IRRIGATION MANAGEMENT FOR CROP DIVERSIFICATION IN THAILAND

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INTRODUCTION

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

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

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

RELEVANT COUNTRY STATISTICS

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

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

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

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

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

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

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

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

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

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

Region	Rice	Upland crops	Vege-tables	Sugar cane	Fruit trees	Peren-nials	Fish ponds	Total
1	1,850	23,780	2,140	0	0	0	0	27,770
2	13,070	14,290	970	0	0	0	0	28,330
3	3,890	8,050	120	12,780	4	40	2	24,886
4	3,890	1,460	410	40	0	2	2	5,804
5	8,240	8,110	960	0	0	0	20	17,330
6	240	2,020	520	0	0	0	0	2,780
7	355,800	1,260	6,980	6,750	6,200	13,920	340	391,250
8	21,060	10,400	420	10	7,540	3,770	11,770	54,970
9	47,800	4,490	1,620	0	2	5	0	53,917
10	47,480	21,060	6,290	40,010	11,770	15,900	140	142,650
11	1,530	250	220	3	0	0	0	2,003
12	7,390	1,130	90	0	0	0	0	8,610
Tot	512,240	96,300	20,740	59,593	25,516	33,637	12,274	760,300

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

Region	Rice	Upland crops	Vege-tables	Sugar cane	Fruit trees	Peren-nials	Fish ponds	Total
1	3,380	23,040	2,440	0	0	0	0	28,860
2	7,490	11,020	480	540	170	10	7	19,717
3	12,510	11,110	110	16,220	4	40	2	39,996
4	11,710	3,920	760	5	0	0	0	16,395
5	4,440	5,400	830	1	0	0	20	10,691
6	3,530	2,220	360	0	0	0	0	6,110
7	348,710	1,740	6,880	5,450	14,210	1,180	1,440	379,610
8	119,970	19,070	340	20	10,790	3,730	6,870	160,790
9	49,310	4,110	440	0	650	250	40	54,800
10	39,510	26,330	6,020	33,890	16,830	15,860	1,920	140,360
11	690	230	330	0	1,420	770	0	3,440
12	5,570	780	120	0	0	0	0	6,470
Tot	606,820	108,970	19,110	56,126	44,074	21,840	10,299	867,239

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

Region	Rice	Upland crops	Vege- tables	Sugar cane	Fruit trees	Peren- nials	Fish ponds	Total
1	2,910	21,350	2,750	1,180	0	0	0	28,190
2	5,580	12,340	700	1	160	0	0	18,781
3	19,570	14,070	380	330	410	110	0	34,870
4	10,150	4,320	760	10	0	0	0	15,240
5	1,300	9,490	730	0	2	0	20	11,542
6	5,460	8,240	1,130	0	0	0	0	14,830
7	332,400	6,430	9,920	7,580	13,250	270	2,540	372,390
8	127,150	20,020	580	10	12,390	3,090	7,580	170,820
9	55,170	1,500	310	0	80	320	4,360	61,740
10	37,370	25,680	7,810	44,590	24,170	18,620	2,220	160,460
11	680	1,100	420	3	5,260	2,900	10	10,373
12	9,290	1,100	90	2	0	0	0	10,482
Tot	607,030	125,640	25,580	53,706	55,722	25,310	16,730	909,718

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

Region	Rice	Upland crops	Vege- tables	Sugar cane	Fruit trees	Peren- nials	Fish ponds	Total
1	2,150	21,330	2,420	0	0	0	0	25,900
2	4,320	11,750	2,030	0	160	0	0	18,260
3	26,670	11,530	660	120	0	0	6	38,986
4	4,780	5,870	550	8	0	0	0	11,208
5	2,700	3,900	590	2	0	0	30	7,222
6	4,060	7,990	1,950	0	0	0	0	14,000
7	311,260	4,910	6,650	10,310	15,470	1,560	3,390	353,550
8	109,290	17,010	950	20	16,380	3,090	12,180	158,920
9	51,440	1,120	600	0	30	20	10,630	63,840
10	36,060	20,370	10,290	38,990	18,080	13,670	2,850	140,310
11	1,420	420	530	7	6,840	4,790	10	14,017
12	14,950	1,160	180	2	30	0	0	16,322
Tot	569,100	107,360	27,400	49,459	56,990	23,130	29,096	862,535

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

Figure 1. Physiographic regions of Thailand.

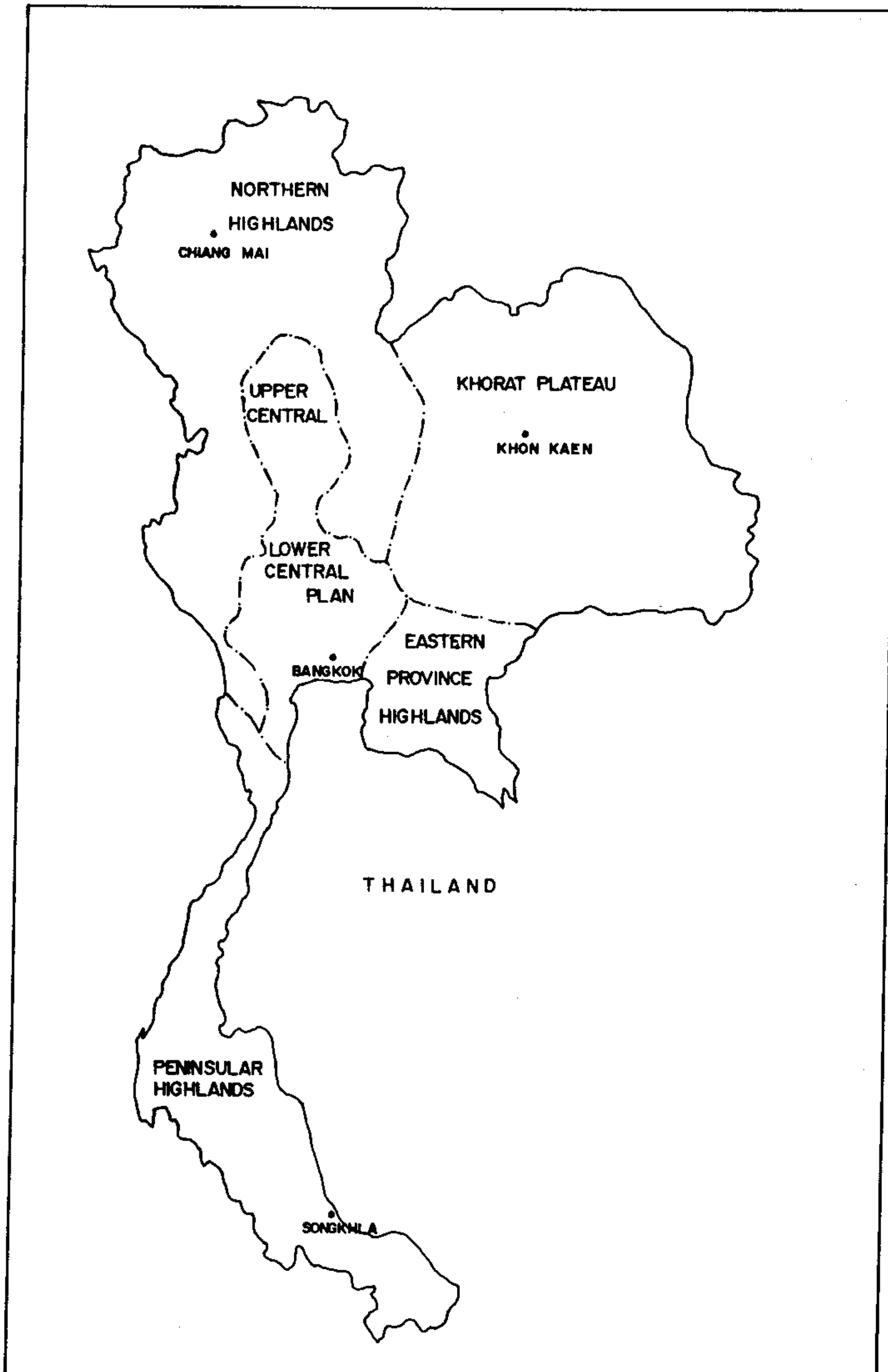
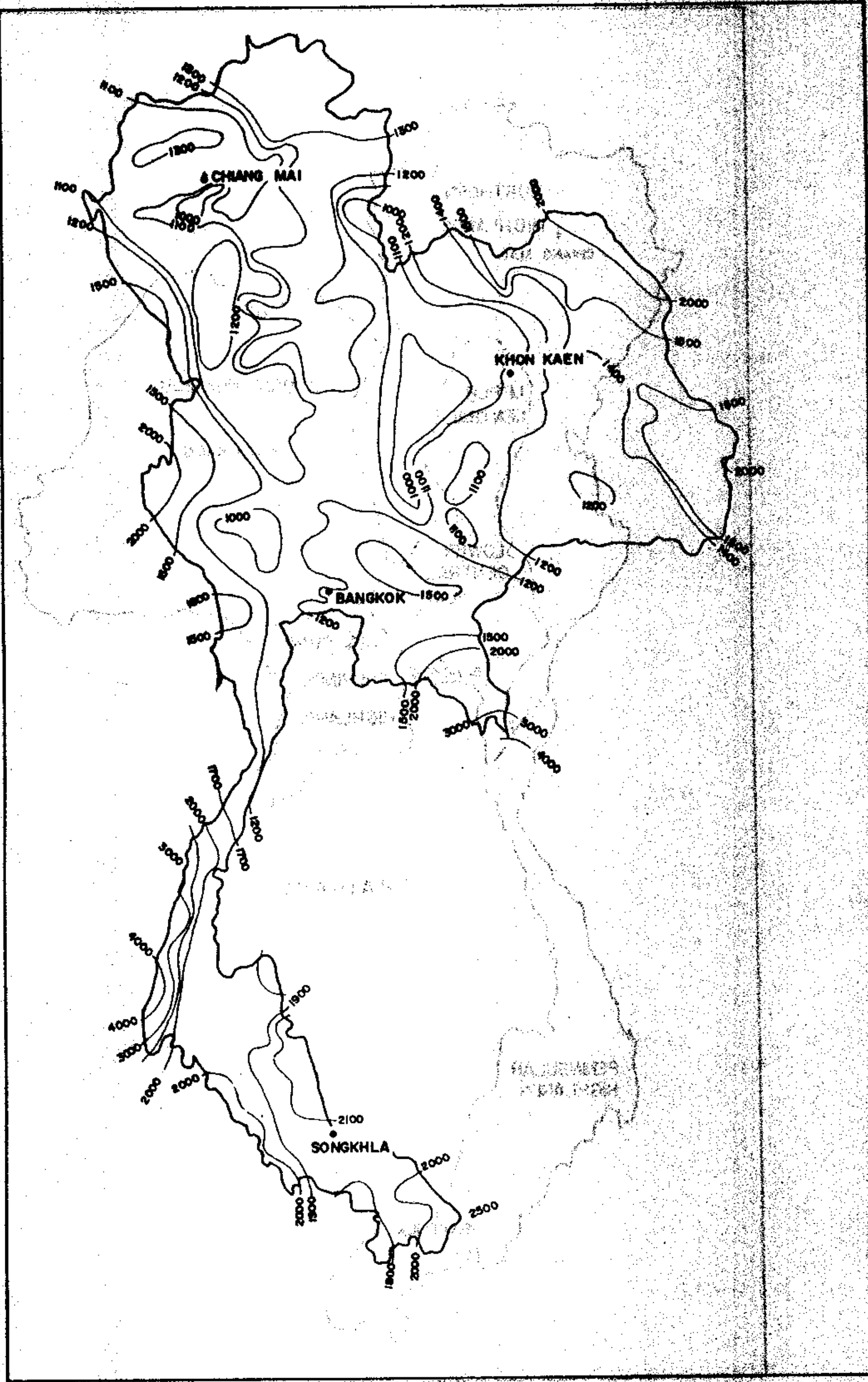


Figure 2. Average rainfall in Thailand (in millimeters)



Present Crop Potential

The present crop potential in Thailand includes herbs, tobacco, sugar bean, mungbean, groundnut, sorghum, vegetables, and fruit trees. Herbs include various export oriented crops such as cardamom, betel leaf, and turmeric. Crops like climbing lily, clove, and nutmeg are also promoted as import-substitution crops. Thailand imported tobacco worth 1,100 million baht (about 26 baht = US$1.00) in 1980 and 1,320 million baht in 1983. At the same time Thailand exported Virginia, Burley, and Turkish tobacco valued at more than 1,500-2,500 million baht. Tobacco therefore should be promoted.

Domestic demand for soybean is estimated at approximately 600,000 tons against a local supply of only 200,000 tons. Soybean is to be promoted in the north, northeast, and central regions. Each year Thailand exports about 200,000 tons of mungbeans to other Asian countries. There is also potential in the European market with increasing diversity in consumer taste.

The country's present annual earnings from exported fruit are about 1,000 million baht. Durian, rambutan, pomelo, and longan are popular fruits overseas. Horticulture development therefore is promising.

ON-GOING RESEARCH RELATED TO CROP DIVERSIFICATION

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

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

Constraints and irrigation measures to relax them.

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

Issues for Research

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

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

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

Marketing. Although marketing is not related to crop diversification it has been identified as a real constraint to diversification. The market must meet the supply of upland perishable crops and vegetables. A national long term plan in terms of local and international demand is needed for an executing agency like RID to be able to carry out its implementation program.

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

NATIONAL POLICY IMPLICATIONS FOR PRICING, MARKETING, AND SUPPORT SERVICES

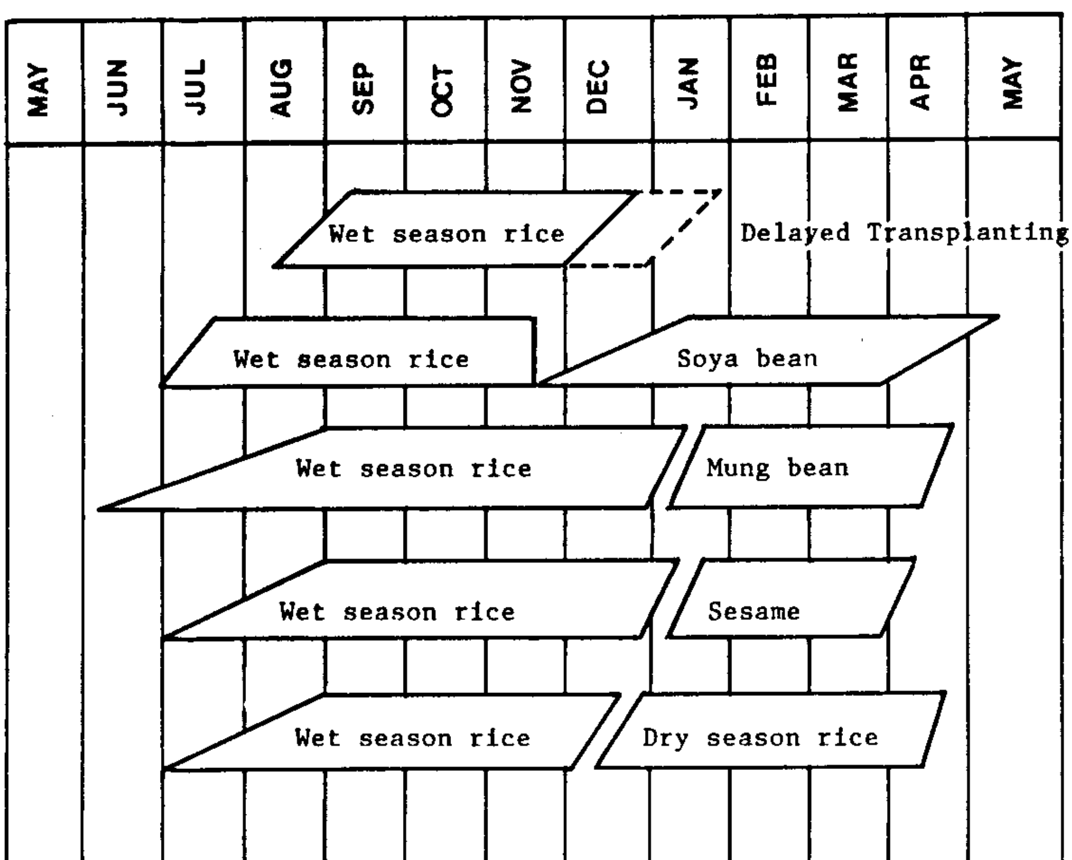
For the past few years, the fluctuating price of regional agricultural products has caused a reduction in the country's earnings. It was further reduced when other countries of the region responded to the price decreases by increasing agricultural exports and decreasing imports. This in turn lead to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

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

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

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

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



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

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

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

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

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

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

IRRIGATION MANAGEMENT FOR CROP DIVERSIFICATION IN SRI LANKA

Sunil Dimantha*

INTRODUCTION

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

COUNTRY STATISTICS

Cultivated Extent

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

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

Climate

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

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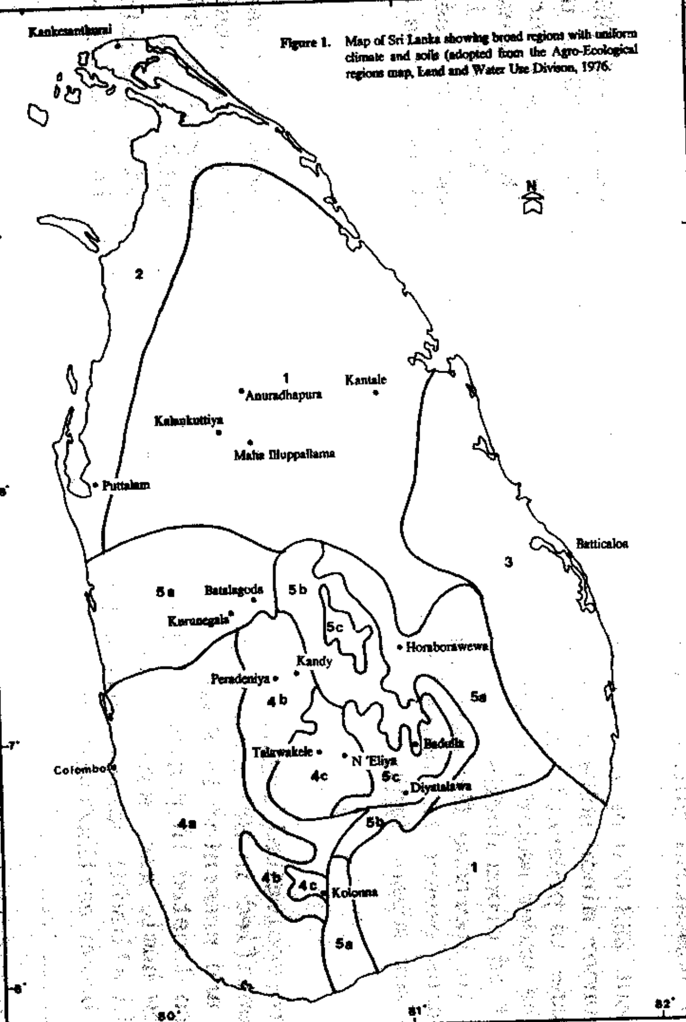

Figure 1. Map of Sri Lanka showing broad regions with uniform climate and soils (adopted from the Agro-Ecological regions map, Land and Water Use Divison, 1976.

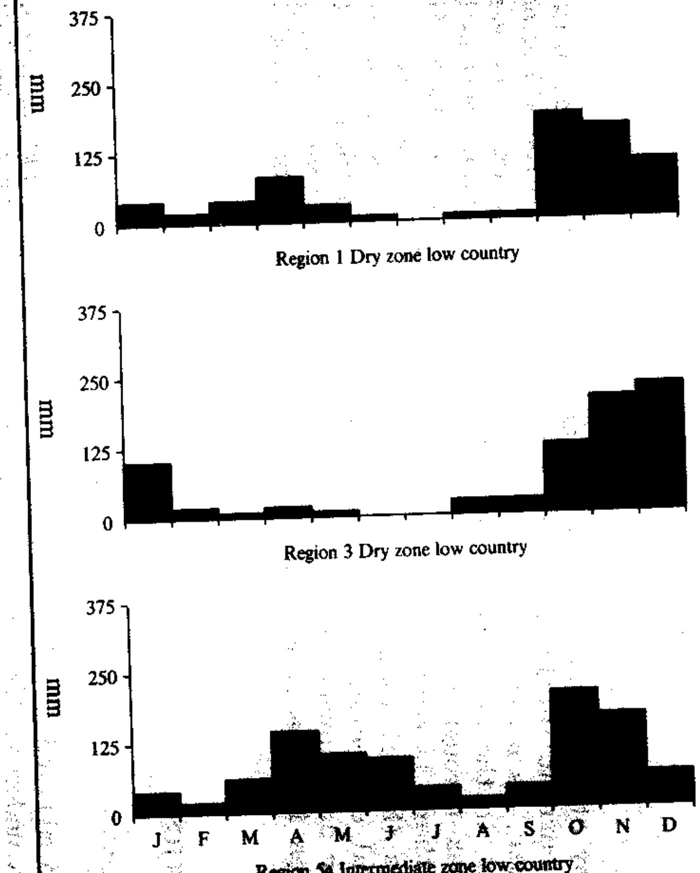

Figure 2. Monthly 75% rainfall probability histograms of the regions where most irrigation schemes are located.

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

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

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

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

Soils

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

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

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

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

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

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

Irrigation Water Quality

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

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

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

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

Crops

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

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

DIVERSIFIED CROPS UNDER IRRIGATION

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

Potential for Diversified Cropping

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

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

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

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

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

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

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

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

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

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

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

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

Constraints to Diversified Cropping and Irrigation

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

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

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

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

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

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

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

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

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

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

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

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

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

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

RESEARCH

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

Crops

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

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

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

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

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

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

Irrigation Layout and Procedures

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

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

Land Shaping

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

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

Hydrology

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

Table 4. Seepage from channels and fields.

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

Further Investigations

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

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

RECOMMENDED PRACTICES

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

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

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

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

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

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

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

NATIONAL POLICY

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

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