphasis is on technology development that can fit the prevailing dryland farming situations.

Walagambahuwa, Sri Lanka. Walagambahuwa is a traditional tank-based village settlement representing around 3,000 similar settlements occupying 104,200 ha in the dry zone (Sikurajapathy and Senaratna 1977). The region has a bimodal rainfall pattern that is typical for most of the country. There are two well-defined seasons. Maha, the major rainy season, lasts from early October to February with about 760 mm. Normally, the heaviest downpours occur in November, after which the rain recedes through December and January. Yala, the minor rainy season, March-May, has a rainfall of 380 mm. Normally, half of these rains occur in April. Soils are in a catenary sequence in the undulating landscape. The convex uplands and lower midslopes have well-drained and imperfectly drained Reddish Brown Earths (Rhodustalfs), respectively. The poorly drained low humic gley soils (Tropaqualfs) occur on the concave valleys and bottomlands. The site has three land-use patterns: *chena* (shifting cultivation area), *gangoda* (settlement proper), and *wel-yaya* (paddy tract). The tank and its catchment constitute the center of the settlement's agricultural and domestic activities. The tank is used to irrigate the rice crop in the 10.5-ha paddy tract during the wet season. There are 48 farm families in the Walagambahuwa village with an average size of about 5 persons. Fifteen of these families were selected for economic monitoring activities.

Katupotha, Sri Lanka. Katupotha is located in the intermediate agroecological zone with Red-Yellow Podzolic soils. The selected research area encompasses two rainfed wetland paddy tracts — Alankara and Moragane. Coconut and rice are the major commodities (Fernando 1978). Rice yields are low and range from 1 to 2 t/ha. The Alankara paddy tract, about 25 ha in size, has various soil problems, including plant nutrient deficiencies and soil moisture stress. The Moragane paddy tract is larger and exhibits fewer soil problems, but is affected by flash floods brought by heavy rains. The lands under each paddy tract are classified into

the crest, the side paddies, or the valley bottoms.

There are approximately 30 farm families in the Alankara paddy tract and 50 in the Moragane. The cultivation of annual upland crops is minimal. The farmers almost exclusively use a rice - rice double-cropping pattern. The cropping systems research was started at this site to improve the overall productivity of the rice - rice pattern and to replace the second rice crop in the pattern with suitable upland crops for each land category.

Paranthan, Sri Lanka. The Paranthan site is located in the northern tip of the island just before entering the Jaffna Peninsula. Although the average rainfall during the maha season is about 1,300 mm (comparable with most of the country), the yala season (March-September) has very limited rains (Senthinathan and Sritharan 1978, cited by Fernando 1978). The cropping systems research program is focusing on the rainfed bunded paddy lands, known locally as *Manawari* lands. These lands have a sandy surface and some exhibit salinity problems because of the low elevation and proximity to Jaffna Lagoon, a salt-producing area. The present land-use pattern includes growing a single crop of rice, preferably under dry-seeded conditions, in the maha season and extensive pasturing of cattle and goats on the stubble during the yala season. The grazing herds belong to the absentee landlords from Jaffna and pose a serious constraint to any second cropping during the yala season. Also, because of the low rainfall, crop cultivation during the yala season is almost exclusively restricted to patches near wells or along the creeks with drainage water from the command area of the big Iranamadu tank just south of the site. The farms are relatively large, ranging from 7 to 15 ha. The research aims at improving the yields of the rainfed wetland rice during maha and exploring the possibility of a second crop after rice.

Pyinmana, Burma. The Pyinmana site is located in the vicinity of the Agricultural Research Institute at Yezin near the foot of the Shan plateau in Pyinmana township. It is almost midway between Rangoon and Mandalay and has a landscape gently sloping toward the Sinthay River (Saing et al 1981). The area has a moderate monsoon climate with an average annual rainfall of 1,415 mm and 4 wet and 6 dry months. Predominant soil belongs to the Gysol dystric group and the texture is medium loam in the eastern part and heavy loam on the western. The Yezin Dam, located in the northern part of Pyinmana township, irrigates about 6,500 ha of farmland while the rest of the area is rainfed. Temperatures are as low as 18° C in December-January. The average farm size is 5 ha. Draft animals are the usual power source, but tractors are also used for land preparation and transport of harvests. Rice, maize, sorghum, sesame, sunflower, and chickpea are included in different rice-based patterns.

Sedawgyi, Burma. The Sedawgyi site is located in Patheingyi township, which is situated in the central dry zone. It is under the Sedawgyi Irrigation and Land Consolidation Project with a 45,700 ha command area spread in Patheingyi, Amarapura, and Madaya townships. The area is in a valley between the Shan plateau and Irrawaddy River and has flat topography. A major part of the area has Pellic Vertisol soil (Hla Aye 1981, cited by Saing et al 1981). The soil texture includes dark compact clay soils — heavy in texture, very hard when dry, and sticky when wet; and loamy soils with crumb structure. The latter soil type

constitutes about 88% of the pump irrigation area (Saing 1979). The average annual rainfall is about 940 mm with 1 very wet month and 5 successive moderately wet months. The farms range from 3.5 to 4.5 ha, averaging 4.4 ha. Under irrigated conditions, the site is suitable for rice, cotton, peanut, and pulse.

North Nawin, Burma. Most of the North Nawin site, situated on the bank of the Irrawaddy River, is riceland irrigated by the North Nawin Dam, 16 miles northeast of Prome. The average annual rainfall is about 1,300 mm with 4 wet and 6 dry months. The topography undulates near the dam, with a gentle slope toward the bank of the Irrawaddy River (Saing 1979). The major soil type is silty loam, covering about 60% of the cultivated area, and the rest is loamy sand, silty clay loam, and sandy loam. Farmers plant premonsoon sesame in March-April; maize, peanut, and jute in May; and wet-season rice in June. In the cool season, food legumes, especially mungbean, and vegetables are grown.

Wakema, Burma. About 50% of the lower Burma rice area is situated in the Irrawaddy delta, which contributes the major portion of exported rice (Saing 1979). The site is in the Wakema township in the middle delta area. There are three distinct seasons in the delta: a wet season from mid-May to mid-October, a dry cool season from mid-October to mid-February, and a hot humid summer from mid-February to mid-May. The area has a heavy monsoon climate with 2,540 mm average annual rainfall and with 4 wet and 6 dry months. The middle delta island is surrounded by freshwater rivers and subjected to monsoon floods. The major soil type is clay loam on higher parts constituting the major rice area, while the lowlands are generally meadow swampy soils with high organic matter. The average farm is 5.5 ha and uses animals for draft power.

Ubon, Thailand. The Ubon site represents a 500,000-ha rainfed area and is located in the northeastern region about 700 km from Bangkok (Chandrapanya 1977). There are three distinct seasons: the monsoon rainy season from May to September, the cool season from November to February, and the warm season during March and April. The average annual rainfall is about 1,400 mm. Regular rains come during the early monsoon, but drop off sharply toward the end of the rainy season. The soil textures include sandy loam, loamy sand, and sandy. Soils have low fertility with about 1% organic matter and pH values ranging from 4.5 to 5.5. Farmers usually grow a single crop of rainfed wetland rice with a yield of about 1.5 t/ha. Farms are about 5 ha. Research aims at improving yields and developing suitable double cropping patterns.

Pimai, Thailand. The Pimai site is also located in the northeastern region, about 300 km from Bangkok. This site is representative of the country's 850,000 ha of rainfed land (Chandrapanya 1977). This area has also three distinct seasons. The rainfall pattern is bimodal with about 1,200 mm annually. Soil types found at the site are derived from semirecent and old alluvium. The soil textures range from light to heavy clay composed of low humic gley, grey podzolic, and alluvial soils. In general, soil fertility is low and there are salinity problems in some areas. During the rainy season, farmers grow a crop of rainfed wetland rice. In the upland areas, cassava, kenaf, sesame, and other upland crops are grown. The average farm is about 5 ha. Farmers are poor and when crops fail because of drought, they seek jobs in the cities. Research at the site aims at stabilizing rice production and

introducing suitable field crops to grow before the monsoon rice crop.

Bangpae, Thailand. The Bangpae rainfed site is located in Rachaburi Province in the Central Plain, approximately 100 km southwest of Bangkok. In general, the area is a large plain only 2.2 m above sea level. Rainfall is low. Twenty-year (1958-1977) average annual rainfall ranged from 463 to 1,515 mm (Chandrapanya 1978). The soil is generally alluvial deposit and has a clayey texture with high water-holding capacity and poor aeration. The pH varies greatly from 5.3 to 7.16 and the organic matter content from 2.1 to 3.0%. Rice is the exclusive rainy season crop; maize and mungbean are the other major crops.

An average farm family has about six members. Farm income, mainly from rice and mungbean, constitutes 51% of the family income.

Kampangphet, Thailand. The rainfed site is located in the Kampangphet Province in the southern portion of the northern region. It is in the lowest rainfall zone of Thailand, with a range of 800 to 1,000 mm per year (Chandrapanya and Banta 1979). Early rains are highly variable, peaking at 300 mm in September. In 1981, 11 months were dry, with less than 100 mm/month (Chandrapanya 1981a). The silty clay soils are low in fertility and difficult for rice transplanting. The average farm is 6 ha. Farmers transplant a single rice crop in August if their seedbeds survive. The research objective is to grow a short-duration crop before the traditional rice crop or to direct-seed a rice crop with the first heavy showers, and follow it by a nonrice crop.

Phrae, Thailand. Research in Phrae — the northern region site — focuses on the rainfed wetland areas. The average annual rainfall is about 1,405 mm with 1 wet month and 7 dry months. The topography is flat and the elevation is about 160 m above sea level. The surface soil has a silty clay loam texture while silty clay predominates at the subsurface. The soil pH is about 6.1. The average farm is 2 ha, ranging from 1 to 5 ha. Animals are the source of draft power. Farmers grow a single crop of rainfed rice. Other crops, such as tobacco, peanut, and soybean, are occasionally grown after the rice crop.

Tanjung Karang, Malaysia. Tanjung Karang is situated in the Selangor State. The average annual rainfall is 1,880 mm, heaviest from October to December (Wahab 1977). The soils are mainly organic clays, mucks, and clays of marine origin. Construction of irrigation facilities was completed in 1961 to support double cropping of irrigated rice.

Besut, Malaysia. The Besut irrigation scheme is the largest in the Trengganu State (Daud 1979). The rainfall pattern is unimodal. Rainfall is highest during the monsoon period (October-January) and lowest during the intermonsoonal period (March-August) (Wahab 1977). The average annual rainfall is 3,356 mm. Soils include newly formed soil of parent materials, river alluvium, and marine deposits. The lands where rice is grown have the river terrace alluvium soil. Both perennial (rubber, coconut, fruit trees) and annual crops (rice, tobacco, peanut, soybean) are grown. The rice farms average about 1.2 ha and owner-operators constitute 40% of them. The site is considered a depressed yield area and the research efforts are focused on the development of an irrigated double-rice cropping pattern (Samy 1976).

Kuala Brang, Malaysia. Also located in the Trengganu State, Kuala Brang has vast existing and potential arable lands. The rainfall pattern is unimodal with an annual average of about 3,566 mm (Daud 1979). The soil conditions are similar to those of the Besut site. This area is also considered a depressed yield area. Research is centered on rice and upland crops such as peanut, soybean, and green grams.

Indramayu, Indonesia. Indramayu is located within the north coastal plain of Java in the eastern part of West Java Province, about 198 km east of Jakarta. The topography is generally level and ranges from 5 to 20 m above sea level. The average annual rainfall is about 1,765 mm with 4 wet and 5 dry months. The wet season occurs between November and April and the dry season between May and October. Alluvial soils predominate. Farmers generally grow a single rice crop under partially irrigated conditions. The cropping systems program is focused on land with 10, 7, and 5 months of irrigation. The potential cropping patterns include rice - rice and rice - dryland crop. The site is representative of 1.1 million ha in Java alone (Effendi et al 1976).

Serang, Indonesia. Located in West Java, Serang is 7 m above sea level and flat. The average annual rainfall is about 1,900 mm. The soil has a silty clay loam surface, a silty clay subsurface, and pH of about 5.1. Research is directed mainly toward rainfed wetland rice areas with a view to developing productive double-rice cropping patterns introducing early maturing *gogorancah* (direct-seeded) rice.

Sampang, Indonesia. The major soil type of Sampang, located in the hilly drylands and low-lying coastal areas of Madura, is Red-Yellow Mediterranean (about 70%) on which the dryland crops (*Palawija*) are generally grown. Alluvial soil (about 15%) is used for rice cultivation. In Madura, teak plantations are found on Regosol and Grumusol soil types (CRIA 1980). The site has three land categories. The dryland area, located at Blega, has 5 wet and 4 dry months. The farmers commonly use a triple cropping pattern. The rainfed wetland rice area, located at Jrengek, has 3 wet and 5 dry months. The common cropping pattern is rainfed wetland rice - dryland crop. The rainfed rice area with hilly topography, located at Kedundung, has 2 wet and 4 dry months. The common cropping pattern is wetland rice - dryland crop. The main constraint in all three categories has been low soil fertility. Therefore, research focuses on the soil and fertilizer management and efficiency of added fertilizers.

Bandar Jaya, Indonesia. Located in Lampung in Sumatra, Bandar Jaya has an eroded, poor, Red-Yellow Podzolic soil, which is mostly infested with *alang alang* (*Imperata cylindrica*). The elevation is about 50 m above sea level (Syarifuddin et al [1975]). The rainfall amount and distribution are suitable for year-round crop cultivation. There are 6 wet and 3 dry months. Each of the remaining 3 months has more than 100 mm. Rains usually start in the first week of October and end in June. Because the fields have been annually cultivated for more than 20 years with no fertilizers except small amounts of stable manure, the soil is infertile and eroded. The soils are also characterized by excessive drainage and low pH, about 4.5 (Effendi and McIntosh 1977). However, since the soils are well drained, dryland crops can be grown during the rainy season. Rapid infiltration of rainwater minimizes the run-off problems, but the soils are leached and acid.

Fortunately, the soils do not exhibit excessive levels of aluminum. There are sufficient clay and organic matter to hold applied nutrients, which results in good crop response to added fertilizers. Upland rice, maize, sorghum, cassava, peanut, and rice beans are grown. Work at Bandar Jaya has been concluded.

Tajau Pecah, Indonesia. Located in the transmigration project areas undertaken by the Government of Indonesia in South Kalimantan (Borneo), Tajau Pecah is about 65 km from Banjarmasin. The average slope is 3-15% and the land is 20-25 m above sea level. The dominant soil type in the area is Red-Yellow Podzolic soil, which is low in N, P, K, organic matter, and pH. The site has an average annual rainfall of 2,438 mm with 6 wet and 4 dry months (CRIA 1980). Intercropping of maize and rice followed by a second crop of rice is the predominant cropping pattern. There is great potential for sustained food crop production for family subsistence. Also, the scope for diversification of land use through the introduction of livestock and perennial crops is tremendous.

Barambai, Indonesia. Selected as representative of tidal swamp areas, Barambai is located within the Barambai Transmigration Project area. It is about 40 km north of Banjarmasin in South Kalimantan. The topography is flat and only 1-3 m above sea level. The soil is classified as part of the alluvial delta of Petale Island overlain with 30-80 cm of peat (CRIA 1980). Long-term management strategies are required for the fragile nature of these potentially acid sulfate soils (Effendi 1981). The rainfall is considerably high with an annual average of 2,500-3,000 mm. The hydrology is affected by both rainfall and tidal action of the sea, causing almost continuous submergence over most of the area (Ismail and Effendi 1980). Therefore, construction of raised beds, known in Java as the *sorjan* system, is necessary to grow dryland crops in the paddy fields. Adaptation of this furrow-bed system is important to circumvent the problems of flooding for dryland crops and of insufficient water for wetland rice. The present cropping pattern includes two crops of maize on the raised beds and only one crop of long-duration photoperiod-sensitive rice in the furrow beds. The main research problem is to determine the relative size of bed to furrow for different crops and moisture regimes. Also, research necessitates long-term experiments because the beds must be developed slowly to preclude the acid sulfate soil problems, and the perennial crops planted on the beds take time to produce yields.

Batangas, Philippines. The first on-farm cropping systems research site operated by IRRI in cooperation with the Philippine Bureau of Plant Industry (BPI) is located in the village of Cale in Tanauan Municipality of Batangas Province, lying in the southwest corner of Luzon, about 60 km south of Manila and 28 km from IRRI. The farmers' rainfed cropping systems are complex and productive. The site represents upland rice areas and the topography is rolling to gently rolling. There are 5 wet (June-October) and 5 dry (December-April) months. The annual average rainfall is about 1,950 mm and the rainfall pattern has a rapid transition from dry to wet season and a gradual transition from wet to dry season. The soils are of recent volcanic origin. Taal Volcano, only 8 km west of the site, occasionally erupts, spreading thin layers of volcanic ash on the area. The soil is well-drained clay loam (Carangal 1977a), with pH 5.4, 1.7% organic matter, 38 ppm available phosphorus, and 248 ppm exchangeable potassium. An average

farm has about 1.45 ha arable land plus 0.5 ha permanent tree crops (Banta 1980). Twenty-three percent of the farms are less than 1 ha; 58% farms 1-3 ha; 15% farms 3-5 ha; and 4% farms more than 5 ha. Upland rice followed by maize is the most common cropping pattern. Farmers also grow a number of vegetables and have earned a good reputation throughout the Philippines. Initiated in 1973, the cropping systems research here has already been phased out.

Iloilo, Philippines. The research site in Iloilo has been operated by the IRRI Cropping Systems Program in cooperation with BPI. It is in the municipalities of Oton and Tigbauan in the province of Iloilo, which is located on Panay Island in the western Visayas. The study area covered nine villages with rainfed wetlands and partially irrigated wetlands. The average annual rainfall is about 2,100 mm with 5-6 wet months during May-October and 2-4 dry months during January-April. Soils are relatively homogeneous with clay loam to heavy clay textures. An analysis of soil samples from 70 fields showed an average soil pH of 5.8, 2.07% organic matter, 27 ppm available phosphorus, and 218 ppm exchangeable potassium (Palada et al 1976). The fields in Tigbauan are plateau or bottomland while those in Oton include plateau, bottomland, side-slope, and dryland (Magbanua et al 1978). The average farm is 1.86 ha (Banta 1980). About 20% of the farms are less than 1 ha; 57%, 1-3 ha; 16%, 3-5 ha; and 7%, more than 5 ha. The traditional cropping pattern used to be rice - fallow with less than 10% of the farms planting low-management dryland crops after rice (Carangal 1978b). Findings from research here have already been incorporated in a large-scale production program.

Pangasinan, Philippines. The site in Pangasinan, in the northwest corner of the central plains of Luzon, approximately 200 km north of Manila and 100 km south of Baguio City, is operated jointly by IRRI and BPI. The study area includes five villages — Anis, Lipit Sur, Lipit Norte, Pao, and Caaringayan (Banta 1980). The area represents rainfed wetland and partially irrigated rice areas (Carangal 1977a). The topography is almost level plain. The average annual rainfall is about 1,980 mm with 4 consecutive wet months and 6 consecutive dry months. There are two distinct water tables. A deepwater table is found in Lipit Sur, Lipit Norte, and Pao while the two other villages, Caaringayan and Anis, have a shallow watertable with several artesian wells (Banta 1980). The soils are relatively homogeneous and have a calcareous clay loam texture with an average pH of 7.4. The soil has 2.1% organic matter, 128 ppm available phosphorus, and 237 ppm exchangeable potassium. Availability of iron is low under aerobic conditions and zinc availability is low under anaerobic conditions (Herrera et al 1976). The average farm is about 1.45 ha. Twenty-eight percent of the farms are less than 1 ha; 59%, 1-3 ha; 11%, 3-5 ha; and 2%, over 5 ha. Rice - mungbean is the most common traditional cropping pattern.

Solana, Philippines. The IRRI cropping systems program established the Solana site in 1980 in cooperation with the Cagayan Integrated Agricultural Development Project (CIADP) and the Philippine Council for Agricultural Resources Research (PCARR). It is located in the municipality of Solana, Cagayan, about 8 km northeast of Tuguegarao and about 500 km north of Manila. The site includes three contiguous villages — Bangag, Bauan, and Iraga. It has 5

wet months (July-November) and 4 dry months (January-April). Rain normally starts in late May and declines starting the first week of December. The average annual rainfall is about 1,755 mm. The site is broadly classified into two land types — *bangkag* and *talon*. The bangkag area comprises the cultivable portions of the recent floodplains bordering the Cagayan River. The silty clay loam soil has a lighter texture and a pH of about 6.6. The cation exchange capacity (CEC) of the bangkag soil is 32.9 meq/100 g. The soil contains 1.23% organic carbon and 0.13% total N, 268 ppm K, and 12 ppm P. During the nonflooded period from December to July, farmers grow dryland crops, mainly maize and peanut. Some farmers also grow these two crops in an intercropping combination. The talon area is about 2-3 m higher than the bangkag area and about 1 km away from the Cagayan River. On the basis of relative elevation and field level water regime, the talon is further divided into three land strata (Gines and Morris 1981). The soils are predominantly silty clay loam on the first stratum and silty clay on the second and third. The soil pH is about 6.2. The CEC values are 34.6 meq/100 g for the first stratum, 41.8 for the second, and 44.5 for the third. Water accumulates much faster in the third stratum than in the first and second strata, and the fields remain flooded longer. Traditionally, farmers grow a mungbean - rice pattern in the first and second strata, and a single crop of traditional long-duration rice variety in the third stratum. In some years, depending on hydrology, some fields in the third stratum are kept fallow. Relatively shorter duration rice varieties are used in the first and second strata. The average farm is about 3 ha. The average family comprises six members, of whom 2.5 persons are full-time farm workers (Gonzaga and Price 1980).

Agusan, Philippines. The site in Agusan is under the Agricultural Service Center component of an International Bank for Reconstruction and Development (IBRD)-funded Second Rural Development-Land Settlement Project in Agusan del Sur in southern Philippines. The settlement area is about 86 km south of Butuan City and 258 km north of Davao City. It is within the municipalities of Prosperidad, San Francisco, San Luis, and Talacogon with an area of 16,440 ha and a population of about 12,249, according to the 1978 Census (Villanueva 1981). The topography includes broken terrain with steep slope dissected by narrow, fast-flowing drainage canals, and patches of flatlands toward the north and east. The elevation ranges from 20 to 200 m above sea level. The site has rainfed lowland and upland rice culture.

The area has a humid climate with maximum rainfall from October to January, with only 3 months receiving less than 200 mm rainfall each. The average annual rainfall is 3,251 mm. The soils belong to the Butuan and Camansa series. The Butuan series includes fine clayey, deep, and poorly drained soils. The Camansa series is also clayey but moderately deep and well drained and is usually found on dryland hillsides (Sagun et al 1982). The soil pH ranges from 4.6 to 5.2.

The average farm is about 5.5 ha (Quisumbing 1981a). The inhabitants belong to four major ethnic groups — Ilongos, Boholanos, Cebuanos, and the Manobos. Farming is the major occupation, with subsistence farming predominating (Villanueva 1981). Road transportation is a problem in the area and agricultural products are transported by horse, carabao, and human labor. Rice, maize, rubber, and abaca are important crops.

Bukidnon, Philippines. The Bukidnon Settlement Project is another IBRD-funded Second Rural Development-Land Settlement Project in southern Philippines. The settlement covers the towns of Maramag, Pangantucan, and Kalilangan with approximately 36,000 ha (Gamila et al 1979). The topography mostly consists of rolling hills (15-37% slopes) with plateau upland and plain lowland. The area has an elevation of 500 to 1,100 m above sea level and a mean annual temperature of about 22°C. There are 6 wet and 3 dry months. The average annual rainfall is about 2,200 mm, usually falling in light but frequent showers. The site has a heavy-textured brown clay loam soil with a pH of about 4.77. Farms range from 2 to 12 ha with an average of 6.4 ha. The area has a population of 49,151 in 11,773 households (Gamila et al 1979). About 75% of the population are engaged in farming, 15% in business, 3% in handicrafts, 7% are employed elsewhere. About 56% of the area in the settlement is arable. The cultivated area is 18,000 ha, with 67% planted to maize and a considerable area under double-cropping. Upland rice and partially irrigated rice are grown on 4,000 ha and 1,200 ha, respectively. Other minor crops include coffee, root crops, vegetables, and legumes. Road communications are poor, and therefore, farm gate prices are well below central market prices.

Capiz, Philippines. The Capiz Settlement Project is an IBRD-funded Second Rural Development-Land Settlement Project in the northeastern part of Panay Island. The topography is generally upland with varying slopes (15-37%) to relatively flat land. The vegetation includes forests on upper slopes, grasses, and cultivated crops (Jereza et al 1979). The soil texture is silty clay loam with pH values ranging from 4.8 to 5.4. The annual average rainfall is about 2,400 mm with 8 wet months and 3 dry months (February to April). Farm sizes range from 0.5 to 5 ha and average 2.8 ha. Human, animal, and mechanical (tractor) power are used for crop production. Most of the areas grow a single rice crop and only a small percentage is planted to dryland crops such as maize, bean, peanut, cassava, and sweet potato. Research is focusing on crop intensification and higher crop yields.

Iri, South Korea. Iri is located in the southwestern part of the country at an elevation of 10 m above sea level. The site is classified as irrigated wetland with assured water supply (Kim 1981). The average annual rainfall is about 1,200 mm. The soil has a silty loam texture with a pH of 6. Power tillers are used for field operations. Cropping patterns include single cropping of rice and rice followed by wheat, barley, rape, onion, and pea.

Milyang, South Korea. Milyang is located in the southeastern part of the country betwen Daegu and Busan, the second and third largest cities in South Korea (Kim 1981). The elevation is about 13 m above sea level and the average annual rainfall is approximately 1,260 mm. The site has irrigated wetlands. The soil texture ranges from silty clay loam to clay with pH values from 5.6 to 6.0. The power tiller serves as the source of power. Rice, wheat, maize, and potato are grown at this irrigated site.

Suweon, South Korea. Suweon is located in the central part of the county at 37 m above sea level (Kim 1981). This site also has irrigated wetlands. The average annual rainfall is about 1,250 m. It has a sandy loam soil with a pH of 6. Farmers grow rice, barley, wheat, pea, potato, and rye.

Research sites in China. Scientists from the Chinese Academy of Agricultural Sciences (CAAS) participated in the ACSN meetings starting 1980. In 1982, China formally became a member of the IRRI-coordinated network. Three rice-based cropping systems research sites included in the network are Beijing, Hangzhou, and Changsha. At each site, a research team will record physical and climatic environment, evaluate the present cropping patterns, design and test new cropping patterns, and introduce new component technologies.

ACSN site management

An on-farm research site represents one or more major land types or agro-ecological environments of a wider target farming systems area. Selection of sites is based on the future cropping systems development potential, representativeness of the target area, operational facilities (including farmer cooperation), and other desirable characteristics.

A research team operates from an on-site office. Staffing depends on manpower availability and overall research setup in a program or country. Usually the site team comprises an agronomist, an economist, and three to four supporting field staff members. Entomologists, plant pathologists, soil scientists, and scientists from other disciplines usually work on a part-time basis for the site-specific cropping systems research.

Zandstra et al (1981) described in great detail the range of activities performed by a site research team. The major activities include benchmark surveys and monitoring activities to describe existing cropping systems, design and testing of improved cropping patterns and component technologies, identification of field problems, and evaluation of farmer feedback for future research. Usually a research center, headquarters, or regional office is used as a support base for site-specific, on-farm research. Some of the more acute technological problems that cannot be tackled at the site are taken to research stations for controlled experiments. In some cases, the potential cropping patterns for a site are initially tested at a relevant research station with recommended management practices or under simulated farmers' conditions. The research station also provides the team with training facilities, seed multiplication services, equipment and implements, and other administrative functions.

ON-FARM RESEARCH SETTING IN THE COUNTRY PROGRAMS

As cropping systems concepts and methodologies spread, more and more organizations are gradually adopting this approach to agricultural development. In Asian farming, a great part of which is crop production, this approach must be adopted if new knowledge and technology for increasing yields are to reach farms rapidly. In addition to ACSN research sites, there are national sites in Bangladesh, Burma, Indonesia, Malaysia, Nepal, Philippines, Sri Lanka, and Thailand. Research methodologies are similar.

Agroecological zones and research sites

On the basis of six rainfall patterns and seven soil groupings existing in South and Southeast Asia, Panabokke (1979) identified and demarcated 30 agroecological

zones (App. Tables 1, 2, and 3). He maintained that within each of these zones, the degree of transferability of agrotechnology should be high. But because the homogeneity in soil groupings and rainfall regimes within each agroecological zone varies, the degree of extrapolation of agrotechnology will be different for each zone. Locations of the cropping systems research sites in the respective agroecological zones are indicated in the country maps in the Appendix. This will help future extrapolation of research results from a research site to a similar area.

Bangladesh. Up to early 1982, cropping systems researchers in Bangladesh had established 36 specific sites to improve the productivity of farmers' cropping patterns and increase cropping intensity (App. Fig 1). BRRI, the leading cropping systems research organization in the country, started the program in 1974 and conducted on-farm research at six sites — Bhogra, Salna, Jarunbari, Laskarchala, Daudkandi, and Alimganj. All these sites, except Jarunbari, are in the ACSN The Directorate of Land and Water Use, Bangladesh Water Development Board (BWDB), conducted cropping systems research at 10 sites (Shimrail, Dharmicpara, Bheramara, Amla, Swastipur, Chandpur, Suk-Akcha, Durgapur, Kachubari, and Munshirhat) in collaboration with BRRI. Dharmicpara is included in the ACSN. The Bangladesh Agricultural Research Institute (BARI) started two sites (Hathazari and Bagherpara) in 1980. In the same year, the Bangladesh Jute Research Institute (BJRI) started two sites at Manikganj and Kishoreganj. Bangladesh Agricultural University (BAU) worked at Bahadurpur and in 1980 opened another site at Trishal. The Sugarcane Research Institute (SRI) has a site at Ishurdi. The Forestry Department under the Ministry of Agriculture and Forests conducted research on intensive mixed cropping at four agroforestry sites (Kaptai, Fasiakhali, Ukhiya, and Teknaf) with technical assistance from BRRI. A few voluntary organizations are also doing excellent work on site-specific cropping systems research in Bangladesh. Since 1979, the Mennonite Central Committee (MCC) has been working at Gunabati, Kalacha, and Charbata. The HEED (Health-Education-Economic Development)-Bangladesh has been working at three sites (Jugibeel, Radha Nagar, and Bharatpur) in the northeastern part of Bangladesh since 1979. The Christian Reformed World Relief Committee (CRWRC) has two research sites (Kathoum and Anantabala) in Bhogra District. The National Christian Council of Bangladesh (NCCB) has a site at Gournadi in tidal flood-affected areas. In addition to these voluntary agencies, the Cooperative American Relief Everywhere (CARE), in cooperation with the Bangladesh Krishi (Agricultural) Bank (BKB) and Bangladesh Agricultural Development Corporation (BADC) and with technical assistance from BRRI, is operating pilot production programs in four irrigated areas. BRRI organized two annual review meetings (June 1980 and September 1981) where all these organizations reviewed their progress and future plans for cropping systems work. The Bangladesh Agricultural Research Council (BARC) has now initiated a nationwide coordinated research project on cropping systems research and development.

Burma. In addition to the four ACSN research sites, the Agricultural Research Institute, under the Agricultural Corporation in Burma, conducts research at Hmawbi, Heho, and Kyetmauktaung (App. Fig. 2).

India. The agroecological zones in India and the location of the ACSN research site are in Appendix Figure 3.

Indonesia. The cropping systems researchers in Indonesia have established 25 on-farm research sites (App. Fig. 4). Nine are in Java, one in Madura, nine in Sumatra, two in South Kalimantan, three in South Sulawesi, and one in East Timur. Six of these sites operated by CRIFC are included in the ACSN.

Malaysia. In addition to the three ACSN sites, scientists of MARDI work at Alor Star, Parit, Batu Berendam, and Negeri Sembilan in West Malaysia (App. Fig. 5).

Nepal. In addition to the ASCN sites, the Department of Agriculture has sites at Lele, Khandbari, Ratna Nagar, and Chauri Jhari (App. Fig. 6).

Philippines. By early 1982, cropping systems scientists from IRRI and the Philippine Ministry of Agriculture had established about 33 on-farm research sites (App. Fig. 7). Twenty-six are non-ACSN sites. Guimbal, Janiuay, and Sara in Iloilo Province are under the well-known KABSAKA (Kabusugan sa Kaumahan or KABSAKA-SALUD-ULAN) project. The Cagayan Integrated Agricultural Development Project (CIADP), which receives Japanese technical assistance, works in the low-lying *bangkag* areas at Solana. Betinan is under the Philippine-Australian Development Assistance Program (PADAP). The Bicol River Basin Development Project - Farming Systems Development Project (BRBDP-PSDP) has sites at Nabua, San Fernando, Ocampo, and Polangui. Catubig, Lope de Vega, and Pambujan in Samar are under the Samar Integrated Rural Development Program (SIRDP). The Eastern Visayas Farming Systems Program conducts cropping systems research in Gandara, Matalom, Jaro, Villaba, Bontoc, and Basey. The Rainfed Agriculture Development Outreach Sites (RADOS) include Vigan, Santa Barbara, Carmen, Abuyog, Naujan, Magsaysay, Tantangan, and Matalam. The research sites at Brooke's Point and Aborlan are under the Palawan Integrated Agricultural Development Project (PIADP).

Sri Lanka. The Department of Agriculture administers, in addition to the ACSN sites, sites at Mahaweli, Bandarawela, Karadiyan Aru, Mannar, and Angunakolapellesa (App. Fig. 8).

Thailand. Khon Kaen University (KKU) and Chiang Mai University each have one site in addition to the ACSN sites (App. Fig. 9).

CLASSIFICATION OF CROPPING SYSTEMS RESEARCH SITES

Almost all cropping systems research sites are rice-based, that is, at least one rice crop is grown annually. The cropping systems research sites in Asia are broadly classified on the basis of type of rice culture, hydrology, water management, and topography into eight categories. Individual sites may fall into more than one category.

Rainfed wetland sites

In rainfed wetland sites, rice is grown on puddled soil in fields bounded by dikes capable of ponding water to about 30 cm. The water depth in the fields seldom exceeds 30 cm. These sites receive no irrigation. Depending on the amount and

distribution of rainfall over the year, one or two puddled wetland rice crops are grown. Nonrice crops may be grown before or after the wetland rice.

Fifty-six (41%) of the 137 sites are in this category, indicating the importance of cropping systems research in rainfed wetland areas. There are 8 sites in Bangladesh, 3 in Burma, 1 in India, 8 in Indonesia, 4 in Sri Lanka, 6 in Thailand, 4 in Nepal, and 22 in the Philippines. As shown in Table 3.1, these sites are scattered in 19 agroecological zones.

Irrigated wetland sites

The irrigated wetland sites may have year-round or seasonal irrigation facilities. In the dry season, rice may be grown with irrigation. One to three rice crops may be grown on the same land in a year. The fields usually have well maintained dikes that can hold 30 cm water. During the rice-growing season, the fields may be flooded for weeks within this depth. The water depth may temporarily exceed 30 cm when rains are excessive. Where one to two rice crops are grown on the same land in a year, other nonrice crops, particularly high-value crops, are grown with irrigation in rice-based patterns. There are 41 irrigated wetland sites scattered in 14 agroecological zones (Table 3.2).

Rainfed dryland sites

The rainfed dryland sites depend on rainfall for crop production. Water does not accumulate on the land because rainwater runoff or infiltration is high. Most of these sites have sloping lands or higher elevations than surrounding areas. Upland rice varieties are grown in fields prepared and seeded under dry conditions. Nonrice dryland crops are important at these sites and are grown in the wet and dry seasons. There are 51 rainfed dryland cropping systems research sites scattered in 15 agroecological zones (Table 3.3).

Irrigated dryland sites

In the irrigated dryland sites, water does not accumulate and irrigation is used mainly for dryland crops such as wheat, maize, sugarcane, and other high-value crops. Upland rice may also be grown with intermittent irrigation. The source of irrigation water may be deep tubewells, streams flowing with water from a higher elevation, or reservoirs from where water is lifted with pumps. There are 13 research sites in this category: Bagherpara, Kachubari, Suk-Akcha, Munshirhat, Durgapur, Trishal, Ishurdi, and Laskarchala in Bangladesh; Ketmauktaung in Burma; and Pumdi Bhumdi, Chauri Jhari, Lele, and Ratna Nagar in Nepal.

Deepwater sites

The deepwater sites are located in areas where water depth is higher than 1 m. Depth may reach up to 6 m at certain times during the deepwater rice (DWR) growing season. DWR is direct seeded under rainfed conditions or may be transplanted if irrigation is available. In the rainfed areas, after DWR harvest the land becomes dry and may be planted to dryland crops which use the residual soil moisture. With irrigation, DWR may follow a dry-season irrigated rice crop or any other high-value dryland crops. So far, researchers have done work on DWR-

Table 3.1. An inventory of rainfed wetland cropping systems research sites.

Agroecological zone	Site
R_1S_1	Agusan, Philippines
R_1S_2	Abuyog, Philippines Catubig, Philippines
R_1S_4	Cibarusa, Indonesia Serang, Indonesia Lope de Vega, Philippines Pambujan, Philippines
R_2S_1	Bharatpur, Bangladesh Radha Nagar, Bangladesh
R_2S_3	Tantangan, Philippines
R_2S_5	San Fernando, Philippines Matalam, Philippines
R_2S_6	Bukidnon, Philippines Betinan, Philippines Carmen, Philippines Naujan, Philippines Magseysay, Philippines
R_3S_1	Charbata, Bangladesh Wakema, Burma
R_3S_5	Katupotha, Sri Lanka[b]
R_3S_6	Hathazari, Bangladesh Demak, Indonesia Phree, Thailand Solana, Philippines Capiz, Philippines Sara, Philippines
R_3S[a]	Maros, Indonesia Wajo, Indonesia
R_4S_1	Gunabati, Bangladesh Hmawbi, Burma Vigan, Philippines
R_4S_6	Bhogra, Bangladesh Ranchi, India
R_5S_1	Chandpur, Bangladesh Alimganj, Bangladesh Ubon, Thailand Bangpae, Thailand
R_5S_3	Pangasinan, Philippines Guimbal, Philippines Janiuay, Philippines Sta. Barbara, Philippines
R_5S_4	Iloilo, Philippines
R_5S_5	Pyinmana, Burma Pati, Indonesia Sampang, Indonesia Karadian Aru, Sri Lanka[b] Pimai, Thailand Kampangphet, Thailand

Continued on opposite page

Table 3.1. continued

Agroecological zone	Site
R_5S_6	Paranthan, Sri Lanka[b] Mannar, Sri Lanka[b]
R_6S_1	Khon Kaen, Thailand
Areas not covered by present agroecological classification	Atambua, Indonesia Parsa, Nepal, Lele, Nepal Khandbari, Nepal Ratna Nagar, Nepal

[a]Soil-grouping information not available. [b]Has a bimodal rainfall pattern.

Table 3.2. An inventory of irrigated wetland cropping systems research sites.

Agroecological zone	Site
R_1S_1	Batu Berendam, Malaysia
R_1S_6	Polangui, Philippines Negeri Sembilan, Malaysia
R_2S_1	Jugibeel, Bangladesh Besut, Malaysia
R_2S_5	San Fernando, Philippines
R_3S_1	Parit, Malaysia Tanjung Karang, Malaysia
R_3S_5	Bandarawela, Sri Lanka[a]
R_3S_6	Alor Star, Malaysia Kuala Brang, Malaysia
R_4S_1	Gournadi, Bangladesh Manikganj, Bangladesh Bahadurpur, Bangladesh North Nawin, Burma
R_4S_6	Shimrail, Bangladesh Saina, Bangladesh Laskarchala, Bangladesh
R_5S_1	Amla, Bangladesh Bheramara, Bangladesh Swastipur, Bangladesh Kathoum, Bangladesh Indramayu, Indonesia
R_5S_3	Pangasinan, Philippines
R_5S_4	Iloilo, Philippines
R_5S_5	Sedawgyi, Burma Pyinmana, Burma Walagambahuwa, Sri Lanka[a] Mahaweli, Sri Lanka[a] Angunakolapelessa, Sri Lanka[a] Karadian Aru, Sri Lanka[a]

Continued on next page

Table 3.2. continued

Agroecological zone	Site
R_6S_6	Mannar, Sri Lanka[a] Chiang Mai, Thailand
Areas not covered by present agroecological classification	Beijing, China Changsha, China Hangzhou, China Iri, South Korea Milyang, South Korea Suweon, South Korea Parsa, Nepal Khandbari, Nepal

[a]Has a bimodal rainfall pattern.

Table 3.3. An inventory of rainfed upland cropping systems research sites.

Agroecological zone	Site
R_1S_1	Agusan, Philippines
R_1S_3	Basey, Philippines Jaro, Philippines Villaba, Philippines Catubig, Philippines
R_1S_6	Karangpucung, Indonesia Way Abung, Indonesia Batu raja, Indonesia Lahat, Indonesia Sitiung, Indonesia Katanegara, Indonesia Pematang Panggang, Indonesia Tulang Bawang, Indonesia Bandar Jaya, Indonesia Tajau Pecah, Indonesia Nabue, Philippines Ocampo, Philippines Gandara, Philippines Lope de Vega, Philippines Pambujan, Philippines
R_2S_3	Tantangan, Philippines
R_2S_6	Pasirpangarayan, Indonesia Bukidnon, Philippines Betinan, Philippines Magsaysay, Philippines Matalom, Philippines Bontoc, Philippines
R_3S_1	Trishal, Bangladesh Kishoreganj, Bangladesh
R_3S_3	Aborlan, Philippines
R_3S_6	Kulon Progo, Indonesia Gunung Kidul, Indonesia

Continued on opposite page

Table 3.3. continued

Agroecological zone	Site
R_3S_6	Hathazari, Bangladesh Panawangan, Indonesia Demak, Indonesia Capiz, Philippines
R_3S[a]	Wajo, Indonesia Wawatobi, Indonesia
R_4S_6	Heho, Burma Ranchi, India
R_5S_1	Bagherpara, Bangladesh Anantabala, Bangladesh Alimganj, Bangladesh
R_5S_3	Batangas, Philippines
R_5S_5	Sampang, Indonesia Angunakolapelessa, Sri Lanka[b] Brooke's Point, Philippines
R_6S_1	Khon Kaen, Thailand
Areas not covered by present agroecological classification	Atambau, Indonesia Pumdi Bhumdi, Nepal Chauri Jheri, Nepal

[a]Soil-grouping information not available. [b]Has a bimodal rainfall pattern.

based cropping systems only in Bangladesh. The four research sites include Daudkandi and Kalacha (R_4S_1) and Dharmicpara and Jarunbari (R_4S_6).

Tidal swamp sites

The tidal swamp sites are located in low-elevation areas and are affected by tidal flooding. Soil problems are encountered and mainly indigenous local rice varieties are grown. Growing dryland crops requires special management and care. At present, two cropping systems research sites are operational in the tidal swamp areas at Barambai in South Kalimantan, Indonesia (R_1S_7), and Gournadi, Bangladesh (R_4S_1).

Agroforestry sites

In the agroforestry sites, the topography is undulating or has slopes of varying degrees. Various dryland crops, including rice, are intensively mixed and intercropped under permanent plantation crops or forest trees. At the Khon Kaen site in Thailand (R_6S_1), dryland crops such as cassava, peanut, and sesame are grown under forest trees. In Bangladesh, the four agroforestry sites are at Kaptai (R_4S_6), Fasiakhali, Ukhiya, and Teknaf (R_3S_6). In the Philippines, agroforestry research is done at Jaro (R_1S_3), Basey (R_1S_3), and Bontoc (R_2S_6).

Hill agriculture sites

These are high-altitude (700-1,500 m above sea level) terraced sites. The individual fields have strong dikes that can hold rainwater or water flowing through streamlets from higher areas up to a depth of about 30 cm. Rainfed

wetland or partially irrigated wetland rice crops are grown in the terraced paddies as well as dryland crops such as maize, millet, sorghum, potato, etc. Because of low temperatures, these sites have potential for year-round vegetable production. The four sites in the hills of Nepal are Pumdi Bhumdi, Chauri Jhari, Lele, and Khandbari. Their elevations above sea level are 750-1,270 m, 700 m, 1,300-1,500 m, and 462-1,077 m, respectively (Malla and Manzano 1981). In Sri Lanka, Bandarawela, at 1,300 m above sea level, is the hill site. It is characterized by Red-Yellow Podzolic soils and an annual rainfall of about 1,150 mm (Fernando et al 1982). Lowest temperatures (12-14° C) are experienced from January to March and increase to 15-17° C in April through December. The land includes paddy tracts on terraced mountain sides and in broad valleys with vegetables on adjacent mountain sides.

Chapter 4

TRADITIONAL CROPPING SYSTEMS IN ASIA

About 58% of the Asian population is agricultural (FAO 1981), making agriculture the most important source of livelihood. Traditional agriculture for these subsistence farmers has been a way of life for centuries. Only recently have improvements been introduced to farmers in some areas.

Cropping systems research is relatively new. It emphasizes an understanding of traditional systems that exist in different agroecological and socioeconomic environments. ACSN scientists consider descriptive research a prerequisite to developmental research and future promotional activities. Based on the information from research sites, particularly those under the ACSN, I present a description of existing cropping systems.

CHARACTERISTICS OF A TYPICAL ASIAN FARMER

An average Asian farmer lives with his wife and four children on an approximately 1.5-ha farm. In good years he produces 4 t of rough rice equivalent food for year-round subsistence. Production of cash crops and family labor for off-farm cash income largely depend on the amount of food produced and labor required to produce it. The farmer always gives first priority to his family food supply.

A wooden plow with a steel shear is the symbol of a farmer's life. Other farm implements are a harrow made of wood or bamboo, a spade, weeding hoes, harvesting sickles, baskets, and a few gunny sacks. The family raises several chickens and ducks and owns one or two draft animals. A compost pit or heap in the homestead provides organic manures. The farm has about two full-time family laborers who are occasionally loaned to neighbors at the peak of rice transplanting and harvesting. The farmer usually stores seeds in a traditional method, but he may use them for food during famine. Cash is the most scarce resource on his farm and it is very difficult to get credit.

Over the centuries the farmer has developed traditional cropping systems through trial and error. While the productivity of his system is, in general, low, stability and rate of economic return are usually high. The farmer is a rational decision maker and uses his limited resources effectively. He is not particularly responsive to price changes of the crops the family consumes, but he is responsive to prices of cash crops (Banta 1980). In general, he is quick to adopt new technologies that can significantly increase his food supply and cash income if he gets the required resources.

Major constraints that put a majority of small farmers at a socioeconomic disadvantage are the land tenure systems, fragmentation of landholdings, lack of appropriate improved technologies, and lack of suitable credit and marketing programs that can serve as production incentives and bring the small farms into the stream of a market-oriented economy. Despite their sharing constraints, the

farms are not homogenous. About 25% of the farms are less than 0.5 ha in size; 20%, between 0.5 and 1 ha; 22%, between 1 and 2 ha; and 33%, above 2 ha (Harwood and Price 1976). The farms differ in available resources, productivity, needs, institutional government support, and production constraints.

Wide yield gaps are commonly observed, which suggests a need for sharing better technologies between high yielding and low yielding farms. Government policymakers and agricultural agencies must provide support to farmers for this technology adoption. The major focus of cropping systems research should be the development of technology that can efficiently utilize limited resources.

MAJOR FIELD CROPS IN ASIA

Almost 90% of the world rice-growing area is in Asia (Table 4.1). The rice area in South and Southeast Asia is about 62% of the world total, but rice yield is lower there than in East Asia.

The other major field crops include wheat, maize, sorghum, millet (App. Table 4); roots and tubers (App. Table 5); pulses and oil seeds (App. Table 6); sugarcane, jute, cotton, and tobacco (App. Table 7).

CROPPING SYSTEMS IN RAINFED WETLAND AREAS

Rainfed wetland rice-based cropping systems are extensively practiced throughout South and Southeast Asia. Some 35% of the riceland is in this category, but accounts for only 28% of total rice output (Huke 1982). Climatic and soil conditions are extremely variable and droughts and floods are frequent. Because large-scale water development projects for most areas are not expected in the near future, practical cropping systems research and development programs are urgently needed.

Land-use patterns

Table 4.2 presents the rice-based cropping patterns commonly grown in several rainfed wetland areas. Single and double cropping of rice is most predominant. During the main rainy season, use of modern varieties (MV) has been widespread, although in many cases there are physical and socioeconomic constraints to their potential spread. After a rainfed rice crop, farmers grow wheat, maize, barley, millet, pulses, and oil seeds with residual soil moisture. In other cases, jute, maize, and mungbean are also grown during the early part of the rainy season, before the rice is transplanted. Farmers in several areas also practice intensive multiple cropping with three- or four-crop patterns under rainfed wetland conditions (Table 4.2). Mixed cropping, intercropping, and relay cropping are practiced, particularly in the dry season, to avoid total crop failures.

Input level and crop management practices

In general, input levels for the rainfed wetland crops are low. However, when high yielding crops, such as rice, maize, and wheat, are grown, farmers usually try to apply moderate levels of inputs, particularly fertilizers. When planting rice, much

Table 4.1. Area and production of rice in the world.[a]

Location	Area		Production (rough rice)	
	thousand ha	% of world total	thousand t	% of world total
East Asia	39 583	27.5	168 778	43.7
China	34 400	23.9	140 001	36.2
Taiwan, China	704	0.5	3 181	0.8
Japan	2 474	1.7	14 291	3.7
Korea, North	773	0.5	4 333	1.1
Korea, South	1 232	0.9	6 972	1.8
Southeast Asia	34 722	24.1	77 122	20.0
Burma	4 751	3.3	10 578	2.7
Indonesia	8 917	6.2	27 276	7.1
Kampuchea	1 307	0.9	1 356	0.4
Laos	690	0.5	973	0.3
Malaysia	680	0.5	1 894	0.5
Philippines	3 521	2.4	7 585	2.0
Thailand	9 449	6.6	17 253	4.4
Vietnam	5 407	3.7	10 207	2.6
South Asia	54 059	37.5	103 731	26.8
Bangladesh	10 233	7.1	19 952	5.2
India	39 749	27.6	74 770	19.3
Nepal	1 257	0.9	2 288	0.6
Pakistan	1 991	1.4	4 780	1.2
Sri Lanka	784	0.5	1 941	0.5
West Asia and North Africa	1 079	0.7	4 581	1.2
North Africa	433	0.3	2 440	0.6
West Asia	646	0.4	2 141	0.6
SubSahara Africa	4 150	2.9	5 763	1.5
West Africa	2 338	1.6	2 960	0.8
Central & East Africa	1 812	1.3	2 803	0.7
Europe	379	0.3	1 907	0.5
USSR	619	0.4	2 429	0.6
Latin America	8 228	5.7	15 217	3.9
Brazil	6 169	4.3	8 721	2.2
Others	2 059	1.4	6 496	1.7
USA and Oceania	1 345	0.9	6 906	1.8
USA	1 235	0.8	6 218	1.6
Oceania	110	0.1	688	0.2
World	144 [illegible]4	100.0	386 434	100.0

[a]Palacpac (1982).

care is taken in land preparation, weeding, and rainwater management. However, the secondary crops grown before or after rice usually receive very low levels of input and management. In some cases, seeding and harvesting are the major field operations in the production of minor crops, such as mungbean, cowpea, blackgram, lentil, and mustard.

Table 4.3 presents data on input levels and management practices for the first and second rice crops in the rainfed wetland areas at Bhogra, Bangladesh (Hoque and Hobbs 1980). In both seasons there were not many land preparation differences between the local and modern rice varieties. Farmers used younger

Table 4.2. Traditional cropping patterns in several rainfed wetland areas in Asia.

Cropping pattern	Sites where cropping pattern is grown	Sources of site-specific information
Rice	Alimganj, Bangladesh	Hoque et al (1981a)
	Bhogra, Bangladesh	Hoque and Hobbs (1978)
	Radha Nagar, Bangladesh	Paul et al (1981)
	Paranthan, Sri Lanka	Fernando (1978)
	Walagambahuwa, Sri Lanka	Fernando (1978)
	Parsa, Nepal	CSP, Nepal (1981)
	Ubon, Thailand	Chandrapanya (1978)
	Pimai, Thailand	Chandrapanya (1978)
	Phrae, Thailand	Chandrapanya (1981b)
	Solana, Philippines	Gines et al (1980)
	Iloilo, Philippines	Carangal (1977b)
	Pangasinan, Philippines	Carangal (1977b)
Rice - rice	Bhogra	
	Alimganj	
	Gunabati, Bangladesh	Dick et al (1981)
	Charbata, Bangladesh	Godshalk (1981)
	Bharatpur, Bangladesh	Paul et al (1981)
	Katupotha, Sri Lanka	Fernando (1978)
	Agusan, Philippines	Quisumbing (1981a)
	Capiz, Philippines	Quisumbing (1981a)
	Iloilo, Philippines	Quisumbing (1981a)
	Bukidnon, Philippines	Quisumbing (1981a)
Rice - wheat	Ranchi, India	Pendleton et al (1981)
	Alimganj	
	Ratna Nagar, Nepal	CSP, Nepal (1981)
Rice - barley	Ranchi	
	Alimganj	
Rice - maize	Ranchi	Saing et al (1980)
	Wakema, Burma	
Rice - finger millet	Parsa	
Rice - mungbean	Pangasinan	
	Iloilo	
	Bangpae, Thailand	Pookpakdi (1980)
	Sampang, Indonesia	Ismail and Effendi (1980)
Rice - chickpea	Ranchi	
	Alimganj	
	Pyinmana, Burma	Saing et al (1980)
Rice - cowpea	Wakema	
Rice - blackgram	Wakema	
Rice - lentil	Ranchi	
Rice - peanut	Wakema	
Rice - mustard	Ranchi	
	Ratna Nagar	
Rice - sunflower	Wakema	
	Pyinmana	
Rice - sesama	Wakema	
Jute - rice	Wakema	
Green maize - rice	Pyinmana	
Blackgram - rice	Pyinmana	
Mungbean - rice	Solana	
Rice - rice - chickpea	Alimganj	
Rice - maize - peanut	Sampang	
Maize - rice - mungbean	Pangasinan	
Rice - rice - barley + chickpea	Alimganj	

Table 4.3. Levels of input and management for rainfed first and second rice crops at Bhogra, Dhaka, Bangladesh, 1976-1978.[a]

	1976		1977		1978	
	Local varieties	MV[b]	Local varieties	MV	Local varieties	MV
			1st rice crop (aus)			
% plots	38	62	15	85	3	97
% transplanted	12	100	100	100	100	100
No. plowings, ladderings	4, 4	5, 5	5, 3	5, 4	6, 3	5, 4
Transplanting date	14 Jun[c] (1 May[d])	22 May	14 May	19 May	19 Jun	30 May
Seedling age (d)	26	36	25	32	20	36
% farmers using NPK	63-25-0	100-65-10	56-0-0	79-49-26	50-0-0	100-50-25
kg N-P_2O_5-K_2O/ha[e]	27-42-0	51-44-25	49-0-0	61-40-29	62-0-0	59-36-20
Weeding (av no.)	0.17	1.08	0.56	0.71	0	1.0
% farmers using insecticide	0	40	11	27	0	24
Field duration (d)	75[c] (81[d])	97	70	101	67	91
			2nd rice crop (t. aman)			
% plots	74	26	60	40	71	29
No. plowings, ladderings	5, 4	5, 5	4, 5	5, 5	4, 5	4, 5
Transplanting date	28 Aug	3 Aug	2 Sep	18 Aug	13 Sep	23 Aug
Seedling age (d)	44	34	40	33	57	44
% farmers using NPK	93-43-9	95-35-13	85-35-13	97-45-23	100-59-16	100-65-13
kg N-P_2O_5-K_2O/ha[e]	38-33-13	54-28-22	40-32-32	52-32-32	42-32-33	69-39-20
Weedings (av no.)	0.14	0.50	0.13	0.55	0.16	0.56
% farmers using insecticide	11	65	7	6	23	65
Field duration (d)	101	120	108	115	88	107

[a]Hoque and Hobbs (1980). [b]MV = modern varieties. [c]For transplanted crop. [d]For direct-seeded crop. [e]Average application rate.

seedlings of local varieties (20-26 d old) of shorter maturity (67-75 d) in the aus season, compared with the MVs transplanted with older seedlings (32-36 d old). During the t. aman season, younger seedlings were used for the MVs, while older seedlings were used for the local photoperiod-sensitive varieties. More farmers applied fertilizers and the average rates of NPK fertilizers were higher in both seasons for the MVs than for the local varieties (Table 4.3). MVs received more weed control and insecticides than the local varieties.

Power and labor use

In the rainfed wetland, farmers widely use draft animals as the power source for land preparation and, in India and Bangladesh, for threshing by trampling. However, power tillers and threshers have been introduced in many areas, particularly where modern rice and wheat varieties have affected total production. Human labor mostly does other field work. At Bhogra, the labor requirements for the first rainfed transplanted rice (aus) crop were 652 h/ha and, for the second (aman), 600 h/ha (Hoque and Hobbs 1980). The aus crop required 176 h/ha for land preparation, 184 for transplanting, and 165 for weeding and harvesting; plus 19 h for trimming dikes, 13 for fertilizer application, and 3 for insecticide application. The labor requirements for the t. aman crop were 161 h/ha for land preparation, 27 for trimming dikes, 7 for fertilizer application, 189 for transplanting, 108 for weeding, 4 for insecticide application, and 172 for harvesting. Labor costs were $78/ha for the first rainfed rice crop and $68 for the second crop (Hoque and Hobbs 1980). The second rice crop required less labor for land preparation and weeding.

At the rainfed wetland site in Katupotha, Sri Lanka, the maha-season rice required about 560 h in the Alankara paddy tract and 832 h in the Moragane paddy tract (Fernando 1978). The return per hour of labor was about $0.13/ha at Alankara and $0.15 at Moragane. During the yala season, the labor requirements were 928 h at Alankara and 408 h at Moragane. Corresponding rates of return to labor were $0.04/h at Alankara and $0.15 at Moragane (Fernando 1978).

In the Iloilo areas of the Philippines, a single crop of rainfed wetland rice required 1,154 h/ha (Roxas 1977). The distribution of labor requirements was 2% for nursery management, 18% for land preparation, 22% for transplanting, 1% for fertilizing, 1% for pesticide application, 2% for hand weeding, 6% for other operations, and 48% for harvesting - threshing. For the rice - rice pattern, 2,180 h/ha were needed, of which 16% was spent for land preparation; 18% for transplanting; 1% each for nursery management, fertilizer application, and pesticide application; 3% for hand weeding; and 60% for harvesting - threshing (Roxas 1977). The rice - dryland crops pattern required 1,790 h/ha, of which 11% was spent for land preparation; 9% for transplanting; 1% each for nursery management, pesticide application, and miscellaneous work; 3% for hand weeding; and 74% for harvesting - threshing (Roxas 1977). Labor requirements were 2,351 h/ha for a rice - rice pattern at a shallow water table site (Pangasinan, Philippines) and 2,255 h for a rice - dryland crop (mainly mungbean) pattern (Gines et al 1978).

Cropping pattern productivity and profitability

In the rainfed wetlands of Bangladesh, farmers traditionally have a rice - rice cropping pattern. In most areas, the first rice crop is direct seeded, followed by a transplanted rice crop. However, at Bhogra, farmers have been transplanting both crops for the last several years. In 1976, a rice - rice pattern with local varieties (Pukhi and Nizersail) produced an average 4.4 t/ha, 1.8 t/ha from the first rice crop (Pukhi), and 2.6 t/ha from the second crop (Nizersail). The Pukhi-Pajam variety combination gave 1.9 plus 2.3 t/ha, the Chandina-Nizersail combination produced 2.8 plus 2.2 t/ha and the IR8-Nizersail, 3.5 plus 3.2 t/ha (Hoque 1978). Thus, the total production from the rice - rice pattern at this rainfed wetland site in 1976 ranged from 4.1 to 6.7 t/ha depending on the rice varietal combination. In 1979, farmer yields during the aus season were about 2.5 t/ha from the local varieties and 4.0 t/ha from the MVs, with corresponding net returns of $485/ha for the local varieties and $735 for the MVs (Hoque et al 1980a). During the t. aman season, the yields were about 2.3 t/ha for Nizersail, 3.7 t for Pajam, and 5.3 t for BR3. Corresponding net returns were $324/ha for Nizersail, $665 for Pajam, and $927 for BR3. Farmers obtained higher yields and net returns from the MVs during both seasons.

At the Radha Nagar site in northeastern Bangladesh, farmers traditionally grow a single rainfed t. aman rice crop. Heavy rainfall causes occasional flash floods. In 1980, rice yields ranged from 1.8 to 4.8 t/ha depending on variety and management (Paul et al 1981). Biroin averaged 1.8 t/ha; Balam, 2.5 t; Latisail, 2.8 t; and BR4, 4.8 t. However, farmers grew Latisail and Balam on about 90% of the fields because of their fine grain quality.

At the rainfed wetland site in Bharatpur, Bangladesh, the yields from the medium-duration MV rice - local rice pattern were about 6.6 t/ha in 1979 and 6.8 t/ha in 1980 (Paul et al 1981). The yields from the long-duration MV rice - local rice pattern were 7.0 t/ha in 1979 and 8.3 t/ha in 1980. The local rice - local rice pattern produced about 4.3 t/ha in 1979 and 5.1 t/ha in 1980. In 1980, farmers grew the local rice - MV rice pattern and got an average 6.7 t/ha; a single crop of local aman rice averaged 2.5 t/ha. The annual rainfall at this site was higher in 1980 than in 1979. In 1979, rain did not start till early June (normally it starts in April). The average rice yield in 1979 at Bharatpur was about 5.1 t/ha compared with 6.8 t/ha in 1980 (Paul et al 1981).

In the 1976-77 rainy maha season at Katupotha, Sri Lanka, the harvest averaged about 0.8 t/ha in the Alankara paddy tract and 1.7 t/ha in the Moragane paddy tract. The corresponding average yields during the dry yala season were 0.8 t/ha at Alankara and 1.5 t/ha at Moragane (Fernando 1978). BG94-1 outyielded all other varieties, averaging 2.5 t/ha at Moragane during the maha season and 1.1 t/ha at Alankara and 1.8 t/ha at Moragane during the yala season (Fernando 1978).

Roxas (1977) reported an average 3.4 t/ha for the 1976-77 single wet-seeded rice crop pattern in the Iloilo areas of the Philippines. The average yield from a single crop of transplanted rice was about 2.0 t/ha. The material costs were $41/ha; labor costs, $127; and the net returns, $322 for the wet-seeded rice crop. For the transplanted rice, the material costs were about $21/ha; labor costs, $106; and net

returns, $137. The 1976-77 wet-seeded rice crop appeared to be more successful than the transplanted rice crop at Iloilo.

In 1976-77, based on the monitoring data on 25 fields at Iloilo, the rice - rice pattern averaged 2.3 t/ha for the first crop and 1.7 t for the second rice crop (Roxas 1977). The pattern had a variable cost of $306/ha ($84 material cost plus $222 labor cost) with a net return of $249/ha. The wet-seeded rice - mungbean pattern yielded 2.0 t rice/ha and 0.3 t mungbean; the variable cost was $152/ha and net returns were $192/ha. The transplanted rice - mungbean pattern yielded about 2.1 t rice/ha but a very low 0.05 t mungbean/ha. This pattern had a net return of $199/ha with a total variable cost of $142/ha. The transplanted rice - cowpea pattern produced about 3.0 t rice/ha and 0.8 t cowpea/ha. This pattern had a net return of $291/ha and a variable cost of $250/ha. The transplanted rice - maize pattern yielded a satisfactory 2.0 t rice/ha but a very poor 0.02 t maize/ha, resulting in a net return of $123/ha and a variable cost of $176/ha (Roxas 1977).

In 1975-76, the economic performance of a single rice cropping pattern was monitored in 34 fields at the Pangasinan site in the Philippines. On an average, the cash costs were $53/ha; labor costs, $88; and net return above total variable costs, $113 (Price 1977). The total variable costs for the rice - mungbean with tillage (27 fields) were $219/ha, rice - mungbean without tillage (12 fields) $164, and rice - tomato (15 fields) $330. The corresponding net returns above variable costs for these cropping patterns were $274, $304, and $404/ha (Price 1977). The highest benefit-cost ratio (2.85) was obtained for rice - mungbean without tillage followed by 2.25 for rice - mungbean with tillage.

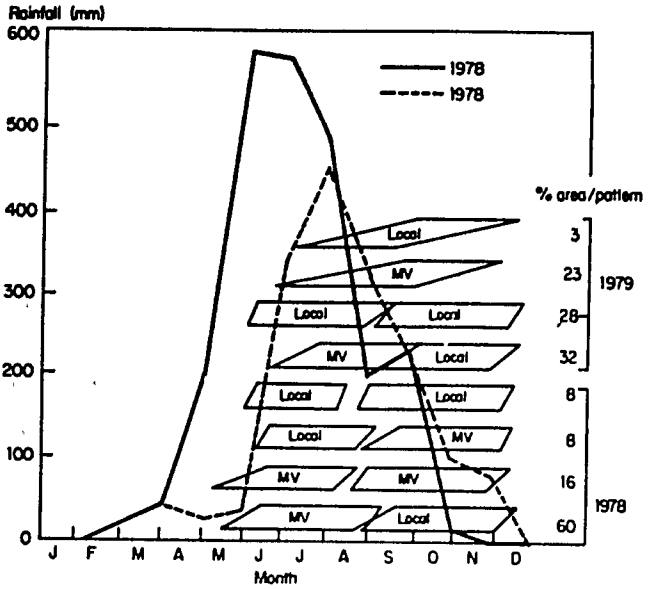
In 1977-78, the agroeconomic performance of a transplanted rice - transplanted rice pattern was monitored in 27 fields at the Agusan Settlement areas in the Philippines. The average yields in this pattern were 1.0 t/ha for the first rice crop and 1.2 t/ha for the second (Sagun et al 1979). The pattern had a variable cost of $107/ha, including $23 for labor, $9 for power, $24 for materials, and $51 for miscellaneous items. The net return from this rice - rice pattern was about $178/ha.

Based on the above descriptions, the productivity and rate of return to cash, labor, and land in the rainfed wetland situation vary considerably depending on cropping pattern, production investment, and environment.

Factors affecting crop production

Several factors affect cropping patterns and yields in the rainfed wetlands.

Rainfall pattern. In a monsoon climate, time of onset and end of rains can influence the cropping patterns. Also the rainfall amount and distribution determine the yields of rainfed crops. For example, the rainfall and cropping patterns at Bhogra in 1978 and 1979 are in Figure 4.1. It is clear that the delayed onset of rains in 1979 brought about drastic changes in the cropping patterns (Hoque et al 1982a). The patterns, local aus rice - MV t. aman rice and MV aus rice - MV t. aman rice, followed by farmers in previous years, were not grown in 1979. Instead, a single MV rice crop or a single local rice was grown due to the rainfall change (Fig. 4.1).



4.1. Rainfall and rice cropping patterns in 1978 and 1979 at the rainfed double rice-cropped site at Bhogra, Dhaka, Bangladesh (Hoque et al 1982). Area under other cropping patterns not shown in figure: 1978 = 8%, 1979 = 14%.

Drought. Drought at the beginning or end of the rainy season affects the growth of the first rice crop and the performance of the second crop in the rainfed wetland areas. In some cases, severe drought causes a total crop failure. At the Walagambahuwa minor tank area, farmers with technical assistance from the Sri Lankan cropping systems scientists had been growing two rice crops annually since 1976-77. A severe drought in 1981-82 dry season caused a complete crop failure at this site. There are vast rainfed wetland areas in Asia where just partial irrigation will not only prevent total crop failure, but will also significantly increase the production and income.

Floods. Heavy rains with or without typhoons subject many rainfed areas in South and Southeast Asia to flash floods. This causes damage to both the rice and nonrice crops. At the IRRI research site at Solana in 1981 and 1982, floods damaged rice seedbeds as well as transplanted rice seedlings. The mungbean crop grown before the monsoon rice crop was totally wiped out in many fields, particularly in the lower part of the toposequence. At Radha Nagar, Bangladesh, flash floods often cause total failure of the single rice crop.

Crop establishment. Inadequate rainfall at the beginning of the growing season creates difficulties in establishing the first crop in rainfed wetlands. Excess rainfall affects the establishment of direct-seeded or wet-seeded rice as well as nonrice crops such as mungbean and maize. The amount of residual soil moisture after the harvest of the rainy-season rice crop also determines the feasibility of establishing nonrice crops.

Lack of suitable varieties. The development of varieties of rice and other crops for the rainfed wetlands has been, in general, inadequate. Farmers need rice varieties tolerant of drought and flooding at different growth stages and varieties of dryland crops tolerant of drought and excess moisture.

Institutional support. In general, the farmers in the rainfed wetland areas have received little input supplies and other support services such as credit, crop insurance, and price support. Well-organized programs on crop insurance and disaster preparedness are badly needed.

IRRIGATED WETLAND AREAS

Thirty-three percent of the total rice area in South and Southeast Asia was under irrigation by 1979 and about 57% of total rice production came from this irrigated area (Huke 1982). While rice yields in the irrigated areas have almost doubled during the last 20 years, the potential for increasing total agricultural production using irrigation is still tremendous. In the development of improved irrigated rice-based cropping systems for the small farms in monsoon Asia, two considerations are very important. First, the available rainfall must be efficiently used in the cropping patterns so that the irrigation requirements and costs are minimized. Second, highly productive and profitable intensive cropping patterns with adequate input supply and credit support must be developed and extended to the irrigated farms for year-round land use. With these objectives, cropping systems scientists have initiated work at about 41 irrigated wetland sites. The researchers have developed an understanding of existing cropping systems at several sites, which will be helpful in improving them.

Land-use patterns

The major cropping patterns in several irrigated wetland areas are in Table 4.4. Farmers use single, double, or triple cropping patterns. Rice - rice is important over a vast area. Triple rice cropping patterns are possible because of the availability of short-duration, improved rice varieties. Where low temperature is a limiting factor during the dry winter season, such as in Nepal, Bangladesh, and South Korea, farmers grow wheat, mustard, and potato after one or two rice crops. Some farmers produce only one crop to optimize crop yields through higher input levels and management practices. However, there are other physical, technological, and socioeconomic constraints that limit crop intensification. Usually farmers grow major food or cash crops in these areas.

Input use and crop management practices

In most of the irrigated wetlands, farmers use sequential cropping patterns. Because water availability is not a constraint, farmers try to plant at optimal times considering such seasonal factors as temperature, solar radiation, and insect pest incidence. Where the use of the irrigation facilities is communal, farmers usually follow a well-defined routine of field activities based on water distribution plans. As a result, block farming or cooperative efforts are common. This also influences labor and input utilization patterns. In the single rice cropping pattern, a

Table 4.4. Dominant cropping patterns in several irrigated wetland areas of Asia.

Cropping pattern	Site
Rice	Parsa, Nepal[a]
	Salana, Bangladesh[b]
	Walagambahuwa, Sri Lanka[c]
	Indramayu, Indonesia[d]
	Iri, South Korea[e]
	Milyang, South Korea[f]
	Suweon, South Korea[f]
Rice - rice	Parsa
	Saina
	Shimrail, Bangladesh[g]
	Indramayu
Rice - wheat	Parsa
	Iri
	Milyang
Rice - barley	Iri
Rice - maize	Milyang
Rice - potato	Parsa
	Milyang
Rice - cowpea	Indramayu
Rice - soybean	Indramayu
Rice - pepper	Indramayu
Rice - tomato	Indramayu
Rice - rape/mustard	Iri, Parsa
Rice - rice - rice	Saina
	Shimrail
Rice - rice - wheat	Parsa
	Saina

[a]Nepal Cropping Systems Program (1979). [b]Hoque et al (1977). [c]Fernando et al (1982). [d]Djauhari (1977), McIntosh (1980). [e]Kim (1981). [f]Shin (1981). [g]Hoque et al (1982b).

transplanted crop is usually grown during the most suitable period, which may differ among locations. However, in some areas, direct seeding may be the major crop establishment method. For example, in Bangladesh, farmers grow a transplanted single boro crop during the dry winter season with high yields, whereas in the minor tank-based systems in the dry zone of Sri Lanka, farmers grow a direct-seeded single rice crop with supplemental tank irrigation during the main rainy season. In the rice - rice pattern, the turnaround time between the two crops varies considerably. When farmers attempt to make efficient use of the available rainfall, they grow the two rice crops in quick succession with a reduced turnaround time of about 10-20 d. However, when they grow a rice crop during the dry season with full irrigation, the turnaround time between the wet- and dry-season crops is widened by as much as 90 d. In triple cropping patterns, farmers reduce the turnaround time between crops still further and use shorter duration varieties. The amount of fertilizer used in the irrigated wetlands depends on location. At Parsa, Nepal, 65% of the surveyed farms applied N fertilizer, 5% applied P, 10% applied K, and 60% applied compost (Mathema et al 1980). In 1979, average rates of application for C.H. 45 at Parsa were 14.67-4.42-4.42 kg (N,

P, K)/ha, and 1,370 kg compost/ha. For Jhali the average rates were 20.73-17.32-17.32 kg (N, P, K)/ha, and 1,029.40 kg compost/ha. In the rice - wheat pattern, farmers applied no fertilizers to the local rice variety, but applied about 30-30 kg (N, P)/ha to the wheat crop (Malla et al 1982). Farm survey results at Parsa indicated that farmers use low levels of fertilizers on their rice crops. The N rate varied from 16 to 41 kg N/ha (Mathema et al 1980). However, most farmers at this site use compost in their ricefields. The rate of compost application was from 1.9 to 2.4 t/ha. The rice seeding rates at Parsa ranged from 35 to 78 kg/ha (Mathema et al 1980).

At Salna, Bangladesh, farmers prepare their ricefields with three to six plowings and two to five ladderings. They grow both modern high yielding and traditional local rice varieties in all three seasons. However, they use local varieties less during the aus and boro seasons. During the t. aman season, some farmers use photoperiod-sensitive local varieties, particularly those with fine grain quality. Farmers sometimes use short-duration local rice varieties for a triple rice cropping pattern. Fertilizer use is maximal during the boro season. At Salna in 1977, the average fertilizer rates were 120-24.2-42.3 kg (N, P, K)/ha for improved boro varieties and 57-24.2-29 kg (N, P, K)/ha for the local boro varieties. For the t. aman crop, farmers used average rates of 49-25.5-21.5 kg (N, P, K)/ha for the improved varieties and 74-22-22.4 kg (N, P, K)/ha for the local varieties. During the aus season, farmers averaged rates of 35-20.2-0 kg (N, P, K)/ha for the improved varieties and no fertilizer for the local varieties. Farmers at this site are gradually increasing the rate of fertilizer use.

In the irrigated areas of Bangladesh where wheat follows a wetland rice crop, farmers usually use modern wheat varieties with moderate fertilizer rates. In 1978-79, farmers at Salna applied average rates of 79-18-5 kg (N, P, K)/ha to the wheat crop. At Jugibeel, Bangladesh, the average rates on the irrigated wheat crop following two rice crops were 72-26.8-21.6 kg (N, P, K)/ha plus 16 t cowdung/ha (Paul et al 1981). Hand weeding is satisfactory for weed control. Pesticide use is minimal (3-12% of the farms), depending on season and crop varieties (BRRI 1979).

At Walagambahuwa, Sri Lanka, rice cultivation commences in mid or late December with sufficient stored water in the tank. The average N rate ranges between 30 and 40 kg/ha (Fernando and Upasena 1980).

At the irrigated Indramayu site in Java, farmers are aware of improved technology and its importance in increasing agricultural production. Survey work in this area in 1976-77 indicated that about 96% of the farmers use fertilizers, 75% use pesticides, and 72% use MV seeds (Saefuddin et al 1977). The number and kind of crops and the irrigation availability influence the amount of fertilizer and pesticide applied. Fertilizers are usually applied in the local *enclo* system in which a certain amount is applied per hill 15-20 d after transplanting of rice, requiring about 150 kg urea or urea + triple superphosphate/ha (Saefuddin et al 1977). Farmers broadcast another 150 kg urea/ha 35-60 d after transplanting. While the enclo system has a higher labor requirement, it increases fertilizer efficiency and helps control early weeds in the ricefields. Brown planthopper (BPH) is the most threatening pest to rice production at Indramayu. Diazinon and Sevin 85, in

concentrations of 2 cc/liter, are commonly sprayed after each weeding or as necessary for BPH control (Saefuddin et al 1977).

At Milyang, South Korea, 40 kg rice seeds/ha and 190 kg wheat seeds/ha are used for the rice - wheat irrigated pattern (Kim 1981). The rates are 150-44-83 kg (N, P, K)/ha for the rice and 100-35.2-66.4 kg (N, P, K)/ha, for the wheat.

Power and labor utilization

A farm survey at Dhobini Panchayat around the Parsa site in Nepal revealed that about 44% of the farmers have labor and power constraints in crop production (Mathema and Van der Veen 1979). These farms averaged 2.71 family laborers and 0.79 draft animals. The remaining 56% reporting no labor or power constraints averaged 3.33 family laborers and 1.45 draft animals. At the Parsa rice area in 1979, farmers used about 400 paired animal-hours/ha for plowing and 1,942 man-hours (h)/ha for all labor requirements. Transplanting was done entirely by adult females, about 562 h/ha or 29% of the total (Mathema et al 1980). Adult males plowed and prepared the land (517.6 h/ha), carried compost to the fields (2.8 h/ha), planted seeds and uprooted seedlings (351 h/ha), applied the fertilizers (9.8 h/ha), irrigated (43.9 h/ha), and did the weeding (28 h/ha), harvesting (228.5 h/ha), and all other tasks (197.5 h/ha).

During the 1979 aus season at Salna, Bangladesh, the labor requirements were 584 h/ha for the local (Pukhi) variety and 716 h/ha for the improved rice (BR3) variety (Hoque et al 1980a). For the 1979 crop, the labor requirements were 572 h/ha for the local variety and 871 h/ha for BR3. Farmers used 237 paired animal-hours/ha for local variety cultivation and 253 paired animal-hours/ha for the modern rice varieties. During the 1979-80 boro season, laborers spent 690 h/ha on cultivating the local variety Muktahar, 1,131 h on the modern variety BR3, and 826 h on the intermediate-type variety Pajam. The corresponding draft power requirements for land preparation were 143 paired-animal hours/ha for Muktahar, 291 h for BR3, and 207 h for Pajam. The major field operations of plowing, transplanting, weeding, and harvesting accounted for 86% of the labor requirements for Muktahar, 91% for BR3, and 88% for Pajam (Hoque et al 1980b). Labor costs were $75/ha for Muktahar, $125 for BR3, and $104 for Pajam. Power costs amounted to $15/ha for Muktahar, $29 for BR3, and $21 for Pajam.

At the Walagambahuwa minor tank village site in Sri Lanka, farmers use hired and exchanged labor for field operations, in addition to family labor (Upasena 1981a). Farmers used more exchanged labor in fields outside their own villages. Mahendraraja (1977) reported that the size of the family labor force at Walagambahuwa varied from 3 to 9, averaging 5.27 workers per farm. An underutilization of available labor was observed in the area much of the year. Use of the labor force for off-farm cash income appeared important. Children make up a reserve labor force during peak periods (Mahendraraja 1977). The labor cost for rice cultivation at Walagambahuwa was about $94/ha ($51 for land clearing, preparation, and planting; $3 for fertilizing and spraying; $5 for weeding; $15 for harvesting; $14 for threshing, and $6 for other operations). The labor costs were $113/ha for finger millet, $215 for maize, $200 for chili, $214 for cowpea, and $290 for vegetables at Walagambahuwa (Mahendraraja 1977).

At Indramayu, Indonesia, hired labor ranges from 65 to 80% of the total requirement depending on the crop and irrigation regime (Sudana et al 1979). In areas with 10 months irrigation, farm data indicated that laborers need 1,584 h/ha for the first transplanted rice. About 43% of this requirement is spent for the seedbed and land preparation, and for transplanting; 20% for water management, weeding, fertilizing, and pest control; and 37% for harvesting and postharvest operations. The second rice crop established with no tillage required 480 h/ha for cutting the stubble of the previous rice crop, trampling it below the soil surface, and then transplanting the seedlings; crop maintenance required 424 h/ha and harvesting, threshing, and drying required about 504 h/ha (Sudana et al 1979).

In the areas with 7-9 months available irrigation, laborers spent 1,192 h/ha on the first-season transplanted rice and 1,112 h on the second no-tillage rice crop (Sudana et al 1979). In areas with 5-6 months of irrigation, labor requirements were about 2,344 h/ha for the first transplanted rice crop. For this crop, stubble cutting and land preparation took 680 h/ha and weeding, 672 h. The no-tillage crop required about 1,176 h/ha (Sudana et al 1979).

Productivity and profitability of cropping patterns

Artificial irrigation in the irrigated wetlands has helped farmers increase yields. When assured of a water supply, farmers more readily adopt improved management practices and higher input levels than do their counterparts in rainfed areas.

At Dhobini panchayat near the Parsa site, average yields from the traditional rice varieties of the Nepalese farmers were 1.8 t/ha for Basmati, 2.3 t for Hathighamar, and 2.1 t for Barchha. Yields of the improved varieties were 2.1 t/ha for Masuli and 4.1 t for Pankaj (Mathema et al 1980). Yields ranged from 0.8 to 3.7 t/ha for the local rice varieties and from 1.2 to 4.3 t/ha for the improved varieties. Total variable costs were $150/ha for Basmati, $157 for Hathighamar, $152 for Barccha, $146 for Masuli, and $156 for Pankaj. Corresponding net returns for these varieties were $130, $197, $178, $175, and $482/ha. Pankaj, an improved variety from India, was the most profitable at Parsa.

Under farmer management the yields at Parsa averaged 2.3 t/ha for rice, and 1.3 t for both wheat and maize (Malla 1980). The present yield levels from the rice - rice - wheat pattern are 1.6-1.8-1.3 t/ha; from rice - wheat, 2.0-1.7 t/ha; from rice - rice + lentil, 1.6-1.1-0.5 t/ha; from rice - potato, 1.6-7.1 t/ha; and from rice - mustard, 2.0-0.6 t/ha (Malla 1981c). These data indicate the potential for increasing yields further through improved varieties and management practices.

In 1977, during the aus season at Salna, Bangladesh, yields were about 1.8 t/ha for the local variety (Pukhi) and 2.8 t/ha for the improved variety (Chandina) (BRRI 1978). During the t. aman season, yields were 2.6 t/ha from local varieties, 2.4 t from the improved variety (IR5), and 2.9 t from Pajam. The local varieties include Nizersail, Chandrasail, and two other fine-quality rices, Chinigura and Kalijira. Pajam was planted in about 54% of the fields, IR5 in 32%, and the local varieties in 14%. During the boro season, yields were 3.8 t/ha from IR8, 3.6 t from BR3, 2.5 t from Pajam, and 2.0 t from the local variety Muktahar (Hoque and Hobbs 1978). In 1978-79, detailed monitoring was done in 62 fields at Salna. Daily

record keeping on field operations, input use, and crop cutting determined input-output of the farmers' cropping patterns (Hoque et al 1980a). The boro crop was grown with full irrigation and the aus and t. aman crops were mainly rainfed. Results indicated that annual rice production could vary from 2.3 to 10.3 t/ha depending on cropping pattern (Table 4.5). The table shows that growing a single boro rice crop can give higher net return and benefit-cost ratio than some double- or even triple-rice cropping patterns. Similarly, some double-rice cropping patterns could outperform some triple-cropping patterns. Net return and benefit-cost ratio were influenced by the costs of production and prevailing market prices for different rice varieties. Results of this monitoring study may explain why farmers sometimes do not go for intensive cropping patterns even when irrigation and other facilities are present.

Farmers at the Walagambahuwa minor tank settlement area in Sri Lanka used to get average yields of about 2 t/ha up to 1976-77 (Upasena 1981a). A successful rice crop was probable only once every 4-5 years. Now farmers are adopting better component technologies and in 1980-81 the average yield was 2.9 t/ha (Upasena 1981a).

The agroeconomic performances of farmers' traditional transplanted rice - no tillage rice (*Walik jerami*) pattern for three irrigation regimes in the Indramayu area of West Java are indicated in Table 4.6. The agronomic productivity and net return of both the crops in the pattern were much greater where increased irrigation was available. Data on variable cost indicate that farmers increased their

Table 4.5. Average productivity, costs, and returns of rice cropping patterns, Saina, Bangladesh, 1978-79.[a]

Rice cropping pattern	Total yield (t/ha)	Total variable cost ($/ha)	Net return ($/ha)	Benefit-cost ratio[b]
MV aus	2.3	205	120	1.6
Pajam t. aman[c]	3.2	141	423	4.3
Local t. aman	2.7	242	216	1.9
MV boro	5.0	222	844	4.8
Local boro	2.9	235	420	2.8
MV aus - local t. aman	5.5	328	532	2.6
MV aus - Pajam t. aman	5.4	268	564	3.1
MV aus - Pajam boro	5.9	362	746	3.1
Pajam t. aman - local boro	7.0	251	1069	5.3
Pajam t. aman - MV boro	7.3	430	957	3.3
Pajam t. aman - Pajam boro	6.5	378	927	3.4
MV t. aman - Pajam boro	7.4	567	948	2.6
Local aus - Pajam t. aman - Pajam boro	9.2	628	1114	2.8
MV aus - local t. aman - MV boro	7.6	442	890	3.0
MV aus - Pajam t. aman - local boro	9.5	470	1200	3.6
MV aus- local t. aman - local boro	8.0	580	1026	2.8
Local aus- local t. aman - MV boro	5.5	589	489	1.8
MV aus - Pajam t. aman - Pajam boro	9.9	542	1293	3.4
MV aus - Pajam t. aman - MV boro	10.3	480	1324	3.8

[a]Hoque et al (1980a). [b]Gross return divided by total variable cost. [c]Pajam is not considered an MV or a local variety in official statements in Bangladesh; it is also known as Masuli or Mashuri in other countries.

Table 4.6. Agronomic productivity and economic profitability of farmers' traditional rice - rice pattern with 3 irrigation regimes in Indramayu areas, West Java, Indonesia, 1975-76.[a]

Observation	Irrigation regime (mo)	Cropping pattern[b]		Pattern total
		Transplanted wetland rice	Zero-tillage rice	
Grain yield (t/ha)	5	5.0	0.8	5.8
	7	5.8	1.6	7.4
	10	6.3	6.4	12.7
Variable cost ($/ha)	5	369	209	578
	7	411	201	612
	10	427	433	860
Net return ($/ha)	5	383	-86	297
	7	466	58	524
	10	518	610	1120

[a]Adapted from Saefuddin et al (1977). [b]In both the rice crops, Pelita I/1 was used.

investment in both rice crops, and thus in the pattern, as the duration of irrigation increased. Grain yield and net return in the 5-month, irrigated no-tillage rice crop indicated that this irrigation regime may not be suitable for a rice - rice pattern because it involves the risk of crop failure. The benefit-cost ratios of the transplanted rice - no-tillage rice pattern were about 1.5 with 5 months of irrigation, 1.9 with 7 months, and 2.3 with 10 months. Clearly, this demonstrates the importance of good irrigation facilities in improving the production and income of wetland farmers.

Factors affecting crop production

Based on the experiences at the ACSN irrigated wetland research sites, the following factors appear to influence crop production significantly.

Capacity, maintenance, and utilization of irrigation systems. Amount of annual rainfall directly affects the total availability of irrigation water in surface systems as well as in shallow and deep tubewell systems. So, in low-rainfall years farmers face difficulties in raising their crops. In the case of severe drought, the irrigation sources may be completely inadequate, so that, as in the dry zone of Sri Lanl , total crop failure is possible. The management and operation of communal irrigation systems in the developing countries are not easy tasks. Farmers' traditional beliefs, socioeconomic backgrounds, village politics, and government support services all determine the mode and extent of irrigation facility utilization. In many cases, there is underutilization of the irrigation systems. Technical and institutional support, production incentives, and cooperative attitude among farmers are necessary to ensure capacity utilization and maintenance of the irrigation systems.

Production inputs. To take advantage of the complementary effect of irrigation, production inputs such as inorganic fertilizers must be available. Unfortunately, in many irrigated wetland areas, improved-variety seeds, fertilizers, and pesticides are not available.

Crop and soil management problems. Because of prolonged waterlogging in the irrigated wetlands, soil problems such as zinc and sulfur deficiencies are gradually becoming critical constraints to higher rice yields. Proper research will overcome these field problems. Also, it is difficult to establish dryland crops, such as wheat, pulses, or oilseeds, after irrigated wetland rice.

Credit and market facilities. Farmers need adequate credit on suitable terms to purchase required production inputs. Production incentives, especially marketing facilities and assured price support and procurement, are also needed.

RAINFED DRYLAND AREAS

Vast rainfed dryland areas under subsistence agriculture are found in Indonesia and the Philippines. In Thailand, India, Sri Lanka, Bangladesh, and Burma, rainfed dryland areas also constitute a considerable part of the cultivated areas. Appreciable attention, therefore, has been focused on the research and development of cropping systems in the rainfed drylands.

Land-use patterns

Growing of drought-resistant, short-duration crop species has been an important feature of rainfed farming in the dryland areas. Although high crop yields have been difficult to obtain, traditional cropping patterns usually do exhibit a high degree of stability Another important feature is the extensive use of mixed cropping and intercropping of annual crops. These practices provide farmers with opportunities for harvesting diverse crops from the same land; increasing total land productivity; maintaining and improving soil fertility through the use of legumes; and, above all, reducing or avoiding risks of crop failures due to weather. The traditional cropping patterns are listed in Table 4.7. These patterns include one to six crops, depending on site. Upland rice and maize are the most important commodities. When more than two crops are included in the pattern, mixed cropping, intercropping, or relay cropping are practiced (Table 4.7).

Input use and crop management practices

Farmers mostly use traditional local varieties in the rainfed drylands. In general the development and introduction of improved varieties for these areas have been insignificant. Also, input levels are generally low. The major production inputs are seeds and human labor.

Where farmers have recently adopted high yielding maize and upland rice varieties or where they grow vegetables, fertilization rates have increased to some extent. For example, at Alimganj, Bangladesh, farmers used a fertilizer rate of 34-19.4-33.2 kg (N, P, K)/ha. They did two hand weedings and used no insecticides for the local direct-seeded rice variety Hashi Kalmi. For the modern BR3 variety, they used a fertilizer rate of 92-19-15.7 (N, P, K)/ha, four hand weedings, and two insecticide applications (Akanda 1981). Farmers demonstrate a considerable degree of skill and competence in the mixed cropping, intercropping, and relay cropping practices. They have also developed suitable soil management

Table 4.7. Locations of traditional cropping patterns in several rainfed upland areas.

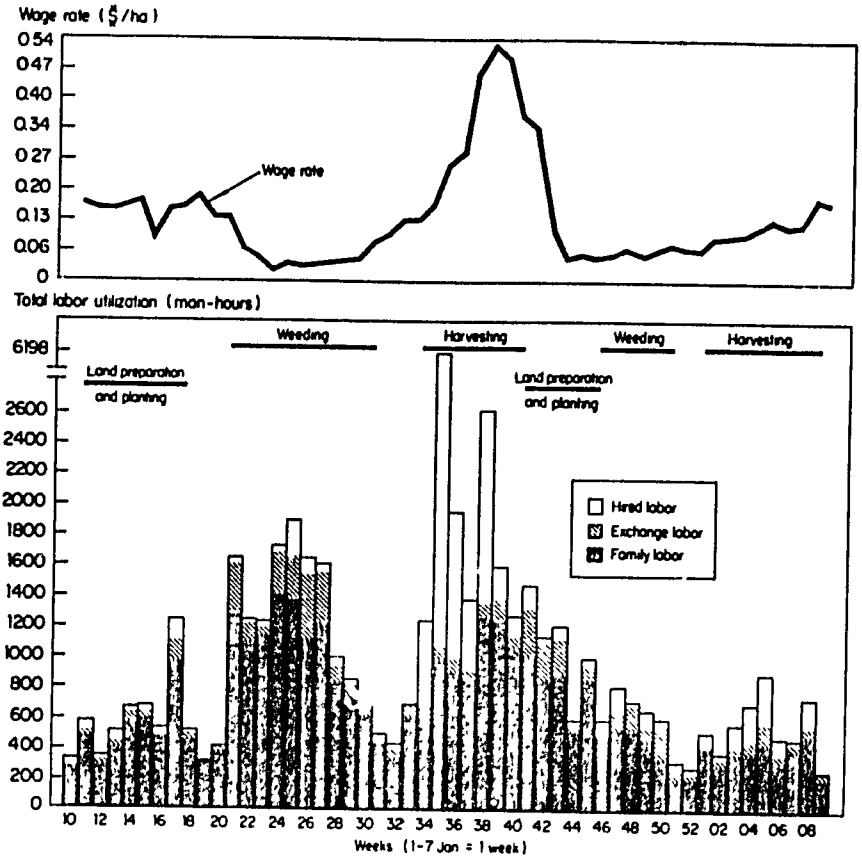
Cropping pattern	Site[a]
Upland rice	Alimganj, Bangladesh
	Batangas, Philippines
	Bukidnon, Philippines
	Capiz, Philippines
Maize	Agusan, Philippines
	Bukidnon
	Capiz
Sweet potato	Capiz
Upland rice - upland rice	Agusan
Upland rice - maize	Batangas
	Bukidnon
	Capiz
Upland rice - barley	Alimganj
Upland rice - wheat	Alimganj
Upland rice - potato	Alimganj
Upland rice - gourd	Batangas
Upland rice - garlic	Batangas
Maize - maize	Agusan
	Bukidnon
	Capiz
Maize - sweet potato	Agusan
Maize - sorghum	Capiz
Maize - peanut	Capiz
Maize - mungbean	Capiz
Maize - soybean	Capiz
Maize - radish	Capiz
Peanut - peanut	Bukidnon
Sweet potato - sweet potato	Bukidnon
	Capiz
Onion - onion	Bukidnon
Upland rice - maize + peanut	Sampang, Indonesia
	Baturaya, Indonesia
Upland rice - barley + chickpea	Alimganj
Upland rice - linseed + chickpea	Alimganj
Upland rice - wheat + chickpea	Alimganj
Maize + upland rice/cassava	Way Abung, Indonesia
Maize + upland rice - maize	Tajau Pecah, Indonesia
Upland rice - mungbean - maize + peanut	Sampang
Upland rice - barley + chickpea + linseed	Alimganj
Maize + upland rice - cassava + peanut	Sampang
Maize + upland rice - maize + sweet potato - maize + peanut	Sampang
Maize + upland rice - maize + peanut - maize + peanut	Sampang
Maize + peanut - maize + peanut - maize + peanut	Sampang

[a]Sources: Alimganj (Akanda 1981), Batangas (IDRC-UPLB Project 1979), Bukidnon (Manos 1979), Capiz (Paraico 1979), Agusan (Gonzaga 1979), Sampang (CSP, Indonesia 1981), Baturaja (Ismail et al 1978), Way Abung (Ismail et al 1978), Tajau Pecah (CRIA 1980).

practices that allow continuous cropping year after year without destroying the soil structure. Crop configurations and planting schedules are planned to maximize utilization of available rainfall.

Power and labor utilization

Human labor is the single most important power source in the rainfed drylands. In Indonesia alone, thousands of hectares are managed by farmers using single hand implements. Draft animals are not used on sloping or rolling land. However, animals are sometimes used in land preparation on relatively level areas. Table 4.8 shows the labor requirements of different field operations for various dryland crops at Batangas, Philippines. Usually, farmer estimates on labor requirements are higher than figures estimated by researchers using a stopwatch. The average weekly labor-use pattern on 36 dryland farms at Batangas is indicated in Figure 4.2. Farmers mostly use family labor, but will exchange labor with neighbors and hire labor, particularly at harvest. The imputed wage rate goes quite high during the peak period of harvesting the first crop and preparing the land for planting the second crop (Fig. 4.2).



4.2. Weekly labor utilization and imputed weekly wage rates on 36 farms in Cale, Batangas, 1975-76 (Price and Barker 1977). Exchange rate US$1 = ₱7.4.

Table 4.8. Labor requirements for various operations on crops as estimated by stopwatch, Cale, Batangas, Philippines, 1974-75.[a]

Crop	Labor (man-days[b]/ha) required for									
	Plowing	Harrowing	Furrowing	Planting	Fertilization	Hilling up	Spraying	Off-barring	Harvesting	Total
Sorghum	4.1	0.9	1.4	3.6	1.5	1.3	–	1.7	18.6	33.0
Glutinous maize	3.6	1.2	1.1	4.9	2.8	1.9	–	2.0	6.6	24.1
Field maize	3.6	1.2	1.2	3.8	2.6	1.8	–	–	3.6	17.8
Sweet potato + maize	4.6	1.2	1.1	5.6	3.4	2.0	–	2.2	–[c]	20.1
Mungbean	3.9	0.9	1.3	4.7	1.9	–	3.3	2.4	43.4	61.8
Soybean	3.9	1.2	1.2	4.9	1.5	–	1.2	1.7	14.4	30.0
Cowpea	4.5	1.2	1.7	5.0	2.0	–	8.3	1.5	86.6	110.8
Peanuts	4.4	1.8	1.4	9.3	1.5	–	N	1.7	–	20.1
Cowpea after glutinous maize	1.9	1.5	1.3	3.9	1.3	1.4	0.7	1.4	26.5	39.9

[a]IRRI (1976). [b]One man-day equals 8 man-hours. [c]Missing data.

During 1977-78 at Agusan, Philippines, in an upland rice - upland rice pattern on three farms, the labor requirements were 411 h/ha for the first crop and 351 h for the second (Gonzaga 1979). For both crops, 44% of the labor went to land preparation and 11% to harvesting. About 16% of the labor went to planting and 29% to weeding for the first crop compared with 22% to planting and 23% to weeding for the second. In a maize - maize pattern at Agusan, labor requirements were 324 h/ha for the first crop and 264 h for the second crop (Gonzaga 1979).

Producing the local upland rice variety at Alimganj, Bangladesh, required 855 h/ha (Akanda 1981). The percentage breakdown of the labor was 38% for weeding, 30% for harvesting, 27% for land preparation, 4% for application of manures and fertilizers, 0.5% for seeding, and 0.5% for pest control. Farmers used 255 paired animal-hours/ha for land preparation.

Cropping pattern productivity and profitability

Cropping patterns at Batangas were broadly classified into six systems. Table 4.9 indicates that these systems exhibit a significant interrelationship among crops, livestock, and wages.

During 1974-75 at Batangas, the average yields of crops in farmers' fields were rice, 1.4 t/ha; maize, 1.5 t/ha; sorghum, 2.5 t/ha; ratoon sorghum, 1.0 t/ha; mungbean, 0.4 t/ha; soybean, 1.0 t/ha; and peanut, 0.8 t/ha. In 1975-76, the yields were rice, 3.1 t/ha; maize, 4.1 t/ha; sorghum, 3.9 t/ha; ratoon sorghum, 0.6 t/ha; mungbean 0.6 t/ha; soybean, 0.7 t/ha; and peanut, 1.8 t/ha (IRRI 1976).

The data on the productivity and profitability of seven cropping patterns are in Table 4.10. Except the rice - maize and rice - peanut patterns, all other cropping patterns had a net economic loss. Because family labor constitutes a major part of the total variable costs, farmers probably are not too concerned about such economic evaluations. Informal meetings for discussing research findings help motivate farmers to adopt improved cropping patterns.

During 1977-78 at the Baturaja-martapura areas in Sumatra, the yields were 1.9 t/ha for upland rice, 0.4 t/ha for maize, and 0.5 t/ha for peanut (Ismail et al 1978). Rice produced 4,494 kcal/ha; maize, 1,427 kcal/ha; and peanut, 2,373 kcal/ha. The protein yield of the pattern was 298 kg/ha — peanut (134 kg/ha), rice (127 kg/ha), and maize (37 kg/ha). The pattern had variable costs of $815/ha — $320 for labor and $495 for materials, with a net return of $212/ha.

The agronomic productivity and economic profitability of four intensive rainfed dryland cropping patterns were monitored in Sampang, Madura, Indonesia (Table 4.11). Except for the yields of upland rice in two of the cropping patterns, yields of all crops were very low, probably because of poor soil fertility and low management intensity. However, these intensive patterns assure farmers of a continuous food supply for their families. The highest edible food production (7.7 t/ha) came from the maize + rice - cassava + peanut pattern. The highest calorie production per hectare (28,552,000) came from the maize + peanut - maize + peanut - maize + peanut pattern. Although the maize +rice - cassava + peanut pattern produced the highest bulk of food materials (Table 4.11), it suffered a net economic loss. The fact that farmers still grow the pattern indicates

Table 4.9. Sources of farm cash income, types of cash expenditure, labor requirements, cash inputs, and gross returns in different cropping systems, Batangas, Philippines, 1974-75.[a]

System	Crops		Farmers (no.)	Income (% of total)					Expenses (% of total)			Labor requirement (h/ha)	Cash input ($/ha)	Gross return ($/$ input)
	First season	Second season		Tree crops	Field crops	Live-stock	Wages	Contri-butions from relatives	Crops	Live-stock	House-hold and other items			
I	Rice	Maize	5	1	21	30	29	19	10	20	70	409	100	2.42
II	Rice, FV[b]	Maize, vine, vine-root, intercrop	13	3	65	21	6	5	16	18	66	723	118	2.71
III	Rice - trellis	Maize, vine, vine-root, intercrop, trellis	6	3	69	7	9	12	17	10	73	855	173	3.93
IV	Rice, FV	Maize, vine, vine-root, intercrop, trellis	11	3	67	11	7	12	15	11	74	777	122	3.56
V	Rice, maize FV	Maize, vine, vine-root, intercrop, trellis	12	2	65	14	12	7	21	11	68	728	132	2.90
VI	Rice, sugarcane, trellis	Sugarcane, trellis	3	3	23	12	56	6	5	8	87	1091	157	4.22

[a]IRRI (1976). [b]Fruit-vegetables, e.g. eggplant, tomato, chili.

Table 4.10. Agronomic productivity and economic profitability of seven cropping patterns at Batangas, Philippines, 1975-76.[a]

Cropping pattern	Yield (t/ha)			Total variable cost ($/ha)	Net return ($/ha)
	1st crop	2nd crop	3rd crop		
Rice - maize	3.1	4.1	–	974	161
Rice - mungbean	3.2	0.6	–	1 205	–253
Rice - soybean	3.3	0.7	–	1 234	–469
Rice - peanut	3.0	1.8	–	1 816	666
Rice - green maize - mungbean	3.0	38 750[b]	0.8	1 702	– 20
Rice - sorghum - sorghum (ratoon)	3.0	3.9	0.6	1 360	–185
Green maize - maize - mungbean	34 938[b]	3.0	0.6	1 894	–396

[a]Carangal (1980a). [b]Number of harvested green ears.

Table 4.11. Agronomic productivity and economic profitability of four cropping patterns under rainfed upland situations at Sampang, Madura, Indonesia, 1979-80.[a]

Cropping pattern			Fields monitored (no.)	Yield (t/ha)			Per-pattern cost[b] ($/ha)			Per-pattern net return	
1st season	2nd season	3rd season		1st season	2nd season	3rd season	Labor	Material	Total	$/ha	%
Maize + peanut	Maize + peanut	Maize + peanut	13	0.48 0.75	0.49 0.83	0.25 0.47	333	100	433	805	100
Maize + upland rice	Maize + sweet potato	Maize + peanut	9	0.60 4.70	0.37 2.81	0.09 0.42	518	160	678	769	96
Maize + upland rice	Maize + peanut	Maize + peanut	3	0.83 5.10	0.31 0.73	0.12 0.81	569	237	806	888	110
Maize + upland rice	Cassava + peanut	–	3	0.42 0.90	6.25 0.41	– –	437	179	617	–51	– 6

[a]Indonesian Cropping Systems Program. [b]No power cost was incurred.

they are more concerned about food security for the family than about profits.

At Alimganj, Bangladesh, the yields of local upland rice ranged from 2.1 to 2.6 t/ha in 1980-81 (Akanda 1981). The yields of wheat and potato following rice were 2.5 and 30.2 t/ha. The variable costs were $322/ha for rice - wheat, $1,141 for rice - potato, $209 for rice - barley + chickpea, and $202 for rice - linseed + chickpea. Corresponding net returns were $660, $2,271, $1,017, and $780/ha. These figures indicate that if farmers adopt appropriate cropping patterns and make best use of the rainfall, and if markets are available, they can obtain high economic returns.

Factors affecting crop production

Fluctuations in annual rainfall, particularly in the onset of rains, adversely affect planting schedules, thereby influencing the entire cropping pattern. Frequent droughts often reduce crop yields, particularly of rice, and in some years, cause total crop failures. Farmers need improved drought-resistant rice and nonrice crop varieties. Also, there is a need for extensive research on mixed cropping, intercropping, and relay cropping systems to develop more stable, productive, and profitable patterns. Soil and fertilizer management, particularly in the Red-Yellow Podzolic soil areas of Indonesia, is difficult. Soil erosion, nutrient leaching, yield instability, and weeds are inherent problems.

IRRIGATED DRYLAND AREAS

Irrigation in well-drained dryland soils provides farmers the opportunity to produce high-value crops — particularly where adequate marketing facilities exist. If located near big cities, irrigated cropping patterns involving vegetables and other cash crops become profitable. Lighter textured soils in dryland areas require irrigation to realize their production capabilities. Except in the highly intensive vegetable-producing pockets, upland rice is usually grown during the rainy season.

Land-use patterns

Predominant cropping patterns grown under partially irrigated conditions in several dryland sites are in Table 4.12. The rainy-season crop in a majority of the patterns is direct-seeded rice. However, maize, jute, sugarcane, cotton, and mungbean may also be the rainy-season crops in some patterns. During the dry season, farmers grow major dryland crops such as wheat, potato, mustard, chili, and vegetables with irrigation. Table 4.12 indicates that double cropping is the most common practice. In some cases, cropping intensity is increased through intercropping profitable crops as in the direct-seeded rice - onion + garlic pattern. Farmers in Bangladesh now extensively intercrop short-duration dryland crops such as potato, chickpea, and wheat, with sugarcane during its early growth stage.

Input use and crop management practices

Farmers make little use of many new inputs and management practices. However, to make best use of irrigation, farmers do try moderate management for the cash crops, and intensive care for the vegetable crops. Input use and management

Table 4.12. Cropping patterns in several irrigated dryland areas.

Cropping pattern	Sites
Direct-seeded rice (DSR)	Laskarchala, Bangladesh[a]
DSR - wheat	Bagherpara, Bangladesh[b]
	Munshirhat, Bangladesh[c]
	Kachubari, Bangladesh[c]
	Durgapur, Bangladesh[c]
DSR - mustard	Laskarchala
	Bagherpara
DSR - potato	Bagherpara
	Laskarchala
DSR - chili	Laskarchala
DSR - mungbean	Bagherpara
DSR - onion + garlic	Bagherpara
DSR - vegetables	Laskarchala
Jute - wheat	Suk Akcha, Bangladesh[c]
Jute - mustard	Bagherpara
Long staple cotton - rice	Kyetmauktaung, Burma[d]
Food legumes - rice	Kyetmauktaung
Rice - sunflower	Kyetmauktaung
Maize - rice	Kyetmauktaung
Maize - vegetables	Laskarchala
Sugarcane + wheat	Ishurdi, Bangladesh[e]
Sugarcane + potato	Ishurdi
Sugarcane + chickpea	Ishurdi
Sugarcane	Ishurdi

[a]Hoque and Hobbs (1978). [b]Elias and Haque (1981). [c]Towheed and Asadullah (1980). [d]Palis et al (1981). [e]Hossain (1981).

practice monitoring at Laskarchala, Bangladesh, indicated that in the MV rice - chili pattern, farmers applied, on an average, only 31 kg N/ha on the rice but 53-25 kg (N, P)/ha on the chili (Hoque et al 1979a). In the MV rice - mustard pattern, farmers used 39-12.3 kg (N, P)/ha for the rice and only 17 kg [illegible]/ha for the mustard. In the local rice - mustard pattern, farmers reduced fertilizer application on the rice (only 19 kg N/ha) but increased it for the mustard to 20-15.8-20 kg (N, P, K)/ha. In the local rice - potato pattern, they applied only 28 kg N/ha to the rice while they gave the potato crop 98-38.7 kg (N, P)/ha. These observations indicated that a particular crop, such as mustard or MV rice, received different fertilizer applications, depending on the cropping pattern. Because of irrigation availability, farmers can regulate, somewhat, the planting schedule for a selected cropping pattern. However, in most cases, farmers are reluctant to invest in partial irrigation during the rainy season unless crop failure is likely.

Power and labor utilization

Draft animals serve as the major source of power in the irrigated drylands. However, in large-scale block farming where farmer cooperatives exist, such as in the sugarcane and wheat areas, tractors, if available, are used. Farmers use family and hired manual labor extensively in all field operations. Women and children work in the cultivation of vegetables and in postharvest operations. At Laskarchala, the human labor requirements for four patterns were 1,017 h/ha for MV rice - chili, 1,750 h for MV rice - mustard, 1,110 h for local rice - mustard, and 1,901 h for local rice - potato (Hoque et al 1979a).

Table 4.13. Agroeconomic performance of four partially irrigated cropping patterns at Laskarchala, Bangladesh, 1978-79.[a]

Cropping pattern	Yield (t/ha)	Total cost ($/ha)	Net return ($/ha)	Benefit-cost ratio
MV rice - chili	2.7	98	338	4.4
	0.5	106	431	5.1
Total		204	769	4.8
MV rice - mustard	2.3	139	235	2.7
	0.3	119	- 1	0.99
Total		258	234	0.9
Local rice - mustard	1.5	90	149	2.7
	0.4	116	16	1.1
Total		206	165	1.8
Local rice - potato	1.7	139	133	2.0
	9.9	613	90	1.1
Total		752	223	1.3

[a]Hoque et al (1979a).

Cropping pattern productivity and profitability

The yield of local rice varieties grown as direct-seeded crops was 1.8 t/ha at Laskarchala (Hoque et al 1980a) and 1.4 t/ha at Bagherpara (Elias and Haque 1981). The yields of modern wheat varieties under farmer management at Bagherpara ranged from 1.5 to 1.8 t/ha. The 1980-81 yields of wheat in the Thakurgaon deep-tubewell project areas of Bangladesh were 1.8 t/ha at both Suk Akcha and Munshirhat and 2.3 t at Durgapur (Miah et al 1981). Yields were 7.8 t/ha for the traditional potato crop at Bagherpara and 13.8 to 18.4 t/ha for the introduced improved varieties (Elias and Haque 1981). At this site farmer yields were 18.5 t/ha for sugarcane, 1.7 t for both jute fiber and maize, 0.3 t for mustard and 1.1 t for chickpea. The data on the agronomic productivity and economic profitability of four partially irrigated cropping patterns at Laskarchala are in Table 4.13. How small subsistence farmers view this economic evaluation of the cropping patterns is a subject for further research.

Factors affecting crop production

A major limitation to increased food production at the irrigated dryland areas is the unavailability of MVs. Another problem is the marketing of cash crops, particularly perishable vegetables. The year-to-year price fluctuations also place farmers in uncertainty, which affects production. In some cases, farmer reluctance to use the irrigation facilities during drought in the wet season affects cropping schedules as much as yield performance. In some years, though, excessive rains may cause difficulties in establishing the dryland crops before and after the rice crop.

DEEPWATER RICE AREAS

About 10% of the rice area in South and Southeat Asia is devoted to deepwater rice (DWR). The major DWR-producing countries are India (2.5 million ha), Bangladesh (1,142,000 ha), Thailand (436,000 ha), and Vietnam (407,000 ha)

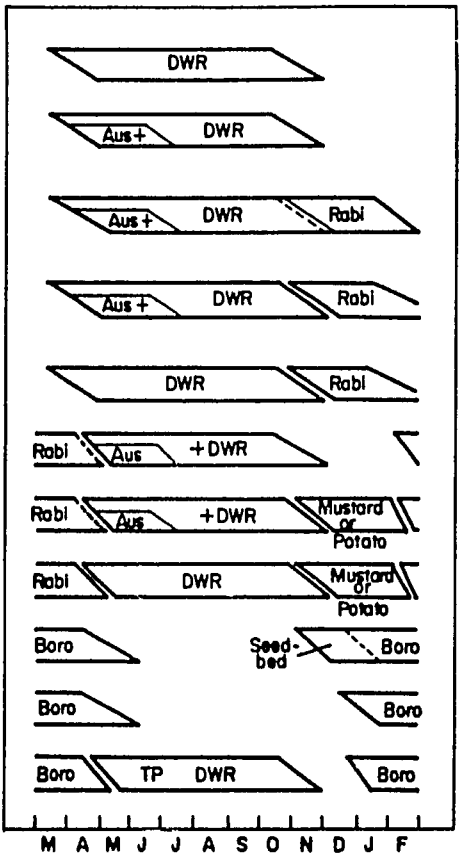
(Palacpac 1982). Cambodia and Indonesia each have about 281,000 ha of DWR. Burma has 155,000 ha and Nepal, 53,000 ha. The cropping systems in the DWR areas are very different from those in other ricelands. The following discussion is based on observations from nationwide surveys and research findings at four on-farm research sites (Daudkandi, Kalacha, Dharmicpara, Jarunbari) in the DWR areas of Bangladesh.

The DWR crop is grown in large saucer-shaped basins scattered over the annually flooded plains and broad and narrow depressed valleys in the highland areas. The crop is broadcast-sown on drylands in March-April with the first monsoon showers, grows gradually along with the rising floodwater, and is harvested in October-December, when most of the floodwater subsides. The usual water depth in these DWR areas varies from 1 to 6 m.

Land-use patterns

The cropping patterns commonly grown in the DWR areas of Bangladesh are in Figure 4.3.

Farmers use single, double, or triple cropping patterns. Single cropping of DWR is usually done in the deeper and heavy soil areas, where hydrology and residual soil moisture do not favor mixed cropping of aus rice or other crops



4.3. Cropping patterns in deepwater rice areas of Bangladesh.

(foxtail millet, sesame, jute, chili) with DWR and production of rabi (winter-season nonrice) crops. Farmers practice single cropping of boro rice in the low-lying saucer-shaped basins. Double cropping patterns include mixed aus and DWR; DWR followed by rabi crops; jute followed by rabi crops; and boro rice followed by DWR. Triple-cropping patterns include mixed aus and DWR followed by rabi crops; DWR or jute followed by early and late rabi crops. Usually mustard and potato are the early rabi crops. Others include wheat, foxtail millet, chickpea, grasspea, lentil, sesame, flax, safflower, watermelon, tobacco, onion, and chili. DWR areas are also excellent fishing grounds. Many fish are trapped in the entangled mass of DWR plants when floodwater recedes. Farmers catch fish before and after harvest, using traditional fishing techniques. Many areas where rabi crops do not follow DWR are used as grazing lands for cattle in the dry winter months.

Input use and crop management practices

Farmer interviews and crop-cut studies from 1977 to 1979 throughout the major DWR areas of Bangladesh revealed that in 50-66% of the fields, farmers follow a monoculture of DWR rice (Catling and Alam 1981). About 25-36% DWR fields are mix-cropped with aus rice at higher elevations and 6-15% mixed with other crops such as foxtail millet, sesame, and chili. Observers also noted mixed cropping of two DWR varieties in the same field. In some areas, DWR is successfully transplanted after a boro rice. Eighty-eight to 92% of the fields are double or triple cropped; a rabi crop of pulses, mustard, or wheat follows rice in 81-85% of the fields. Farmers apply fertilizer to 19-35% of the pure-stand fields and 26-30% to mixed stands. Fertilizer is used most frequently on the Meghna floodplain where the average grain yield is also higher. In the direct-seeded DWR fields, farmers, on an average, apply two rakings and two hand weedings. During recent years, no serious disease outbreaks were encountered and farmers applied insecticides to less than 1% of the fields (Catling and Alam 1981).

The management practices adopted by farmers for the DWR crop and jute and the following rabi crops were monitored at Daudkandi (Table 4.14). On an average, farmers seeded the DWR on 10 April after two plowings and two ladderings. They used a seed rate of 83 kg/ha. No organic manure and fertilizers were used for the DWR and farmers hand weeded. There was intensive land preparation with a high rate of fertilization for the potato crop. Fertilizer use was also high for wheat and mustard.

Organic manures were applied in foxtail millet, potato, sesame, and chili (Table 4.14). Among the rabi crops, mustard was earliest, followed by potato and mungbean.

Power and labor utilization

In the deepwater areas, draft animals (cattle) are the only power sources for land preparation, weed raking, mulching, and threshing. Most of the owner-farmers have draft animals and also share and rent animals among themselves. However, draft power is usually a constraint in the deepwater areas, and farmers sometimes adopt minimum or no-tillage and relay-cropping techniques. Sometimes,

Table 4.14. Management practices adopted by farmers for different crops in a deepwater-rice area. Bangladesh Rice Research Institute cropping systems research site at Daudkandi, Bangladesh, 1980-81.[a]

Management factor	Deepwater rice (40)	Jute (10)	Rabi crops						
			Wheat (18)	Foxtail millet (7)	Potato (11)	Mustard (14)	Sesame (12)	Mungbean (5)	Chili (7)
Variety used	Local	Local	MV	Local	MV	Local	Local	Local	Local
Plowings, ladderings (no.)	2-2	2-2	3-4	3-4	6-7	2-3	3-3	3-4	3-3
Seeding date	10 Apr 80	28 Mar 80	13 Dec 80	18 Jan 81	7 Dec 80	19 Nov 80	24 Feb 81	12 Feb 81	17 Jan 81
Seeding rate (kg/ha)	83	10	131	9	153	18	7	10	(TP)
% using organic manure	–[b]	–	–	28	27	–	8	–	14
Organic manure rate (kg/ha)[c]	–	–	–	4783	3421	–	3804	–	8697
% using NPK	–	–	100-94-92	28-14-0	90-90-54	78-71-74	–	40-40-0	42-57-0
N-P_2O_5-K_2O rate (kg/ha)[c]	–	–	77-82-49	25-43-0	234-262-10	63-88-37	–	31-56-0	29-44-0
% weeding once	100	100	100	100	–	–	100	100	100
% weeding twice	68	90	–	100	–	–	58	80	100
% weeding thrice	10	20	–	–	–	–	–	–	–
Harvest date	12 Nov 80	19 Jul 80	23 Mar 81	25 Apr 81	21 Feb 81	1 Feb 81	30 May 81	29 Apr 81	16 May 81
Field duration (d)	216	114	100	87	76	74	95	76	119

[a]Figure in parentheses indicates number of sample fields monitored. [b]Not used. [c]Average application rate.

excessive floods drown draft animals. Availability of adequate livestock feed is also a problem.

Most farmers use family labor and hired labor at peak periods for weeding and harvesting. Some have a permanent hired laborer. In some deepwater areas, field operations such as weeding are done cooperatively. Usually, farm laborers are available within the villages.

The power and labor requirements for different field operations in DWR, jute, and following rabi crops are in Table 4.15.

Cropping pattern productivity and profitability

In 1980-81, the BRRI cropping systems program monitored DWR cropping patterns at Daudkandi (Table 4.16). Farmers used 15 patterns in a contiguous block of 43 fields. Seventy-five percent of the area in the block was under a double-cropping pattern and the remainder was triple cropped. DWR - wheat was the most common pattern followed by DWR - Italian millet, DWR - potato, and DWR - lentil (Table 4.16). The data clearly indicate that the relative economic profitability of the cropping patterns ranged from 60 to 550%. Inspite of a relatively lower profitability, farmers adopt the DWR - wheat pattern mainly to meet the grain requirements for family consumption. Variable costs, particularly cash requirements per hectare, also determine the adoption rate of the patterns.

In 1980-81, the Mennonite Central Committee monitored DWR-based cropping patterns at Kalacha (Table 4.17). At this site, mixed-cropping of short-duration local aus and DWR followed by a rabi crop is the basic cropping pattern. Farmers use different aus and DWR varieties as well as different rabi crops. In most cases, rabi crops are seeded with tillage after the DWR harvest. In some cases, no tillage and relay-seeding patterns of rabi crops in the maturing DWR are also followed.

The variation in the total per-hectare rice production from the aus + deepwater mixed cropping (Table 4.17) can be attributed to cultivar combination, input use, and other management practices adopted by the farmers. The highest variable production cost was in the aus + DWR - onion pattern while the lowest was in the aus + DWR - fallow pattern. The most common cropping pattern of aus + DWR - wheat gave a net return of $240/ha and a total variable cost of $484/ha. The labor and material costs ranged from $151 to $471 and from $59 to $240/ha.

Factors affecting crop production

The farming practices and crop performance in the deepwater areas are markedly influenced by the components of the deepwater ecological system. The major factors that influence the management and performance of DWR-based cropping systems are toposequence, rainfall, drought, flood, water depth, cropping technique, DWR varieties, pests, and diseases (Hoque et al 1982b).

Toposequence. Most obviously, the relative toposequence in the deep-water basins reflects the hydrological pattern. In the bottom part of the basin, inundation occurs first and floodwater recession last. The ridges remain unflooded during the early rainy months. DWR land preparation and seeding must be tuned to the position of individual fields in the toposequence. The toposequence dictates

Table 4.15. Power and labor requirements for different field operations in deepwater rice, jute, and following rabi crops, BRRI cropping systems research site, Daudkandi, Bangladesh, 1980-81.[a]

Crop	Power requirement for land preparation (paired animal-hours/ha)	Labor requirement (man-hours/ha)					
		Land preparation	Seeding/ planting	Manure/fertilization application	Weeding	Harvesting	Total
Deepwater rice	143	133	4	–	447	215	799
Jute	123	115	6	–	416	368	905
Wheat	139	143	5	4	225	335	712
Foxtail millet	140	125	3	6	351	139	624
Potato	225	215	413	18	–	509	1155
Mustard	115	143	5	5	–	207	360
Sesame	97	100	3	2	369	118	592
Mungbean	145	150	5	3	658	182	998
Chili	142	153	213	20	516	260	1162

[a]Hoque et al (1981a).

Table 4.16. Coverage and agroeconomic performance of deepwater rice (DWR)-based cropping patterns, BRRI cropping systems research site at Daudkandi, Comilla District, Bangladesh 1980-81.[a]

Cropping pattern			Area planted to pattern (%)	Yield (t/ha)			Total variable cost per pattern[b] ($/ha)	Net return per pattern		Benefit-cost ratio
DWR/ jute	Early rabi crop	Late rabi crop		DWR/ jute	Early rabi crop	Late rabi crop		$/ha	%	
DWR	Wheat	Fallow	39.95	2.6	2.0	–	364	415	100	2.14
DWR	Fallow	Chili	5.52	2.7	–	0.5	384	670	161	2.74
DWR	Fallow	Italian millet	9.90	2.5	–	0.8	265	249	60	1.93
DWR	Mustard	Fallow	1.90	2.7	0.8	–	289	492	119	2.70
DWR	Lentil	Fallow	7.13	3.1	0.6	–	257	463	112	2.80
DWR	Potato	Fallow	7.17	2.8	32.2	–	976	1644	396	2.68
Jute	Potato	Fallow	2.92	1.8	33.4	–	1007	1371	330	2.36
Jute	Potato	Sesame	1.73	1.4	39.2	0.6	816	1561	376	3.78
DWR	Potato	Sesame	4.60	2.9	38.3	0.6	972	2283	550	3.34
DWR	Potato	Chili	2.64	3.1	29.0	0.5	1039	2210	533	3.01
DWR	Mustard	Chili	1.86	2.8	1.3	0.4	471	1175	283	3.49
DWR	Mustard	Sesame	7.65	2.7	0.9	0.6	405	682	164	2.68
DWR	Mustard	Mung	2.94	2.1	0.9	0.4	422	555	134	2.31
DWR	Mustard	Italian millet	1.31	2.9	1.2	0.9	283	877	211	4.10
Jute	Mustard	Italian millet	2.79	1.6	0.7	1.3	372	1124	271	4.02

[a]Hoque et al (1982b). [b]US$1 = TK15.00.

Table 4.17. Agroeconomic comparison of cropping patterns in a medium deepwater rice (DWR) area. MCC cropping systems research site, Kalacha, Comilla District, Bangladesh, 1980-81.[a]

Cropping pattern	Sample fields (no.)	Turnaround time (d)	Yield (t/ha)		Per-pattern cost ($/ha)		Net return/ pattern		Benefit-cost ratio
Aus rice DWR Rabi crop			Aus rice + DWR	Rabi crop	Labor	Material	$/ha	%	
Aus + DWR – wheat	6	32	3.25	1.21	348	136	240	100	1.52
Aus + DWR – millet	4	26	3.08	1.29	329	83	267	111	1.69
Aus + DWR – mustard	2	11	3.76	0.70	355	121	344	143	1.75
Aus + DWR – mustard[a]	2	5	1.95	0.97	190	129	257	107	1.81
Aus + DWR + grasspea[b]	3	–31	3.13	0.69	252	92	634	264	2.98
Aus + DWR – mungbean	2	47	3.90	0.41	318	62	512	213	2.36
Aus + DWR + lentil[b]	1	–26	3.62	0.44	155	86	721	300	4.00
Aus + DWR – cowpea	1	28	2.97	1.60	471	59	865	360	2.63
Aus + DWR – onion	1	10	2.27	1.50	443	240	758	316	2.12
Aus + DWR – fallow	2	–	3.23	–	151	62	306	128	2.43

[a]Adapted from Saha et al (1981). [b]In this pattern, Laksmibilash – a poor performing early DWR variety – was used and mustard was grown with no tillage after DWR harvest. [c]Rabi crop was relay-seeded in maturing DWR crop with overlaps indicated under turnaround time.

which DWR variety and monoculture and mixed-cropping practices to use. Mixed cropping of DWR with aus rice or other crops such as millet and sesame is done mostly on the higher ridges. Also, farmers grow winter rabi crops on the ridges after DWR harvest. During the early growth stages of DWR, grassy weeds and sedges are more predominant in the upper areas.

Monsoon rains. Usually the monsoon rains start in late March and gradually increase into August, when highest precipitation occurs. Then the rainfall decreases and eventually ends during early November. The period from November to February is practically dry. Delayed onset of the rains delays DWR seeding. In some areas this may subject the crop to flood damage. Heavy rains during March-April interfere with DWR planting and with harvesting of wheat and other rabi crops; they also damage standing rabi crops such as millet, lentil, and mungbean. Rains in November-December may sometimes reflood the DWR fields, interfering with rice harvesting and causing crop losses. However, if the DWR is already harvested, mild showers in November-December help planting of rabi crops. Rains during the dry months, particularly in January-February, also help restore soil moisture, which can significantly increase rabi crop yields. In 1980 at Daudkandi, the surface soil showed a 17% soil moisture content in the first week of January but only 10% by the third week of April (Hoque et al 1980a).

Drought. Drought at seeding time causes poor DWR seed germination, resulting in sparse plant population Also, weed problems become serious when a drought period is followed by good monsoon rains. Most DWR varieties in Bangladesh can tolerate a mild drought spell during the early growth stage.

Floods. Early floods in June-July affect the aus rice in the aus + DWR mixed cropping areas. If floods come in July, the aus rice may be safely harvested, but DWR growth is adversely affected Sometimes lodging of DWR stems becomes apparent because of lack of floodwater support Flood recession time affects DWR harvest and rabi crop planting. If floodwaters recede late, farmers must harvest the rice in standing water, sometimes from boats In cases of early heavy floods in June-July, farmers harvest the ripening panicles of aus rice by diving under the rising water. The panicles are bundled up, bound together, and carried as a float. Floods in deepwater areas of Bangladesh rise gradually from June to late August, after which they start receding.

Water depth. Flooding depth significantly affects DWR variety performance and yield. Five years of extensive surveys in farmers' fields throughout the DWR areas in Bangladesh indicate that depths of less than 0.9 m or higher than 1.8 m gave identical low (1 8 t/ha) grain yields (Catling et al 1979, 1980) Highest yield (2.52 t/ha) was obtained at depths from 1.51 to 1.80 m followed by depths of 1.21 to 1.5 m. Grain yields were about 5, 25, and 34% higher at 0.91-1.2 m, 1.21-1 5 m, and 1.51-1.8 m, respectively, than at depths below 0.9 m or above 1 8 m.

Mixed cropping vs monoculture. In the shallow water areas, farmers widely use mixed cropping of aus and other crops with DWR Such mixed cropping can reduce the DWR yields by 12-25% compared with monoculture yields (Table 4.18). Unless the aus rice or other crop yields compensate for these losses, such mixed cropping is not profitable. However, subsistence farmers in the DWR areas do not always consider this land equivalent ratio criterion; they think of mixed cropping more as ensurance of food availability.

Table 4.18. Mean deepwater (DWR) crop yields as influenced by fertilizer application, monoculture, and mixed-cropping practices in Bangladesh, 1978-79 (cooperative survey work between British ODA DWR project at BRRI and Division of Rice Cropping Systems, BRRI).

Stand type	Observations (no.)	Fields receiving fertilizer application (%)	Mean (DWR) yield (t/ha)		Av yield of all fields	
			With fertilizer	Without fertilizer	t/ha	%
		1978				
Pure DWR stand	37	35	2.53	2.56	2.55	100
DWR + aus rice/other crops[b]	38	26	2.05	2.08	2.07	81
Total/mean	75	31	2.32	2.30	2.31	–
		1979				
Pure DWR stand	68	31	2.43	2.13	2.22	100
DWR + aus rice	27	30	1.67	1.68	1.67	75
DWR + other crops[b]	6	17	2.02	1.95	1.96	88
Total/mean	101	30	2.21	2.00	2.06	–

[a]Adapted from Catling etl (1979, 1980). [b]Other crops include Foxtail millet, sesame, chili.

DWR varieties. DWR varieties are rather zone-specific in Bangladesh and exhibit considerable variability among themselves in maturity, interaction with flooding pattern preference, and yield. To delineate their environmental zones, multilocation testing of several top-yielding varieties is needed.

Harvesting period. The harvesting period affects the DWR yield considerably, though its effect is confused with that of different maturity group varietal characteristics. However, survey data for 3 years (1977-79) showed that harvesting dates 17-31 October and 16-30 November gave identical average yields (2.16 t/ha). The 1-15 November harvesting date gave an average yield of 2.46 t/ha (14% higher) and 1-15 December gave 1.68 t/ha (22% lower). So, the best harvesting period for DWR in Bangladesh appears to be 1-15 November.

Pests and diseases. Catling and Alam (1981) stated that no serious disease outbreaks in DWR were encountered in recent years, but slight ufra damage was observed in 1977 and 1978. Mealy bug damage was considered severe in the 1979 drought year. Yellow rice borer is considered as the major DWR pest. Rice ear-cutting caterpillar is a problem. Rat damage is usually a serious problem in the deepwater areas.

Because of poor road transportation during the nonflood period, when most of the rice and other crops are harvested, farmers face marketing difficulties. During the floods, farmers can use country boats. Provision for pump irrigation during the dry season can significantly increase production of wheat, potato, and chili following DWR.

TIDAL SWAMP AREAS

In Indonesia, Kalimantan is one of the big islands with a tremendous potential for agricultural development. The large swampy areas along its coast have proven to be suitable for crop production (Noorsyamsi and Hidayat 1974). The tidal swamp areas of the coastal plain are where the water level fluctuates with the tide, by way

of numerous natural and man-made canals and creeks. Tidal fluctuations of the river level determine the inundation and drainage in the tidal swamp areas. However, the water level seldom exceeds 30-50 cm. The tidal action may occur as far as 100 km inland and is noticeable when the discharge capacity of the narrow and winding creeks is increased. At high tide, frequent flooding occurs throughout the year, on both sides of the river mouths. The ground and surface waters become saline during the dry season. In Indonesia, there are 35 million ha of tidal swamp areas of which 2.2 million ha are considered potential rice-cultivating areas (AARD 1982). In South and Central Kalimantan, there are about 560,000 and 1.5 million ha of potential swamp ricelands. At present farmers are utilizing only 88,373 ha in South Kalimantan and 21,672 in Central Kalimantan (Noorsyamsi and Hidayat 1974). Utilization of the tidal swamp areas is increasing through the transmigration program of the Indonesian Government.

Along the 1,970-km coast of the Bay of Bengal, the southern parts of Bangladesh have considerable tidal swamp areas where rice has been grown for centuries. The tidal areas are divided into saline and nonsaline tidal flood plains (Rashid 1978). The tidal effect is much stronger in the saline areas, and has a noticeable scouring effect. During the monsoon, the interior basins are deeply flooded. The river water turns brackish in the dry season. At the mouth of the big rivers in the saline tidal floodplains, slow deposition continues. The nonsaline tidal floodplains, which consist of shallow basins with ridges along the rivers, are shallowly flooded, the depth varying with the tide. During the dry season, only the deeper basins are tidally flooded.

Land-use patterns

The fields at the tidal swamp site at Barambai, South Kalimantan, are divided into two categories: the direct tidal swamp along the primary and secondary canals and the indirect tidal swamp which is far from the secondary canals but reached by the tidal water. Farmers have developed the lands into furrows and raised beds. They grow rice in the furrows and nonrice dryland and tree crops such as maize, cassava, cowpea, sweet potato, vegetables, banana, coffee, citrus, and rambutan on the raised beds. The most common cropping pattern includes the growing of a long duration (9-10 months) traditional rice crop in the furrows and two maize crops on the raised beds. Some farmers are also trying to raise fish in the rice paddies.

The Gournadi site in Bangladesh is in the nonsaline tidal flood area. The major cropping patterns include a single crop of local transplanted rice, direct-seeded rice - transplanted rice, transplanted rice - dryland crops, and mixed cropping of direct-seeded aus and aman rice crops. Jute and sugarcane occupy some minor areas on higher lands. Dryland crops include lentil, mungbean, sesame, and chili; coconut and betelnut plants are the most common landscape feature; and river fishery is significant in the area.

Input use and crop management practices

In the South Kalimantan tidal swamp areas, adapting techniques to water level changes made rice cultivation possible. In some areas, a network of man-made canals reduces the magnitude of water changes (Noorsyamsi and Hidayat 1974).

This canal system has decreased the direct effect of tidal action; the result is rare overflooding. Locally, the tidal swamp ricefields are called *sawah pasang surut* and the group of photosensitive varieties that are traditionally grown are *sawah bayar*. These varieties have a strong ability to adapt to swamp conditions, produce numerous tillers, and tolerate high water levels. Because of improved water control, farmers are growing new MVs of rice such as IR36.

Farmers seed the bayar varieties on raised seedbeds in October or November. They do the first transplanting when the seedlings become 40 d old and the second transplanting after at least another 30 d. After another 55-60 d, they transplant the third and final time. These transplantings increase the number and vigor of the tillers and allow the farmer to wait for a suitable water depth for transplanting to the main field. The amount and duration of rainfall determine transplanting time. Before final transplanting, farmers clean and prepare the lands manually using local implements. They use no definite plant spacing, but usually transplant five hills to 1.7 m with two or three seedlings/hill. They take special care to retain water in the field, particularly when the dry season sets in earlier than normal (Noorsyamsi and Hidayat 1974). Fertilizer application is a problem because of the tidal water. Usually, rates of 40 kg N and 8.8-17.6 kg P/ha are considered optimum for the newly introduced MVs. Foliar application of urea fertilizer might have an impact. In general, there are fewer weed problems because of tidal water movement. But in some cases, water weeds can be a serious problem. Farmers usually hand weed because herbicides are dangerous to fish. In the furrow-bed system, farmers grow local maize varieties on the beds for either green cobs or dry seeds. Cassava, cowpea, and other dryland crops are grown with low management and care. Considering the requirements for the dryland crop products, farmers may widen the raised beds in the fields gradually as the initial beds stabilize.

In the tidal swamp areas at Gournadi, Bangladesh, farmers do not double- or triple-transplant. However, they have a special planting technique known locally as the *para* method where they broadcast rice seeds in May-July in the well-prepared main fields. Tidal water usually arrives about a month after seeding. Farmers wait for another 25-30 d and then thin the main fields. They transplant the uprooted seedlings in other fields located at lower levels. Sometimes, tidal water temporarily submerges the newly transplanted seedlings, but mortality is usually very low. Every year, the tidal flooding causes siltation from 2.5 to 3.0 cm (Stockley 1980). In the single-rice cropping pattern, farmers transplant local varieties with fine grain quality. The crop is harvested in November-December. In some areas, after the rice crops have been harvested, farmers grow the dryland crops. In many cases, grasspea is relay-seeded into the maturing rice. In other areas, farmers first grow a short-duration (85-95 d) local direct-seeded aus rice, seeded in April-May, and then a transplanted aman rice. Also, some farmers mix the seeds of aus and aman rices and broadcast them in April-May. Aus rice is harvested in July-August while the photosensitive aman rice continues to grow until harvested in November-December. Fertilizer use for the rice is negligible because the crops do not yield well with N-P-K fertilizers unless a high amount of crop residues and other organic materials are incorporated into the soil and allowed to decompose before planting. Dryland crops are grown in limited areas

mainly with low management. Farmers have recently protected some areas from flooding by constructing an embankment, which has led to changes in cropping patterns. In this protected area, farmers raise seedlings of intermediate-height, high yielding varieties, such as BR7 and BR9, on peat soils in 15- to 20-cm standing water and raise transplanted rice crops with good grain yields (Stockley 1980). Although farmers still do not use much irrigation and fertilizer, timely harvests allow three crops per year.

Power and labor utilization

Only human labor is used at Barambai. At Gournadi, farmers use bullocks for land preparation by traditional plowing and laddering. Other operations are done by human labor. At Barambai, it takes 576 h/ha to grow a cropping pattern of local rice in the furrow and two successive local maize crops on the raised bed (CRIFC 1981). The labor breakdown is: 112 h for nursery management, 88 for land clearing and preparation and dike making, 192 for planting and transplanting, 72 for weeding, and 112 for harvesting.

Cropping pattern productivity and profitability

On the newly reclaimed lands in South Kalimantan tidal swamp, the average rice yields ranged from 0.7 to 1.0 t/ha (Noorsyamsi and Hidayat 1974). However, on the long-established tidal swamp rice fields, farmers usually obtain higher yields (2.2 t/ha). Very recently, with MV introduction, farmers have been getting relatively higher yields (2.3-3.9 t/ha). Dryland crop yields are low. Farmers harvest 6,000-7,500 green maize cobs/ha. Excluding the cost of family labor, farmers may obtain a net return of $428/ha from a rice (furrow) - maize (bed) - maize (bed) pattern at this site (CRIA 1980). The yields of the tidal-flooded transplanted rice crop at the Gournadi range from about 2.0 to 2.5 t/ha while those of the direct-seeded, preflood, first-rice crop range from 1.5 to 2.0 t/ha. Dryland crop yields of grasspea, lentil, and sesame are low, between 0.5 and 1.0 t/ha.

Factors affecting crop production

Proper water control, including installment of ditches, dikes, and pumps, as well as drainage from the paddies is important for increasing yields and cropping intensity in the tidal swamps. At Barambai, intermediate-height, early-maturing varieties that can tolerate low-pH, acid sulfate soil, submergence, as well as drought at later growth stages are needed. During the dry months, salinity problems do much harm to the rice crop. Rice stem borers and rats are serious pests. In the furrow-bed system, preparation and stabilization of the beds are difficult, laborious, and expensive. At Gournadi, zinc deficiency is widespread. In both areas, fertilizer management is a problem. Long-term research efforts are needed to develop stable and productive cropping systems for the tidal swamp areas.

AGROFORESTRY AREAS

In the agroforestry system, annual crops are grown, mostly in intensive mixed or intercropping methods, under the perennial forest trees or fruit-cum-timber trees.

In some areas, agroforestry is called forest gardening. Multi-storied production of different species of economic plants with suitable plant geometry on the soil is the main feature of agroforestry. It has been called a 6F program that provides food for man, feed for livestock, fiber for clothing, fuel for village and urban homes, furniture timber and funds for the poor forest villagers and government development programs. Growing annual crops under the perennial trees reduces weed growth, encourages growth of perennial crops through periodic soil care, and reduces the production cost of the plantation crop. Agroforestry also decreases soil desiccation during the dry season and minimizes soil erosion during the rainy season (Alim 1981). Introduction and extension of agroforestry in the forest belts help improve the quality of life in the forest villages and prevent pilferage of national forest resources and deforestation by unemployed villagers. Development of year-round mixed farming systems in the agroforestry areas can generate enough employment and food supplies for the farmers and forest laborers.

Scientists at eight research sites in Bangladesh, Thailand, and the Philippines are now attempting to understand the intricacies of the existing agroforestry systems and to develop more efficient production systems to harness the biophysical potential in the forests.

Land-use patterns

In the southeastern hill tract of Bangladesh, the forest villagers traditionally practiced the slash-and-burn type of shifting cultivation known locally as *jhum* cultivation. As population increased and lands for shifting cultivation became more and more scarce, shifting cultivation began to give way to subsistence plow agriculture. Moreover, the government started development programs in the hill tracts and encouraged villagers to settle and practice permanent farming, including agroforestry. The hazards of the slash-and-burn system were reduced and permanent human settlements became a common feature.

The mixed cropping patterns at the agroforestry sites in Bangladesh include growing pigeon pea, upland rice, maize, millet, sesame, cotton, cowpea, amaranthus, and squash in mixed populations among the young forest trees. Farmers usually harvest from these lands for 3 consecutive years. In some cases, they resume planting certain crops in the second or third year. At Khon Kaen, Thailand, the major pattern is growing cassava, and sometimes sesame and peanut, under the perennial trees. Also, cassava is intercropped with peanut and cowpea under the widely spaced forest trees. At the three agroforestry sites in the Eastern Visayas in the Philippines, agroforestry is practiced mainly under coconut plantations. At Basey, farmers grow coconut + taro, coconut + legumes, coconut + cacao + pineapple, and coconut + coffee + pineapple. At Bontoc, abaca is grown widely and intercropped with coffee or coconut. Under the coconut plantations at this site, farmers grow coconut + cacao + mungbean and coconut + cacao + peanut. At Jaro, farmers grow root crops and fruit trees in the coconut plantations. In some areas, maize is grown under coconut with satisfactory yields.

Input use and crop management practices

Research on existing agroforestry systems has been negligible. As a result, data on input use and crop management practices are rare. At the four sites in Bangladesh,

the forest villagers practice mixed cropping systems around their homestead on a small scale and cooperate with the government's forest department in large-scale forest plantations. Previously, they mixed seeds of different crops and planted them in hills randomly made between forest plants, with no fertilizer application. Weeding was difficult and sometimes only the regrowths of shrubs and bushes were cleared. Crops planted differed in their maturity so that individual crops from the mixed population were harvested when ready. Recently, the forestry department has improved these management practices. Farmers now plant annual crops, including pigeon pea, upland rice, maize, cotton, and cassava along the rows of forest trees, regulating the seed rate or plant population according to the relative importance of the individual crops. In some cases, e.g. upland rice, farmers apply low amounts of commercial fertilizers; in others, they use composts or ashes. Because of row planting, a uniform plant population of the individual crops is maintained and field operations are easier. Farmers use crop succession, such as upland rice followed by cucurbits, or make several harvests from the same planting, such as from pigeon pea, cotton, and papaya.

At Khon Kaen, Thailand, large-scale cassava planting is done under trees. Although price support and marketing facilities are available for cassava, farmers apply almost no fertilizer. Other crops such as kenaf and sesame are grown under a low level of management. At the three agroforestry sites in the Philippines, farmers first pay attention to the spacing and row arrangement of perennial crops — coconut, abaca, coffee, and cacao. When more than one of these perennial crops are grown together, they are spaced so that annual crops can grow between the perennial trees. Farmers grow such crops as maize, sweet potato, and peanut, under partial shade with a low level of management. In most cases, planting and harvesting are the major field operations. Cropping systems research workers and extension staffs are trying to develop suitable component technologies and motivate farmers to adopt better management practices.

Power and labor utilization

At the Bangladesh sites, farmers do almost all operations manually. Usually, in the government plantations, each forest family receives about 0.5 ha of agroforestry area to manage and harvest. Family members, particularly women, work laboriously using indigenous tools. Sometimes, several families may work together for a major field operation such as planting. At the Thai and Philippine sites, animal power is used sometimes, particularly in initial land preparation. Research has just begun to determine labor and power requirements for land use alternatives, though from 500 to 700 h/ha per year may be required in an agroforestry system.

Cropping pattern productivity and profitability

The yields of individual crops in an agroforestry system are determined mainly by the plant population. With about 60% of the normal plant population, upland rice yields may range from 1.0 to 1.5 t/ha. More than 2.0 t/ha has been harvested, particularly when suitable high yielding varieties (Purbachi) have been used. Pigeon pea is one of the most productive and profitable crops. While it provides

shade for growing forest plants, farmers harvest considerable amounts of dry seeds up to the third year after planting. At sites of the forest department in Bangladesh, the gross incomes from annual crops were $260/farm in 1977-78 and $330/farm in 1978-79. Corresponding net incomes were $197/ha in 1977-78 and $280/ha in 1978-79 (Alim 1981). With an approximate cost of about $60/ha, the systems are quite satisfactory to the poor farmers.

At Khon Kaen, the yield of a solid cassava crop ranges from about 6.0 to 12.0 t/ha. There is sometimes a 60% yield reduction when cassava is intercropped with crops such as cowpea (Limpinuntana et al 1978). In the Philippines, the yields of gabi (5.48 t/ha) and ramie (0.16 t/ha) are favorable when grown under shade (Carandang 1979). Under shade the yields were 7.66 t/ha for cassava, 2.54 t for maize, 1.6 t for sorghum, 2.57 t for sweet potato, 0.71 t for soybean, and 0.37 t for mungbean (Gomez and Gomez 1981). Yields from these crops are usually much higher in open fields.

Factors affecting crop production

Crop production under agroforestry systems is affected by lack of improved shade-tolerant crops and varieties, inadequate knowledge about mixed crop geometry and cultivation techniques, abundance of pests, and marketing constraints. When perennial trees are in the early growth stages, the annual crops receive almost as much solar energy as in the open spaces. As the perennial trees develop canopies, the rate of light interception increases. At the maximum canopy stage of coconut, for example, only about 40% of open space solar energy may be available for the annual crops under them. There is a need for development of more efficient cultivars that can produce more yields under the agroforestry conditions.

Farmers need more knowledge on planting methods, crop configuration, and crop management practices. The hot humid conditions in most agroforestry areas favor insect pests and plant diseases. Birds, rabbits, and monkeys can damage the field crops. The most important constraint in remote areas is marketing because of difficult road systems. In some cases, the cost of transporting produce to market is more than the value of the product. Marketing perishable products, such as pineapple, watermelon, tomato, and other vegetables during the peak harvesting time is a serious problem. Better organized marketing systems and agricultural industry development in the agroforestry belts will help small farmers and increase the flow of products to deficit areas.

HILL AGRICULTURE AREAS

Agriculture in the hills is characterized by diverse farm enterprises. Crops, livestock, and various off-farm employment combine to provide livelihood for small hill farmers. Survey research at four hill farming areas of Nepal revealed a range of annual income per farm from $348 to $710. Between 41 and 61% of this income came from crops, between 17 and 28% from livestock, and between 16 and 42% from off-farm employment depending on the survey areas (Mathema and Van der Veen 1981). More women and children participate in hill farm activities. Farm

size and number of workers and draft animals determine the technology, cropping intensity, and amount of off-farm work.

Hill agriculture is important in Nepal. The hills account for about two thirds of the country's total land area, but contain only one third of the cultivated land (Malla 1980). About 60% of the Nepalese live in the hills and the remainder live in the Terai where two thirds of the country's cultivated lands are located. About 70% of all grains produced comes from the Terai, making it a surplus area. The majority of the hill population engage in subsistence farming and need more appropriate technologies, extension services, and other institutional support. Realizing the importance of technology generation for the small hill farms, the cropping systems scientists in Nepal have focused on four on-farm research sites in the hills — Chauri Jhari, Khandbari, Lele, and Pumdi Bhumdi.

In Sri Lanka, the Bandarawela site represents a hill farming area in the southeastern part of the country.

Land-use patterns

The hill cropping systems sites are characterized by terraced lands or a rolling landscape of different valley types. During the rainy season, enough water is available, sometimes up to a depth of about 30 cm at field level. Except for the high slopes, rice is usually grown during the rainy season and may be followed by different crops, depending on water availability or residual soil moisture. The relative position of the individual fields in the toposequence determines the field level moisture regime and the cropping patterns. Traditional cropping patterns grown at the five hill research sites are in Table 4.19. Most of the patterns are rice-based. However, in the dryland areas of Khandbari, Lele, and Pumdi Bhumdi, farmers grow maize-based patterns. The number of cropping patterns at a particular site may range from 2 to 11, indicating wide differences in crop diversity. Table 4.20 indicates pronounced crop diversity and relative importance of different crops at cropping system hill sites in Nepal.

At Bandarawela, farmers grow rice in vertical folds in the mountains, in rotation with vegetables. Potato and beans are the major vegetables.

Input use and crop management practices

In general, input levels and crop management intensity in the hills are low. In Nepal, about 80% of the wheat and 20-25% of the rice and maize areas are planted to MVs, but the fertilizer rate is only 9.13 kg NPK/ha (Mallick and Pathic 1981). The average fertilizer rate is much lower in the hills (3.07 kg/ha) than in Terai areas (10.7 kg/ha). However, the fertilizer rate at Kathmandu Valley is very high (275 kg/ha) and near the saturation point because of a higher crop response. Mallick and Pathic (1981) reported that at 30 kg N/ha, MV rice yields per kilogram of N fertilizer were 26.6 kg at Khumal, Kathmandu, and 19.3 kg at Parwanipur in the Terai. At 60 kg N/ha, the yields per kilogram N were 25.5 kg at Khumal and 14.1 kg at Parwanipur. With 120 kg N/ha, the yields per kilogram N were 16.1 kg at Khumal and 11.2 kg at Parwanipur. The MV rice yield response to added N fertilizer was 37 to 112% higher at Khumal than at Parwanipur. Similarly, MV maize yield response was 34.2 kg per kilogram N at Khumal and 10.9 kg per

Table 4.19. Traditional cropping patterns at five hill agriculture sites in Asia.[a]

Cropping pattern	Research sites[b]				
	Chauri Jhari, Nepal	Khandbari Nepal	Lele, Nepal	Pumdi-Bhumdi, Nepal	Bandarawela, Sri Lanka
Rice	•	••	–	••	–
Rice - wheat	–	•	••	•	–
Rice - maize	–	•	–	•	–
Rice/lentil	•	–	–	–	–
Rice - potato	•	–	•	–	••
Rice - mustard	–	–	–	•	–
Rice - vegetables	–	–	–	–	••
Rice - rice	•	•	–	–	–
Rice - maize	•	–	–	–	–
Rice + maize – *Sesbania*	•	–	–	–	–
Rice + maize – lentil	•	–	–	–	–
Rice + maize – chickpeas	•	–	–	–	–
Rice + maize – wheat	•	–	–	–	–
Rice + maize – wheat + mustard	•	–	–	–	–
Rice + maize – lentil + linseed	•	–	–	–	–
Maize - maize	–	••	–	–	–
Maize - finger millet	–	••	–	–	–
Maize + soybean – wheat	–	–	••	–	–
Maize + soybean – mustard	–	–	••	–	–
Maize + beans/finger millet – wheat	–	–	–	••	–
Maize + beans/finger millet – mustard	–	–	–	••	–

[a]Adapted from Malla and Manzano (1981) and Fernando et al (1982). [b]• Other existing cropping patterns, ••Predominantly existing cropping patterns, – Traditionally not grown by farmers.

Table 4.20. Percentage of farms growing each of the major crops at the four cropping systems hill sites in Nepal, 1977-1978.[a]

Hill site	Sample farms surveyed (no.)	Farms growing an individual crop (%)						
		Rice	Wheat	Maize	Millet	Potato	Mustard	Pulses
Pumdi Bhumdi	82	87	65	98	94	7	61	61
Khandbari	86	85	9	98	93	1	78	37
Lele	74	85	86	96	18	24	57	–
Chauri Jhari	73	99	97	84	66	3	79	67
	–	89	64	94	68	9	69	55

[a]Mathema and Van Der Veen (1981).

kilogram N at Rampur in the inner Terai. At Lele and Pumdi Bhumdi, the efficiency of N fertilizer, at 30 kg N/ha, was 20 kg of grain per kilogram N.

At the research sites in Nepal, farmers apply compost, but usually no commercial fertilizers (Malla et al 1980). Fertilizer response under farmer management is low. This calls for training to help farmers become more efficient fertilizer managers. Hand weeding provides satisfactory weed control. Rice is planted in May-June and harvested between September and November. Farmers grow winter crops such as wheat, barley, potato, mustard, and pulses during the

cooler months (November-March) and maize, millet, peanut, and soybean during March-April to July-August.

At Bandarawela, Sri Lanka, rice cultivation before January results in sterility because of the temperature regime (Fernando et al 1982). Severe blowing during May, June, and July can damage standing crops. Therefore, farmers plant rice in early January and harvest in late May before winds come with the onset of the southwest monsoon. Farmers plant traditional varieties such as H4 and MI 273, which mature within 120-135 d. However, the growth duration at this hill site is extended by about 4 weeks because of cool night temperatures (Upasena 1981a). Farmers grow potato and other vegetables after harvesting rice. They devote a good level of management to rice and potato crops, with particularly good drainage systems in the potato fields. Vegetable crops usually receive intensive care.

Power and labor utilization

At all the research sites, human labor and draft animals provide the power sources. Except for land preparation, most of the field operations are done manually. At Bandarawela, in addition to family labor, exchange labor is used for various farming operations (Fernando et al 1982). In Nepal, 288 paired bullock-hours/ha cost about $64 for cultivating high yielding rice varieties (Mallick 1982). For traditional cropping patterns, women contribute a major part of labor requirements. The farmer and his family meet most of the farm labor requirements. Exchange labor is used during planting, weeding, and harvesting (Mathema and Van der Veen 1978). Some of the Brahmins (higher caste Hindus) hire plowmen on a wage or contract basis. There are labor and power shortages at peak periods. The magnitude and timing of shortages differ among the sites depending on the onset of rains, dominant cropping patterns, and other factors. Generally, labor and power shortages occur during land preparation, maize seeding, and rice transplanting in the spring, and maize and rice harvest and land preparation for wheat in the fall (Mathema and Van der Veen 1981). There is a year-round labor demand for livestock care and household activities that reduces labor availability for crop production. Improved farm tools or small-scale mechanization may facilitate more intensive cropping (Mathema and Van der Veen 1978).

Cropping pattern productivity and profitability

At Bandarawela, researchers conducted a crop-cut study to determine the yields and management of the farmers' rice crops. In general, farmers used minimal inputs. The average yields of the three common varieties were 6.8 t/ha for BG90-2, 6.5 t/ha for MI 273, and 6.1 t/ha for H4 (Fernando et al 1982). In another study, the mean tuber yields of various potato varieties ranged from 3.9 to 4.7 t/ha. Usually farmers derive high gross incomes from the traditional rice - potato, rice - vegetables patterns, but the net returns are not high because local marketing facilities cannot handle the increases in the area's agricultural production.

The data on agronomic productivity of eight traditional cropping patterns grown by the farmers in the hills of Nepal are in Table 4.21. Except at Khandbari, triple cropping patterns with considerable yields were grown at all other sites.

Table 4.21. Agronomic productivity of several cropping patterns at four cropping systems hill sites in Nepal, 1977-80.

Site	Farmers' cropping pattern	Yield (t/ha)			
		1st crop	2nd crop	3rd crop	4th crop
Chauri Jhari	Rice + maize – chickpea	1.9	1.9	1.2	
	Rice + maize – wheat + mustard	1.9	1.9	2.0	0.4
Khandbari	Maize	0.9			
	Rice - rice[b]	1.9	2.0		
Lele	Rice - barley	1.9	0.6		
	Maize + soybean – mustard	1.4	0.3	0.4	
Pumdi	Rice - wheat	2.0	1.2		
Bhumdi	Maize - finger millet - wheat	2.4	1.5	1.2	

[a]Adapted from Malla (1981a). [b]MV used.

Table 4.22. Agronomic productivity and economic profitability of traditional cropping patterns at 4 hill sites in Nepal, 1979-1980.[a]

Site	Farmers' traditional cropping pattern	Yield (t/ha)			Production cost ($/ha per pattern)		Net return ($/ha per pattern)[b]
		1st crop	2nd crop	3rd crop	Labor	Materials	
Chauri Jhari	Rice + maize – wheat	1.9	1.9	2.0	–	84	832[c]
	Rice - wheat	2.9	2.9	–	–	51	893[c]
Khandbari	Rice	2.3	–	–	86	13	314
Lele	Rice - wheat	1.9	1.4	–	290	89	255
Pumdi Bhumdi	Rice - wheat - maize	1.7	1.2	2.1	306	47	585

[a]Adapted from Nepal Cropping Systems Program (1981). [b]Exchange rate used: US$1 = Rp12. [c]Not excluding labor cost.

However, the maize + soybean - mustard pattern at Lele did not produce satisfactory yields. By double cropping MV at Khandbari, farmers got yields of about 4 t/ha. The data on the agroeconomic performance of four other cropping patterns are in Table 4.22. Data indicate that farmers used a very low proportion of material inputs, compared with the labor inputs, in growing these cropping patterns. The single rice cropping pattern at Khandbari gave a benefit-cost ratio of 4.17 compared with 1.67 and 2.66 from the rice - wheat pattern at Lele and rice - wheat - maize pattern at Pumdi Bhumdi. The intensity of traditional cropping patterns and the resulting yields in the hill areas indicate great potential for increased production, particularly through improved input use and management practices.

Factors affecting crop production

Crop production, processing, and marketing are much more difficult in the hills than in other areas.

Marketing. Fernando et al (1982) maintained that increasing agricultural production in the hills without giving proper attention to marketing facilities

reduces farmers' net income and lowers the economic efficiency of production resources. Mathema and Van der Veen (1981) also recognized marketing as a major constraint in the hills. Particularly when improved technologies increase yields and when sound government marketing programs are absent, much of the additional production is marketed at reduced price (up to 20%) or at increased transportation cost.

Cold-tolerant rice varieties. In the hills, farmers need cold-tolerant varieties. At Bandarawela, low temperatures during the heading stage, which cause sterility, affected rice yields (Upasena 1981a).

Farmer traditions. Farmers at Bandarawela prefer red-pericarp rices so introduction of white MV is sometimes difficult. In Nepal, the hill farmers are also somewhat reluctant to accept the introduced Taiwanese rice because of threshing difficulties and unsuitability of the straw for thatching (Mallick and Pathic 1981). The adoption of the high yielding Khumal Yellow maize variety is low because some farmers do not like its taste.

Power and labor shortage. In most hill farming areas, there are power and labor shortages and these are expected to increase as the cropping intensity increases. Unlike in the plains, seasonal migration of laborers from one place to another is difficult.

Farmer knowledge base. The hill farmers are well experienced and knowledgeable in their traditional crop production practices. However, whenever improved management practices are introduced, such as fertilizer management and pesticide application, training is essential. In traditional cropping systems, women take care of many farm operations. However, their low position in the village society excludes them from new technology agriculture, which is an additional constraint to agricultural development in the hills.

Crops vs other enterprises. The importance of the interrelationships among different enterprises, such as crop production, livestock, and off-farm employment, is well recognized on the small subsistence hill farms. A holistic approach will bring appropriate farm technologies. For example, there is a need at Bandarawela for evaluating the relative returns to inputs on rice vs vegetables, as well as for studying the possible interaction of these crops' productivity and profitability with employment at tea plantations or other off-farm income locations.

Credit and input supply. Timely availability of seeds and fertilizers is a problem. As improved technologies are introduced to the hills, farmers will need credit on suitable terms and conditions.

Chapter 5

DESIGN AND TESTING OF IMPROVED CROPPING SYSTEMS

The important criteria that guide the cropping systems researchers in the design process include the existing farm resource base, the biophysical potential of the research site, prevailing socioeconomic conditions, and the availability of improved component technologies from basic or fundamental research groups. The major considerations made in designing improved cropping systems for a site include crop intensification, replacement of old low yielding crop varieties, and incorporation of improved crop management technologies. Where information on new component technologies is rare or not available, the cropping systems scientists carry out simple trials on the farm. The ACSN scientists have been working vigorously on the design and testing of improved cropping patterns and component technologies at their sites. The highlights of these on-farm research activities follow.

RAINFED WETLAND SITES

Considerable research attention has been focused on improving traditional cropping systems in the rainfed wetlands. Short-duration, improved rice varieties have been used, turnaround time between crops has been reduced, and nonrice crops have been included to develop more intensive and productive cropping patterns. New component technologies were necessary to support the new cropping patterns and to increase the productivity of existing ones.

Cropping pattern testing

Researchers have tested modified patterns at Bhogra, Bangladesh, since 1976 when they started preliminary testing with four modified rice - rice cropping patterns and farmers' five double-rice patterns. The highest yield was obtained from the newly designed BR - BR4 pattern (10.2 t/ha) followed by the BR3 - Nizersail pattern (7.4 t/ha). Among the existing patterns, Chandina Pajam gave the highest yield (6.8 t/ha) followed by IR8 - Nizersail and Chandina - Nizersail patterns. The lowest yield (4.1 t/ha) came from the farmers' Pukhi - Pajam pattern followed by the Pukhi - Nizersail pattern. Preliminary pattern testing at Bhogra indicated that under favorable rainfall conditions, growing two MV rice crops in a year could result in high yields. If rainfall was unfavorable, a MV aus - local t. aman pattern was the best alternative. Cropping pattern testing was continued at Bhogra up to 1981 (Hoque et al 1982a).

The summarized results on the testing of seven double rice-cropping patterns at Bhogra are in Table 5.1. Pukhi-Nizersail was the area's old traditional double-rice cropping pattern.

The rice varieties grown in the two seasons (aus transplanted in April-May and harvested in June-July; t. aman transplanted in July-August and harvested in

Table 5.1. Agronomic productivity of seven rainfed rice cropping patterns in farmers' fields at Bhogra Site, Dhaka, Bangladesh, 1976-1981.[a]

Cropping pattern			Yield (t/ha)						Av yield	
Aus rice	–	t. aman rice	1976	1977	1978	1979	1980	1981	t/ha	%
Pukhi	–	Nizersail	4.4	–	–	5.1	4.3	–	4.6	100
Pukhi	–	BR4	6.2	5.6	–	–	5.7	–	5.8	126
Chandina	–	Nizersail	5.0	–	–	6.0	6.4	5.5	5.7	124
Chandina	–	BR4	–	7.1	5.0	–	9.3	6.4	7.0	152
Chandina	–	Pajam	6.8	–	6.2	–	6.8	–	6.5	141
BR3	–	Nizersail	7.4	9.1	5.0	–	7.0	5.9	6.9	150
BR3	–	BR4	10.2	–	7.1	–	8.5	7.3	8.3	180

[a]Hoque et al (1982a).

December-January) were grouped as local and modern. The performances of the four rainfed double-rice cropping patterns at Bhogra from 1976 to 1978 are summarized in Table 5.2. With 3 years of data, the modern aus rice - modern t. aman rice pattern gave the highest yield (7.1 t/ha) followed by modern - local (5.9 t/ha), local - modern (5.3 t/ha), and local - local (4.3 t/ha). Compared with the local aus - local t. aman pattern, the local - modern pattern gave 23% higher grain yields, the modern - local 37%, and the modern - modern 65%. In the relative contribution to total production per pattern, the aus and t. aman crops made up 49 and 51% of the local - local pattern, 34 and 66% of the local - modern, 63 and 27% of the modern - local, and 57 and 43% of the modern - modern. Considering the average values of the four patterns, the relative contributions of

Table 5.2. Yield performance of rainfed double-rice cropping patterns at Bhogra, Dhaka, Bangladesh, 1976-1978.[a]

Year	Cropping pattern		Yield (t/ha)			Pattern yield index (%)	Relative yield contribution (%)	
	1st rice crop (aus)[b]	2nd rice crop (t. aman)[c]	1st crop	2nd crop	Total		1st crop	2nd crop
1976	Local	Local	1.9	2.6	4.5	100	42	58
	Local	Modern	1.7	3.2	4.9	109	35	65
	Modern	Local	3.3	2.3	5.6	124	59	41
	Modern	Modern	4.4	3.2	7.6	169	58	42
1977	Local	Local	2.0	2.5	4.5	100	44	56
	Local	Modern	2.3	3.5	5.8	129	40	60
	Modern	Local	4.6	2.4	7.0	156	66	34
	Modern	Modern	4.3	3.6	7.9	176	54	46
1978	Local	Local	2.3	1.5	3.8	100	61	39
	Local	Modern	1.4	3.9	5.3	139	26	74
	Modern	Local	3.2	1.9	5.1	134	63	37
	Modern	Modern	3.5	2.4	5.9	155	59	41

[a]Hoque et al (1982a). [b]Aus rice: transplanted April-May and harvested June-August; local variety used is Pukhi; MVs include Chandina (BR1), BR3, BR6, and IR8. [c]T. aman rice: transplanted July-August and harvested November-December; local variety used is Nizersail; MVs include BR4 and Pajam.

the aus and t. aman crops to the total yield per pattern were almost identical. However, considering the productivity of the individual patterns, the modern aus crop is of special significance for this rainfed site.

Table 5.3 presents data on the relative efficiency of different rice cropping patterns in terms of available rainfall utilization. Researchers found that 1,600 mm of rainfall could sustain a two-rice crop pattern with a combined yield of about 6 t/ha. In high-rainfall years, efficient rainwater use by the farmers in double-rice cropping patterns was reduced, indicating rainwater loss or availability in excess of the requirements. Rainfall distribution over the crop season is very important for satisfactory yields.

Researchers undertook studies to determine the relative yield advantage of higher crop management over traditional management. In 1976, yields due to higher management ranged from 7 to 32% above yields realized from traditional management. On an average, yields were 5.1 t/ha with farmer management and 6.1 t/ha with higher management. The additional cost involved in the higher management was equivalent to the price of about 140 kg grain, so the marginal benefit-cost ratio was about 7.14. In 1977, the yields due to higher management levels ranged from 23 to 42% above the yields realized under traditional management practices On an average, higher management resulted in a 27% yield increase.

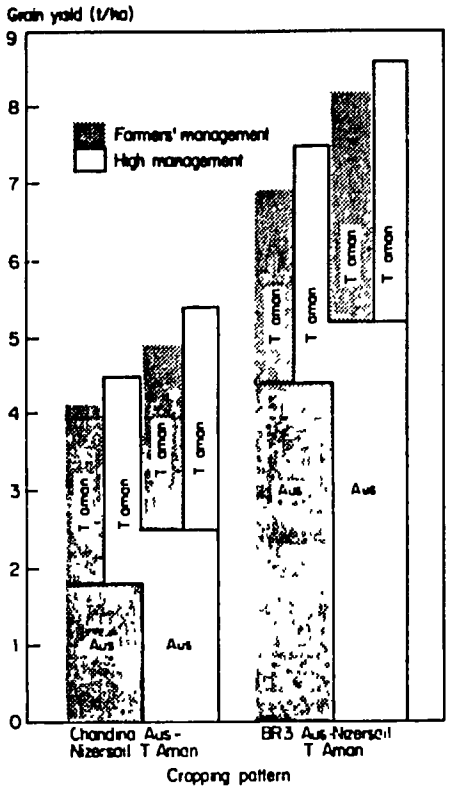
Experiments were also conducted at Bhogra to determine the residual effect of the management practices done for the aus crop on the performance of the t. aman crop. The results on two patterns are in Figure 5.1. The high management increased the yields of both the aus and t. aman crops compared with traditional management. High management for the aus crop had significant residual effect on yield performance of the t. aman crop.

Economic net returns obtained from different cropping patterns at Bhogra during 1978 to 1981 averaged $432/ha for local aus - local t. aman, $430 for the local - modern, $595 for the modern - local, and $591 for the modern - modern.

Table 5.3. Available rainfall utilization efficiency of seven rainfed rice cropping patterns at Bhogra, Dhaka, Bangladesh, 1976-1981.[a]

Cropping pattern			Grain yield (kg/ha) per mm available rainfall during crop season						
Aus rice	–	t. aman rice	1976	1977	1978	1979	1980	1981	Av
Pukhi	–	Nizersail	2.26	–	–	3.18	2.04	–	2.49
Pukhi	–	BR4	3.17	2.61	–	–	2.69	–	2.82
Chandina	–	Nizersail	2.53	–	–	3.77	3.00	3.38	3.17
Chandina	–	BR4	–	3.29	2.15	–	4.41	3.91	3.44
Chandina	–	Pajam	3.48	–	2.65	–	3.11	–	3.08
BR3	–	Nizersail	3.77	4.21	2.15	–	3.28	3.63	3.41
BR3	–	BR4	5.18	–	3.05	–	4.01	4.46	4.18
Av			3.40	3.37	2.50	3.48	3.22	3.85	3.30
Available rainfall during aus – t. aman crop seasons			1963	2155	2329	1601	2121	1629	1966

[a]Hoque et al (1982a).



5.1. The effect of management level on the productivity of two rainfed rice cropping patterns at Bhogra site, Dhaka, Bangladesh, 1976 (Hoque et al 1982).

The modern aus - local fine-quality rice pattern averaged a return of $845/ha, indicating a much higher profitability (Hoque et al 1982a).

The agroeconomic analysis of farmers' 1980 cropping patterns indicated that the total variable costs in double rice crop patterns including one modern rice crop was higher by 19-23% compared with the local aus - local t. aman pattern. The modern aus - modern t. aman had the highest variable cost ($726/ha), but also had the highest net return ($716/ha) with a benefit-cost ratio of 1.99. Although the modern aus - local fine-quality rice pattern yielded less (6.5 t/ha) than the modern aus - modern t. aman and modern aus - local t. aman, it still gave a high net return ($711/ha). The high net return in the modern aus - local fine-quality rice pattern can be attributed to the higher market price of the local fine-quality rice. The benefit-cost ratio was also highest in this pattern. The cost required to produce 1 kg rough rice at Bhogra ranged from $0.08 to $0.10 depending on the pattern (Hoque et al 1982a).

The results of on-farm cropping pattern testing at Bhogra have formed the basis for large-scale multilocation testing and pilot production programs in the rainfed wetland areas of Bangladesh.

In 1980-81, at the Katupotha rainfed wetland site in Sri Lanka, the traditional rice - rice pattern yielded 1.1 t/ha from the first crop and 0.9 t from the second

crop (Upasena 1981a). The rice - rice experimental pattern at this site yielded about 3.9 t/ha from the first crop and 1.0 t from the second. The variable cost for this pattern was $425 ($85 for material cost and $340 for labor and power costs) while the net return was $470/ha for both patterns. The rice - green gram pattern yielded about 2.8 t rice/ha and 0.9 t green gram/ha. The material cost was about $76/ha, labor and power cost $298, and net return $684 (Upasena 1981a). The rice - peanut pattern yielded about 2.8 t rice/ha and 2.7 t peanut/ha (Upasena 1981a). The material cost was $110/ha, labor and power cost $367, and the net return $949. This cropping pattern had the highest net return as well as highest benefit-cost ratio (about 3.0) compared with the rice - green gram (2.8) and rice - rice (2.1) patterns.

At Ubon in northeastern Thailand, rice-based double cropping patterns have been designed and tested to replace the farmers' single rice cropping pattern. The agroeconomic performance of the cropping patterns tested at this site in 1977 and 1978 are in Table 5.4. Results on the double rice cropping patterns, rice - rice, or rice - rice ratoon were not encouraging because of poor yields and net economic loss. In 1977, the yields and net returns of yardlong bean - rice and rice - peanut patterns looked promising. In 1978, the glutinous maize - rice, peanut - rice, and yardlong bean - rice patterns gave satisfactory yields and net returns. These results on cropping pattern testing at Ubon indicated that if required support services are provided to the farmers, double cropping patterns involving dryland crops such as maize, peanut, yardlong bean, etc. before or after the rainfed wetland rice crop could be adopted on a large scale.

At Pimai in northeastern Thailand, attempts have been made since 1977 to

Table 5.4. Agronomic productivity and economic profitability of cropping patterns tested at Ubon, northeastern Thailand, 1977-78.[a]

Year, cropping pattern[b]	Crop yield (t/ha)		Variable cost ($/ha)	Net return ($/ha)
	1st crop	2nd crop		
1977				
Yardlong bean - rice (Niew Sanpatong)	6.0	1.4	414	663
DSR (RD6) - cowpea	2.2	0.9	226	80
DSR (RD9) - sweet maize	1.7	2.3	247	123
DSR (RD7) - peanut	2.7	0.7	297	159
DSR (PMI) - TPR (HY71)	2.2	0.6	326	-36
1978				
Yardlong bean - rice (RD6)	2.1	2.1	308	269
Peanut - rice (RD6)	1.4	2.3	269	366
Glutinous maize - rice (RD7)	28 438[c]	3.1	356	493
MungBean - rice (RD7)	0.2	1.8	278	8
Rice (RD7) - rice (RD6)	1.5	2.4	309	181
Rice (RD5) - ratoon rice	0.8	0.6	250	-83

[a]Adapted from Chandrapanya et al (1982). [b]DSR = direct seeded rice. TPR = transplanted rice. [c]Number of marketable ears.

intensify cropping patterns by growing additional crops before the usual monsoon rice (Chandrapanya et al 1982). In 1977, the mungbean - rice pattern yielded about 0.5 t mungbean/ha and 2.8 t rice/ha and gave a net return of about $43/ha with a variable cost of $190/ha. In the maize - rice pattern, the yields were 35,450 marketable ears/ha and 3.8 t rice/ha, a net return of about $291/ha, and a variable cost of about $215/ha (Chandrapanya et al 1982). The peanut - rice pattern yielded about 3.9 t peanut/ha and 3.2 t rice/ha, giving a net return of about $190 with a variable cost of about $382/ha. In another pattern, farmers grew cucumber before rice, which yielded 5.0 t cucumber/ha and 1.5 t rice/ha, and gave a net return of about $283/ha and a variable cost of about $215/ha (Chandrapanya et al 1982). Three crops were attempted at this rainfed site in 1977. A pattern of maize + mungbean - rice yielded about 20,362 marketable ears/ha, 0.4 t mungbean/ha, and 3.6 t rice/ha. This pattern had the highest net return ($293/ha) and the highest variable cost ($466/ha) among all the cropping patterns tested in 1977. The highest benefit-cost ratios were obtained in the maize - rice pattern (2.35) followed by cucumber - rice (2.32), maize + mungbean - rice (1.63), peanut - rice (1.50), and mungbean - rice (1.20). Availability of the early maturing varieties should greatly help the farmers in adopting these double cropping patterns at Pimai (Chandrapanya et al 1982).

In 1978, the sweet maize + peanut - rice pattern produced 18,894 marketable ears maize/ha, 0.3 t peanut/ha, and 1.7 t rice/ha at Pimai (Chandrapanya et al 1982). The mungbean - rice pattern yielded about 0.3 t mungbean/ha and 1.7 t rice/ha. The peanut - rice pattern yielded about 0.2 t peanut/ha and 1.7 t rice/ha. In 1978, all these experimental patterns incurred economic loss at Pimai (from $91 to $219/ha) because of relatively high variable costs ($380 to $534/ha).

In 1979, at Pimai, the mungbean in the mungbean - rice pattern yielded 0.5 t/ha when seeded in rows and 0.3 t/ha when broadcast seeded. The rice yielded 1.0 t/ha when broadcast seeded and 0.5 t/ha when transplanted (Chandrapanya et al 1982). In 1979 heavy rain in the early monsoon, and then an early cutoff of the rainy season, adversely affected crop yields. The yields from the peanut - rice, sesame - rice, and sweet maize + upland rice - rice patterns were all low. In 1980, the peanut - rice pattern yielded 2.5 t peanut/ha and 1.9 t rice/ha and the sesame - rice pattern yielded 0.4 t sesame/ha and 1.7 t rice/ha (Chandrapanya et al 1982). The glutinous maize/mungbean - rice pattern yielded 28,750 marketable ears maize/ha, 0.3 t mungbean/ha, and 1.7 t rice/ha. Farmers in the area prefer peanut because it provides a better income. Results of cropping pattern testing at Pimai indicate that with a favorable rainfall, farmers can successfully grow peanut, glutinous maize, and mungbean before the traditional monsoon rice (Chandrapanya et al 1982).

At Serang, Java, Indonesian scientists have been trying to intensify cropping in the rainfed wetlands. In 1980-81, a maize + rice - rice - cowpea pattern yielded 1.0 t maize/ha, 3.7 t intercrop rice, and 3.7 t rainy season main rice. The cowpea crop grown in the dry season failed (CSP, Indonesia 1981). The variable cost for this pattern was about $665/ha ($347 for labor, $213 for material, and $105 for power). The net return was about $747/ha. The mungbean - rice - cowpea pattern yielded 0.3 t mungbean/ha, 4.2 t rice/ha, and 0.4 t cowpea/ha. The

variable cost was relatively higher at $920/ha ($642 for labor, $173 for material, and $105 for power). The net return was only $273/ha.

In the rainfed wetlands at Sampang, Madura, Indonesia, a newly designed rice - rice - mungbean pattern yielded about 5.0 t rice/ha, 3.7 t rice/ha, and 0.4 t mungbean/ha (CSP, Indonesia 1981). The total variable cost was $1,320/ha ($503 for labor, $157 for power, and $660 for material). The net return was $874/ha. When cowpea was grown in place of mungbean, the variable cost was reduced by about 3.5% ($46/ha), but the net return was reduced by about 19% ($168/ha). The cowpea yield was only 0.16 t/ha.

The results on the testing of three cropping patterns at Iloilo, Philippines, in 1976-77 under farmer and research management are in Table 5.5. Yields of all crops, except the second rice crop in the rice - rice pattern, were increased by improved management practices. There were higher net returns in all three patterns under research management.

At Pangasinan, Philippines, the cropping pattern of rice - mungbean appeared economically attractive. Summarized data from 1975-78 on cropping patterns testing indicated that the rice - mungbean pattern under farmer management (86 field trials) averaged a net return of $396/ha with a variable cost of $227/ha ($160 for labor and $67 for material) (Momen 1979). Attempts were made in 46 fields to determine the effect of intensive management practices on the rice - mungbean pattern managed by researchers and involving more material and labor cost. This effort averaged a net return of only $192/ha with a variable cost of $564/ha ($306 for labor and $258 for material). The benefit-cost ratios of the rice - mungbean pattern were 2.74 under farmer management and 1.34 under researcher management.

The highest net return ($500/ha) came from a farmer-managed rice - cowpea pattern with a variable cost of $473 ($410 labor and $63 material) (Momen 1979). This pattern had a net return of $192/ha under experimental management with a variable cost of $600/ha ($322 labor and $278 material). The benefit-cost ratios were 2.06 for farmer management (17 fields) and 1.32 for experimental management (16 fields). Based on trials in 15 fields under farmer management, a rice - rice pattern at Pangasinan had a net return of $334/ha with a variable cost of $388/ha ($259 labor and $79 material) (Momen 1979). The average net return under experimental management from this pattern on 16 fields was $330/ha with a variable cost of $714 ($422 labor and $292 material). The benefit-cost ratios of the rice - rice pattern were 1.99 under farmer management and 1.46 under experimental management. Farmers' traditional single rice crop (55 fields) averaged a net return of $113/ha with a variable cost of $156/ha ($117 labor and $39 material). Researchers tested a rice - rice - dryland crop pattern in 23 farmers' fields, which resulted in a variable cost of $991/ha ($549 labor and $442 material). The net return was $217/ha (Momen 1979).

The Pangasinan farmers traditionally grew a single crop of rice and a rice - mungbean cropping pattern. The cropping systems research program introduced several other cropping patterns such as rice - cowpea, rice - rice, and rice - rice - dryland crops. The on-farm research program has also motivated the farmers to adopt better levels of crop management. Cropping pattern testing indicated that

Table 5.5. Agroeconomic performance of three cropping patterns under farmer and researcher management at Iloilo, Philippines, 1976-77.[a]

Management level	Sample fields (no.)	Crop yield (t/ha)			Variable cost[b] ($/ha per pattern)				Net return ($/ha)	Benefit-cost ratio
		1st crop	2nd crop	3rd crop	Material cost	Preharvest labor cost	Harvesting, threshing labor cost	Total		
					Rice - rice					
Farmer	73	2.9	2.7	–	112	90	131	333	455	2.37
Researcher	50	4.9	1.9	–	158	82	168	408	597	2.46
					Rice - upland crops[c]					
Farmer	30	2.4	0.3	–	55	59	68	182	225	2.24
Researcher	14	5.0	1.7	–	218	120	191	529	618	2.17
					Rice - rice - upland crops[d]					
Farmer	10	1.8	2.5	0.01	108	70	102	280	337	2.20
Researcher	50	5.5	3.5	0.16	248	135	235	618	795	2.29

[a]Adapted from Roxas (1977). [b]Exchange rate used: US$1 = Philippine ₱7.4. [c]Cowpea, soybean, sorghum, [d]Mungbean, cowpea, soybean, bush sitao, sorghum.

Table 5.6. Total volume of edible food, total digestible carbohydrate, digestible protein, and calorie productions from different cropping patterns at the rainfed wetland sites, Asian Cropping Systems Network, 1979-80.[a]

Cropping pattern	Site	Total edible food[b] (t/ha)	Total yield of		
			Carbohydrate (t/ha)	Digestible protein (kg/ha)	Calories (kcal/ha)
Rice	Bhogra, Bangladesh	3.0	2.42	210	11 040
	Paranthan, Sri Lanka	1.9	1.50	131	6 882
Rice - rice	Bhogra	4.3	3.49	303	15 934
	Katupotha, Sri Lanka	2.3	1.87	163	8 574
Rice - wheat	Parsa, Nepal	4.1	2.99	337	5 028
Rice - rice - wheat	Parsa	6.5	4.63	585	15 897
Rice - rice - mungbean	Sampang, Indonesia	6.2	4.90	512	11 722
Rice - rice - cowpea	Sampang	5.9	4.63	448	10 956
Maize - rice - mungbean	Bangphae, Thailand	6.6	3.58	636	16 924
Mungbean - rice - mungbean	Bangphae	2.7	2.09	241	19 401
Rice - rice - maize + peanut	Sampang	5.9	3.87	652	13 628
Rice - rice - maize + mungbean	Sampang	6.9	5.26	674	18 562

[a]Hoque (1981). [b]Total milled products ready for consumption.

the farmers have already adopted these levels of management for the cropping patterns considered economically profitable.

Researchers tested double-rice cropping patterns in the rainfed wetland areas at Agusan and Bukidnon in the Philippines (Alemania et al 1981). At Agusan, wet-seeded rice - transplanted rice produced 8.7 t/ha (4.0 t, first crop; and 4.7 t, second crop). The pattern had a variable cost of $357/ha ($142 labor and $215 material), providing a highly profitable net return of $1,178/ha. At Bukidnon in 1979-80, transplanted rice - transplanted rice produced 9.9 t/ha (5.5 t, first crop; 4.4 t, second crop). The variable cost was $344/ha ($119 labor + $225 material) and gave a net return of $1,112/ha (Alemania et al 1981).

Several cropping patterns were monitored by the national cropping systems research programs under the ACSN to determine their relative productivity at different sites (Table 5.6) A specific cropping pattern, such as rice - rice, produced quite different amounts of food, energy, and nutrients at two different sites. These variations can be attributed to individual site characteristics and crop management practices. Similarly, at a specific site such as Bangpae the production of edible food, digestible carbohydrate, proteins, and energy differed substantially among individual cropping patterns. A set of cropping patterns was also monitored at the rainfed wetland sites in 1980-81 (Table 5.7). Data in Tables 5.6 and 5.7 indicate that a specific cropping pattern at a site may produce the highest calorie yields but may not have the highest protein yields. The inverse is also true. Thus there is a need to select cropping patterns depending on the specific criteria.

Component technology research

The component technology studies at the rainfed wetland areas have concentrated on identifying improved shorter duration rice varieties, reducing turnaround time between crops, improving tillage practices, identifying improved varieties, and establishing dryland crops before or after the rainy season rice crops. Scientists have also given considerable attention to other areas such as fertilizer efficiency, weed and insect control, and management levels.

At Paranthan, Sri Lanka, where farmers grow a single crop of rainfed rice, attempts were made to identify rice varieties that could significantly increase yields. In the 1978-79 maha season, a trial with six improved rice varieties had yields from 1.7 to 4.1 t/ha (Fernando 1979). The variety 94-1 had the highest yield followed by 76-7283 (3.9 t/ha), 401-1 (3.4 t/ha), and 280-1 (3.1 t/ha). At Katupotha in Sri Lanka during the 1979 yala season, a trial with 10 entries of green gram had yields ranging from about 0.2 to 0.9 t/ha. Variety CES-J-2Y and selection 76-187 had the highest yields (Fernando et al 1982).

At Pangasinan, Philippines, the yields in a 1975 transplanted rice variety trial ranged from about 2.5 to 5.0 t/ha (Carangal et al 1976). The five top yielders were IR2070-747 (5.0 t/ha), IR28 (4.8 t/ha), IR2071-625-1-252 (4.4 t/ha), IR2071-588-5-4-5 (4.3 t/ha), and IR2153-26-3-5-6 (4.2 t/ha). The maturity of these five entries ranged from 99 to 135 days with IR28 maturing in 99 days, the earliest among the 15 test entries. In the 1975 dry season, the maize yield at Pangasinan ranged from 2.0 to 4.2 t/ha (Carangal et al 1976). The four top yielders were TCH #1 DMR × Medok F_3 (4.2 t/ha), Thai Comp. 1 Early (3.9 t/ha), Early

Table 5.7. Total volume of edible food, total digestible carbohydrate, digestible protein, and calorie production from different cropping patterns at the rainfed wetland sites under the Asian Cropping Systems Network, 1980-81.[a]

Cropping pattern	Site	Total edible food[b] ($/ha)	Total yield of		
			Carbohydrates (t/ha)	Digestible protein (kg/ha)	Calories (kcal/ha)
Rice	Alimganj, Bangladesh	1.2	0.97	84.0	4 416
	Parsa, Nepal	0.9	0.75	65.1	3 422
Rice - rice	Phrae, Thailand	2.4	1.95	168.7	8 869
	Ubon, Thailand	2.0	1.63	141.4	7 434
	Bhogra, Bangladesh	4.9	3.92	339.5	17 847
	Alimganj	2.4	1.91	165.2	8 685
Rice - wheat	Parsa	4.6	3.21	434.5	19 205
Rice - ratoon	Ubon	1.3	1.04	89.6	4 710
Mungbean - rice	Ubon	1.7	1.35	172.1	6 333
Peanut - rice	Pimai, Thailand	3.7	1.32	750.4	18 492
	Ubon		1.22	331.5	9 985
Sesame - rice	Pimai	1.3	0.91	125.6	5 440
Rice - rice - mungbean	Capiz, Philippines	6.6	5.33	462.0	24 288
Rice - rice - cowpea	Capiz	8.5	6.63	289.4	30 934
Rice - wheat - mungbean	Ratna Nagar, Nepal		3.59	714.6	21 757
Rice - wheat - maize	Ratna, Nagar	5.4	4.19	588.7	23 366
Mungbean - rice - rice	Agusan, Philippines	8.6	6.83	729.4	31 564
Mungbean - rice - maize	Phrae	3.5	2.71	402.9	12 850
Mungbean - rice - soybean	Phrae	4.0	2.65	603.7	15 993
Mungbean - rice - cowpea	Serang, Indonesia	3.5	2.69	378.2	12 668

[a]Hoque (1981). [b]Total edible food = total milled products ready for consumption.

DMR Comp. 1 (3.3 t/ha), and Medium Early Comp. 1 (3.3 t/ha). During the same season, the sorghum yields in a variety trial ranged from about 3.2 to 6.3 t/ha. The five top yielders were CS 106 (6.3 t/ha), Cosor 2 (5.7 t/ha), CS 107 (5.6 t/ha), Cosor 3 (5.5 t/ha), and IS-2940 (5.3 t/ha) (Carangal et al 1976). In a trial with 10 mungbean entries, the yields in 1975 dry season at Pangasinan ranged from about 0.4 to 0.8 t/ha. The four top yielders were M350 (0.8 t/ha), M101 (0.7 t/ha), Bhacti (0.6 t/ha), and CES 14 (0.5 t/ha) (Carangal et al 1976). Cowpea yields ranged from 0.01 to 0.6 t/ha. Red Cowpea 6-1 and All Season were the two top yielders among 11 test entries (Carangal et al 1976). In a 1975 dry season trial in areas with a shallow water table, sweet potato yields ranged from 0.6 to 6.5 t/ha (Carangal et al 1976). The three top yielders were Kaogban (6.5 t/ha), Bangued (6.0 t/ha), and BNAS 51 (5.5 t/ha). In the areas with a high water table, sweet potato yields ranged from about 1.4 to 17.7 t/ha with Bangued yielding the most. The other promising sweet potato varieties for the high water table areas were SP #45 (11.3 t/ha), BNAS 51 (9.2 t/ha), Georgia Red (7.7 t/ha), and Daja (7.6 t/ha) (Carangal et al 1976).

In a 1978 wetland rice variety trial at Agusan, yields ranged from 2.9 to 6.8 t/ha. High-yielding entries included IR2035-242-1 (6.8 t/ha), SI-496 (6.5 t/ha), IR2061-213-3 (5.6 t/ha), MRC-172-9 (5.3 t/ha), and IR3880-13 (5.2 t/ha) (Sagun et al 1979). Soybean yields in 1978 ranged from 0.7 to 1.4 t/ha. Clark 63 (1.4 t/ha), UPL-SY-2 (1.2 t/ha), L114 (1.2 t/ha), and TK5 (1.0 t/ha) were the top yielders (Sagun et al 1979). Peanut yields in a variety trial ranged from 0.7 to 1.4 t/ha. Mocket had the highest yield followed by CES 101 (1.3 t/ha), CES 102 (1.2 t/ha), and Kidang (1.2 t/ha) (Sagun et al 1979). In a 1979-80 rice variety trial in the wetland field at Capiz, Philippines, the rice yields ranged from 3.9 to 5.2 t/ha (Palada et al 1980). The five top yielders were IR46 (5.2 t/ha), MRC-172-9 (5.1 t/ha), IR43 (5.0 t/ha), C-171-120 (4.9 t/ha), and IR36 (4.8 t/ha).

At Pangasinan, the research team gave considerable attention to ratoon rice cropping. In the 1975 wet season, IR28 and IR30 were tested in 11 farmer fields to determine ratoon potentials. On an average, the main crop rice yield was 3.7 t/ha and the average ratoon yield was 0.8 t/ha (Herrera et al 1976). The yields ranged from 3.0 to 4.8 t/ha for the main crop and from 0.5 to 1.1 t/ha for the ratoon crop. IR28 had the highest total production of 5.7 t/ha (4.8 from the main crop and 0.9 t/ha from the ratoon crop).

At Paranthan, Sri Lanka, the yield of rainfed wetland rice was increased from 1.3 t/ha without any N fertilizer to 3.2 t/ha with 40 kg N/ha applied 2 weeks after sowing plus 40 kg N/ha 6-7 weeks after sowing (Fernando 1979). At Kampangphet, Thailand, 1980 wet season yields were about 2.4 t/ha for the local variety and 3.0 t for RD7 without fertilizer, and 3.5 t/ha for the local and 3.9 t for RD7 with fertilizer [56.25-16.50 kg (N, P)/ha] (CSP, Thailand 1980). At Agusan, the yields of transplanted IR36 were 4.5 t/ha at 0 kg N/ha, 5.2 t at 20 kg, 5.4 t at 40 kg, 6.6 t at 60 kg, 6.9 t at 80 kg, 7.0 t at 100 kg, 7.1 t at 120 kg (Sagun et al 1979). The rates 60, 80, 100, and 120 kg N/ha were statistically identical, but superior to the other three rates, which were also statistically identical in terms of grain yields. The IR36 yield was 2.6 t/ha without insect control and 3.6 t/ha with carbofuran applied 50 d after transplanting (Sagun et al 1979).

At Bhogra, Bangladesh, the 1977 yield of transplanted aman rice was 2.5 t/ha with 60 kg N/ha and no applications of sulfur and insecticide, and 4.0 t/ha with application of 80-26.4-33.2-34 kg (N, P, K, SO_4)/ha plus three applications of diazinon granules (Hoque and Hobbs 1980). During the 1978 aus season, partial irrigation increased farmer yields by 24% and insecticide application increased yields by 17%. Providing supplemental irrigation during periods of moisture stress increased the yields of local varieties and MVs by 34 and 12% during the following transplanted aman season. Insecticide application on local transplanted aman varieties increased yield 20%, but there was no benefit for MVs (Hoque and Hobbs 1980).

These results indicate a tremendous potential in the rainfed wetlands for substantial yield increases through development and adoption of improved component technologies. These technologies increase the crop yields under the farmers' conditions and help obtain the maximum production from the improved intensive cropping patterns.

IRRIGATED WETLAND SITES

Cropping systems research programs have focused heavily on technology improvement for the irrigated wetlands. Because most national governments have introduced large-scale agricultural production programs in their irrigated areas, the design, testing, and subsequent recommendations of improved crop production technologies from the irrigated wetland research sites are vital to Asia's agricultural development. Research results from several of these cropping systems research sites are briefly discussed.

Cropping pattern testing

At Parsa, Nepalese scientists have attempted to improve traditional cropping patterns by introducing improved varieties and management practices (Table 5.8). In all cases, the improved cropping patterns gave much higher yields. In the partially irrigated Suckchaina area at Parsa, the single cropping of local rice produced an average yield of 1.4 t/ha during 1977-80 (CSP, Nepal 1981). This yield was increased to 3.1 t/ha by replacing the local variety with the improved variety Janaki. Also three new cropping patterns were tested. The rice (Sabitri) - wheat (RR21) pattern yielded 3.7 t rice/ha and 1.6 t wheat/ha; rice (Laxmi) - potato (Kufri Sinduri) yielded 4.0 t rice/ha and 10.1 t potato/ha; and rice (Laxmi) - mungbean (Pusa Baisakhi) yielded 3.8 t rice/ha and 0.04 t mungbean/ha. The farmers' rice - mustard pattern yielded 1.4 t rice/ha and 0.07 t mustard/ha. Using the rice variety Janaki and mustard variety T9 increased yields to 3.6 t rice/ha and 1.0 t for mustard. The agroeconomic performance of the improved cropping patterns have been encouraging and have formed the basis for multilocation testing of improved cropping systems technologies and pilot production programs in several areas of Nepal.

At the deep tubewell-irrigated Salna site in Bangladesh, 10 rice-based cropping patterns were tested under farmers' management level from 1978 to 1981. Results are in Table 5.9. The double-rice cropping patterns of BR10-BR3 and BR3-BR4

Table 5.8. Agroeconomic performance of existing cropping patterns and improved patterns at Parsa, Nepal, 1977-79.[a]

Cropping pattern[b]	Yield (t/ha)			Extra cost of new pattern ($/ha)	Extra net return of new pattern ($/ha)
	1st crop	2nd crop	3rd crop		
FP: rice - rice - wheat	1.6	1.8	1.3		
FIP: rice - rice - wheat	3.2	2.1	2.[illegible]	149	261
FP: rice - wheat	2.0	1.7	–	–	–
FIP: rice - wheat	4.5	2.1	–	94	269
FP: rice - potato	2.3	7.5	–	–	–
FIP: rice - potato	3.4	13.8	–	99	827
FP: rice - mustard	2.3	0.6	–	–	–
FIP: rice - mustard	3.4	0.9	–	51	121
FP: rice - lentil	2.3	0.5	–	–	–
FIP: rice - lentil	3.4	0.9	–	69	169

[a]Adapted from Cropping Systems Program, Nepal (1979). [b]FP = farmers' cropping pattern; except for wheat, farmers used local varieties. FIP = farmers' improved cropping patterns; except for lentil, farmer used improved varieties.

and the triple-rice cropping pattern of Chandina-BR4-Pajam appeared to be the best for the deep tubewell-irrigated areas at Salna.

Results of rice cropping pattern testing at Shimrail under the DND irrigation project of the BWDB indicated that a single MV rice crop yielded 4.4 t/ha and the double and triple MV rice cropping patterns yielded 8.2 and 12.0 t/ha (Hoque et al 1981). At Jugibeel, Bangladesh, farmers built a cross dam over a stream flowing down from the hills, allowing intensive multiple cropping. In 1980-81, a rice - rice - wheat pattern was tested using different rice varieties (Paul et al 1981). The Purbachi (aus rice) - BR3 (t. aman rice) - Sonalika (wheat) pattern yielded 4.9 t aus rice/ha, 1.2 t aman rice/ha, and 2.9 t wheat/ha. The BR3 - BR5 - Sonalika pattern yielded 6.0 t rice/ha, 4.9 t rice/ha, and 3.1 t wheat/ha. The Purbachi - Pajam - Sonalika pattern yielded 4.0 t/ha each for both rices, and 1.4 t/ha for wheat. The BR3 - BR4 - Sonalika pattern yielded 4.6 t rice/ha, 4.0 t rice/ha, and 3.0 t wheat/ha. And finally, the Chandina - Pajam - Sonalika pattern yielded 1.9 t rice/ha, 2.1 t rice/ha, and 1.1 t wheat/ha. The best of these patterns appears to be BR3 - BR5 - Sonalika.

Before 1976 at Walagambahuwa, Sri Lanka, farmers got about 1.0 to 1.3 t/ha from a single crop (Fernando et al 1982). The site research team then introduced rice - rice and rice - rice - vegetables patterns. The double-rice cropping patterns in normal rainfall years were successful. Starting in 1977-78, the farmers using the new technology obtained rice yields of 3.6-4.1 t/ha — a threefold increase (Fernando et al 1982). In 1980-81 yield from the single-rice cropping pattern at Walagambahuwa was still about 1.3 t/ha. Costs were $51/ha for material, and $28/ha for labor and power (Upasena 1981a) and the net loss was $10/ha. On the other hand, the rice - rice pattern yielded 5.2 t/ha, with costs of $80/ha for materials and $331/ha for labor and power. The pattern gave a net return of

Table 5.9. Agronomic productivity and economic return from different cropping patterns under farmer management at Saina, Bangladesh, 1978-1981.[a]

Rice cropping pattern			Yield (t/ha)												Per-pattern av	
			1978-79				1979-80				1980-81					
Aus	t. aman	Boro	Aus	t. aman	Boro	Total	Aus	t. aman	Boro	Total	Aus	t. aman	Boro	Total	Yield (t/ha)	Net return ($/ha)
Fallow	Pajam	Pajam	–	2.5	3.9	6.4	–	3.3	3.4	6.7	–	3.0	4.2	7.2	6.8	965
Fallow	BR3	Pajam	–	–	–	–	–	3.1	4.2	7.3	–	3.5	4.2	7.7	7.5	1001
Fallow	Pajam	BR3	–	3.0	4.3	7.3	–	3.1	3.7	6.8	–	3.1	4.1	7.2	7.1	922
Fallow	BR4	Pajam	–	4.2	3.5	7.7	–	3.9	3.3	7.2	–	–	–	–	7.5	947
Fallow	BR3	BR4	–	–	–	–	–	3.0	4.3	7.3	–	–	–	–	7.3	1060
Fallow	BR10	BR3	–	–	–	–	–	–	–	–	–	4.2	4.1	8.3	8.3	1040
Chandina	Pajam	Pajam	2.3	3.5	4.1	9.9	4.6	3.7	3.5	11.8	3.6	2.9	3.9	10.4	10.7	1569
Chandina	Pajam	BR3	3.4	3.4	3.5	10.3	–	–	–	–	3.8	2.9	4.4	11.1	10.7	1290
Chandina	BR4	Pajam	–	–	–	–	3.7	4.4	3.4	11.5	–	–	–	–	11.5	1929
BR3	Nizersail	Wheat	–	–	–	–	–	–	–	–	5.1	2.2	1.4	8.7	8.7	988

[a]Hoque (1982).

$316/ha. Based on the MV rice - MV rice pattern with improved crop management practices, pilot production programs have been initiated in minor tank village settlements with similar environments in the dry zone of Sri Lanka. These programs have ultimately served as the basis for large-scale production programs now under way.

At Indramayu, West Java, the Indonesian cropping systems scientists designed and tested improved cropping patterns for the areas with 5, 7, and 10 months of irrigation. In 1975-76, in all three irrigation categories, they attempted to determine if the productivity and profitability of the traditional transplanted rice (Pelita I/1) - no-tillage rice (Pelita I/1) pattern could be increased mainly by removing input constraints. Also evaluated was a new cropping pattern of transplanted rice - no-tillage rice - cowpea or soybean. IR28 was used in the first and IR30 in the second rice crop, except in the 7-month irrigation area where Pelita I/1 was used (Saefuddin et al 1977).

In the 5-month irrigation areas, yields were about 5.8 t/ha from the traditional rice - rice pattern and 7.0 t/ha from the pattern without input constraints. The rice (IR28) - no-tillage rice (IR30) - cowpea pattern produced 8.6 t rice/ha and 0.5 t cowpea/ha. The variable costs in these three cropping patterns were about $518/ha for the traditional, $699 without constraints, and $1,102 for IR24-IR30-cowpea. Corresponding net returns were $297, $379, and $534/ha. All three patterns had a benefit-cost ratio of about 1.5. Although the rice - rice - cowpea and rice - rice pattern without input constraints gave high net returns per hectare, on a partial budgeting analysis, these did not appear to be as attractive as the traditional rice - rice pattern under farmer management. It took an extra $121/ha to remove input constraints from the traditional rice - rice pattern, but this investment gave only $82/ha extra income over the traditional pattern. The rice - rice - cowpea pattern required an additional variable cost of $524/ha with an additional net return of only $237/ha over the traditional pattern. However, results indicated that if financial resources and production inputs are increased and with 5 months of irrigation, the total production from the land can be substantially increased through the removal of constraints from the traditional cropping system and through the adoption of the new pattern of rice - rice - cowpea with improved management practices.

In the 7-month irrigation areas, the yields were 7.4 t/ha from the traditional pattern, 9.3 t from the traditional pattern without input constraints, and 10.3 t rice/ha rice plus 0.9 t cowpea/ha from the introduced new pattern (Saefuddin et al 1977). The variable costs were $612/ha for the traditional pattern, $694 for the traditional without constraints, and $1,077 for the new. The corresponding net returns were $524, $736, and $1,084/ha.

In the 10-month irrigation areas, the traditional pattern with farmer management yielded about 12.6 t/ha with variable costs of $860/ha and a net return of $1,120/ha (Saefuddin et al 1977). The yields and net returns in the pattern without input constraints as well as in the introduced pattern were lower than those in the traditional pattern. The pattern without input constraints yielded 12.0 t/ha with a net return of $947/ha and variable costs of $942/ha. The yields of the introduced rice - rice - soybean pattern were 5.2-4.7-1.0 t/ha with a net return of $1,091/ha

Table 5.10. Agronomic productivity of four new cropping patterns in 10-, 7-, and 5-month irrigation areas at West Java, Indonesia, 1976-78.[a]

Cropping pattern[b]	Yield (t/ha) when water was available for		
	10 mo/yr	7 mo/yr	5 mo/yr
TP rice -	5.5 (IR34)	5.9 (IR28)	4.7 (IR28)
TP rice (WJR)	5.4 (IR26)	4.3 (IR30)	5.0 (IR30)
Legume	0.5 (Cowpea)	0.9 (Soybean)	0.6 (Cowpea)
TP rice -	6.3 (IR28)		
TP rice (WJR) -	4.3 (IR30)		
TP rice (WJR)	4.8 (IR28)		
TP rice -		6.0 (IR28)	
TP rice (WJR) -		4.7 (IR34)	
Cowpea		0.7	
Direct-seeded wetland rice			5.1 (IR26)
Wetland rice (WJR) -			5.1 (IR30)
Cowpea			0.6

[a]Adapted from Effendi et al (1982). [b]TP = transplanted, WJR = walik jerami (zero tillage) rice.

and a variable cost of $1,076/ha. IR28 and IR30 in the introduced pattern could not outyield the farmers' varieties in the 10-month irrigation areas, which resulted in lower productivity and profitability for this cropping pattern (Saefuddin et al 1977).

The results of testing four cropping patterns under the three irrigation regimes at Indramayu in 1976-78 are in Table 5.10. Results indicated that triple cropping patterns of transplanted rice - transplanted no-tillage rice - legume; transplanted rice - transplanted no-tillage rice - transplanted no-tillage rice; and direct-seeded wetland rice - transplanted no-tillage rice - legume were potential alternatives for the irrigated wetlands. There has been extensive evaluation of alternative rice-based cropping patterns in the irrigated wetlands of South Korea. Table 5.11 summarizes results of some cropping pattern testing activities at three irrigated locations under experimental station conditions. In general, crop yields at all the sites are quite high. The traditional cropping patterns are highly productive and profitable. Cropping patterns, such as rice - wheat and sweet maize - rice, appeared to be quite advantageous from agronomic and economic standpoints. However, the production costs, including those of the traditional cropping patterns at the three sites, are quite high.

Several dominant cropping patterns were monitored in 1979-80 at different ACSN irrigated wetland sites. The food and nutrient yields from some of these cropping patterns are in Table 5.12. Results indicated that the production of edible food, energy, and protein at a particular site may vary considerably depending on the cropping pattern. Also, the food, energy, and nutrient yields of a particular cropping pattern vary depending on site and management practices. A cropping pattern may produce a higher amount of edible food per hectare and it may provide fewer proteins and calories and vice versa. Therefore, it is important to evaluate cropping patterns using all the different criteria so that the most

Table 5.11. Agroeconomic performance of traditional and promising cropping patterns at three irrigated wetland sites in South Korea.[a]

Site	Traditional pattern	Promising pattern	Yield[b] (t/ha)		(US$[c]/ha per pattern)		
			1st crop	2nd crop	Material cost	Labor cost	Net return
Suweon	Rice - fallow		6.76		324	1471	2064
		Potato - rice	12.97 (FW)	6.32	1095	2382	2194
		Rice - rye (fodder)	6.62	20.75	—	—	—
Iri	Rice - barley/wheat		7.63	4.60	575	902	3341
	Rice - rape		7.35	2.91	424	2634	2891
		Rice - wheat	7.48	5.18	575	2465	3744
		Rice - potato	7.00	13.79 (FW)	1028	2975	3557
		Rice - strawberry	7.31	4.67 (FW)	998	4047	3612
Milyang	Rice - barley/wheat		7.7	4.7	342	2461	2598
	Rice - fallow		7.9		282	1472	1818
		Sweet maize - rice	36 440[d]	4.5	665	2661	7172
		Rice - wheat	6.8	5.1	484	2418	3608
		Rice - potato	8.4	5.1 (FW)	764	2755	3148

[a]Adapted from Shin (1981). [b]FW = fresh weight. [c]US$1 = 700 won. [d]Ears.

Table 5.12. Total edible food, digestible carbohydrate, digestible protein, and calorie production from different irrigated cropping patterns, Asian Cropping Systems Network, 1979-80.[a]

Cropping pattern[b]	Site	Total yield of			
		Edible food (t/ha)	Carbohydrate (t/ha)	Calories (kcal/ha)	Digestible protein (kg/ha)
LV rice	Parsa	1.9	1.56	7 102	135
MV rice	Parsa	2.6	2.10	9 568	182
	Iri	3.3	2.69	12 254	233
	Milyang	1.9	1.56	7 102	135
LV rice - LV rice	Parsa	3.1	2.47	11 261	214
MV rice - MV rice	Parsa	4.9	3.99	18 199	346
	Salna	4.7	3.83	17 443	332
	Shimrail	5.4	4.40	20 019	381
MV rice - wheat	Iri	6.4	4.20	27 200	638
	Milyang	6.8	4.22	29 824	726
Rice - maize	Milyang	10.7	4.87	22 996	1 022
Rice - soybean	Milyang	5.4	2.45	20 909	1 399
Rice - rice - rice	Salna	6.8	5.50	25 061	477
	Shimrail	8.0	6.46	29 440	560
Rice - rice - wheat	Parsa	6.5	4.64	26·506	585

[a]Hoque (1981). [b]MV = modern variety, LV = local variety.

advantageous ones can be identified and adopted for specific purposes — food production, nutrient yield, energy production, or profit.

Component technology research

In the irrigated wetlands, major emphasis has been on identifying suitable rice varieties, fertilizer management, tillage methods, and crop establishment practices. Findings of several component technology trials from a number of ACSN sites are discussed.

In a variety trial at Langari-Dhobini area at Parsa, Nepal, Chandina yielded 3.8 t/ha; IET 2938, 3.3 t/ha; CH 45, 3.3 t/ha; IR 2061, 3.4 t/ha; and PPI, 3.5 t/ha (Lohani et al 1978). At Walagambahuwa, BG 276-5 was identified as the most suitable variety, averaging about 4.6 t/ha within 3 months (Upasena 1981b). In a direct-seeded trial with six rice varieties at the Indramayu site in 1976-77, Pelita I/a and C4-63 Gb failed to produce because of brown planthopper damage; IR26 yielded 8.1 t/ha; IR30, 7.2 t/ha; IR34, 6.3 t/ha; and IR28, 5.4 t/ha (Marzuki and Effendi 1980). Maturities of these varieties were 122, 107, 133, and 102 d. During the 1977 dry season, there were yield trials on cowpea, soybean, and mungbean at the Indramayu (Marzuki and Effendi 1980). Cowpea yields ranged from 0.8 to 1.2 t/ha with variety EG Green Pod #2 yielding the highest. Among the 11 soybean varieties, the highest yield (1.5 t/ha) came from Orba and CES16-103; Clark 63 yielded 1.4 t/ha; Lincoln, 1.2 t/ha; and CES 16-17, 1.0 t/ha. Mungbean varieties had promising yields: EG MG 174-3, 1.4 t/ha; CES 10-21, 1.3 t/ha; and CES 1K-25Y, 1.3 t/ha.

At Salna during the 1979 t. aman season, researchers conducted a tillage experiment under wetland conditions to determine the effect of no and minimal

tillage on the yield of the second rice crop variety (Pajam) following the aus crop (Hoque et al 1981a). The no-tillage treatment involving transplanting of the t. aman crop 1 d after harvesting the aus crop yielded 4.3 t/ha whereas the minimal tillage (one plowing plus one laddering) with transplanting 2 d after harvesting the aus crop yielded about 3.9 t/ha. The high-tillage treatment (five plowings plus three ladderings) and 4 d turnaround time between the two crops yielded 4.1 t/ha. The traditional tillage (six plowings plus five ladderings) with 12-d turnaround time yielded 3.1 t/ha. Results indicated that delayed transplanting of the t. aman crop reduces yield even under the farmers' high-intensity tillage operations. The land preparation costs were $52/ha for the farmers' method, $47 for the experimental high-tillage level, and $21 for the minimum-tillage level. There was no land preparation cost for the no-tillage treatment. Farmers can save about $52/ha by adopting no tillage for the wetland t. aman crop, and can increase its yield by transplanting earlier, particularly with photoperiod-sensitive varieties. No tillage in the wetlands, particularly where irrigation keeps the soil moist and suitable for rice seedling transplanting, may be adopted in other relevant areas in Asia.

In 1978 at Parsa, the yield of the farmers' regular rice crop without fertilizer was about 2.3 t/ha; an application of 40 kg N/ha produced 2.7 t/ha (Lohani et al 1978). Most of the farmers at Walagambahuwa do not apply basal N fertilizer for their rice crop, but they topdress the crop with about 30-40 kg N/ha at the maximum tillering stage (Upasena 1980b). The average yield from BG 34-8 (2.0 t/ha) was more than doubled by incorporating N with a basal fertilizer (P & K) mixture. In 1977 at Salna the yield of the farmers' first crop with IR8 (2.5 t/ha) was increased by as much as 46% (to 3.6 t/ha) by applying better levels of NPK fertilizers and weed control (Hoque et al 1977). At this site, sulfur deficiency appeared to be a serious problem. In the 1977 aus season, a rate of 34 kg SO_4/ha was applied in addition to the farmers' fertilizer rate of 54 kg N/ha. The yields were 2.6 t/ha with N fertilizer only and 3.1 t/ha with N and SO_4. The extra cost for SO_4 was only $15/ha and the extra net return was $103/ha (Hoque et al 1981a). Increasing the N rate to 80 kg N/ha increased yield from 2.6 t/ha to 3.1 t/ha. The extra cost was only $14/ha and the extra net income was $104/ha. When both 80 kg N/ha and 34 kg SO_4 were applied, the yield rose to 4.1 t/ha with an extra net income of $357/ha. At the Shimrail cropping systems research site in the DND Project of BWDB, there has been severe zinc deficiency, particularly in the MVs. In 1979, the IR8 yield at this site without zinc application was 2.7 t/ha; root dipping of seedlings in 2% zinc oxide solution at transplanting produced a yield of 3.9 t/ha. These component technology studies on the irrigated wetlands indicated a tremendous potential for attaining large-scale production increases in these areas through better fertilizer management. At Salna, the BRRI cropping systems scientists successfully produced a crop of *Tilapia nilotica* fish with the irrigated rice. The average yield of fish was 226 kg/ha while the yields of the first season rice crop with and without fish were similar, 2.7 t/ha (Hoque et al 1981a). This rice + fish production practice holds great hope for increasing total production in the wetland rice areas with irrigation facilities.

RAINFED DRYLAND SITES

Indonesian scientists have worked extensively on the design and testing of improved cropping patterns and component technologies, particularly in the dryland areas of Sumatra with Red-Yellow Podzolic soils. Recently, researchers have initiated many design and testing activities at the rainfed dryland research sites in the Philippines where increased cropping intensity and improved management practices have been emphasized.

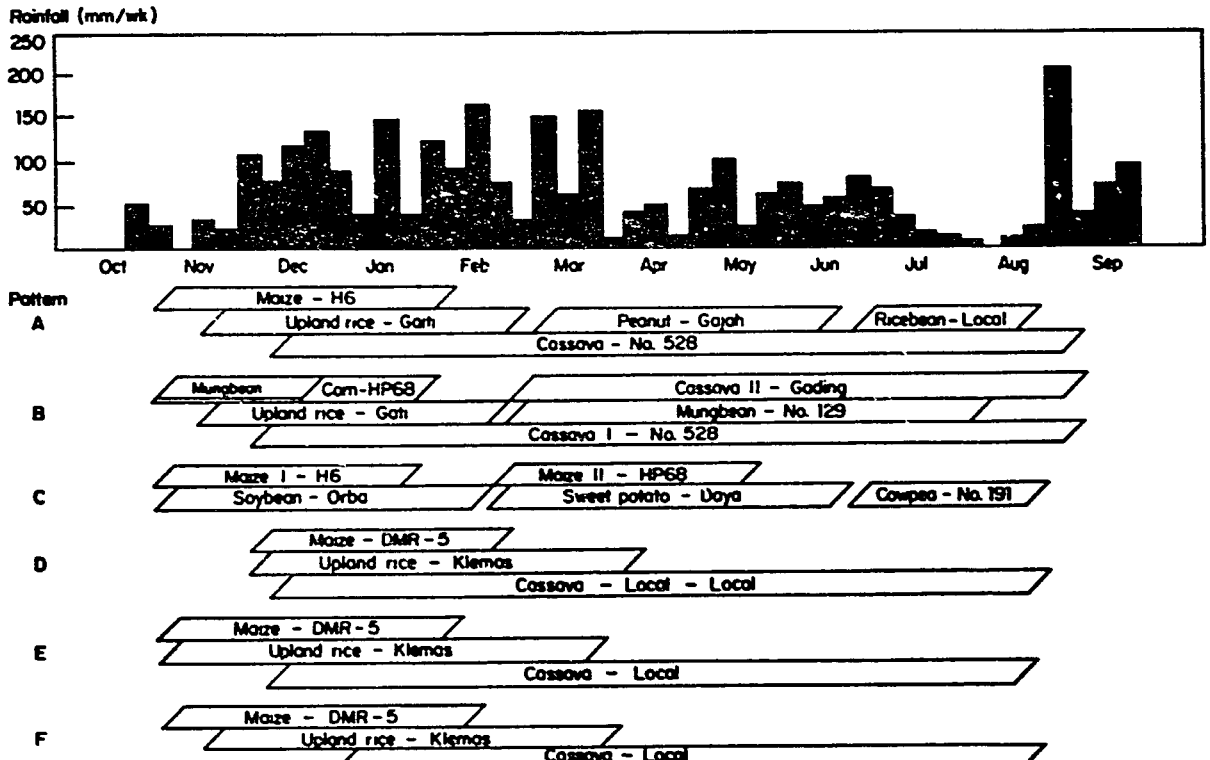
Cropping pattern testing

Intensive cropping patterns involving intercropping and relay cropping have been tested at the rainfed dryland cropping systems research sites in Sumatra. Figure 5.2 presents the cropping patterns tested at Way Abung in 1977-78. In this trial the farmers' traditional cropping pattern (Pattern F) was compared with three new intensive cropping patterns (A, B, and C) with high inputs and management. The traditional pattern was also subjected to two additional levels of management (patterns D and E). The results are in Table 5.13. The three new cropping patterns produced substantially more food, calories, protein, and gross returns than the traditional pattern. This indicated a higher production potential of the Red-Yellow Podzolic dryland soils in Sumatra if there are adequate input supply and management practices.

There was not much difference in total calorie and protein production per hectare nor in gross economic return among the three levels of inputs and management on the traditional cropping pattern (Patterns D, E, and F). The variable costs per hectare for the patterns were $4.9 (A), $394 (B), $492 (C), $154 (D), $240 (E), and $135 (F). Corresponding net returns per hectare were $655 (A), $593 (B), $519 (C), $225 (D), $221 (E), and $201 (F). In all the research-managed patterns the labor costs were lower than the material costs per hectare. In the farmer-managed patterns, the opposite was true except pattern E wherein more materials were used to remove production constraints. The labor costs per hectare were $220 (A), $174 (B), $177 (C), $91 (D), $112 (E), and $100 (F). Corresponding material costs per hectare were $259 (A), $220 (B), $315 (C), $63 (D), $128 (E), and $35 (F) (Ismail et al 1978). It is apparent that higher production and income are possible from the rainfed dryland areas at Way Abung, but higher inputs of labor and material are necessary.

At Sampang in Madura, researchers compared three cropping patterns under rainfed dryland conditions. The patterns were: (A) maize + peanut - maize + peanut + cassava - maize + peanut; (B) maize + upland rice - cassava - mungbean - peanut; and (C) maize + upland rice - cassava - mungbean - cowpea (CRIA 1980). The labor costs per hectare were $382 (A), $544 (B), and $483 (C); the corresponding material costs per hectare were $96 (A), $217 (B), and $180 (C). The net returns per hectare were $584 (A), $309 (B), and $95 (C). Pattern A was the most profitable of the three (CRIA 1980).

In 1978-79, Indonesian scientists tested three intensive cropping patterns at the rainfed dryland site at Tajau Pecah in the transmigration area of South



5.2. Weekly rainfall distribution and cropping patterns tested. Way Abung, Sumatra, Indonesia (Ismail et al 1978). (Patterns A, B, C are new patterns with research management; Pattern D is farmer's pattern with research management; Pattern E is farmer's pattern under his management but with no input constraints; and Pattern F is farmer's traditional pattern.)

Table 5.13. Yield of crops, gross returns, calories, and protein production in six cropping systems, Way Abung, Indonesia, 1977-78.[a]

Cropping pattern	Yield (t/ha)	Gross return[b] ($/ha)	Yield	
			Calories (kcal/ha)	Protein (kg/ha)
A. Introduced				
Maize +	2.6	163	9 063	235
Upland rice/	3.7	354	8 829	260
Cassava/	19.9	191	23 866	139
Peanut -	0.6	325	2 622	148
Rice bean	0.3	101	1 266	70
Total		1 134	45 646	842
B. Introduced				
Maize +	1.8	116	6 443	167
Mungbean I +	0.3	128	1 104	71
Upland rice/	3.5	332	8 274	235
Cassava I/	28.7	276	34 470	201
Mungbean II +	0.3	112	966	62
Cassava II	2.4	23	2 848	17
Total		987	54 105	753
C. Introduced				
Maize +	1.0	67	3 692	96
Soybean -	1.4	507	4 460	491
Maize +	1.5	96	5 339	138
Sweet potato -	5.6	135	6 922	101
Cowpea	0.6	206	1 953	131
Total		1 011	22 567	957
D. Traditional research management without input constraint				
Maize +	0.6	41	2 251	58
Upland rice/	2.4	233	5 822	165
Cassava	10.9	105	13 087	76
Total		379	21 160	300
E. Traditional farmer management without input constraint				
Maize +	1.3	86	4 761	123
Upland rice/	2.6	254	6 339	180
Cassava	12.6	121	15 064	88
Total		461	26 164	391
F. Traditional				
Maize +	0.9	69	3 280	85
Upland rice/	1.9	183	4 561	130
Cassava	9.8	94	11 746	69
Total		336	19 587	284

[a]Ismail et al (1978). [b]Exchange rate: US$1 = Indonesian Rp625.

Kalimantan. They were: A) farmers' pattern: maize + upland rice - maize; B) introduced pattern: maize + upland rice + cassava - cowpea with medium input levels; and C) introduced pattern: maize + upland rice + cassava - peanut

with high input level (CRIA 1980). The variable costs per hectare were $233 (A), $360 (B), and $535 (C). The corresponding net returns per hectare were $82 (A), $358 (B), and $309 (C).

In 1979-80, at Tajau Pecah, the patterns tested were: A) farmers' pattern: maize + upland rice - maize; B) maize + upland rice/cassava/maize - peanut with low level management, and C) maize + upland rice/cassava/maize - peanut with medium level management (CRIFC 1981). In terms of rice equivalent, pattern A produced 2.30 t/ha; pattern B, 6.33 t/ha; and pattern C, 6.43 t/ha. The corresponding protein productions per hectare were 150 kg (A), 240 kg (B), and 250 kg (C). The variable costs were $264, $350, and $452/ha; the corresponding net returns were $121, $394, and $345/ha. These results indicate considerable agroeconomic potential for the newly developed agricultural lands in South Kalimantan.

In 1976-77 at Batangas, Philippines, IRRI scientists tested eight cropping patterns in 38 farmers' fields under rainfed dryland conditions. These were: rice - bush sitao; rice - maize; rice - sorghum - sorghum ratoon; rice + green maize - peanut; rice + field maize - soybean; rice - green maize/sweet potato; rice - green maize - mungbean; and green maize - field maize - mungbean (Carangal 1980a). Rice + green maize - peanut produced 2.4 t rice/ha, 9,500 ears green maize/ha, and 1.1 t peanut/ha. This pattern had variable costs of $737/ha and the highest net return, $1,745/ha. The next highest net return came from rice - green maize/sweet potato ($1,230/ha) followed by green maize - field maize - mungbean ($1,058/ha). The benefit-cost ratios for the green maize - field maize - mungbean, the rice + green maize - peanut, and rice - green maize/sweet potato patterns were 4.0, 3.4, and 2.9.

In 1977-78, three cropping patterns were tested at Batangas (Carangal 1980a). Short-duration crops such as green maize were used in an attempt to increase cropping intensity. Net returns of these patterns per hectare were $936 for rice - green maize + peanut, $977 for rice - field maize + green maize/sweet potato, and $1,101 for rice + green maize - green maize/sweet potato. Corresponding variable costs were $394, $372, and $412/ha. Pattern testing at Batangas indicated that intercropping of upland rice + maize followed by a third crop such as peanut or sweet potato has a higher agroeconomic potential than the traditional cropping patterns.

During 1979-80 and 1980-81, alternative cropping patterns were evaluated at Agusan, Bukidnon, and Capiz, Philippines (Alemania et al 1981). At Agusan, the intensive cropping pattern of maize + peanut - maize + mungbean - upland rice was the most productive and profitable pattern in both years (Table 5.14). The maize - maize - mungbean pattern had the second highest net return. Thus, these two cropping patterns appeared to be quite promising for the rainfed dryland areas at Agusan. At Bukidnon, the upland rice - maize - mungbean pattern produced good yields and the highest net return in 1979-80 (Table 5.15). The maize - maize - mungbean pattern produced much more food per hectare than the maize - mungbean pattern in both years. However, the maize - mungbean pattern had better economic efficiency. The 1980-81 trials at Bukidnon identified

Table 5.14. Agronomic productivity and economic profitability of cropping patterns tested in rainfed upland areas at Agusan, Philippines, 1979-81.[a]

Cropping pattern	Yield (t/ha)			Variable cost ($/ha)		Net return ($/ha)	Rate of return ($/$ invested) to		
	1st crop	2nd crop	3rd crop[b]	Material	Labor		Material	Labor	Total variable cost
				1979-80					
Maize - mungbean - maize	2.5	0.3	2.8	161	230	509	4.17	3.21	2.30
Maize - maize - mungbean	3.6	2.2	0.8	177	224	712	5.02	4.18	2.78
Maize + peanut - maize + mungbean - upland rice	1.2 + 1.1	1.1 + 1.2	1.5	152	228	1217	9.01	6.34	4.20
				1980-81					
Maize - mungbean - maize	1.9	0.2	*	157	146	56	1.36	1.38	1.18
Maize - maize - mungbean	2.4	1.5	*	210	165	158	1.76	1.96	1.42
Maize - maize - sweet potato	2.4	1.6	*	209	207	134	1.64	1.65	1.32
Maize + peanut - maize + mungbean - upland rice	2.8 + 1.1	1.1 + 0.2	*	241	154	162	1.67	2.05	1.41

[a]Alemania et al (1981). [b]*Indicates that crop failed because of flooding caused by excessive rains.

Table 5.15. Agronomic productivity and economic profitability of cropping patterns tested in rainfed upland areas at the Bukidnon site, Philippines, 1979-81.[a]

Cropping pattern	Yield (t/ha)			Variable costs ($/ha)		Net return ($/ha)	Rate of return ($/$ invested) to		
	1st crop	2nd crop	3rd crop	Material	Labor		Material cost	Labor cost	Total variable cost
				1979-80					
Dryland rice - maize - mungbean	2.8	3.8	0.4	343	145	609	2.78	5.20	2.25
Maize - maize - mungbean	3.5	3.4	0.4	262	175	235	1.91	2.37	1.55
Maize - mungbean	3.3	0.7	—	169	161	450	3.66	3.80	1.36
				1980-81					
Maize - maize - mungbean	4.3	3.6	0.2	363	344	833	3.29	3.42	2.18
Rice - mungbean	4.5	0.5	—	306	136	837	2.29	7.16	2.89
Rice - soybean	4.5	1.2	—	306	136	839	3.71	7.09	2.86
Rice - peanut	4.5	0.7	—	306	180	1394	5.55	8.74	3.87
Maize - maize - mungbean	3.6	3.6	0.2	1.37	343	610	3.04	2.78	2.27
Maize - mungbean	3.6	0.6	—	137	109	807	6.89	8.41	4.28
Maize - soybean	3.6	1.3	—	137	109	775	6.65	8.11	4.15
Maize - peanut	3.6	0.7	—	137	153	1336	10.75	9.72	5.61
Rice + maize/cassava[b] + mungbean	4.5+ 1.5	0.6	—	332	265	932	3.80	4.52	2.56

[a]Alemania et al (1981). [b]Cassava yield data not available.

the rice - peanut and maize - peanut patterns as highly profitable (Table 5.15). Testing at Capiz indicated the potential of rice - rice + maize, rice - sweet potato, and rice - maize patterns.

Component technology research

In most of the rainfed dryland research sites, researchers have attempted to identify rice varieties that can outyield the traditional local direct-seeded varieties. In 1976-77, 12 varieties were evaluated under dryland conditions at Baturaja, Sumatra (Imtias et al 1977). The grain yields ranged from 0.1 to 1.9 t/ha. Three promising entries were Gamma-61 (1.9 t/ha), Dayang rindu (1.5 t/ha), and C22 (1.0 t/ha). In 1979 at Sampang, Madura, eight rice varieties were tested under dry-seeded conditions. The lowest yield (0.9 t/ha) came from the local check; IR32 had the highest yield of 2.7 t/ha (Bernstein et al 1981). IR36, Serayu, and C4-63 each yielded 2.6 t/ha; Asahan, 2.4 t, Pelita I-1, 2.3 t; and Brantas, 2.1 t. In a trial with seven dryland rice selections at Batangas, Philippines, in the 1976 wet season, the local variety Dagge produced 2.7 t/ha and the entries C166-135, 4.6 t; C171-136, 4.6 t; BPI 76 (NS), 4.0 t; MRC-1729, 3.7 t; and C22, 3.6 t (Coffman and Nanda 1980). In the 1977 wet season, 14 dryland rice selections were evaluated at Batangas (Coffman and Nanda 1980). Yields ranged from about 2.6 t/ha for the local variety Dagge to 5.6 t/ha for IR3839-1. Eleven entries produced more than 4 t/ha under rainfed dryland conditions. The entry IR1529-430-3 yielded 4.9 t/ha at 105 d maturity and IR36 produced 4.6 t/ha at 100 d maturity. In 1980 at Alimganj, Bangladesh, two local and four improved rice varieties were evaluated in 20 farmers' fields under rainfed dryland conditions (Akanda 1981). Yields of the local varieties HashiKalmi and Dharial averaged 2.3 and 2.2 t/ha. The yields of improved varieties averaged 3.2 t/ha for BR3, 2.5 t/ha for Purbachi, 2.8 t/ha for Chandina, and 2.2 t/ha for BR9.

In 1976-77 six maize varieties were evaluated at Baturaja, Sumatra (Imtias et al 1977). The local variety yielded nothing because of severe downy mildew (*Sclerospora maydis*) infestation. H-6, H-43, HP-68, Early Thai, and Bogor DMR-4 yielded about 4.5, 3.2, 2.8, and 2.4 t/ha. Early Thai had 61% downy mildew infection, and Bogor DMR-4, 71%.

Experiments in farmers' fields at Batangas, Philippines, during 1973-1976 demonstrated that yields of upland rice, maize, sorghum, cowpea, mungbean, sweet potato, peanut, and soybean crops can be substantially improved if farmers adopt better management practices (Table 5.16). In 1980, the average grain yield of local direct-seeded rice varieties increased from 1.9 t/ha to 2.7 t/ha through improved fertilizer application and weed and insect control at Alimganj, Bangladesh (Akanda 1981). Similarly, better management brought about considerable yield increases and higher net returns for wheat, chickpea, intercropping of barley + chickpea, barley + chickpea + linseed, and linseed + chickpea. Fertilizer use in the acidic Red-Yellow Podzolic soils in Sumatra is critically important for obtaining satisfactory crop yields. In 1977-78 at Baturaja, the mungbean yield without fertilizer was only 0.05 t/ha. With application of 23-19.8-20.75 kg (N, P, K)/ha, the yield was about 0.7 t/ha (Ismail et al 1978). Phosphatic

Table 5.16. Actual farmers' and potential yields of field crops, using the best available crop technology for upland rice farms of eastern Batangas, based on highest recorded yields of research and farmer-managed trials, 1973-76.[a]

Crop	Potential yield		Actual yield
	Research managed	Farmer managed	Farmer managed
Upland rice	4.6	4.0	1.9[b]
Maize (dry)	4.1	3.7	2.8
(green ears)	32 000[c]	31 000[c]	33 000[c]
Sorghum (main crop)	4.2	4.2	3.1
Sorghum (ratoon)	–	1.9	1.6
Cowpea (green)	5.5	6.1	3.5
Mungbean	1.5	1.0	0.5
Sweet potato	15.0	12.0	9.3
Peanut	1.0	0.9	0.9
Soybean	1.1	1.1	0.6

[a]Harwood et al (1976). [b]Drought-affected. [c]Number of ears/ha.

fertilizers were particularly beneficial at this dryland site. However, suitable credit programs are essential to enable the small subsistence farmers in the rainfed areas to adopt higher levels of management.

IRRIGATED DRYLAND SITES

Research at irrigated dryland sites is in the early stages. Available research findings are presented briefly.

Cropping pattern testing

Researchers designed and tested new cropping patterns for the irrigated drylands at Laskarchala, Bangladesh. Wheat was first introduced at the site in 1976. Farmer yields averaged 1.5 t/ha, ranging from 0.4 to 2.4 t/ha. In 1977, yields of 46 farmers averaged 1.7 t/ha (Hoque and Hobbs 1978). These initial successes excited the farmers. In 1978, 44 farmers grew wheat. They carefully prepared lands with an average six plowings and 10 ladderings. They used an average seed rate of 116 kg/ha and an average fertilizer rate of 31-23.76-6.64 kg (N, P, K)/ha. Farmers applied no insecticide and did no weeding. However, each field averaged two irrigations. The wheat yields ranged from 0.9 to 2.8 t/ha and averaged 1.8 t/ha. After 3 years of successful large-scale demonstrations, wheat became a commercial crop at Laskarchala. In 1978-79, three cropping patterns involving wheat were tested in farmers' field (Table 5.17). Wheat yields in the three patterns were encouraging. The MV rice - MV wheat pattern gave higher grain yields and net return than did the local rice - MV wheat pattern. However, the local rice - blackgram - MV wheat had the highest net return and benefit-cost ratio. The per-hectare calorie production was 13.3 million from the local rice - MV wheat, 12.9 million from MV rice-MV wheat, and 15.6 million from the local rice - blackgram - MV wheat. The corresponding protein yields were 326, 287, and

Table 5.17. Agronomic productivity and economic profitability of 3 partially irrigated cropping patterns tested at Laskarchala, Bangladesh, 1978-79.[a]

Cropping pattern			Test fields (no.)	Yield (t/ha)			Variable cost ($/ha)				Net return		Benefit-cost ratio
1st crop	2nd crop	3rd crop		1st crop	2nd crop	3rd crop	Labor cost	Power cost	Material cost	Total cost	$/ha	%	
Local rice	Fallow	MV wheat	20	1.1	–	2.3	78	40	20	138	253	100	2.8
MV rice	Fallow	MV wheat	20	2.8	–	1.8	117	40	116	273	389	154	2.4
Local rice	Blackgram	MV wheat	6	2.0	0.3	2.1	88	47	95	230	428	169	2.9

[a]Hoque (1981).

413 kg/ha (Hoque 1981). In terms of grain, protein, and calorie yields, as well as soil fertility maintenance, the local direct-seeded rice - blackgram - MV wheat pattern was the most advantageous at Laskarchala.

Component technology research

Superimposed trials in farmers' fields at Laskarchala indicated that the aus rice yield (2.7 t/ha) could be increased about 48% by applying a higher fertilizer rate of 80-26.4-33.2 kg (N, P, K)/ha than the farmer rate of 26-20.7-0 kg (N, P, K)/ha. The extra net income was about $292/ha with a marginal benefit-cost ratio of 10.5 (Hoque et al 1979). At the Thakurgaon deep tubewell irrigation project sites, the wheat yields were increased from 1.7 to 2.7 t/ha by increasing the seed rate from 100 kg/ha to 175 kg/ha (Miah et al 1981). At Laskarchala sweet maize and soybean were introduced successfully. At Ishurdi, in 1980, yields in intercropping trials with sugarcane were 0.5 t/ha for lentil, 0.4 t/ha for chickpea, 0.2 t/ha for peanut, 0.4 t/ha for coriander, 1.4 t/ha for spinach, and 0.6 t/ha for mustard (Hossain 1981).

DEEPWATER SITES

Since 1976, scientists in Bangladesh have attempted to design and test improved cropping patterns and component technologies for the deepwater areas. Results of these studies are briefly discussed.

Cropping pattern testing

In 1976-77 boro season, boro rice - deepwater rice (DWR) cropping pattern trials were begun in farmers' fields at Jarunbari, Dhaka District (Hoque et al 1977). Deepwater rice was successfully grown after a boro crop of BR6 was harvested. The highest total production from the two-crop system was 5.4 t/ha (4.0 t boro/ha, and 1.4 t DWR/ha). Total production could be increased another 1 t/ha using a higher yielding boro variety such as BR3. However, use of such long-duration varieties in the double-crop system should be confined to higher ridges of deepwater areas, which are flooded late.

In 1979-80, BRRI and BWDB undertook a cooperative boro - DWR pattern testing project in farmers' fields at Dharmicpara (Hoque et al 1982b). Results (Table 5.18) confirmed that irrigated boro rice followed by transplanted DWR was a viable system.

In 1980-81, the work on the DWR system was expanded in the DND project (Khan and Hoque 1981). Attempts were made to grow short-duration rabi crops after the boro and DWR (Table 5.19). The DWR crop after the boro rice gave an additional 2 t/ha. The boro - DWR pattern had 24% higher net return than did the farmers' single boro crop pattern. The short-duration mustard crop between the DWR and boro crops appeared highly profitable. Data in Table 5.19 indicate that the net return could be increased as much as 107% if farmers adopt intensive cropping patterns. Again, necessary financial and technical assistance must be extended to the farmers so that they can adopt the new patterns. DWR-based cropping systems research is also under way elsewhere in Bangladesh.

Table 5.18. Productivity of a newly introduced boro deepwater (DWR) pattern compared with that of the existing single boro crop pattern at Dharmicpara, DND irrigation project, Dhaka 1979-1980 (Cooperative study between Rice Cropping Systems Division, BRRI, and DND Project, BWDB.[a]

Cropping pattern		Sample fields (no.)	Turnaround time (d)	Yield (t/ha)		
Boro rice	DWR			Boro	DWR	Total
MV	Khama	8	37	6.2	1.5	7.7
MV	Fallow	9	–	5.2	–	5.2
Pajam	Fallow	1	–	4.5	–	4.5

[a]Hoque et al (1980).

Component technology research

To facilitate relay planting of DWR in ripening boro rice, researchers at Jarunbari compared close (15-cm) pair rows with normally spaced (20-cm) rows (Hoque et al 1977). The two treatments produced identical grain yields, but the wider space facilitated relay planting of DWR. The DWR establishment was also better with the wider spacing. In another trial, DWR was transplanted, direct row-seeded, and broadcast into the boro rice fields at flowering and harvesting. Broadcasting was the best method. DWR yields were also good with relay-seeding at boro flowering stage. Transplanting and direct row seeding at boro harvesting had better results than at flowering (Hoque et al 1977). In another trial, DWR yields were significantly increased by adding a N topdressing after the boro harvest and before DWR seeding or transplanting. In 1979-80, a superimposed trial was made in the DND irrigation project to determine the effect of seedbed management (N, insecticide, seed rate) and seedling age on DWR yield following boro rice. Results indicated better seedbed management and younger seedlings favored DWR yield (Hoque et al 1981a). In 1980-81, a trial at the Daudkandi determined the effect of seeding method, seed rate, and straw mulching on wheat yield following DWR. Regardless of the seeding and seed rate, straw mulch significantly increased wheat yield.

Fertilizer application significantly increased mustard yields following DWR at the Kalacha MCC site. The mustard yield without fertilizer was 0.5 t/ha; yields at other rates were 1.2 t (65-35.2-29 kg N, P, K/ha), 1.1 t (65-35.2-0), 0.9 t (65-0-29), and 0.8 t (65-0-0) (Saha et al 1981).

The cropping intensity in most of the DWR areas in Bangladesh is quite high. Therefore, the development and introduction of improved varieties and crop management practices are the important ways to increase farm production.

TIDAL SWAMP SITES

Cropping pattern testing

At Barambai, a 3-year cropping pattern test has been completed. Attempts were made to compare improved cropping patterns with the traditional pattern and ultimately to replace the old pattern with the better ones. Cropping patterns for the furrow-bed cultivation method now widely practiced in the area were designed

Table 5.19. Agroeconomic performance of new intensive cropping patterns and existing farmers' pattern in deepwater-rice (DWR) areas with dry season irrigation, DND Project, Dhaka, Bangladesh 1980-1981.[a]

Cropping pattern			Sample fields (no.)	Turnaround time (d)	Yield (t/ha)			Total variable cost[b] ($/ha)	Net return	
Boro rice	DWR	Early aus crop			Boro rice	DWR	Early aus crop		$/ha	%
Farmer pattern										
IR8	Fallow	Fallow	4	250	4.43	–	–	461	496	100
Newly introduced patterns										
IR8	Lal Khama	Fallow	13	23, 77	4.21	2.01	–	743	614	124
IR8	Lal Khama	Mustard (Tori 7)	6	8, 12, 10	4.39	2.10	0.82	809	888	179
IR8	Lal Khama	Mustard[c] (Tori 7)	5	11, 13, 3	4.40	2.03	0.54	780	803	162
IR8	Lal Khama	Mustard (TS-72)	1	9, 12, 4	4.36	1.99	0.80	779	1025	207
IR8	Lal Khama	Red amaranthus[c] (*Lalsak*)	2	10, 12, 2	4.34	1.81	0.64	772	648	132

[a]Adapted from Khan and Hoque (1981). [b]Exchange rate used: US$1 = TK15.00. [c]Established with no tillage after DWR harvest.

and tested. Included in the designing of new patterns were improved modern varieties of rice and other crops, higher cropping intensity, and different input and management levels. In 1978-79, a new cropping pattern at medium and high input levels was compared with the traditional pattern (Table 5.20). Although the yields of the first rice crop in the furrow in the new pattern at both the medium and high input levels were identical to the traditional rice crop's, those of the second rice crop in the furrow were substantially higher. On the raised beds, yields of upland rice and maize intercrops were very low because of the low plant populations. Including a cassava crop substantially increased the amount of food produced compared with the traditional pattern. The high-input level, compared with the medium-input level, used an additional 64 h/ha for land preparation; 104 h/ha for planting, fertilizing, and spraying; 40 h/ha for weeding; 56 h/ha for harvesting; 100 cassava sticks/ha; 35 kg urea/ha, 8 kg triple superphosphate/ha, and 143 kg NPK fertilizer/ha. But these high inputs failed to produce higher yields and net returns than did the medium inputs (Table 5.20). With an additional cost of $93/ha in the medium-input pattern, and an additional net return of $398/ha, the marginal benefit-cost ratio was 4.27. The results indicated that a furrow (rice - rice) and raised bed (upland rice + maize + cassava) pattern with a medium-input level (1,008 h labor, 14.5 kg insecticides, 84 kg urea, 56 kg triple superphosphate, 55 kg rice seeds, 8 kg maize seed, and 2,900 cassava cuttings, all per hectare) has considerable potential for this tidal swamp area.

In 1979-80, researchers tested another pattern consisting of furrow transplanted (rice - rice) and raised bed planted (maize + cassava + maize) at two input

Table 5.20. Agronomic productivity and economic profitability of traditional cropping pattern and two new cropping patterns in the furrow-bed method of cultivation at Barambai Site, Indonesia, 1978-79.[a]

Cropping pattern		Yield (t/ha)	Cost of production[b] ($/ha)	Net return $/ha	Net return %	Benefit-cost ratio
Traditional pattern			80	428	100	6.35
Furrow:	rice (local)	1.9				
Bed:	maize (local)	6000[c]				
	maize (local)	7500[c]				
New pattern (medium inputs)			173	826	193	5.77
Furrow:	rice (IR36)	2.0				
	rice (Lemo)	1.5				
Bed.	Upland rice +	0.4				
	maize +	0.4				
	cassava	3.8				
New pattern (high inputs)			240	822	192	4.43
Furrow:	rice (IR36)	1.8				
	rice (Lemo)	1.9				
Bed:	Upland rice +	0.5				
	maize +	0.4				
	cassava	3.9				

[a]Adapted from CRIA (1980). [b]US$1 = Rp625. [c]No. of marketable ears.

levels (Table 5.21). Results indicate increased cropping intensity was the main reason that the new pattern had a higher production of food, calorie, and protein than did the traditional pattern. The variable costs per hectare were $96 for the traditional pattern, $240 for the medium-input pattern, and $281 for the high-input pattern; corresponding net returns were $340 (traditional), $797 (medium), and $803 (high). The traditional pattern had a higher benefit-cost ratio (4.54) than the new pattern at both medium (4.32) and high (3.86) input levels. However, the new pattern had higher net returns with medium (134%) and high (136%) input levels than the traditional pattern. The new pattern with medium input appeared to have the greatest potential for production and economic return.

In 1980-81 at Barambai, three new cropping patterns with similar input and management levels were compared with the traditional pattern (Table 5.22). The first rice crop in the furrow in the three new patterns substantially increased total production. Yields from the second rice crop in the new patterns were almost identical with those of the rice crop in the traditional pattern. Whereas the traditional pattern had two successive maize crops on the raised bed with poor yields, the new patterns replaced one maize crop with cassava, resulting in substantially higher food production. Production costs were much higher (644 to 660%) for the new patterns than for the traditional pattern. The higher variable

Table 5.21. Agronomic yields, and calorie and protein production from traditional and new cropping patterns grown in the furrow-bed method at Barambai, Indonesia, 1979-80.[a]

Cropping pattern		Yield (t/ha)	Calorie production (kcal/ha)	Protein production (kg/ha)
Farmer's pattern				
Furrow:	rice	2.70	9 569	181
Bed:	maize[b]	1.2	333	8
	maize[b]	1.0	302	7
	Total	–	10 204	196
New pattern with medium inputs				
Furrow:	rice	2.9	10 400	196
	rice	2.6	9 216	174
Bed:	maize[b]	1.2	333	8
	cassava	3.9	4 628	27
	maize[c]	0.2	710	18
	Total	–	25 287	423
New pattern with high inputs				
Furrow:	rice	2.6	9 270	175
	rice	3.0	10 901	205
Bed:	maize[b]	1.6	464	10
	cassava	4.3	5 194	30
	maize[c]	0.2	817	21
	Total	–	26 646	442

[a]CRIFC (1981). [b]Harvested for green ears. [c]Harvested for dry seeds.

Table 5.22. Agronomic productivity and economic profitability of traditional cropping pattern and new cropping patterns grown in the furrow-bed method at Barambai, Indonesia, 1980-81.[a]

Cropping pattern	Yield (t/ha)	Cost of production[b] ($/ha)	Net return	
			$/ha	%
Traditional pattern		73	512	100
Furrow: rice (local)	2.7			
Bed: maize (local)	0.2			
maize (local)	0.1			
New pattern		482	799	156
Furrow: rice (modern)	3.1			
rice (modern)	2.6			
Bed: maize (local)	0.2			
cassava (local)	4.8			
New pattern		470	1049	204
Furrow: rice (modern)	4.2			
rice (local)	2.5			
Bed. maize (modern)	0.3			
cassava (local)	5.8			
New pattern		479	930	182
Furrow: rice (modern)	3.7			
rice (local)	2.6			
Bed: maize (local)	0.3			
cassava (local)	5.0			

[a]Data source: Cropping Systems Program, CRIFC, Indonesia (Cropping pattern monitoring scheme, Asian Cropping Systems Network). [b]Exchange rate used: US$1 = Indonesian Rp625.

costs in the new patterns were due to more labor, fertilizer, and pesticide. The new patterns had higher net returns (156 to 204%) than the traditional pattern.

Cropping pattern testing at Barambai indicated a potential for increasing agricultural productivity at this tidal swamp area. It also appears that area farmers are capable of adopting the new patterns. However, there is a strong need for credit and extension services.

The cropping pattern testing in the tidal swamp areas of Bangladesh is in the early stage. In 1976-77, BRRI scientists at the Barisal Regional Experiment Station found that a pattern of modern aus rice (BR3) followed by a local transplanted aman rice (Dudmona or Kumragoir) can be quite productive (5.1 t/ha) in tidal flood areas There is also potential for growing a nonrice third crop (pulses or oil seed). Farmers could increase the productivity of their traditional local rice - local rice pattern (3.8 t/ha) as much as 32% with better fertilizer application, weed control, and insect pest management.

Component technology research

The yields of the dryland crops grown on the raised beds at Barambai are generally low. The Indonesian scientists are exploring the possibilities of improving these yields along with those of the swamp rice grown in furrows. So far, attention has been focused mainly on the identification of better varieties of dryland crops and development of productive intercropping systems. In 1978-79, a soybean variety

trial with eight entries was conducted at Barambai (CRIA 1980). The soybean yields ranged from 0.36 to 0.82 t/ha, with Orba, CK-IV/6, and Americana performing best. A cowpea variety trial identified No. 126 (Red) and No. 126 (Grey) (0.78 and 0.77 t/ha) as significantly higher yielders than the local variety (0.29 t/ha) (CRIA 1980). In a 1979-80 sweet potato trial with four local varieties, the yields ranged from 9.3 to 12.3 t/ha. Pankur had the highest yield with 94 d maturity followed by Nenus Putih (10.73 t/ha) with a 92-d maturity (CRIFC 1981). Five local cassava varieties were tested at Barambai in 1979-80. The yields ranged from 6.2 to 11.6 t/ha and the maturities from 233 to 254 d. Anjir had the highest yield with a 246-d maturity, while Mentega had the second highest yield (10.44 t/ha) and the lowest maturity (233 d). Three local varieties of string beans were tested in 1979-80 (CRIFC 1981). Yields and maturities were 1.6 t/ha and 56 d for Hijau (green), 1.4 t/ha and 63 d for Putih (white), and 1.0 t/ha and 68 d for Kuning (yellow).

In 1979-80, researchers conducted intercropping experiments on maize + sweet potato, peanut + maize, soybean + maize, and mungbean + maize at Barambai (CRIFC 1981). In the maize + sweet potato intercropping trial, eight maize varieties were compared in combination with the local sweet potato variety. The three promising maize + sweet potato combinations were Harapan + local (1.12 plus 3.69 t/ha), H-159 + local (0.96 plus 4.15 t/ha), and (HR × Md) - 15 + local (1.04 plus 3.10 t/ha). In the peanut + maize intercropping trial, eight peanut varieties were compared in combination with the HP68 maize variety. The best two peanut + maize combinations were Gajah + HP68 (1.83 plus 1.14 t/ha) and Kidang + HP68 (1.63 plus 1.35 t/ha). In the soybean + maize trial, seven soybean varieties were compared in combination with the H6 maize variety. The two promising combinations were B1667 +H6 (1.33 plus 0.43 t/ha) and Herapi + H6 (1.01 plus 0.25 t/ha). The mungbean + maize trial compared 10 mungbean varieties in combination with the H68 maize variety. The three promising mungbean + maize combinations were MB423 + H68 (1.0 plus 1.0 t/ha), MB426 + H68 (0.89 plus 0.82 t/ha), and CES ID-21 + H68 (0.67 plus 1.27 t/ha).

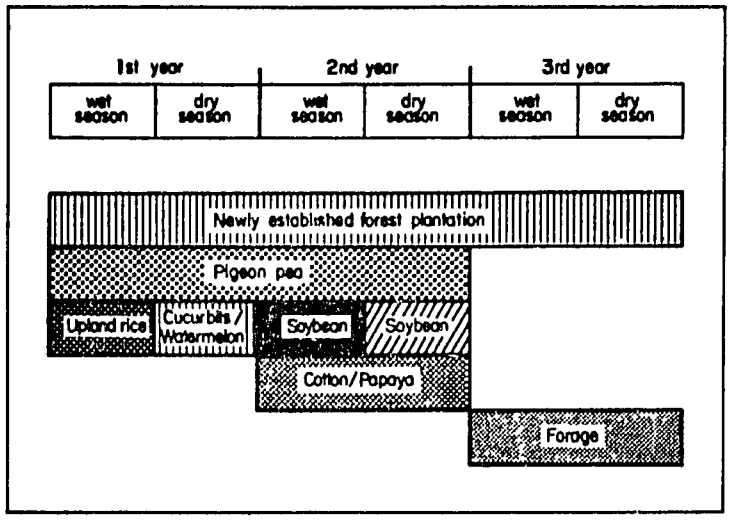
At Gournadi, Bangladesh, the site team, with technical assistance from BRRI scientists, identified widespread zinc deficiency in the ricefields. In many cases, farmers harvested no grains for several consecutive seasons due to the deficiency. The NCCB site team conducted several superimposed trials to determine the effect of seedling root-dipping with 2% zinc oxide solution as well as application of zinc oxide and zinc sulfate in farmers' ricefields. The farmers' rice crop responded significantly with high yields (3.5-4.0 t/ha). This has been the most significant contribution of the site team to date. The BRRI scientists, in cooperation with the International Soybean Program, tested soybean varieties for several seasons and found them suitable for the area. In a 1977-78 trial at Barisal, the soybean yield ranged from 1.58 to 2.25 t/ha. Hood-75, Davis, Williams, and Bossier were the best varieties, all yielding above 2 t/ha.

AGROFORESTRY SITES

Scientific design and testing of improved cropping patterns, crop rotations, and component technologies at the agroforestry sites are just beginning.

Cropping pattern testing

Based on the results of component technology studies at the sites and long working experiences of the forest officers in the agroforestry project in Bangladesh, several alternative crop rotations were worked out for newly planted forest plantations. These crop rotations covered 3,000-4,000 ha annually. One of the important crop rotations is illustrated in Figure 5.3. In this rotation, pigeon pea plants provide shade to the newly planted forest tree saplings for 2 years as well as two annual harvests of several pickings. The forest trees are planted at a 1.8-m row spacing; a row of pigeon pea is seeded closely (about 20-30 cm) along each row of trees. During the first year, four rows of upland rice are grown between two rows of trees in the first wet season, usually starting in May-June. A crop of cucurbits (pumpkin) or watermelon follows the upland rice during the second season. While the saplings and pigeon peas continue to grow, two successive crops of soybeans are grown during the second year. As in the case of upland rice, four rows of soybeans are planted between two rows of trees. Also, at the start of the first soybean crop, a row of cotton or papaya is planted in the middle of the soybean strips. Cotton and papaya are harvested and at the beginning of the third year, the pigeon pea plants are cut and used in composting or as fuel. After the harvest of the second soybean crop, forage crops, such as schoefield stylo and sirate legumes, guinea, and signal grasses, are planted. Depending on the light transmission through the forest canopy and forage crop growth, several cuttings of these legumes and grasses can provide livestock feeds. At the three Philippine sites, cropping systems scientists are determining the relative agroeconomic advantages of different agroforestry patterns under coconut and abaca plantations. The important patterns under test include coconut + cacao + pineapple, coconut + coffee + pineapple, coconut + taro, coconut + cacao + peanut, coconut + upland rice - mungbean, and abaca + coffee.



5.3. A 3-year crop rotation for agroforestry areas in Bangladesh.

Component technology research

Monoculture of cassava under forest trees is common in northeastern Thailand. However, cassava quickly depletes soil fertility. The cropping systems research team at the Khon Kaen University undertook experiments in farmers' fields to determine the relative advantage of solid stand and intercropping of cassava with four legumes — peanut, cowpea, mungbean, and soybean (Table 5.23). In all three villages, solid cassava yields were higher than those in the intercropping combinations. Peanut and cowpea appeared to yield better as intercrops with cassava than did mungbean or soybean. At Ban Jode and Ban Pasan, the solid cassava crop gave a higher net return than did the intercrop combinations. At Ban Haad, cassava + mungbean and cassava + peanut gave slightly higher net returns than did the cassava monoculture. Farmers are not interested in intercropping cassava with other crops, mainly because of high labor and crop-care requirements (Limpinuntana et al 1978).

To develop varieties of dryland crops that can tolerate shade, scientists at the Institute of Plant Breeding (IPB) at Los Baños, Philippines, are screening genetic materials using about 40% of normal solar radiation. Sorghum, soybean, peanut, sweet potato, and tomato produced acceptable yields under shade (Table 5.24). Although the root yields of sweet potato under the shade were low, the vine yields were comparable to vines in the open. Interestingly, the vines under shade contained higher amounts of beta-carotene and can serve as a more nutritious leafy vegetable and animal feed. In one trial on planting different crops under established (5-7 years) forest plantations at Salna Forest orchard, Bangladesh, arrowroot and turmeric were the most suitable commercial crops grown under shade.

HILL AGRICULTURE SITES

Researchers have done considerable work on the design and testing of improved cropping systems for the hills in Nepal and Sri Lanka.

Table 5.23. Agronomic yields and economic net returns from sole cassava crop and different cassava + legume intercropping combinations in farmers' fields in three villages at Khon Kaen, Thailand, 1978.[a]

Intercropping combination	Yield (t/ha)			Net return[b] ($/ha)		
	Ban Jode	Ban Pasan	Ban Haad	Ban Jode	Ban Pasan	Ban Haad
Solid cassava	6.3	10.9	9.6	218	387	340
Cassava +	2.8	6.0	9.2	251	315	443
peanut	0.8	0.6	0.8			
Cassava +	2.7	8.9	6.9	79	314	363
mungbean	0.1	0.2	0.7			
Cassava +	1.2	4.3	5.3	162	189	310
cowpea	0.9	0.4	0.9			
Cassava +	3.4	0[c]	9.5	76	−54	331
soybean	0.01	0[c]	0.1			

[a]Adapted from Limpinuntana et al (1978). [b]Exchange rate used: US$1 = 20 Thai Baht. [c]No harvesting because of very poor seed emergence.

Table 5.24. Yield ranges of crops evaluated under shade and corresponding Philippine national average yields.[a]

Crop	Yield (t/ha)	
	Range under shade[b]	1978 Philippine natl av
Mungbean	0.4 - 0.6	0.9
Cowpea (dry seed)	0.4 - 0.8	–
Peanut	0.7 - 1.1	0.7
Soybean	0.6 - 1.0	0.9
Maize	0.7 - 1.0	0.9[c]
Sorghum	1.7 - 2.4	3.0
Sweet potato: roots	2.1 - 6.5[x]	4.6
tops	2.8 - 6.2[x]	–
Tomato	1.6 - 3.9	7.9

[a]Adapted from Villareal et al (1982). [b]All values are means of several replicated trials except those marked x, which are means of promising entries in unreplicated trials. [c]Source: FAO (1981).

Cropping pattern testing

In the hills, attention has been focused mainly on replacing farmers' low yielding cultivars with MVs and on introducing improved crop management practices. Although cropping intensity is already high in the hills, researchers have added new crops wherever possible.

At Bandarawela, the longer duration rice varieties grown in the rice - potato and rice - vegetable patterns were replaced by shorter duration MVs released from the Batalagoda Breeding Station, reducing crop duration 1 month (Upasena 1981a). These varieties have had satisfactory yields, ranging from 6.5 to 8.4 t/ha, compared with longer duration old varieties, ranging from 6.1 to 6.8 t/ha. A rice - vegetable - vegetable pattern replaced the traditional rice - vegetable pattern mainly because of the shorter duration rice varieties. Recent studies indicate that rice - potato - wheat and rice - potato - soybean patterns can be grown successfully in the southeastern hills of Sri Lanka.

Nepalese scientists have intensively tested a number of cropping patterns at the hill cropping systems research sites in Nepal in recent years. They have evaluated these patterns at farmer and improved levels of management. Summarized results of pattern testing at four hill sites are in Table 5.25. In all patterns, improved management produced higher yields and gave considerable extra net returns compared with farmer management. Improved component technologies consisted mainly of improved varieties, better fertilizer, weed and insect pest management.

Results of cropping pattern testing in the hills of Nepal indicate a tremendous potential for increasing crop production by introducing more efficient cropping patterns and improved management practices. Based on pattern testing in farmers' fields, productive and profitable cropping systems have been identified for large-scale introduction to different hill areas.

Component technology research

Researchers conducted component technology studies in the hill sites on varietal testing, planting methods, soil management, fertilizer management, and pest

Table 5.25. Agronomic, nutritional, and economic performance of nine cropping patterns at two component technology levels at the hill cropping systems research sites in Nepal, 1977-80.[a]

Cropping pattern	Site	Component technology level	Yield: Crop (t/ha) 1st crop	2nd crop	3rd crop	Digestible carbohydrates (t/ha)	Calories (Mcal/ha)	Protein (kg/ha)	Net extra income due to improved component technology[b] ($/ha)
Rice	Khandbari	Traditional	2.3			1.24	5 630	107	
		Improved	3.9			2.10	9 568	182	310
	Pumdi-Bhumdi	Traditional	1.6			0.86	3 938	75	
		Improved	2.3			1.24	5 630	107	62
Rice - wheat	Chauri Jhari[c]	Traditional	3.3	2.0		2.89	17 376	394	
		Improved	4.2	3.4		4.14	26 080	604	278
	Lele	Traditional	1.9	1.4		1.80	11 170	257	
		Improved	4.1	2.1		3.37	19 790	443	522
	Pumdi Bhumdi	Traditional	2.0	1.2		1.73	10 462	237	
		Improved	3.6	2.0		2.05	18 112	408	167
Maize - finger - millet	Khandbari	Traditional	2.7	1.9		3.34	15 609	479	
		Improved	4.2	1.9		4.42	20 829	629	132
Rice - wheat - maize	Pumdi Bhumdi	Traditional	1.7	1.2	2.1	3.09	17 034	433	
		Improved	3.6	2.0	2.1	4.57	25 420	618	206
Rice + maize - wheat[c]	Chauri Jhari	Traditional	2.5	1.0	2.0	3.18	18 906	457	
		Improved	2.8	1.0	4.8	4.88	32 634	807	359
Rice + maize - chickpea	Chauri Jhari	Traditional	2.5	1.0	1.2	2.79	14 018	431	
		Improved	2.8	1.0	2.1	3.48	18 048	605	186
Rice + maize - lentil	Chauri Jhari	Traditional	2.5	1.0	1.7	3.08	15 355	724	
		Improved	2.8	1.0	2.0	3.42	17 102	827	239
Maize + finger millet - wheat	Pumdi Bhumdi	Traditional	2.4	1.5	1.2	3.48	18 825	549	
		Improved	3.7	2.0	2.5	5.51	31 016	890	437
Maize + soybean - mustard	Lele	Traditional	1.4	0.3	0.4	1.23	6 175	269	
		Improved	4.7	0.2	0.7	3.72	17 320	565	482

[a]Adapted from Malla and Sayre (1982). [b]Exchange rate: US$1 = Rp12. [c]With irrigation.

control. In a rice variety trial at Bandarawela, BG304-1 yielded 7.4 t/ha and BG94-1, 7.2 t/ha, both maturing within 110 d (Fernando et al 1982). The farmers' variety H4 matured in 126 d, but yielded 6.0 t/ha. In another trial, under dry-seeded conditions with supplementary irrigation, yields ranged from 4.2 to 5.0 t/ha. Both BG94-1 and BG34-6 yielded 5.0 t/ha. Four bush bean varieties were evaluated at Bandarawela under well-drained and poorly drained soils. Poor soil drainage had a negative effect on the performance of all the bush bean varieties. Top Crop yielded 21.4 t/ha; Wade, 18.0 t/ha; Canadian Wonder, 42.4 t/ha; and Contender, 24.0 t/ha in well-drained soils. Corresponding yields in poorly drained soils were 8.5 t/ha (Top Crop), 8.6 t/ha (Wade), 11.5 t/ha (Canadian Wonder), 12.2 t/ha (Contender). Six green gram varieties yielded from 0.5 to 1.6 t/ha, with Sel 76-236 (1.4 t/ha) and Type 51 yielding the most.

At the cropping systems research sites in the hills of Nepal, researchers attempted to increase rice yields by replacing traditional varieties with improved ones. Local rices averaged 2.34 t/ha at Khandbari, 1.86 t/ha at Pumdi Bhumdi, 2.15 t/ha at Chauri Jhari, and 1.90 t/ha at Lele. Corresponding average yields from improved rice varieties were 3.85 t/ha at Khandbari, 2.90 t/ha at Pumdi Bhumdi, 3.01 t/ha at Chauri Jhari, and 4.40 t/ha at Lele (Mallick 1982). Although some improved varieties, such as Chandina and IET 1444, greatly outyield the local varieties, some farmers are reluctant to accept the improved varieties because of their lower straw yields (Malla and Manzano 1981). The wheat variety NL30 was better than RR21 at Chauri Jhari. The maize variety Arun has high seedling vigor and appears to be very promising for the hill sites.

Fertilizer application significantly increased yields of improved wheat and maize varieties in the drylands. There is a need to reduce N loss from farmers' compost heaps or pits through better maintenance and better soil incorporation (Malla and Manzano 1981). Seed rates for several dryland crops were found to be inadequate to produce good yields. The cropping systems program identified advantageous seed rates for maize planted behind the plow (30-35 kg/ha), mustard (20 kg/ha), lentil, and chickpea (20 kg/ha). Traditional maize planting behind the plow and random transplanting of rice in the small terraced fields were convenient. Fertilizer trials in farmers' fields indicated rice, wheat, and maize, the three major hill crops, did not respond significantly to potassium application. Yields of some local rice varieties such as Jarneli, Thima, and Pahele were significantly increased through the use of a low N rate (30 kg/ha) fertilizer. A seed treatment of 2-3 g Vitavax/kg wheat seed reduced the incidence of loose smut in wheat from 30 to 5% at the Lele site. Furadan or Sevin granules applied in the whorl of maize plants provided good control of stem borer. One or two applications of metacid controlled the rice bugs in the improved varieties. Soybean and mungbean are subject to severe insect attack. Traditionally, farmers do not use insecticides on their local soybean varieties, which apparently have better insect resistance than do the improved varieties (Malla and Manzano 1981). This should be considered when introducing new bean varieties in the hills.

There is a dearth of suitable improved genetic materials and associated cultural technologies for the minor hill crops. Appropriate varietal improvement programs and crop management research are urgently needed for finger millet, pigeon pea, chickpea, peanut, soybean, mungbean, etc.

Chapter 6
CROPPING SYSTEMS RESEARCH AND AREA DEVELOPMENT

The ultimate objective of cropping systems research is to improve farm productivity and profit, thereby increasing the welfare of the farm community. The extent of farmer adoption will determine the impact of improved cropping systems. Widespread adoption requires scientific and well-organized systems and a technology transfer mechanism. The ACSN approach encompasses the steps from site-specific research to production program implementation.

After stable, productive, and profitable cropping patterns are identified through design and testing at a research site, these patterns, along with associated component technologies, are evaluated in a preproduction research phase. This phase includes multilocation testing and organization, implementation, and evaluation of pilot production programs. Then, large-scale production programs are started in delineated target areas.

MULTILOCATION TESTING

The main objective of multilocation testing is to verify the performance of new cropping systems technologies over a wide area (Hoque et al 1980c). And as the national cropping systems programs utilize more of the research results, ACSN scientists have reaffirmed the importance of multilocation testing.

Several concept and methodology papers have been published (Carangal 1981, Denning 1981, Hoque 1980, Hoque 1982a; Hoque et al 1980c; Hoque et al 1981b; Magbanua and Morris 1980; Pantastico et al 1980; Pookpakdi 1980; Zandstra 1980b; Zandstra et al 1981). Multilocation testing highlights of cropping systems undertaken in the Asian Cropping Systems Network member countries follow.

Bangladesh

In 1979, researchers conducted multilocation testing of three rice cropping patterns (BR 3 - Nizersail, Chandina - Nizersail, and BR6 - Nizersail) at Bhogra (Hoque et al 1982a). The yield ranges and averages were 4.9-7 t/ha and 6 t/ha from BR3 - Nizersail, 4.8-6.9 t/ha and 5.7 t/ha from Chandina - Nizersail, and 4.0-7.2 t/ha and 5.5 t/ha from BR6 - Nizersail. The average net return from BR3 - Nizersail was $1,127/ha followed by that from Chandina - Nizersail ($920/ha), and BR6 - Nizersail ($894/ha).

In 1982, a large-scale multilocation testing project was started, based on the findings at Bhogra. Researchers are using modern aus - local t. aman and modern aus - modern t. aman patterns with modest input levels for this project.

Indonesia

The Directorate of Production Development has managed the multilocation adaptive trials since 1976 (Nuryadi and Soedomo 1977). The three treatments

Table 6.1. The best cropping systems for different locations, based on cropping intensity and land equivalent ratio (LER), identified through multilocation testing in Indonesia.[a]

Location (subdistrict: Kecamatan)	Best cropping system[b]	Land type
Pidie	C	Upland
Sunggal	B	Upland
Namorambe	B	Upland
Kabanjahe	A	Upland
Sipoholan	B	Irrigated wetland
Pasaman	B	Upland
Kampar	A	Upland
Bengkalis	A	Upland
Kuantan Tengah	B	Upland
Jambi luar Kota	B	Upland
Nipah Panjang	C	Pasang surut
Terbanggi Besar	B	Lowland
Darangdan	A	Irrigated wetland
Plumbon	B	Upland
Ciawi Gebang	A	Rainfed wetland
Pagerlaran	B	Rainfed wetland
Campaka	C	Rainfed wetland
Dawuan	B	Rainfed wetland
Guntur	C	Upland
Bojong	B	Upland
Banjarejo	B	Rainfed wetland
Klirong	C	Upland
Purwonegoro	B	Upland
Wates	A	Rainfed wetland
Piyungan	A	Rainfed wetland
Prambanana	C	Rainfed wetland
Playen	A	Upland
Benda	B	Upland
Terjun	B	Upland
Kuanyar	B	Upland
Ngesem	C	Upland
Sumobito	C	Upland
Omben	B	Upland
Parang	B	Upland
Dawaan	C	Rainfed wetland
Gerung	C	Irrigated wetland
Belo	C	Upland
Amarasi	B	Upland
Kairatu	C	Upland
P. Ambon	C	Upland
Palarang	C	Upland
Bainamu	C	Upland
Maramu	C	Upland
Martapura	A	Upland
Muara Beliti	C	Upland
Pagar Alam	A	Upland
Ti. Kelapa	C	Upland
Ilir Timur	C	Upland

[a]Nuryadi and Soedomo (1977). [b]A = cropping pattern with farmers' management, B = farmers' cropping pattern with higher management, and C = improved cropping pattern with high level of management.

included traditional cropping patterns, traditional cropping patterns with higher management, and improved cropping patterns with high management. Intercropping and sequential planting are the sources of new component technology. Trained provincial technical officers coordinate trial implementation. They use technical books prepared by the Directorate with significant inputs from CRIFC scientists (Nuryadi and Soedomo 1977). Table 6.1 presents the summary results of the multilocation testing of three cropping system categories in different provinces. The best cropping patterns for each test location were identified on the basis of cropping intensity and land equivalent ratios (LER). Of 48 locations; the traditional patterns did best at 10 locations; the traditional patterns with higher management, at 19 locations; and improved patterns with high management levels, at 19 locations (Nuryadi and Soedomo 1977).

Nepal

The Department of Agricuture in Nepal is considering multilocation testing to be a part of the cropping systems research program (Malla 1981a). To disseminate the cropping systems technologies generated at the sites in the hills and Terai, a large-scale multilocation testing project was started at 23 locations. Cropping systems technologies generated at the hill sites at Lele, Khandbari, and Chauri Jhari and the irrigated Terai site at Parsa were included. During the 1981 winter season, the multilocation testing project was extended to another 22 locations utilizing research results from Parsa and Chauri Jhari (Malla 1981a). To systematically implement testing, guidelines describing technologies and methodologies for selecting test locations were prepared. Commodity program coordinators, regional directors of agriculture, and scientists of different disciplines reviewed the guidelines. Data formats were prepared and are now used by the project-implementing staff. There will be socioeconomic surveys before and after the trials to determine the feasibility of the technology (Malla 1981a).

Philippines

After 3 years of on-farm research at the Agusan, Bukidnon, and Capiz Settlement Projects, promising cropping systems first entered a preproduction evaluation phase during the 1981 wet season (Quisumbing 1981b). The extension staff conducted these multilocation trials with support from the research staff of the Agricultural Service Centers. Assistance from other agencies such as banks and market outlets at the sites were solicited. Table 6.2 presents the cropping patterns included, the number of cooperator farmers, and the area covered by the individual cropping patterns.

Thailand

At Ubon, farmers usually grew a single crop of transplanted rice. Cropping systems research in 1977 and 1978 indicated the possibility of growing an additional crop before the regular rainfed rice. In 1979, four cropping patterns were tested in 31 fields (Votong and Hanviriyapant 1980). Each cooperating farmer was provided with free seed, fertilizer, insecticide, access to a sprayer, and production guidelines for each crop. Farmers managed their crops and kept the

Table 6.2. Cropping patterns included in the multilocation testing at the ABC Land Settlement Projects in the Philippines, 1981-82.[a]

Site, cropping pattern	Farmer cooperators (no.)	Individual cropping pattern (ha)
Agusan Settlement		
Transplanted rice (TPR) - TPR	15	12
Mungbean - TPR - TPR	6	5
Maize + peanut - maize + mungbean	12	10
Bukidnon Settlement		
TPR - TPR - TPR	6	4
Maize - maize - mungbean	9	2
Upland rice - maize - mungbean	7	2
Upland rice + maize - maize + peanut	5	0.5
Maize + peanut - maize + mungbean	4	0.4
Capiz Settlement		
Wet-seeded rice (WSR) - WSR + mungbean[b]	18	10
Upland rice - maize + upland rice	8	2
Maize + peanut - maize + cowpea	10	5

[a]Quisumbing (1981b). [b]Mungbean relay-planted into rice before harvest.

harvests. Two field assistants from the cropping systems program acted as extension workers and took crop cuts for yield assessment. Results are in Table 6.3. Only 16 fields produced successful crops and the peanut crop was a failure in all fields. However, glutinous maize and yardlong beans grown before the regular rice crop and double cropping of rice appeared feasible. Poor germination of maize, peanut, and yardlong bean seeds was the major field problem (Vorong and Hanviriyapant 1980). Heavy rains in August 1979 destroyed the peanut. In the rice - rice pattern, the first crop was also flooded in August and the second crop was adversely affected by moisture stress at the dough stage because of the sudden rain cutoff in October.

The multiplication testing at Bangpae, Thailand, started in May 1981. The on-farm research program identified three patterns for large-scale adoption: glutinous maize - rice - mungbean, sweet maize - rice - mungbean, and mungbean - rice - mungbean (Pookpakdi 1980a). The multilocation project of the Kasetsart University involves testing of these three cropping patterns at five locations — Nakornchisri, Kampangsaen, Wang Yen, and Nong Thiam districts in Ratchburi and Nakorn Pathorm provinces plus the Bangpae site. The three patterns are tested in all locations, each pattern grown in four farmers' fields per location. Thus, the ongoing project involves testing in 60 rainfed fields. ACSN Working Group procedures are used in this multilocation testing project.

PILOT PRODUCTION PROGRAMS

A pilot production program determines the support needed in the large-scale diffusion of recommended technologies and clearly specifies the tasks and

interrelationships of different institutions involved in supporting the farmers (Zandstra 1980b). It also provides a final evaluation of the recommended cropping systems technology, the cost of its extension to the farmers, and the expected benefits (Nicolas et al 1980). The important prerequisite for a successful pilot production program is the availability of a set of improved cropping systems technologies generated and verified through on-farm research. The organization, implementation, and monitoring aspects of the pilot production programs are discussed in detail by Zandstra (1980c), Zandstra et al (1981), Gomez et al (1976), Haws and Dilag (1982), Smith (1977), Carangal (1980b), and Jayasuriya and Denning (1982). Pilot production programs have been carried out in the Philippines, Sri Lanka, and Nepal. In Indonesia and Bangladesh, there has been substantial adoption of cropping systems research findings, and pilot production programs are expected (Jayasuriya and Denning 1982).

Philippines

Pilot production programs have been done in the rainfed wetland and dryland areas.

The integration of rice, maize, and vegetable programs into a multiple cropping scheme. The main objective of the commodity approach is to increase production of a specific commodity. With the cropping systems approach, the objective is to increase profit through more efficient use of farm resources.

The Philippines had three separate production programs — Masagana 99 for rice, Masaganang Maisan for maize, and Gulayan sa Kalusugan for vegetables. All could be focused on the same farmer. These commodity programs were integrated into one extension program. It stressed multiple cropping and shifted loans to a full 1-year base instead of a single crop-loan base. Extension technicians were responsible for all crops in the system and a specific number of farmers in the pilot villages. Cropping intensity increased from 125% to 140% among the farmer cooperators in a 4-year period.

The KABSAKA Project. During the early seventies, IRRI scientists proved that two rice crops could be grown on the same land in Iloilo in 1 year under rainfed conditions. In 1974 IRRI signed a memorandum of understanding with the Philippine Council for Agriculture and Resources Research (PCARR) to conduct nationwide applied research trials on the two-crop system (Cardenas et al 1980).

Table 6.3. Productivity of four rice-based cropping patterns in a multilocation testing program at the Ubon Site in Thailand, 1979.[a]

Cropping pattern			Yield (t/ha)		Harvested fields (no.)
1st crop		2nd crop	1st crop	2nd crop	
Glutinous maize	–	Rice (RD6)	2.6	2.3	3
Yardlong bean	–	Rice (local)	2.2	1.7	1
Peanut	–	Rice (RD6)	–	1.5	8
Rice (RD7)	–	Rice (RD6)	1.5	0.5	4

[a]Votong and Hanviriyapant (1980).

The trials were conducted in 32 locations representing seven rainfall patterns in the Philippines. The Bureau of Agricultural Extension (BAEx), Bureau of Plant Industry (BPI), the Association of Colleges of Agriculture in the Philippines (ACAP), and other private institutions cooperated.

In September 1976, IRRI and PCARR proposed a pilot extension cropping systems project in rainfed wetland rice areas of Iloilo Province. In November 1976, the KABSAKA project (acronym for Kabusugan sa Kaumahan, an Ilongo phrase meaning bounty on the farm) was launched. The project included nine villages in Santa Barbara, Iloilo, which have a relatively stable rainfall pattern and a soil suitable for all kinds of crops. IRRI trained the technicians on the new rainfed rice technology. The technicians then trained the Iloilo farmers. An educational campaign encouraged farmers in the target area to join the program. Farmers obtained credit from the Masagana 99 credit scheme. The National Grains Authority (NGA) guaranteed purchase of rice harvested in the target areas at a specific price support level.

In the first year (1977-78), 88 farmers with 149 ha of riceland joined the project. The first-crop yields averaged 4.9 t/ha, but the second crop, hit by a drought, averaged only 1.5 t/ha (Cardenas et al 1980). In 1978-79, 276 farmers participated with 477 ha. The average yields were 4.4 t/ha for the first crop and 4.6 t/ha for the second. In 1978-79, the project expanded to four more Iloilo towns and three Negros Occidental towns. Additional benefits came from growing dryland crops after the second rice crop on 73 ha. In 1979-80, the project covered 1,041 farmers with 1,500 ha. The average yields were 4.35 t/ha for the first crop and 4.15 t for the second (Quisumbing 1981b). Starting in 1980-81, the pilot KABSAKA project entered into a large-scale production phase in the Western Visayas with a loan support from the World Bank. The target area for the program is 60,000 ha of rainfed wetland rice in Iloilo involving 4,562 farmers (Quisumbing 1981b). The other Philippine provinces are now following the KABSAKA approach.

The success of the KABSAKA project was attributed to practical strategy; well-coordinated support services; a field-tested and proven technology; and the dedication and cooperation of farmers, technicians, and local government administrators (Cardenas et al 1980).

Pilot production programs in the rainfed wetland areas. In addition to the KABSAKA program, four pilot production programs are underway in the rainfed areas: KASATINLU in South Cotabato, MANTISAYON in North Cotabato, ZAMDUGANI in Zamboanga del Sur, and MANBILAYKA in Pangasinan. They are based on a rice - rice double-cropping pattern. The main features of recommended technology include early land preparation for dry seeding of the first rice crop at the onset of monsoon rains in March-April, use of early-maturing (100-d) varieties for the first crop, and wet seeding or transplanting of the second crop with reduced turnaround time after the first crop as early as September (Quisumbing 1981b). A third nonrice crop, such as mungbean, is also planted if the residual soil moisture after the harvest of the second rice crop is adequate. The performances of these pilot programs are indicated in Table 6.4. In the KASATINLU program, the number of participating farmers, the area, and the crop yields steadily increased over the years. The initial achievements in the other three pilot programs were also satisfactory.

Table 6.4. Performance of the pilot production programs with rice - rice cropping patterns in the rainfed wetland areas of Philippines, 1977-81.[a]

Pilot program, coverage, year	Farmers (no.)	Area (ha)	Av yield (t/ha)		
			1st crop	2nd crop	Total
KASATINLU, South Cotabato (1 municipality)					
1977-78	241	262	4.6	4.0	8.6
1978-79	476	496	4.7	4.3	9.0
1979-80	643	782	5.4	4.5	9.9
MATISAYAON, N. Cotabato (8 Barangays)					
1979-80	81	97	4.3	3.7	8.0
ZAMDUGANI, Zamboanga del Sur (7 municipalities)					
1980-81	21	60	3.5	–	–
MANBILAYKA, Pangasinan (24 municipalities)					
1980-81	821	671	3.45	2.0	5.45

[a]Quisumbing (1981b).

Pilot production program in the dryland areas. Under the Philippine-Australian Development Assistance Program (PADAP) in Zamboanga del Sur, researchers are developing appropriate crop production technologies for the dryland areas. Simultaneously, the pilot production program tests the research findings in farmers' fields to determine farmer adoption and institutional support requirements (Quisumbing 1981b). A Philippine National Bank (PNB)-PADAP credit scheme, started in 1979, supports the program. The initial results of the program have been encouraging (Table 6.5).

Sri Lanka

The pilot production program is based on the cropping systems research findings generated at the Walagambahuwa Minor Tank Development Project Site. The project aims at increasing production of rice and other food crops through their intensification and through careful and efficient management of the tank water. Traditionally, farmers grew a single rice crop of 4 months' maturity with the probability of successful harvest once every 4 or 5 years (Fernando 1982). About 120,000 ha of such partially irrigated ricelands depend on 10,000 small reservoirs in the dry zone (Upasena 1981b).

Five years of on-farm research at Walagambahuwa indicated that a rice - rice pattern could be successfully grown with minimum rainfall (742 mm) and productivity of farmers' wetland rice crops could be increased by 3-4 times (Upasena 1981b). The two major components of the new technology are the timely cultivation and use of suitable varieties with 90- to 105-d maturity. Timely cultivation allows farmers to grow the first crop almost entirely from the incidental maha season rains, leaving the tank water almost untapped. The first crop matures

Table 6.5. Performance of a pilot multiple cropping production project in upland rainfed areas of Zamboanga del Sur, PADAP, 1979-81.[a]

Crop	Phase 1 (April-July 1979)			Phase 2 (August-March 1980)		
	Farmers (no.)	Area (ha)	Av yield (t/ha)	Farmers (no.)	Area (ha)	Av yield (t/ha)
Maize	127	126.5	1.23	–	–	–
Upland rice	4	2.5	3.4	2	1	–
Mungbean	54	32.5	0.8	280	192.5	0.72
Peanut	3	2	1.05	11	6.5	1.15
Total	188	163.5	–	293	200	–

[a]Quisumbing (1981b).

just at the tail end of the rainy season and the second crop can be grown immediately, utilizing the stored tank water. Since 1977, the second crop has been grown successfully at Walagambahuwa for 5 consecutive years (Upasena 1981b). In 1977-78 and 1980-81, a third (nonrice) crop has been raised successfully (Fernando 1982).

The average yields at Walagambahuwa rose from about 1.6 t/ha in 1976-77 to about 4.6 t/ha in 1979-80. The total rice output in the village rose from 46.4 t in 1976-77 to 139.3 t in 1979-80 (Fernando 1982). The new Walagambahuwa tank-based technology was passed on to the pilot production programs in different dry zone districts. The Anuradhapura and Kurunegala districts, containing about 80% of the country's small reservoirs, are the initial target area for the program. These districts also have special development projects sponsored by the Asian Development Bank and the United Nations providing for the construction of new and the rehabilitation of old minor reservoirs (Fernando 1982).

The Department of Agriculture extension staff is implementing the program. IDRC and IRRI have trained key officers (Fernando 1982). A specially trained group of specialists is assigned to the program.

The Ten-Tank Program. To study the impact of the Walagambahuwa technology, researchers selected 10 minor tank villages for the pilot program in 1978-79. The extension services staff implemented the project, which covered about 126 ha. The results are in Table 6.6. This initial phase was successful. The farmers cultivated 90- to 105-d maturity group varieties, such as BG34-8 and 62-355. During the first season, the yield increases due to new technology ranged from 0.5 to 1.5 t/ha over the preproject yields. However, only two settlement projects at Nugampola and Kumbuk grew a second crop of rice (those yields averaged 2 t/ha). The failure of farmers in the other eight tank villages to raise a second season crop was attributed to inadequate runoff capacities of their reservoirs (Fernando 1982). The relative size of the reservoir to the service area appears to be important in making the Walagambahuwa concept work in other locations.

The expansion phase. In 1980-81, the new technology was introduced in 145 minor irrigation settlement schemes in the Anuradhapura District with the successful rice cultivation of 3,295 ha during the first season (Fernando 1982).

Table 6.6. Performance of Sri Lanka's 46 cropping systems pilot production program (Ten-Tank Project), Kurunegala District, wet season 1978-79.[a]

Irrigation scheme	Cultivated extent (ha)	Farm families (no.)	Date crop establishment was completed	Crop establishment method	Varieties	Date of first issue of water	Grain yield of 1st crop (t/ha)	
							Before project	After project
Ihalagama wewa	8.4	18	20 Nov 78	Dry sowing	Bg 34-8 62-355 Bg 94-1	5 Oct 78	1.5	2
Monnakulama	18.0	45	30 Dec 78	Sowing Transplanting	Bg 34-8 Bg 33-2	23 Dec 78	1.4	2.7
Nugampola wewa	6.8	16	10 Dec 78	Transplanting	Bg 34-8	27 Dec 78	2.1	3.6
Ihalagama game wewa	25.6	36	12 Dec 78	Sowing	Bg 34-8 62-355	28 Dec 78	1.4	2.5
Kumbuk wewa	12.4	26	23 Dec 78	Sowing	Bg 34-8 62-355	27 Dec 78	1.5	2.7
Nithogama Maha wewa	14.0	36	27 Oct 78	Sowing	62-355	1 Jan 79	—	2.8
Pahala wewalaya Gedera wewa	7.6	35	29 Nov 78	Sowing	Bg 34-8	3 Dec 78	1.8	2.6
Pahala wewa	7.6	31	7 Dec 78	Sowing	Bg 34-8 62-355 H-10	25 Dec 78	1.5	2.0
Maha wewa	11.8	40	14 Dec 78	Sowing	Bg 34-8	3 Jan 79	1.25	2.25
Mamunugama Gederayawa wewa	13.6	52	18 Dec 78	Sowing Transplanting	Bg 34-8 Bg 34-6	9 Jan 79	1.8	2.6

[a]Adapted from Wijessoriya (1982); Information compiled by Mr. K. H. U. Kumarasinghe, subject matter officer - Water Management, District Agriculture Office, Kurunegala - Sri Lanka.

During the second season, 371 ha fed by 40 reservoirs with adequate water produced either rice (87 ha) or other food crops (284 ha), mainly short-duration food legumes and chili. Rice yields ranged from 1.1 to 4.2 t/ha, averaging 1.8 t/ha. Fernando (1982) considered the program a success in that farmers successfully grew at least a rice crop, ensured food and seed supply for the next season, and cultivated previously abandoned ricefields. There were no yield estimates on the other food crops, although the availability of these commodities in the local markets indicated some success. Unfortunately, the targeted production program for 1981-82 in the Anuradhapura District was dropped due to an unprecedented, severe drought during the maha season.

In Kurunegala District, 171 settlements entered the program during the 1980-81 maha season. Farmers grew 1,982 ha of rice with yields averaging about 3.5 t/ha (Fernando 1982). During the following dry season, 176 settlements joined the program, but only 81 managed to grow the second rice crop and only on a limited basis. Farmers in 102 other settlements grew food crops requiring less water. During 1981-82 maha season, 603 minor tank settlements in the Kurunegala District participated in the program, exceeding the targeted 500 tanks. However, because of low rainfall, farmers in only 211 settlements harvested a successful rice crop. Crop production during the 1982 yala season was abandoned in all of the settlements because of severe drought (Fernando 1982).

The Walagambahuwa technology performed better in Kurunegala District than in Anuradhapura District because of a more favorable rainfall pattern and more improved rice varieties. The four major constraints experienced in the widespread application of the Walagambahuwa technology were difficulties in timely tillage, input supply, weed control, and differential hydrology in the minor tanks (Fernando 1982). Research and development activities are now planned to overcome these problems.

Nepal

After 3 years of field testing of improved cropping systems with about 2,000 cooperating farmers, a pilot production program started in 1980 around four cropping systems research sites in the hills and one site in the Terai. The objectives of the program are to demonstrate technology feasibility, to assess extension approaches, and to identify the problems that could constrain program implementation (Malla 1981). A working guideline, including technology specifications, was prepared. An overall program support and coordinating body was formed and coordinating and implementing committees were set up at regional, district, and panchayat levels. IRRI-trained extension technicians with working experience in the Nepalese cropping systems program were assigned to the pilot program.

The well-defined implementation strategy includes organized farmer meetings to introduce the program; informal farm and home visits; posters, leaflets, and signboards on demonstration plots; and field days, including a yield-estimation contest for participating farmers. Farmers also receive assistance in securing credit. The program staff coordinates implementation of these activities with the input agency and cooperatives. Table 6.7 shows farmer participation and areas under different cropping patterns along with the initial agronomic results. The

Table 6.7. Number of farmers and area under maize, rice, and wheat in different cropping patterns in the pilot production program in five areas in Nepal, 1980-81.[a]

Site	Crop	Cropping[b] pattern	Participants per pattern (no.)	Av area (ha)	Total	
					Participants (no.)	Area (ha)
Pumdi Bhumdi	Maize	M/FM - W	39	2.3	62	3.8
		R - W - M	21	1.4		
	Rice	R - F - F	35	5.1		
		R - W - M	28	2.0		
		R - W - F	8	0.6	71	7.7
	Wheat	M/FM - W	102	9.9		
		R - W - M	66	11.7		
		R - W - F	15	1.6	183	23.2
Lele	Wheat	R - W	104	22.5	104	22.5
	Maize	M + SB - MB	52	4	52	4.0
	Rice	R - W	35	10	35	10.0
Khandbari	Wheat	R - W	27	3.7	27	3.7
	Maize	M - FM	86	9.0	86	9.0
		M - M	70	16.0	156	27.0
Chauri-Jhari	Wheat	R + M - W	200	12.0	200+	12.0
	Maize	M - FM	45	5.0	45	5.0
Sukhchaina	Wheat	R - W	47	23.0	47	47.0
	Rice	R - W	47	23.0	23	23.0

[a]Malla (1981b). [b]M = maize, FM = finger millet, W = wheat, R = rice, F= fallow, SB = soybean, MB = mungbean.

program has begun to have an impact on production in most of the pilot areas. Most importantly, researchers have identified the major constraints to widescale diffusion of the improved cropping systems technologies. The major problems are: a) poor commitment, delegation of responsibilities, and coordination among agencies involved in the program; b) inadequate information dissemination; c) poor-quality seeds; and d) unavailability of proper fertilizers (Malla 1981b). These problems can be corrected.

Site-specific on-farm research is clearly the best way for making technology reach a large number of small farms. The improved technologies have succeeded, in almost all pilot cases, in generating substantial extra production, employment, and income. The pilot technology-transfer activities of the last 5-6 years have directly benefited 28,671 farms totaling 76,685 ha of cultivated land. These pilot programs have suffered from biophysical, technological, and infrastructural constraints. Although feedback from these initial efforts will guide researchers in developing even better technologies, it is essential that adequate support structures be set up to properly service them. There is a strong need for integrating and linking cropping systems with other sectors of rural economy. Some attention should be given to rural development in general. The complementary role of cropping systems research and development is apparent in structuring large-scale farming systems or rural development programs. Because cropping systems research has steadily progressed, the opportunity for such integration is now.

Chapter 7

THE IMPACT OF CROPPING SYSTEMS RESEARCH ON THE SMALL FARMS

The task of impact assessment is very difficult. Assessing a cropping systems program based on one or two criteria, such as changes in productivity and income, may be dangerous. Some impacts cannot be quantified. Most importantly, to have any tangible impact on farmer welfare, the improved cropping systems technologies must be adopted on a large scale, which necessitates strong extension services and institutional support. Weaknesses in these support services can definitely undermine the biological potentials of the new technologies. Perhaps the most rational approach is to consider the defined objectives of cropping systems research and to examine the objective accomplishment and the spill-over benefits in other areas. This may provide a practical and useful assessment guideline.

Although systematic and detailed impact assessment studies have yet to be done, different benchmark surveys, monitoring studies, farm-record keeping work, and results of experimental ACSN activities provide helpful clues.

GENERAL IMPACT

The IRRI-coordinated Asian Cropping Systems Network made the systems approach to agricultural research and development in South and Southeast Asia operational and respectable. Banta (1980) stated: "In the early 1970s after the cropping systems program was implemented and a major portion of its work moved to farmers' fields, there were grumblings that it should not be considered scientific research. As the research results started to appear, showing why single-discipline results had not been accepted, the criticism started to die and the curiosity started. Young IRRI-trained scientists started research in farmers' fields. Scientists who had never been off the research station except to tell farmers what to do went to look, and found themselves discussing the research with farmers. It is hard to overestimate the impact that this interaction will have on research programs in the future."

More than 500 Asian scientists have been trained at IRRI on cropping systems research and development. Dozens of research administrators and policymakers from different countries have been oriented to cropping systems concepts and approaches. Thousands of IRRI visitors have also learned about the scope and operation of Asian cropping systems programs. These people have, in turn, helped in the adoption and spread of the systems approach. Without the nonquantifiable achievements of changing thinking and attitudes, quantifiable achievements such as increasing productivity and income would, perhaps, have been impossible. The multidisciplinary on-farm research methodologies have been the vehicle for modern science and technology in solving food and economic problems on small

farms. They have produced a built-in mechanism by which farmers' experiences are tapped, and by which, with active farmer participation, improved systems are developed.

INCREASED PRODUCTION

Improved cropping patterns have led to increased crop yields. The variations in food, nutrients, and energy produced at specific sites can be attributed to cropping patterns and associated management practices. The data in Table 7.1 are from the farmers' dominant and promising new cropping patterns. In most cases, new patterns had higher yields of food, nutrients, and energy than did traditional patterns. The data indicate that the various sites differ considerably in production potential. However, the important achievement of site-specific research is that at the selected sites, the biological production potentials that can help structure a national or regional production program aimed at specific production targets are now known. The new cropping patterns that have maximized productivity levels at the research sites will also have a greater impact on future production in the target areas.

IMPACT ON INCOME LEVEL

Farmers try to adopt improved cropping patterns that demonstrate higher production potential. But because of socioeconomic constraints, they often fail to apply adequate input and management levels to make the patterns work. In some cases, farmers adopt only certain components of the new technology. Researchers

Table 7.1. Yield ranges of edible food, digestible carbohydrate, digestible protein, and calorie production at several rainfed and irrigated cropping systems research sites, irrespective of cropping patterns, Asian Cropping Systems Network, 1979-80.[a]

Site	Range of yield			
	Edible food[b] (t/ha)	Digestible carbohydrates (t/ha)	Digestible protein (kg/ha)	Calories (kcal/ha)
Rainfed				
Parsa, Nepal	4.05 - 6.54	2.99 - 4.64	337 - 586	5 028 - 15 897
Bhogra, Bangladesh	3.00 - 4.33	2.42 - 3.49	210 - 303	1 104 - 16 230
Bangpae, Thailand	2.67 - 6.58	2.09 - 3.58	241 - 636	16 956 - 19 401
Sampang, Indonesia	2.45 - 7.68	0.69 - 5.26	239 - 780	13 628 - 28 552
Irrigated				
Parsa, Nepal	1.93 - 6.54	1.56 - 4.64	135 - 586	7 102 - 26 506
Laskerchala, Bangladesh	2.24 - 4.00	1.81 - 3.23	157 - 413	8 243 - 15 600
Saina, Bangladesh	4.74 - 6.81	3.83 - 5.50	332 - 477	17 443 - 25 061
Shimrail, Bangladesh	5.44 - 8.00	4.40 - 6.46	381 - 560	20 019 - 29 440
Iri, South Korea	3.33 - 6.40	2.69 - 4.20	233 - 638	12 254 - 27 200
Milyang, South Korea	1.93 - 10.70	1.56 - 4.87	135 - 1 399	7 102 - 29 824

[a]Hoque (1981). [b]Edible food means milled products ready for consumption.

Table 7.2. Broad effect of introducing new cropping systems technology on sample farms at Pangasinan and Iloilo, Philippines.[a]

Sample farmer number	Technology[b]	Total return over variable cost[c]			
		Pangasinan		Iloilo	
		$/farm	$/ha	$/farm	$/ha
1	TT	489	201	1140	311
	TT & NT	1034	423	2071	566
2	TT	497	186	454	132
	TT & NT	527	198	711	207
3	TT	444	130	626	255
	TT & NT	672	179	1560	636
4	TT	606	160	280	83
	TT & NT	1332	352	524	155
5	TT	76	48	214	135
	TT & NT	160	102	464	292
Av	TT	422	145	543	183
	TT & NT	745	251	1066	371

[a]Adapted from Jayasuriya (1979). [b]TT = traditional technology, NT = new technology. [c]Exchange rate: US$1 = Philippine ₱7.4.

studied 10 sample farms at Pangasinan and Iloilo, Philippines, to determine the effect of new cropping systems on farm income levels (Jayasuriya 1979). They compared traditional practices with practices that included some partially adopted new technology. Total farm income increased in all the sample farms because of new technology incorporation (Table 7.2). However, in general, the new technology adoption means an increase in variable production costs. Farmers usually adopt new technologies with acceptable marginal benefit-cost ratios, particularly when credit is available. As with agronomic productivity, there are wide gaps in variable costs, net returns, and benefit-cost ratios between individual cropping patterns at a particular site (Table 7.3). The prevailing market prices at a particular site determine the relative economic profitability of an alternative cropping pattern. On-farm cropping systems research has demonstrated the potentials with better cropping systems for obtaining high incomes in both rainfed and irrigated areas.

INCREASED EMPLOYMENT

In general, development of intensive cropping patterns has increased farm employment. The highly productive and profitable cropping patterns have usually provided a satisfactory rate of return to labor. Data (Table 7.4) indicate that the cropping patterns differ in labor employment and rate of return to labor. In all cases, adoption of improved management practices created more jobs. Except in the rice - rice - rice pattern, the rate of return to labor was higher with improved management practices. Improved cropping systems usually create more employment opportunities for farm laborers, spread over the months, and the rate of

Table 7.3. Ranges of variable costs, net returns, and rates of gross returns from cropping patterns monitored at several rainfed and irrigated cropping systems research sites, Asian Cropping Systems Network, 1979-1980.[a]

Site	Per-pattern range		
	Variable cost ($/ha)	Net return ($/ha)	Benefit-cost ratios ($/$ invested per ha)
Rainfed			
Pumdi Bhumdi, Nepal	120 - 409	144 - 999	2.2 - 3.6
Bhogra, Bangladesh	174 - 359	674 - 989	3.3 - 4.9
Bangpae, Thailand	444 - 576	209 - 398	1.4 - 1.7
Sampang, Indonesia	297 - 806	- 51 - 1169	0.9 - 2.8
Irrigated			
Laskarchala, Bangladesh	169 - 273	253 - 681	2.06 - 4.65
Saine, Bangladesh	235 - 691	495 - 1160	1.91 - 3.75
Iri, South Korea	1633 - 4777	-203 - 2243	0.96 - 2.37
Milyang, South Korea	1444 - 4594	-126 - 4893	0.97 - 2.34

[a]Hoque (1981).

return to labor is satisfactory. Labor peaks at the turnaround time between crops are still a major problem. In some instances, introduction of labor-saving technologies, such as wet seeding of rice in place of transplanting, has minimized this problem.

IMPACT ON LAND UTILIZATION

Although ACSN scientists have emphasized improved cropping patterns, due consideration has also been given to the utilization of farm land resources. Scientists have attempted to develop cropping patterns for newly cleared lands such as those in Sumatra, and, to utilize land for crop production during periods, it is usually kept fallow, as in the dry season. These attempts have improved the use of scarce land resources in Asia and have provided hope of a better future for millions.

TECHNOLOGY TRANSFER

At the research sites, farmers often promptly adopt the new cropping systems that demonstrate potential. At the Iloilo site, for example, 82% of the farmers grew a single crop of rice in 1974-75, 5% grew rice - rice or rice - rice - dryland crops patterns, 11% rice - dryland crop pattern, and 2% dryland crop - dryland crop pattern (Jayasuriya et al 1981). In 1978-79, as the new patterns proved more productive, 45% of the farmers grew rice - rice and rice - rice - dryland crop patterns, 28% grew the rice - dryland crop pattern, 14% grew the single rice crop, 4% grew the dryland crop, and 9% grew other patterns. Table 7.5 presents adoption pattern data of MVs in the rice - rice pattern at two rainfed sites. Because farmers obtained better yields from the MV rice - MV rice and MV rice - local rice patterns, more gradually adopted these patterns. Farmers have

participated in the on-farm cropping systems research programs as cooperators. They have directly benefited from the outcomes of the research and have influenced their neighbors and relatives to adopt the improved cropping systems.

THE NET EFFECT IN THE COUNTRIES

On-farm cropping systems research has had a positive and tangible impact on the overall agricultural research and development in many countries. In the hills of Nepal, site-specific research has formed the basis for large-scale hill agriculture development programs. Nepalese scientists have successfully used the new MVs of rice, maize, and wheat in developing highly productive cropping systems for the hills and the Terai. The current pilot production programs are ushering in new hopes for a better life on the small traditional farms.

In Bangladesh, where cropping intensity is already quite high, scientists have demonstrated further crop-intensification prospects for rainfed and irrigated areas. New cropping patterns have more than doubled yields at several sites. The introduction of the double-rice cropping pattern in the traditional single-cropped deepwater areas has created a tremendous impact on the total food production in food-deficit areas. Bangladesh now has a network of 36 operational research sites in different agroecological zones run by various organizations. A nationally coordinated effort is under way to effectively use the research results.

Indian scientists have generated a wealth of information on cropping patterns under diverse agroclimatic conditions. The potential cropping patterns have been

Table 7.4. Labor employment and rate of return to labor in different cropping patterns under traditional management and improved management practices at Iloilo, Philippines, 1976-77.

Cropping pattern/ management category	Sample fields (no.)	Total labor absorption (man-hours/ha)	Return to labor[b] ($/man-hour)
Rice - rice - rice			
Traditional	7	2326	1.52
Improved	16	4779	1.13
Rice - rice - upland crops			
Traditional	10	2004	0.71
Improved	50	3778	1.21
Rice - rice			
Traditional	73	2150	0.76
Improved	22	2503	1.67
Rice - upland crops			
Traditional	30	1866	0.74
Improved	14	3162	1.09
Maize - upland crops			
Traditional	7	1069	0.47
Improved	12	2682	1.09

[a]Adapted from Roxas (1977). [b]Computed as total value of production minus harvesting costs, divided by preharvest labor.

Table 7.6. Rate of MV adoption by farmers in rice - rice cropping patterns at rainfed research sites at Iloilo, Philippines, and Bhogra, Bangladesh, 1976-78.[a]

Varietal combination		Area or field[b] (%)		
1st crop	2nd crop	1976-77	1977-78	1978-79
		Iloilo		
Local	Local	1	–	–
Local	MV	10	1	2
MV	Local	13	14	14
MV	MV	76	85	84
		Bhogra		
Local	Local	24	6	1
Local	MV	18	10	1
MV	Local	46	53	66
MV	MV	12	31	32

[a]Source for Iloilo data, Jayasuriya et al (1981), for Bhogra, Hoque et al (1979). [b]For Iloilo site % area (ha); for Bhogra site % fields.

widely used in extensive farm demonstration programs with remarkable success. The challenge in India continues to be the development of more appropriate farm technologies for dryland and flooded conditions.

In Sri Lanka, the major breakthroughs have been in technology generation for the minor tank-based rice areas in the dry zone. A pattern of land utilization integrating components of modern crop production technology and efficient water conservation and use is now spreading with strong political and institutional support over a wide area.

In food self-sufficient Burma, scientists have emphasized the improvement of predominantly rice-based cropping systems with the objective of attaining well-balanced regional rice production and availability. Burma has a network of research sites and multidisciplinary, multi-institutional task forces at different levels to implement the program. Although there has already been outstanding rice production increase in several townships, the approach has turned to adoption of the cropping systems concept and methodology to raise production levels of rice and nonrice other crops.

In Thailand, a rice-exporting country, cropping systems scientists have demonstrated the potential for crop intensification in several areas. Although large-scale adoption of these intensive cropping systems requires production incentives such as credit, input supply, and price support, the scientists have shown that these systems can help use the country's land resources more efficiently as well as improved income, food, and nutrition on small subsistence farms.

The Indonesian program has so far included 25 on-farm research sites with diverse agroclimatic conditions. In Java, the program has developed efficient irrigated cropping patterns for different irrigation regimes that are now widely used in large-scale production programs. At the sites in Sumatra, most intensive cropping patterns involving mixed and relay cropping methods have been developed for the Red-Yellow Podzolic dryland soils. These cropping patterns,

with some necessary design modification, are now being successfully extended to South Kalimantan and Sulawesi. The agricultural extension service has now adopted the cropping systems approach to increase production. One of the major accomplishments of the Indonesian program has been its support of the government's large-scale transmigration projects on the outer islands. The scientists in Malaysia are now introducing multiple cropping systems with rice as the base crop. Double-rice cropping patterns have been successfully adopted in irrigation projects, such as the MUDA Agriculture Development Project. In the Philippines, scientists have worked with 33 on-farm research sites with diverse agroclimatic environments. Research results from several sites such as Iloilo and Pangasinan have already been utilized in large-scale national production programs such as KABSAKA. The cropping systems approach has been now widely adopted for the country's farming systems research and development.

South Korean scientists have been emphasizing the agroeconomic comparisons of alternative cropping patterns such as single cropping of rice versus double-cropping patterns of rice - nonrice crops. They have generated considerable data on the component technologies for these alternative cropping patterns. Chinese scientists are showing renewed interest in crop intensification. They are attempting to reduce management and resource requirements while maintaining the total productivity levels of the cropping patterns.

During a short time, the cropping systems scientists in Asia have successfully demonstrated the tremendous biophysical potentials for increased food and agricultural production in the tropical and subtropical rice belt. They have succeeded in understanding the existing situations and problems in several major production environments. They have developed alternative sets of cropping systems technologies for several areas that can help feed the increasing population in the region — if adopted with proper technical and institutional support. Work is continuing to develop more productive and profitable cropping systems for specific environments and to solve the emerging field problems. Most critical to the utilization of this scientific systems research is a strong political will of the national governments in Asia to provide the hungry millions with adequate food and nutrition.

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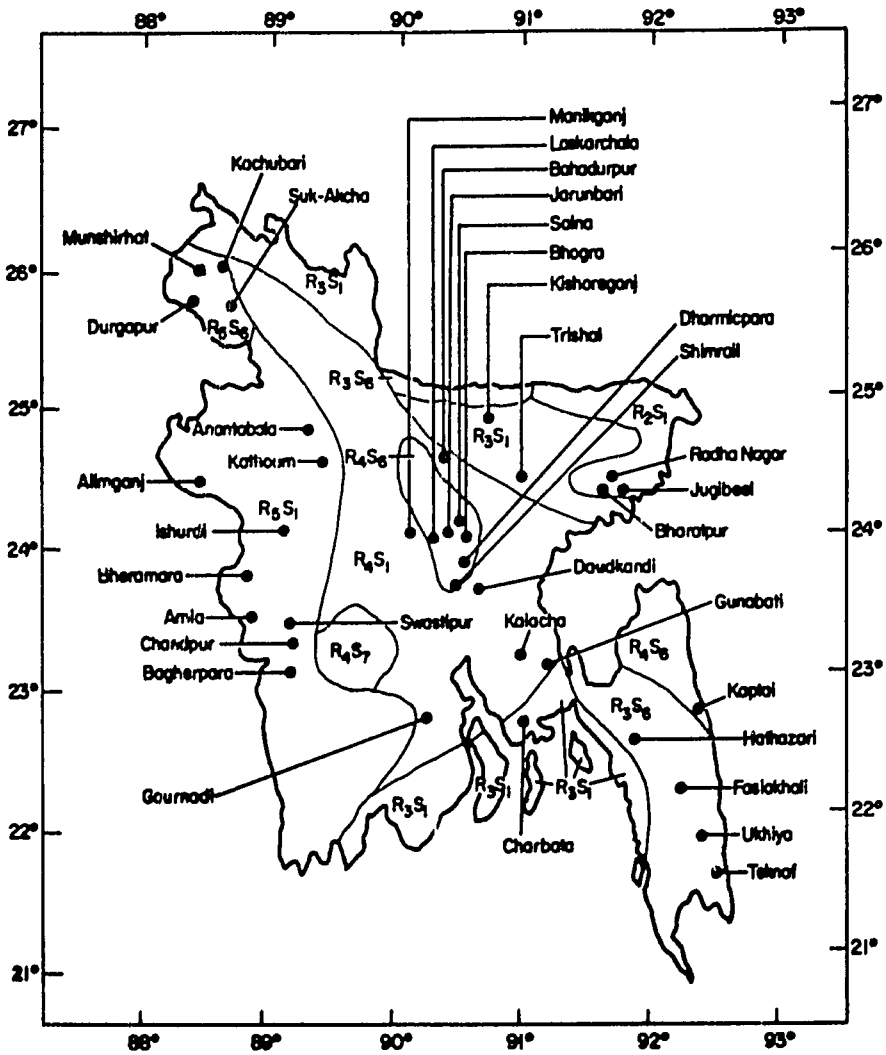
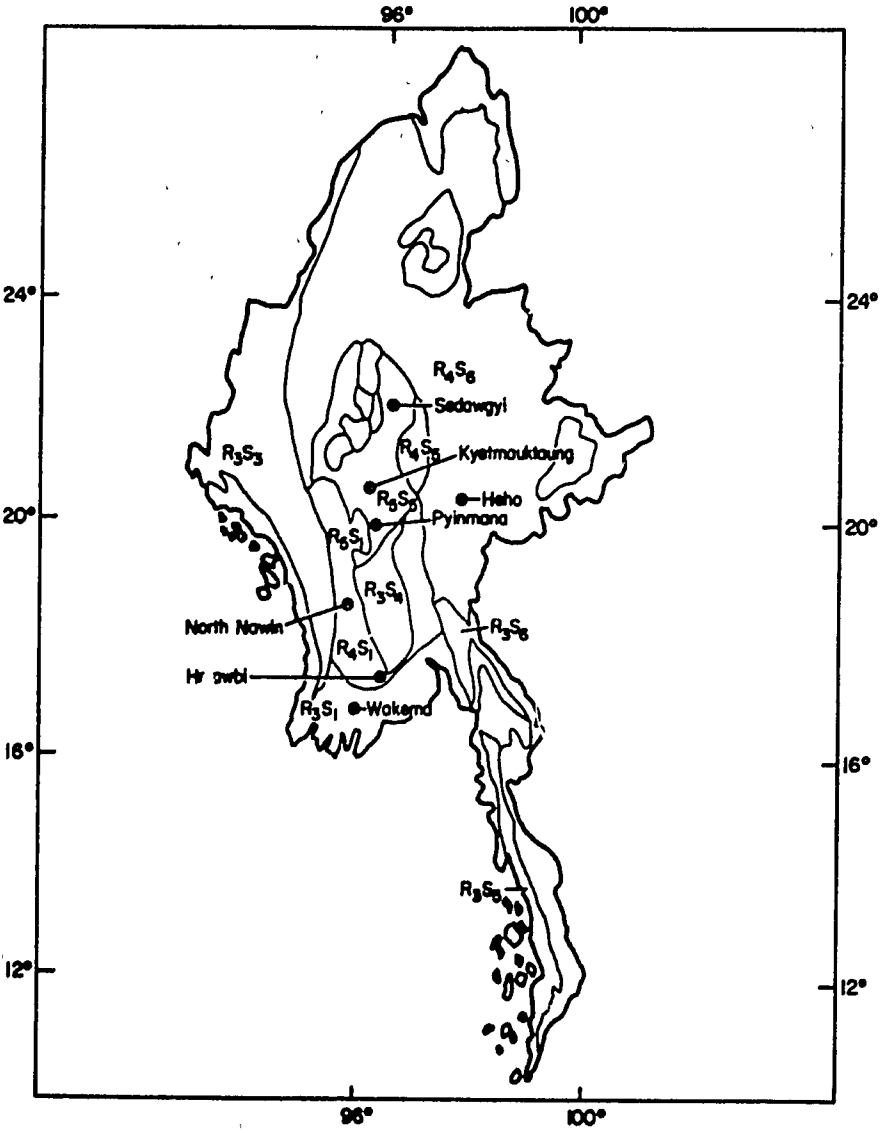
APPENDICES

APPENDIX I

Agroecological zones and locations of cropping systems research sites in nine Asian countries. With the exception of Nepal, all are from Panabokke (1979).



1. Bangladesh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Heho
Pyinmana
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Wakema
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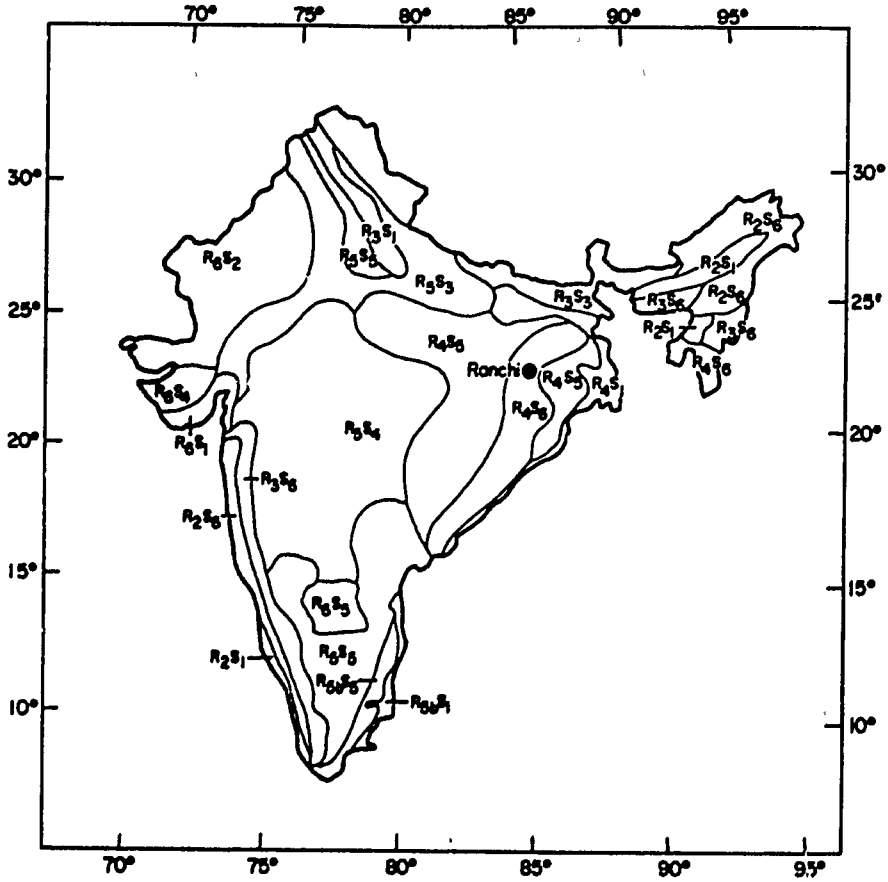
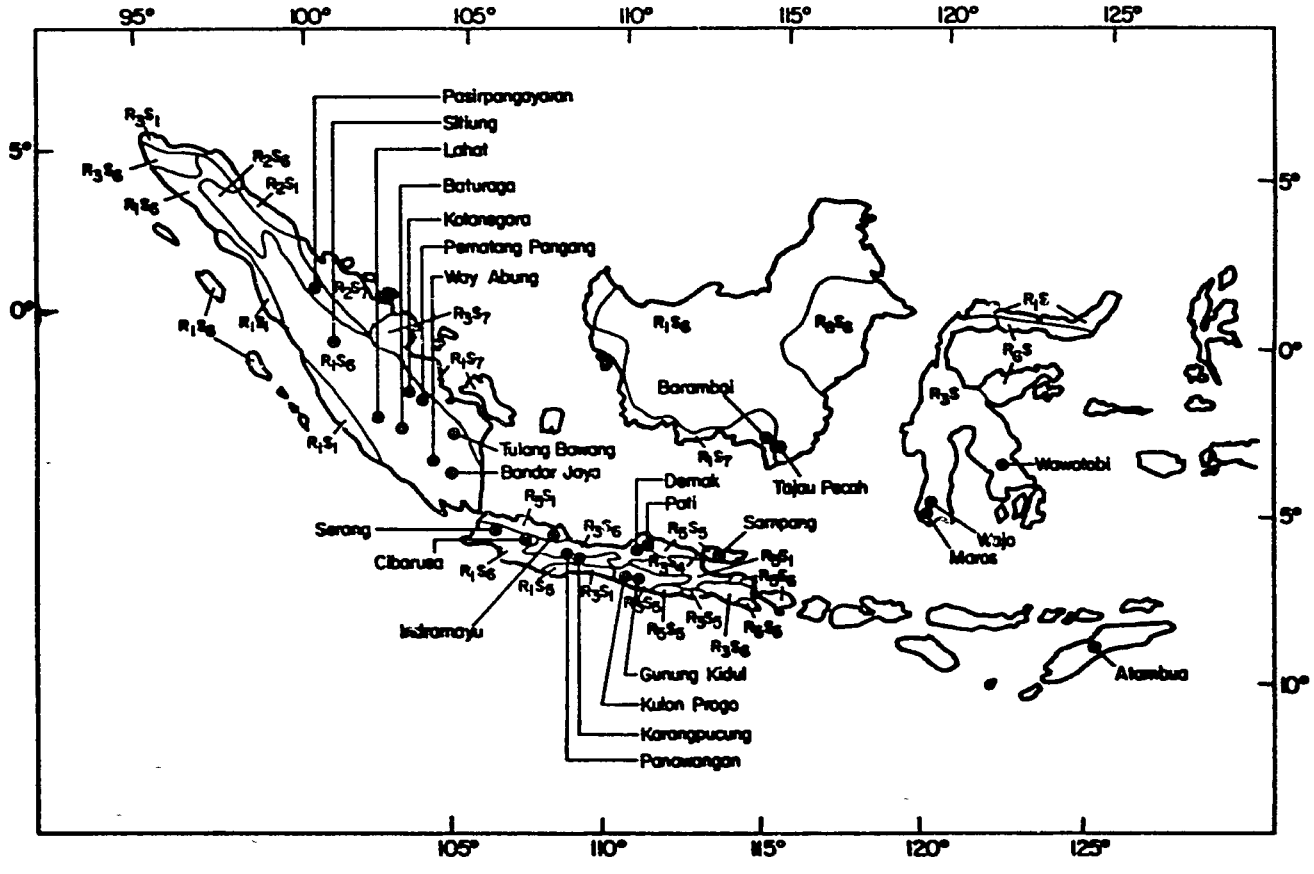
2. Burma



3. India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Bandar Jaya
Serang
Cibarusa
Indramayu
Demak
Pati
Sampang
Gunung Kidul
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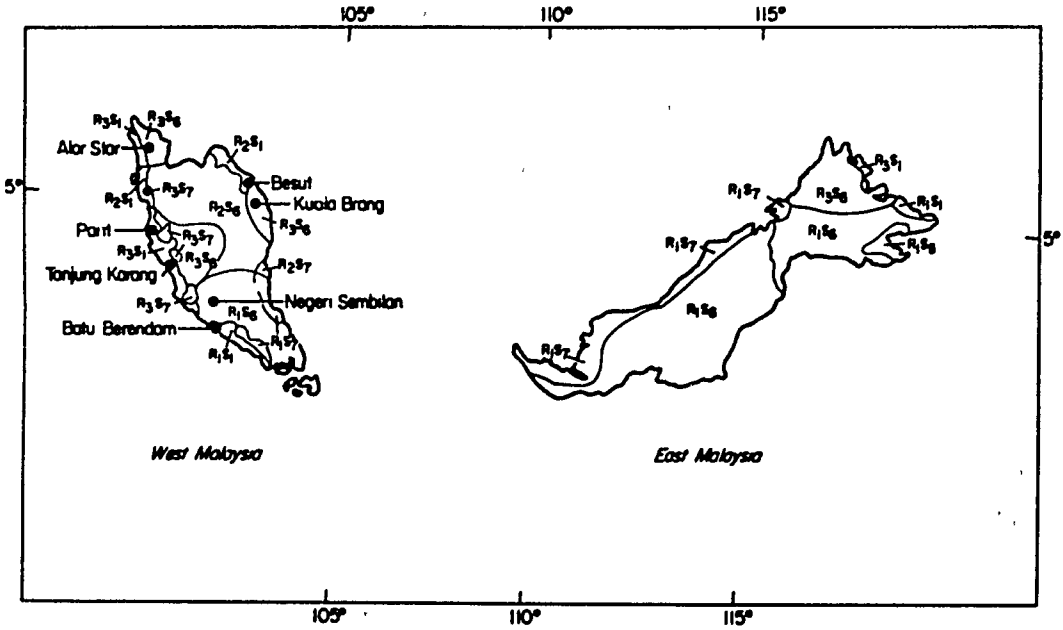
4. Indonesia



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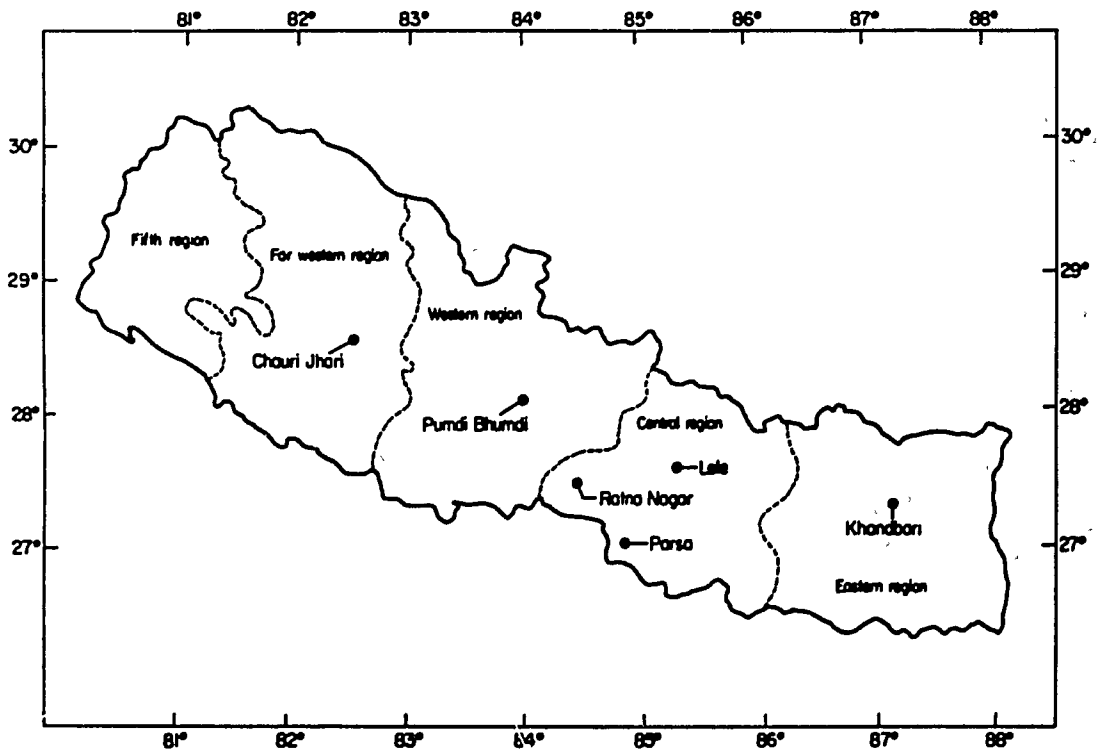
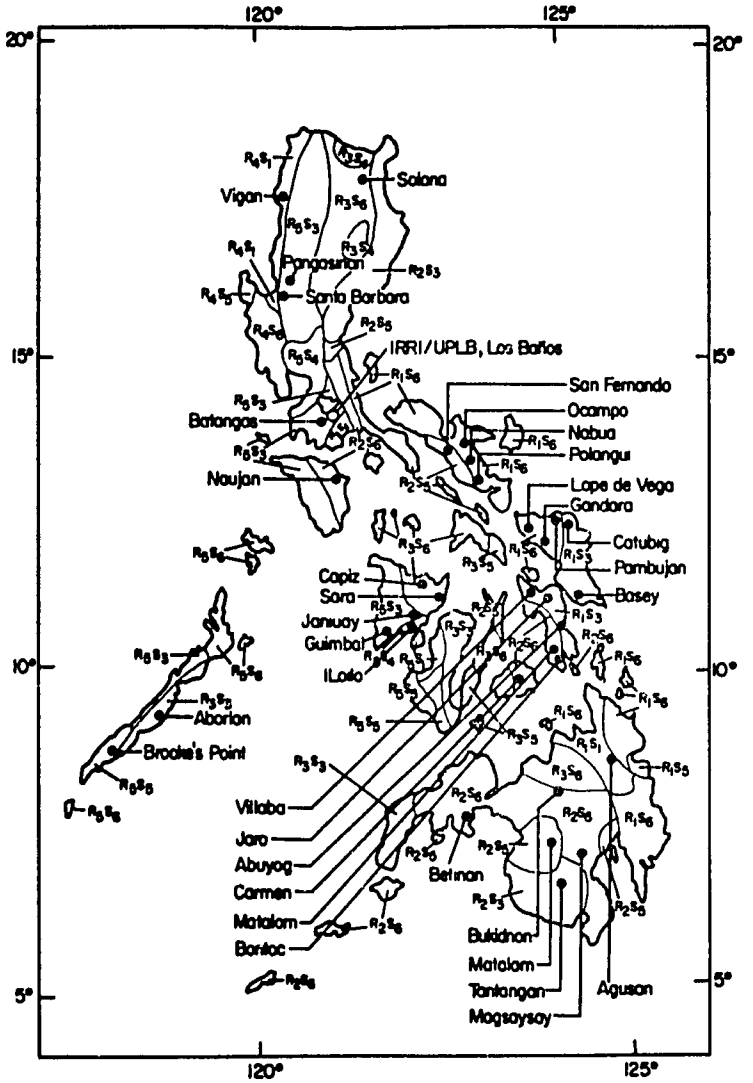
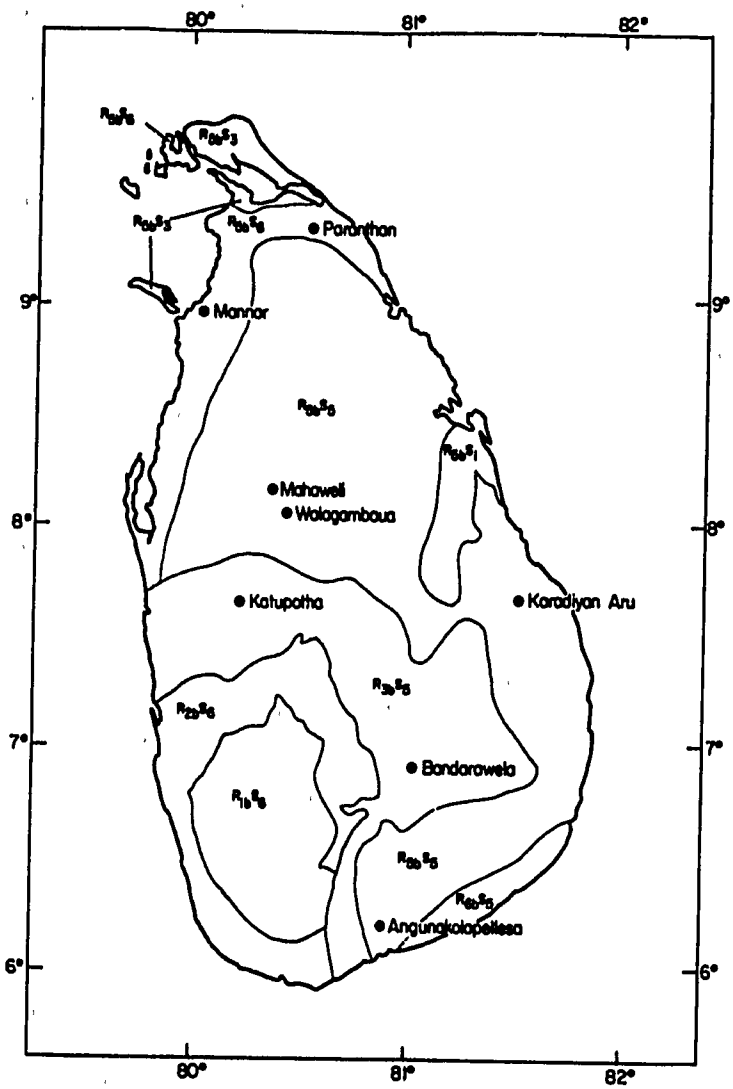


6. Nepal (research sites only)



7. Philippines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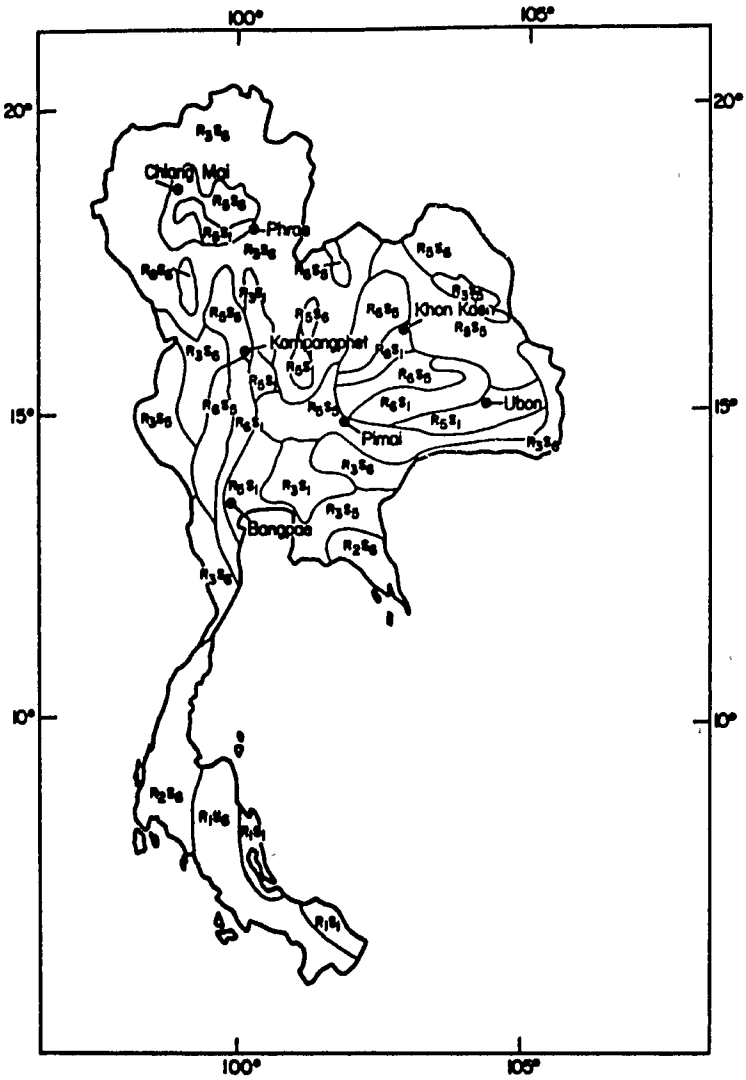
Mahaweli
Walogamboua
Katupotha
Karadiyan Aru
Bandarawela
Angungkolapellesa

8. Sri Lanka


100°
105°
20°
15°
10°
Chiang Mai
Phrae
Khon Kaen
Kamphangphet
Ubon
Pimai
Bangpoa

9. Thailand

APPENDIX II

Table 1. Descriptions of the six rainfall regimes used in the agroecological classification of South and Southeast Asia.[a]

Rainfall regime	Rainfall regime
R_1	Adequate or surplus rainfall throughout the year with no significant intervening dry period. The annual sequential rainfall usually follows a unimodal pattern.
R_2	Adequate rainfall and soil moisture throughout the year with a weakly expressed intervening period of moderately low rainfall or moderately low soil moisture, or both. The annual sequential rainfall usually follows a bimodal pattern where it falls within the equatorial type of climate; and it follows a unimodal pattern where it falls within the tropical rainy summer type of climate.
R_3	Adequate rainfall and soil moisture during the main annual cropping season, followed by a well-expressed dry season of at least 2 consecutive dry months. The annual sequential rainfall pattern can be either unimodal or bimodal according to the regional location.
R_4	Moderate degree of variability from year to year, but usually adequate rainfall and soil moisture within the main annual cropping season followed by a well-expressed dry season of at least 3 consecutive dry months. Moderate probability of a short-duration drought as well as excess rain and flooding during the course of the main cropping season. The annual sequential rainfall usually follows a unimodal pattern.
R_5	Moderate to high degree of variability from year to year as well as within the main cropping season; but rainfall usually exceeds total evaporation during the wet season and is followed by a well-expressed dry season of at least 3 consecutive dry months for a unimodal annual rainfall, or at least 6 consecutive dry weeks for a bimodal annual rainfall. There is also a significant probability of medium-duration drought during the main cropping season.
R_6	High degree of variability within the main annual cropping season followed by a strongly expressed dry season of at least 3.5 consecutive dry months. There also exists a high probability of soil moisture deficiency for variable periods during the main cropping season. It also includes rainfall regimes within the equatorial type of climate of less than 2 consecutive wet months.

[a]Panabokke (1979).

Table 2. Descriptions of the seven soil groupings used in the agroecological classification of South and Southeast Asia.[a]

Soil group symbol	Corresponding soil units represented by the FAO-UNESCO[a]	Equivalent soil order in soil taxonomy
S1	Fluvisols, Gleysols	Entisols
S2	Xerosols, Yermosols	Aridisols
S3	Lithosols, Regosols	Entisols
	Cambisols, Andosols	Inceptisols
S4	Vertisols	Vertisols
S5	Luvisols, Nitosols	Alfisols
S6	Acrisols	Ultisols
	Ferralsols	Oxisols
S7	Histosols	Histosols

[a]Panabokke (1979).

Table 3. Occurrence and extent of different agroecological zones in individual countries of South and Southeast Asia.[a]

Zone no.	Zone symbol	Percentage distribution of agroecological zones within individual country						
		Sri Lanka	India	Bangladesh	Thailand	Malaysia	Indonesia	Philippines
1	R_1S_1	–	–	–	1.6	4.2	2.8	3.0
2	R_1S_3	–	–	–	–	–	–	4.8
3	R_1S_5	–	–	–	–	2.0	0.3	0.6
4	R_1S_6	9.3	–	–	6.2	50.3	59.1	18.4
5	R_1S_7	–	–	–	–	6.0	8.8	–
6	R_2S_1	–	2.0	4.0	–	1.5	0.9	–
7	R_2S_3	–	–	–	–	–	–	8.8
8	R_2S_5	–	–	–	–	–	–	5.7
9	R_2S_6	11.6	6.3	–	6.0	14.9	3.9	16.7
10	R_2S_7	–	–	–	–	0.5	3.4	–
11	R_3S_1	–	–	20.0	3.6	3.3	0.9	–
12	R_3S_3	–	2.9	–	–	–	–	3.7
13	R_3S_4	–	–	–	–	–	1.1	1.4
14	R_3S_5	18.5	–	–	7.1	–	1.1	0.9
15	R_3S_6	–	4.5	11.0	35.8	16.0	4.3	12.3
16	R_3S_7	–	–	–	–	1.3	1.4	–
17	R_4S_1	–	2.6	28.0	–	–	–	2.4
18	R_4S_5	–	14.0	–	–	–	–	0.4
19	R_4S_6	–	6.3	6.0	–	–	–	2.7
20	R_4S_7	–	–	3.0	–	–	–	–
21	R_5S_1	2.8	4.0	25.0	5.7	–	1.7	0.6
22	R_5S_3	3.5	9.0	–	–	–	–	11.9
23	R_5S_4	–	21.8	–	–	–	–	2.5
24	R_5S_5	44.0	13.7	–	13.5	–	1.7	1.8
25	R_5S_6	8.0	–	3.0	7.5	–	0.9	1.4
26	R_6S_1	–	–	–	5.5	–	–	–
27	R_6S_2	–	10.0	–	–	–	–	–
28	R_6S_4	–	1.3	–	–	–	–	–
29	R_6S_5	2.3	1.6	–	6.9	–	–	–
30	R_6S_6	–	–	–	0.5	–	7.7	–

[a]Adapted from Panabokke (1979).

Table 4. Area under major nonrice grain crops in the countries participating in the Asian Cropping Systems Network.[a]

Country	Harvested area under crops (thousand ha) in 1980				
	Wheat	Maize	Sorghum	Barley	Millet
Bangladesh	486	2	1	16	2
Burma	82	80	–	–	180
China	28 001	20 035	3 203	4 401	4 103
India	29 964	5 800	17 000	1 745	17 500
Indonesia	–	2 900	–	–	–
Malaysia	–	10	–	–	–
Nepal	360	450	–	28	125
Pakistan[b]	912	705	480	159	641
Philippines	–	3 281	–	–	–
South Korea	28	–	8	330	2
Sri Lanka	–	20	2	–	35
Thailand	–	1 562	270	–	–
Vietnam[b]	–	410	30	–	–

[a]FAO (1981). [b]Expected to join the Asian Cropping Systems Network in near future.

Table 5. Area under major root and tuber crops in the countries participating in the Asian Cropping Systems Network.[a]

Country	Harvested area under crops (thousand ha) in 1980			
	Roots and tubers	Potato	Sweet potato	Cassava
Bangladesh	173	100	73	–
Burma	18	11	4	3
China	12 388	1 464	10 580	243
India	1 288	693	225	370
Indonesia	1 806	22	300	1 420
Malaysia	63	–	4	40
Nepal	69	56	–	–
Pakistan[b]	61	43	18	–
Philippines	473	4	230	185
South Korea	97	36	61	–
Sri Lanka	75	4	16	55
Thailand	1 052	1	36	–
Vietnam[b]	980	100	400	–

[a]FAO (1981). [b]Expected to join the Asian Cropping Systems Network in near future.

Table 6. Area under major pulses and oil seed crops in the countries participating in the Asian Cropping Systems Network.[a]

Country	Harvested area under crops (thousand ha) in 1980				
	Pulses	Peanut	Soybean	Rapeseed	Sesame
Bangladesh	360	25	–	215	48
Burma	573	525	23	1	763
China	14 062	2 955	9 621	3 753	802
India	22 789	7 500	330	3 475	2 384
Indonesia	625	500	780	–	23
Malaysia	–	6	–	–	–
Nepal	113	–	–	–	–
Pakistan[b]	1 558	37	4	409	36
Philippines	72	55	9	–	–
South Korea	58	12	200	12	65
Sri Lanka	27	10	1	–	25
Thailand	458	120	135	–	31
Vietnam[b]	216	105	46	–	32

[a]FAO (1981). [b]Expected to join the Asian Cropping Systems Network in near future.

Table 7. Area under major industrial crops in the countries participating in the Asian Cropping Systems Network.[a]

Country	Harvested area under crops (thousand ha) in 1980			
	Sugarcane	Jute	Cotton	Tobacco
Bangladesh	155	598	6	50
Burma	42	58	34	62
China	425	270	5414	708
India	2666	1270	2818	450
Indonesia	170	4	2	165
Malaysia	18	–	–	13
Nepal	21	46	–	8
Pakistan[b]	750	1	1400	50
Philippines	450	–	2	75
South Korea	–	–	6	46
Sri Lanka	5	–	8	11
Thailand	416	197	98	152
Vietnam[b]	74	15	3	28

[a]FAO (1981). [b]Expected to join the Asian Cropping Systems Network in near future.

GLOSSARY

AGROCLIMATIC CLASSIFICATION — the grouping of different physical areas within a country, a region, or the world into broadly homogeneous zones based on climatic and edaphic factors.

AGROECOLOGICAL ZONE — a major area of land that is broadly homogeneous in climatic and edaphic factors, but not necessarily contiguous, where a specific crop exhibits roughly the same biological expression.

AGROFORESTRY — a system of land use wherein annual crops are grown, mostly in intensive mixed or intercropping methods, under the perennial forest trees or fruit-cum-timber trees. Also known as agrisilviculture and forest gardening.

ALANG-ALANG — Indonesian term for the Cogon grass (*Imperata cylindrica*).

ARABLE LAND — refers to land under temporary crops, temporary meadows for mowing or pasture, land under market and kitchen gardens (including cultivation under glass), and land temporarily fallow or lying idle.

AUS RICE — derived from the Bengali word "*Ashu*" meaning earliness. Aus is a group of periodically fixed maturing rice varieties that are photoperiod insensitive. In Bangladesh, this group of rice is mostly direct-seeded under dryland preparation (about 90%) in March-April with the premonsoon showers and harvested in July-August, in the middle of the monsoon season. Aus crop is mainly rainfed. However, where irrigation is available, farmers prefer to grow modern varieties of rice under transplanted conditions.

B. AMAN RICE — broadcast aman rice is otherwise known as deepwater rice in Bangladesh. The word "aman" is derived from Arabic meaning "safety" which indicates stability of the crop. *B. aman* rice is direct-seeded under dryland preparation during the premonsoon period (March-April) in the deepwater (1-6 m deep) areas. The rice plants grow with rising floodwater and settles at the ground when the water subsides during the most monsoonal months. The rice crop is photoperiod sensitive and harvested during October-December.

BANGKAG — the low-lying cultivable portions of the recent floodplains bordering the Cagayan River in the Philippines.

BARI — Nepalese term meaning upland field.

BENCHMARK SURVEY — a systematic survey study aimed at collecting data, e.g. on existing crops, varieties, yields, socioeconomic constraints, before a project begins. Data collected depict the existing picture of the survey areas with regard to selected parameters and can be used to evaluate the results of the project.

BIOLOGICAL DETERMINANTS OF CROPPING SYSTEMS — the biological factors such as crop species, varieties, weeds, insect pests, and diseases, which determine the crop configuration and performance of a cropping pattern at a given site.

BORO RICE — winter season rice transplanted in December-January and harvested in April-May, in some cases in June (when long-duration modern varieties are grown). Boro rice is photoperiod insensitive and grown under irrigated conditions.

CHENA — Sri Lankan term meaning land cleared for shifting cultivation on an 8- to 10-year cycle. At present, the cycle has become much shorter and the cultivation more permanent.

COMMODITY RESEARCH — the focusing of research on individual crops in considerable detail.

COMPONENT TECHNOLOGY — the cultural techniques used in the management of a crop or cropping pattern. Component technologies include variety, planting method, tillage operations, fertilizer and water management, pest management, harvesting, etc.

CROP INTENSIFICATION — the concept, approach, method, and process of growing more crops per year by increasing cropping intensity.

CROPPING INTENSITY — total cropped area divided by net area available for cultivation multiplied by 100.

CROPPING PATTERN — the yearly sequence and spatial arrangement of crops on a given land area.

CROPPING PATTERN DESIGN — the crop configuration or sequencing done on paper for year-round land utilization at a given area considering physical, biological, and socioeconomic factors prevailing at that area.

CROPPING PATTERN TESTING — the growing of a designed cropping pattern at a given site and evaluating biological stability, agronomic productivity, and economic profitability.

CROPPING SYSTEM — the crop production activity of a farm. It comprises all cropping patterns grown on the farm and their interaction with farm resources, other household enterprises and the physical, biological, technological, and socioeconomic factors or environments.

CROPPING SYSTEMS RESEARCH — the research activities, mainly in farmers' fields, that focus on the understanding of farmers' existing cropping systems; design, testing, and development of new improved cropping patterns and component technologies for selected environments to efficiently utilize available farm resources.

CROPPING SYSTEMS RESEARCH SITE — a contiguous area or several selected areas representing one or more land types in production environments that occur over an extensive area, where cropping systems scientists conduct on-farm research trials with cooperating farmers.

CULTURAL PRACTICES — crop-care practices including land preparation, seed selection, weed control, fertilizer and insecticide application, water control in the field, etc.

DOUBLE CROPPING — growing of two crops in sequence in a year on a piece of land by seeding or transplanting one after the harvest of the other.

DRYLAND FARMING — cropping systems of farmers in the arid and semiarid zones.

ENCLO SYSTEM — an Indonesian system in which fertilizer is applied in each rice hill.

ENVIRONMENTAL COMPLEX — a union of sites when cropping pattern determinants are the same.

ENVIRONMENTAL FACTORS — factors over which farmers have little direct control, including the physical, biological, and socioeconomic aspects of their setting.

EXTRAPOLATION AREA — adaptation domain of a cropping pattern composed of land types to which the cropping pattern is adapted.

FARM ENTERPRISE — an individual crop or animal production function within a farming system which is the smallest unit for which resource use and cost-return analysis is normally carried out.

FARMER ENVIRONMENT — the physical, biological, economic, and sociocultural conditions under which the farmer operates his cropping systems.

FARMING SYSTEM — a unique and reasonably stable arrangement of farming enterprises that a household manages according to well-defined practices in response to the

physical, biological, and socioeconomic environments and in accordance with the household's goals, preferences, and resources. These factors combine to influence output and production methods. More commonality will be found within the system than between systems. The farming system is part of larger systems and can be divided into subsystems.

FARMING SYSTEMS RESEARCH AND DEVELOPMENT (FSRD) — an approach to agricultural research and development that 1) views the whole farm as a system, and 2) focuses on the interdependencies among the components under the control of farm household members and how these components interact with the physical, biological, and socioeconomic factors not under the household's control. The approach involves selecting target areas and farmers, identifying problems and opportunities, designing and executing on-farm research, and evaluating and implementing the results. In the process, opportunities for improving public policies and support systems affecting the target farmers are also considered.

GEU PROGRAM — Genetic Evaluation and Utilization program of the International Rice Research Institute, Philippines.

GOGONDA — human settlement proper in the minor tank-based farming systems in the dry zone of Sri Lanka.

GOGORANCAH RICE — Indonesian term meaning dry-seeded upland rice.

HILL AGRICULTURE — farming systems practiced on high-altitude terraced lands or valleys with rolling landscape.

HORIZONTAL REVOLUTION IN AGRICULTURE — increased land use by expanding cultivated land area through the utilization of fallow and marginal lands and reclaiming culturable waste lands, thereby increasing land-use intensity.

HUMID TROPICS — the tropical areas with excessive moisture. However, excessive moisture generally occurs only during a certain period of the year, while drought may occur in the same area during another part of the year The humid tropics are characterized by isothermal conditions, which implies that temperatures in these areas are generally suitable for year-round crop production. Total radiation varies from relatively low values during the wet period to relatively high values in the dry season.

INFRASTRUCTURE — the supportive features of and economy often provided by government, but sometimes provided by private industry, such as transportation, electricity, water, communications, and governmental organizations.

INTERCROPPING — growing two or more crops simultaneously in alternate rows in the same field.

INTERPLANTING — all types of seeding or planting a crop into a growing stand. It is used especially for annual crops under stands of perennial crops.

IRRIGATED DRYLAND — areas with well-drained soils where water does not accumulate and irrigation is used mainly for dryland crops such as wheat, maize, potato, and other cash crops. Dryland rice may also be grown with intermittent type irrigation.

IRRIGATED WETLAND — areas where invariably a rice crop is grown with irrigation. Availability of irrigation water may be year-round or seasonal and other nonrice crops, particularly high-value crops, may be grown with irrigation in rice-based patterns.

JHUM CULTIVATION — the slash-and-burn type of shifting cultivation in the hill tracts of Bangladesh.

KHARIF CROPS — crops grown during the main monsoon season (April to September) in Bangladesh, such as aus rice and jute.

KHET — Nepalese term meaning lowland.

LAND EQUIVALENT RATIO (LER) — the land area needed under monoculture to produce the same amount of crop yields as from 1 ha of intercropping or mixed cropping. LER is computed:

$$\text{LER} = \frac{\text{Maize yield in intercropping (2.5 t/ha)}}{\text{Maize yield in monoculture (3.0 t/ha)}} + \frac{\text{Peanut yield in intercropping (1.2 t/ha)}}{\text{Peanut yield in monoculture (1.8 t/ha)}} = 1.50$$

LAND TYPE — a union of locations within which values of cropping pattern determinants are the same.

LAND USE PATTERNS — alternative ways to utilize available land resources over time for agricultural production.

MAHA SEASON — the major cultivation season in Sri Lanka, which commences in mid-September with the onset of the northeast monsoon rains and extends until mid-March.

MANAWARI LAND — bunded rainfed ricelands found in the dry zones of Sri Lanka, generally referring to extreme northern areas.

MAXIMUM CROPPING — the highest possible production per unit area per unit time without considering cost of production or net return.

MIXED CROPPING — growing two or more crops simultaneously in the same field without rows.

MIXED FARMING SYSTEMS — farming systems with integrated crops, livestock, and other possible household enterprises.

MONITORING STUDY — making systematic observations through well-designed procedures on a crop, cropping pattern, farm or experimental trial to relate resultant effects with observed factors or causes.

MONOCULTURE — growing only one crop on the land in a given crop season.

MULTIDISCIPLINARY APPROACH — an approach in which several disciplines become involved in a project or program with common general objectives.

MULTILOCATION TESTING — the testing of cropping systems technologies generated at an on-farm research site at other locations within the large target area to delineate the extrapolation zone as well as to finally verify technology performance before wide-scale diffusion.

MULTIPLE CROPPING — the practice of growing more than one crop on the same land in one year. It involves several alternative patterns of crop arrangement in space and time such as mixed cropping, intercropping, relay-cropping, sequential cropping, double cropping, triple cropping, etc.

MULTIPLE CROPPING INDEX (MCI) — the sum of areas planted to different crops harvested during the year, divided by the total cultivated area.

ON-FARM RESEARCH AND DEVELOPMENT — agronomic and socioeconomic studies conducted on the farms with farmers' active participation. The goals are to develop improved cropping system technologies and to devise ways to combine these technologies with farmers' knowledge and skills to efficiently utilize the available farm resources.

PALAWIJA — Indonesian term meaning upland crops.

PANCHAYAT — administrative unit in Nepal comprising several villages.

PARA METHOD — a method of rice establishment in tidal flood-affected southern Bangladesh. Rice seeds are broadcast in well-prepared fields about 1 month ahead of the advent of tidal water. About 20-30 days after the arrival of tidal water, the young rice plants are thinned from these broadcast fields and used for transplanting in fields situated at relatively lower situations.

PARCEL — the largest contiguous unit of land with a given texture arrangement.

PERMANENT CROP LAND AREA — land cultivated with crops that need not be replanted after each harvest, such as rubber, coffee, cocoa, including land under shrubs, fruit trees, nut trees and vines but excluding land under trees grown for food or timber.

PERENNIAL CROPS — crops occupying land for more than 30 months not including legumes and grasses in permanent pastures.

PHYSICAL DETERMINANTS — the important attributes of climate, water, and land such as rainfall, topography, and hydrology that influence configuration and performance of cropping patterns.

PILOT PRODUCTION PROGRAM — a small-scale (100 to 500 ha) production program to determine the support needed in the large-scale diffusion of recommended technologies as well as to clearly specify the tasks and interrelationships of different institutions involved in supporting the farmers. It also allows a final evaluation of the recommended cropping systems technology, the cost of its extension to the farmers, and the expected benefit.

PREPRODUCTION EVALUATION — higher level on-farm cropping system activities consisting of multilocation pattern testing and pilot production program to delineate the final production program area, verify technology performance, determine institutional support requirements, and to help in structuring large-scale production programs.

RABI CROPS — dryland crops grown during the dry winter season in Bangladesh, such as wheat, barley, pulses, and oilseeds.

RAINFED FARMING — growing crops or animals under conditions of natural rainfall. Water may be stored in a crop field by bunding, as in wetland rainfed rice, but no water is available from permanent water storage areas.

RAINFED DRYLAND — areas that depend on rainfall for crop production, but are not flooded. The run-off and infiltration of rainwater is so high that water does not accumulate on the land.

RAINFED WETLAND — areas where rainfed rice is grown on puddled soil in fields bounded by dikes capable of ponding water to about 30 cm. Water depth seldom exceeds 30 cm. These areas receive no irrigation and nonrice crops may be grown before or after the wetland rice crop.

RATOON CROPPING — the cultivation of an additional crop from the regrowth of stubbles of a main crop after its harvest, thereby avoiding replanting such as in sugarcane, sorghum, and rice.

RELAY CROPPING — growing two or more crops in a sequence, planting the succeeding crop after the flowering, but before the harvesting of the preceding crop.

RESEARCH-MANAGED TRIALS — experiments done in farmers' fields, but managed by researchers to attain higher degree of experimental precision while still getting the effect of variables existing on the farms.

SAWAH BAYAR — group of photoperiod-sensitive rice varieties traditionally grown in the tidal swamp areas of South Kalimantan, Indonesia.

SAWAH PASANG SURUT — the tidal swamp rice fields in South Kalimantan, Indonesia.

SEQUENTIAL CROPPING — growing two or more crops in a sequence, planting the succeeding crop after the harvesting of the previous one.

SHIFTING CULTIVATION — a method of cultivation in which several crop years are followed by several fallow years with the land not under management during the fallow. The shifting cultivation may involve shifts around a permanent homestead or village site, or the entire living area may shift location as the fields for cultivation are moved.

SITE DESCRIPTION — description of an on-farm cropping systems research site with respect to physical and socioeconomic environments and existing cropping systems.

SITE SELECTION — selecting a contiguous area or several areas representing one or more production environments that occur over an extensive target area, to conduct on-farm cropping systems research to develop improved cropping systems technologies for the target area.

SLASH-AND-BURN SYSTEM — a kind of shifting cultivation in high-rainfall areas where the cropping period is followed by a fallow period during which bush or tree growth occurs. For the next cycle of cropping, the bush or tree growth is again cleared by cutting and burning.

SOCIOECONOMIC DETERMINANTS — factors such as marketing facilities, land tenure system, and credit, which influence the cropping systems of a given area.

SORJAN — an Indonesian method of growing two or more crops simultaneously in one field in alternate raised beds and furrows (sinks). For example, rice is grown in the furrows, while maize or peanut is grown on the raised beds.

SUBSISTENCE FARMERS — farmers who produce mainly to meet family needs and have little capacity to purchase production inputs or foods.

SUPERIMPOSED TRIAL — a small set of experimental treatments superimposed on farmers' production plot or cropping pattern trial fields at a research site to evaluate the performance of alternative component technologies. These trials are usually managed by the researchers.

SYSTEMS APPROACH — studying a system as an entity made up of all its components and their interrelationships, together with relationships between the system and its environment. Such study may disturb the real system itself (e.g., via farmer-managed trials or by comparison preadoption and postadoption studies of new technology), but more generally is done via models (e.g. experiments, researcher or farmer-managed on-farm trials [or both], unit farms, linear programming and other mathematical simulations) which to varying degrees simulate the real system.

T. AMAN RICE — transplanted aman rice, a group of traditional photoperiod-sensitive rice varieties transplanted in July-August and harvested in November-December in Bangladesh. However, recently farmers also have been growing photoperiod-insensitive modern rice varieties during the t. aman season in Bangladesh.

TALON — areas at higher elevation and away from the Cagayan River bank, Cagayan Province, Philippines.

TARGET AREA — large priority development area in a country for which improved cropping systems technologies are developed through on-farm cropping systems research conducted at sites in that area.

TERAI — low-elevation plains in Nepal.

TESTING OF CROPPING SYSTEMS — the process of evaluating designed cropping patterns and associated component technologies using selected criteria.

THANA — an administrative unit in Bangladesh comprising several "unions" which, in turn, are composed of several villages.

TIDAL SWAMPS — low elevation coastal areas affected by tidal flooding.

TURNAROUND TIME — period between the harvesting of the preceding crop and planting of the succeeding crop in a specific field.

UPLAND CROPS — crops grown under aerobic soil conditions such as wheat, maize, peanut, mungbean, soybean, etc.

VERTICAL REVOLUTION IN AGRICULTURE — maximizing production per unit land area per unit of time using intensive cropping patterns, high production inputs, and improved management practices.

WALIK JERAMI RICE — an Indonesian term meaning rice crop grown with no tillage in wetland areas.

WEL-YAYO — a Sri Lankan term meaning paddy tract.

WEWA — a Sri Lankan term meaning tank. These tanks are used as water reservoir for irrigation and household use.

WHOLE-FARM ANALYSIS — a methodology designed to search for optimal solutions through incorporation of farmers' objectives, farming systems, and resources to arrive at improved cropping and livestock patterns and management practices for overall farming systems performance.

WHOLE-FARM APPROACH — an essential characteristic of farming systems research and development in which teams look at a whole farm to identify problems, opportunities, and interrelationships, to design and conduct experiments, and to evaluate results.

YALA SEASON — the second cultivation season in Sri Lanka, which extends from March to September when minor southwest monsoonal rains are experienced.

BOTANICAL NAMES

Common name	*Botanical name*	Common name	*Botanical name*
Abaca	*Musa textilis*	Mungbean	*Phaseolus aureus*
Amaranthus	*Amaranthus* sp.	Mustard	*Brassica* sp.
Banana	*Musa sapientum*	Onion	*Allium cepa*
Barley	*Hordeum vulgare*	Papaya	*Carica papaya*
Betelnut palm	*Areca catechu*	Pea	*Pisum sativum*
Blackgram	*Phaseolus mungo*	Peanut, groundnut	*Arachis hypogaea*
Cacao	*Theobroma cacao*	Pigeon pea	*Cajanus cajan*
Cassava	*Manihot esculenta*	Pineapple	*Ananas comosus*
Chickpea, gram	*Cicer arietinum*	Potato	*Solanum tuberosum*
Chilli	*Capsicum frutescens*	Pumpkin	*Cucurbita maxima*
Coconut	*Cocos nucifera*	Radish	*Rapharus sativus*
Coffee	*Cafe arabica, C. liberica, C. robusta, C. excelsa*	Rambutan	*Nephelium lappaceum*
Cogon	*Imperata cylindrica*	Rape	*Brassica napus*
Cotton	*Gossypium* sp.	Rice	*Oryza sativa*
Cowpea	*Vigna unguiculata*	Ricebean	*Phaseolus calcaratus*
Eggplant, Brinjal	*Solanum melongona*	Rozelle	*Hibiscus sabdariffa*
Finger millet	*Eleusine coracana*	Rubber	*Hevea brasiliensis*
Foxtail millet	*Chactochloa italica*	Rye	*Secale cereale*
Itallian millet	*Setaria italica*	Safflower	*Carthamus tinctorius*
Garlic	*Allium sativum*	Sesame	*Sesamum indicum*
Gourd	*Lagenaria vulgaris*	Sesbania	*Sesbania aculeata*
Grasspea	*Lathyrus sativus*	Siratro	*Macroptilium atropurpureum*
Green gram	*Phaseolus radiatus*	Sorghum	*Sorghum bicolor*
Guinea grass	*Panicum maximum*	Soybean	*Glycine max*
Jute	*Corchorus capsularis, Corchorus olitorius*	Squash	*Cucurbita* sp.
Kenaf	*Hibiscus cannabinus*	Stylos	*Stylosanthes guyanesis*
Lentil	*Lens esculenta*	Sugarcane	*Saccharum officinalis*
Linseed, Flax	*Linum usitatissimum*	Sunflower	*Helianthus annuus*
Maize	*Zea mays*	Sweet potato	*Ipomoea batatas*
		Taro	*Colocasia antiquorum*
		Tea	*Camellia thea*
		Tobacco	*Nicotiana tabacum*
		Tomato	*Lycopersicum esculentum*
		Water melon	*Citrullus lanatus*
		Wheat	*Triticum vulgare*
		Yardlong bean	*Vigna sesquipedalis*

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ACRONYMS

AARD. Agency for Agricultural Research and Development, Indonesia
ACAP. Association of Colleges of Agriculture in the Philippines
ACSN. Asian Cropping Systems Network
ADB. Asian Development Bank
ARI Agricultural Research Institute, Burma
AVRDC Asian Vegetable Research and Development Center
BADC. Bangladesh Agricultural Development Corporation
BARC. Bangladesh Agricultural Research Council
BARI. Bangladesh Agricultural Research Institute
BAU Bangladesh Agricultural University
BJRI Bangladesh Jute Research Institute
BKB Bangladesh *Krishi* (Agriculture) Bank
BPI Bureau of Plant Industry, Philippines
BRBDP Bicol River Basin Development Project, Philippines
BRRI Bangladesh Rice Research Institute
BWDB Bangladesh Water Development Board
CAAS Chinese Academy of Agricultural Sciences
CARE Cooperative American Relief Everywhere
CGIAR Consultative Group on International Agricultural Research
CIADP Cagayan Integrated Agricultural Development Project, Philippines
CIDA Canadian International Development Agency
CRIA Central Research Institute for Agriculture, Indonesia
CRIFC Central Research Institute for Food Crops, Indonesia
CRWRC Christian Reformed World Relief Committee
FAO Food and Agriculture Organization of the United Nations
IARC International Agricultural Research Center
IBRD International Bank for Reconstruction and Development
ICAR Indian Council for Agricultural Research
ICRISAT International Crops Research Institute for the Semi-Arid Tropics, India
IDRC International Development Research Centre, Canada
IFAD International Funds for Agricultural Development
IFPRI International Food Policy Research Institute
IITA. International Institute for Tropical Agriculture, Nigeria
IPB Institute of Plant Breeding (University of the Philippines at Los Baños)
IRRI. International Rice Research Institute, Philippines
KKU Khon Kaen University, Thailand
MARDI Malaysian Agricultural Research and Development Institute
MCC. Mennonite Central Committee
MFA. Ministry of Food and Agriculture, Pakistan
NCCB. National Christian Council of Bangladesh
NFAC. National Food and Agriculture Council, Philippines
NGA. National Grains Authority, Philippines

ODA. Overseas Development Authority, British
ORD. Office of Rural Development, South Korea
PADAP. Philippine-Australian Development Assistance Program
PCARR. Philippine Council for Agriculture and Resources Research
PIADP. Palawan Integrated Agricultural Development Project, Philippines
PNB. Philippine National Bank
RADOS. Rainfed Agricultural Development Outreach Sites, Philippines
SIRDP. Samar Integrated Rural Development Program, Philippines
SRI. Sugarcane Research Institute
UPLB. University of the Philippines at Los Baños
USAID. United States Agency for International Development
VIAS. Vietnamese Institute of Agricultural Sciences

END