IRRIGATION MANAGEMENT FOR DIVERSIFIED CROPPING IN TAIWAN

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INTRODUCTION

Irrigation in Taiwan is mainly for rice cultivation. It began in the 14th century on a small scale by immigrants from China. With a few exceptions, systems were built and managed by the farmers without any external control or assistance from the government. By 1895, over 200,000 hectares (ha) had been developed for rice cultivation, of which about 100,000 ha were under irrigation. From 1896-1945, the existing systems were remodelled, consolidated, and enlarged, and new systems were constructed. The irrigation area was increased to 562,000 ha producing 1.4 million metric tons (MT) of rice in 1938. In 1945, 502,018 ha were harvested producing 639,000 MT of rice. Since 1945, both irrigated area and rice production have increased. In 1976 production increased to 786,343 ha with a 2.7 million MT.

Such progress can be attributed mostly to advances in technology, including improved irrigation and drainage (L.J. Wen 1981a; Taiwan Provincial Department of Agriculture and Forestry 1986). For many years Taiwan was self-sufficient in rice and exported the surplus. However, this situation changed as the demand at home and abroad decreased. As a result, a diversified cropping program had to be enforced due to over-production of rice.

Technological innovation played an important role in the diversification of agriculture. The success of early maturing crop varieties, relay interplanting, plant protection measures, fertilization, dense planting, new farm machinery, and extension of upland crop irrigation have increased efficiency of water, land, and labor use which in turn substantially increased the adaptability of diversified cropping, thus maximizing resources use.

NATURAL ENVIRONMENT

Taiwan, located in the subtropical zone, has a total area of 36,006 square kilometers (km), and is about 394 km long from north to south and 144 km at its widest point. Two-thirds of the island is sloping and mountainous. A central range divides the island into eastern and western coastal plains. The western part is characterized by advanced agricultural and industrial activities. The total cultivated land was 883,106 ha (25 per cent of the total area) in 1985. Rice occupied 493,641 ha and upland crops 389,465 ha (ibid. 1986; Council of Agriculture 1986). The total irrigated area of the 17 irrigation associations was 385,423 ha in 1985, of which the double rice-crop area occupied 257,177 ha; the single rice crop, 27,036 ha; the rotation cropping area (including 2- and 3-year rotations, 84,115 ha; and the upland crop area, 17,095 ha. There are other areas totalling 31,500 (ibid. 1986).

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Figures 1 and 2 show that temperatures average 18°C in winter and 28°C in summer on the coastal plain and rainfall averages 251 centimeters; about 78 per cent falls from May to October (National Taiwan University & Joint Commission on Rural Reconstruction 1970).

Figure 1. Average temperature in different parts of Taiwan (1950-69).

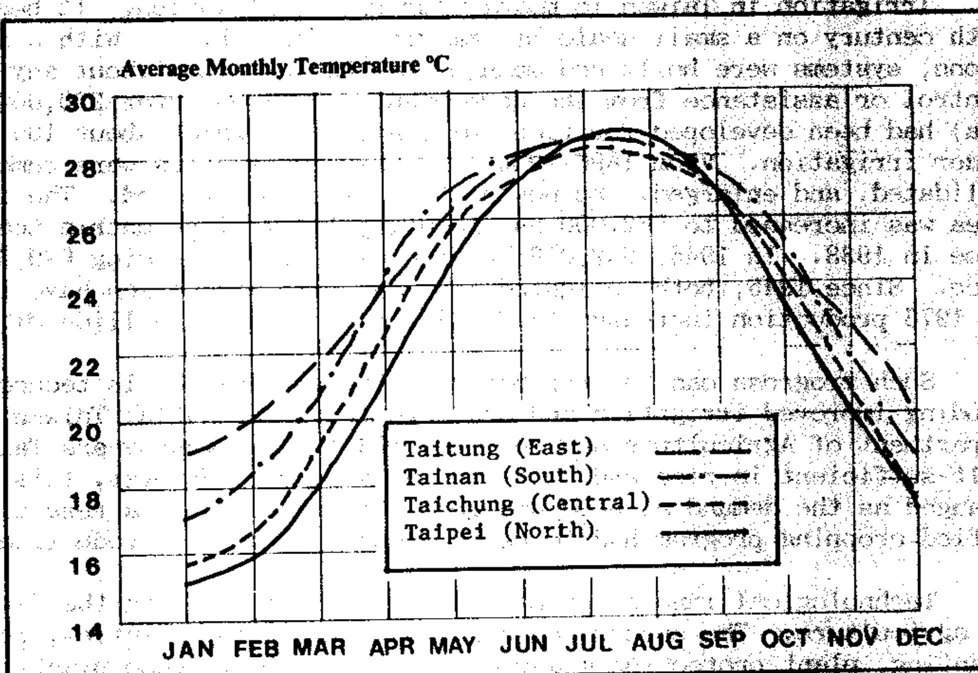
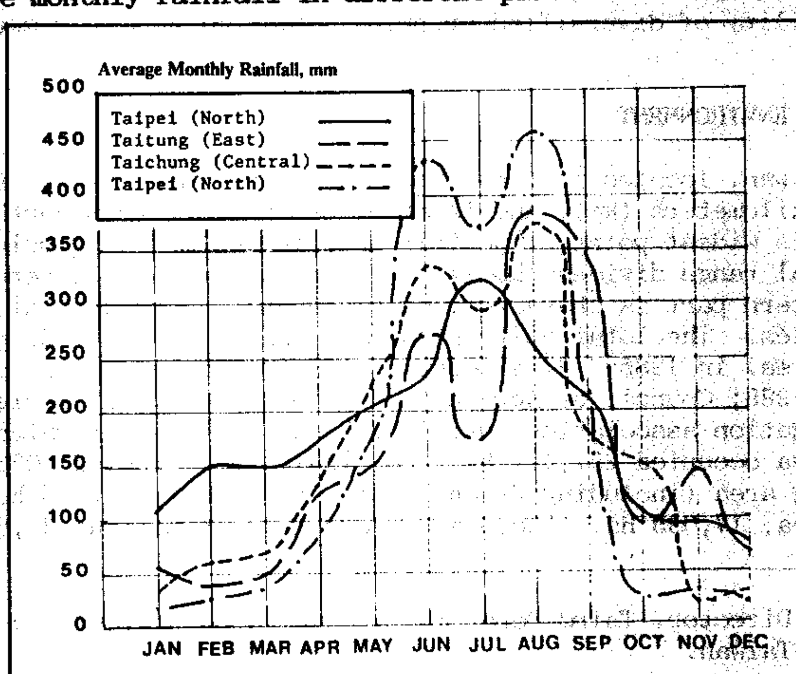


Figure 2. Average monthly rainfall in different parts of Taiwan (1950-69).

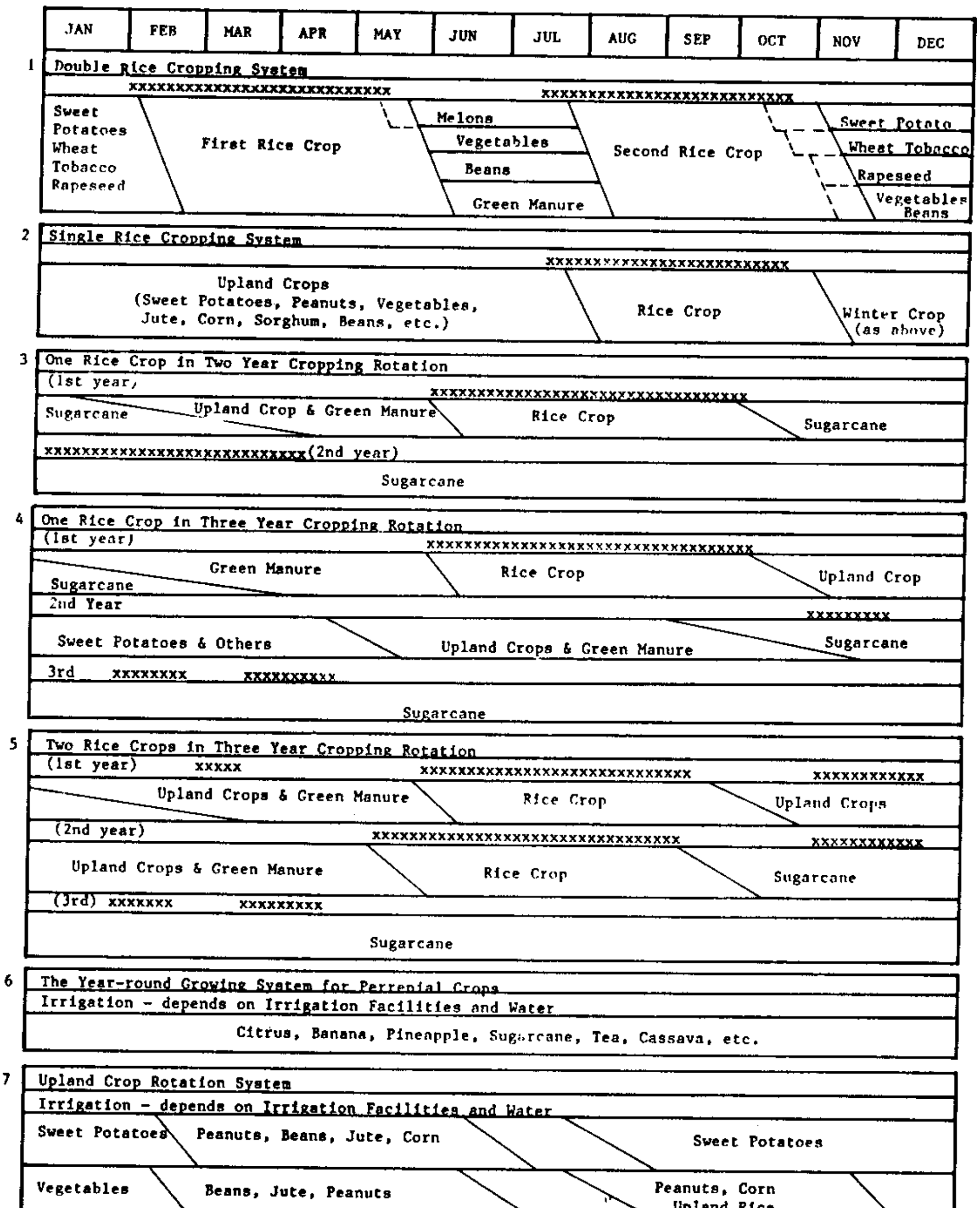


INTENSIVE FARMING

Cropping Patterns

Figure 3 shows that Taiwan's cropping systems and irrigation patterns may be classified into seven groups (Yuan H. Djang 1978; L.J. Wen 1981a). Ordinarily there are three or four crops a year, with rice as the main crop.

Figure 3. Various cropping patterns adopted in Taiwan.



Cropping Index

The motives for intensive diversified cropping are mainly limited land, water and labor resources in Taiwan. Owing to the relatively small size of private farm plots, farmers adopt intensive cropping to increase income, especially in the early stages when family labor is available. The utilization rate of the cultivated land or the multiple cropping index rose from 134.2 in 1939 to 189.7 in 1964 (Table 1; Taiwan Provincial Dept. of Agriculture and Forestry 1986, Yu-Kang Mao 1975). Later, rapid industrialization caused considerable labor migration, and farm labor became short, pushing up production costs. On the other hand, owing to the rapid growth of Taiwan's economy, increasing demands for high protein food items and fruits have encouraged the farmers to grow more perennial crops (Y.T. Wang 1975). Consequently, the multiple cropping index gradually decreased from 189.7 in 1964 to 142.4 in 1985 (Taiwan Provincial Dept. of Agriculture and Forestry 1986).

Table 1. Multiple cropping index (MCI) and agricultural employment (in thousands), 1939-1985.

Year	Crop area	Cultivated area	MCI	Agricultural employment	Employment/ha cultivated land
1939	1154	860	134.2		
1941	1183	859	137.7		
1943	1121	839	133.6		
1945	833	816	102.1		
1947	1249	834	149.8		
1949	1438	865	166.2		
1951	1502	874	171.9		
1953	1488	873	170.4	1647	1.89
1955	1508	873	172.7	1667	1.92
1957	1566	873	179.4	1689	1.92
1959	1590	878	181.1	1722	1.96
1961	1613	872	185.0	1747	2.00
1963	1613	872	185.0	1775	2.04
1965	1680	890	188.8	1748	1.96
1967	1696	902	188.0	1723	1.92
1969	1679	915	183.5	1726	1.89
1971	1620	903	179.4	1665	1.85
1973	1567	896	174.9	1624	1.82
1975	1659	917	180.9	1681	1.82
1977	1566	923	169.7	1597	1.72
1979	1549	918	168.7	1380	1.52
1981	1398	900	55.3	1257	1.39
1983	1334	894	149.2	1317	1.47
1985	1257	883	142.4	1297	1.47

Ibid. 1986; Council for Economic Planning and Development 1986.

ADJUSTMENT OF FARMING SYSTEMS

Group Farming

Migration of rural labor to urban-industry sectors has induced changes in cropping systems, depending on farm size. Small farms (less than 0.5 ha) continue to intensify land use. Two to three harvests of fruit, or seven to eight vegetable crops a year are common. Small farms of around one hectare or larger cannot be managed with family labor alone. Owners have to cut down on crop acreage. Group farming to accelerate farm mechanization has gradually been adopted. Thus, diversified multiple cropping systems tend to change to monoculture and the multiple cropping index declines with increased group farming (Kuang-Chi Su 1983).

There are two common types of group farming activities in Taiwan: joint operations and entrusted farming. Both are based on voluntary cooperation in cultivation and management activities without any change in land ownership within the family farm system. The first trial on joint operation began in 1963. Farmers organized themselves into a group of 20-30 with a total area of 20-30 ha to jointly carry out farming operations including field preparation, planting, weeding, fertilizer application, irrigation and drainage, pest and disease control and harvesting.

Entrusted farming is also popular, and has two types: entrusted cultivation and entrusted management. In the former, a farmer entrusts another farmer to carry out a part or all farming operations by paying an agreed wage. In the latter all farming operations and management are carried out by the entrusted farmer, who acts as an owner/operator/manager and pays the return on land investment in lieu of land rent.

Change in Crop Production

In Taiwan, farmers grow rice, common crops (sweet potato, barley, wheat, millet, corn, sorghum, and soybean), special crops (tea, sugarcane, and tobacco) and horticultural crops (vegetables, banana, pineapple, and citrus fruit). Among these, rice and sugarcane have been the two most important crops. Rice production enables a self-sufficient supply of staple food; sugar is mainly for export.

Increasing per capita income has altered the structure of food consumption. Per capita consumption of rice dropped from 138 kilogram (kg) in 1960 to 96 kg in 1982. On the other hand, production of fruit, vegetables, hogs, and chickens increased tremendously and per capita daily nutrient availability increased (Table 2). The local supply of corn, soybean, and sorghum as feed was insufficient. Consequently, imports of these crops increased, and the acreage of the same kinds of crops locally produced with high production costs decreased year after year.

There is a large rice surplus because of limited domestic and export markets. The best solution is to shift some rice acreage to cultivate corn, sorghum, soybean and other crops by adjusting farming systems.

Table 2. Per capita daily protein availability (in grams), 1952-84.

Year	Calories	Total	Animal	Vegetable
1952	2078	49.04	11.73	37.31
1953	2283	53.42	12.49	40.93
1955	2247	53.15	13.30	39.85
1957	2369	56.80	14.09	42.71
1959	2340	56.57	14.59	41.98
1961	2430	60.34	15.79	44.55
1963	2325	58.76	16.81	41.94
1965	2411	61.20	17.58	43.62
1967	2504	64.47	19.30	45.17
1969	2639	69.06	21.20	47.86
1971	2674	72.42	23.87	48.55
1973	2754	73.68	25.67	48.01
1975	2772	74.70	24.56	50.14
1977	2805	76.59	28.68	47.91
1979	2845	78.72	31.85	46.87
1981	2765	76.43	32.33	44.10
1983	2792	79.16	33.93	43.77
1984	2811	80.22	37.07	43.15

Council of Agriculture 1985b.

Six-year Rice Crop Substitution Program

This program was initiated in 1984 to reduce the rice surplus by shifting to other crops. The target was to reduce rice area from 645,855 ha in 1983 to 515,500 ha in 1989 and to decrease production from 2.48 million MT to 2.0 million MT. Two subsidy measures were adopted: 1) 1.0 MT/ha of rice for shifting to corn, sorghum, soybean, or sugar cane; 2) 1.5 MT/ha of rice for shifting to vegetables, fruit, or for fallow or aquaculture. Rice area and production decreased in 1984 to 587,186 ha and 2.24 million MT, and in 1985 to 564,392 ha and 2.17 million MT, respectively (Table 3).

Table 3. Rice crop substitution program (in hectares) in Taiwan, 1984-85.

	1984		1985	
Items	Area	% target	Area	% target
Corn, sorghum	10,137	40.5	15,905	72.2
Vegetables, fruit	23,104	888.6	24,017	128.6
Aquaculture	204	17.0	435	36.3
Misc crops & fallow	30,359	204.0	55,758	272.1
Total	63,804	146.0	96,115	154.0

Council of Agriculture 1986.

PRESENT POTENTIAL AND PROBLEMS

The total irrigated area in Taiwan decreased from 518,915 ha in 1968 to 416,880 ha in 1985 due to changes in land use for industrial and urban development (Table 4).

Table 4. Irrigated area (in thousand hectares) in Taiwan, 1965-85.

Yr	Grand total	Service area of 17 irrigation assoc Total	Dbl crop	Single crop	Dry crop	Rot crop	Other	Private irrigated area Total	Dbl crop	Single crop	Uplnd field	Rot crop
65	494	478	300	41.0	15.9	121	-	16.4	12.3	1.6	2.3	0.02
66	500	482	300	45.4	11.6	125	-	17.5	12.3	3.0	2.2	-
67	506	490	308	48.8	13.2	120	-	16.2	12.8	2.1	1.4	-
68	519	500	321	44.0	12.0	123	-	19.3	15.7	2.3	1.3	-
69	485	465	284	47.2	3.5	121	12.3	19.2	15.6	2.3	1.3	-
70	500	468	283	47.2	3.5	126	8.1	32.1	29.4	2.2	0.2	0.02
71	510	453	283	45.4	0.9	125	-	57.0	29.9	16.3	10.0	0.82
72	506	449	280	44.1	1.1	123	-	57.0	29.9	16.3	10.0	0.82
73	453	441	274	45.0	0.9	121	-	11.6	3.1	0.8	6.8	0.92
74	468	442	281	42.0	4.4	115	-	26.1	13.2	3.2	8.8	0.99
75	457	428	281	38.5	5.9	103	-	28.5	14.9	3.5	9.3	0.87
76	453	427	282	38.8	3.7	103	-	26.2	11.8	4.1	9.3	1.03
77	439	420	280	36.5	3.7	100	-	18.1	7.5	2.3	7.3	1.03
78	435	417	278	34.9	3.5	100	-	18.2	7.5	2.3	7.5	0.92
79	436	411	277	31.2	12.6	91	-	24.4	11.2	2.7	9.4	1.12
80	428	404	271	29.2	12.8	90	-	24.5	11.2	2.8	9.4	1.12
81	423	398	269	27.8	12.2	89	-	25.4	9.2	4.1	11.0	1.01
82	416	394	269	28.4	13.4	90	-	25.4	8.2	3.8	9.7	1.01
83	411	389	257	28.2	14.5	89	-	22.7	8.1	3.8	9.7	1.03
84	420	388	259	26.9	14.9	88	-	31.5	8.6	7.0	14.8	1.06
85	417	385	257	27.0	17.1	84	-	31.5	8.5	7.1	14.8	1.06

Note: dbl = double, rot = rotational; Taiwan Provincial Dept. of Agriculture and Forestry 1986; Taiwan Provincial Water Conservancy Bureau 1986.

The average annually decreased acreage of 5,669 ha is considerable compared to Taiwan's limited land resources. The decrease of the irrigated area should not be overlooked in predicting rice production for self-sufficiency and estimating acreage for diversified cropping in the future.

Maximum Imaginary Production Area

The maximum imaginary production area (MIPA) of imported crops may be calculated from the following assumption.

MIPA = (local crop production + imported crop quantity) / yield per hectare

The MIPAs of corn, sorghum, soybean, and wheat in 1985 are too large for the limited land in Taiwan (Table 5; ibid.). Therefore, it is impossible to increase production to reach self-sufficiency in feed and edible oil.

Table 5. Maximum imaginary production area (MIPA) of imported crops.

Crop	(1) Cultivated area ('000 ha)	(2) Production ('000 MT)	(3) Unit production (MT/ha)	(4) Imported quantity ('000 MT)	(2+4) Consumption ('000 MT)	(2+4)/(3) MIPA ('000 ha)
Corn	61.6	226.0	3.67	3016.8	3242.8	883.6
Sorghum	19.0	86.7	4.56	564.4	651.1	142.8
Soybean	7.1	12.2	1.72	1469.8	1482.0	861.6
Wheat	1.0	2.1	2.02	754.7	756.8	374.6

Ibid. 1986.

Regional Rice Land Adaptability Survey

To map out a regionally suitable crop system for reference in carrying out the crop substitution program, the Council of Agriculture, in cooperation with the Provincial Department of Agriculture and Forestry and District Agricultural Improvement Stations, initiated a survey project in 1984. An adaptability survey of major crops is based on data concerning water, soil, climate, and other crop production factors. The major crops included corn, sorghum, sweet potatoes, peanuts, grapes, tomatoes, and asparagus. By the end of 1985, the preliminary adaptability survey of corn and sorghum was completed and the survey of other crops was in progress. Table 6 shows the preliminary results for corn in different counties of Taiwan.

Problems Encountered

Small farm size. The average farm size decreased from 1.29 ha in 1952 to 1.12 ha in 1985 (Council for Economic Planning and Development 1986). The smaller the scale of farming, the higher the cost, especially when labor is scarce and machinery cannot be used. Small farm size is a constraint to increasing operational efficiency of family farms (Y.T. Wang and Y.H. Yu 1975).

Shortage of farm labor. A high labor-land ratio is favorable for multiple cropping. Taiwan's experience indicates that the farm labor per hectare of cultivated land is positively correlated to the multiple cropping index (Y.T. Wang 1975; Yu-Kang Mao 1975). Agricultural employment per hectare of cultivated land decreased from 1.89 in 1952 to 1.47 in 1985. Shortage of labor causes high wages resulting in the high cost of crop production.

Market fluctuations. The uncertainty of crop prices affect production of non-rice crops in monsoon agriculture. Setting up processing facilities and marketing channels to collect from numerous farmers scattered over large areas (Chen 1975) is the only solution but complicates management.

Table 6. Estimated areas (in thousand ha) adaptable for regional corn cultivation in different counties in Taiwan.

Counties	Spring crop				Autumn crop			
	Adapt-able	Rel adapt	Sub-total	% of field	Adapt-able	Rel adapt	Sub-total	% of field
Ilan	4.0	3.1	7.1	36	1.4	-	1.4	8
Taoyuan	1.3	5.5	6.8	17	11.3	1.4	12.8	33
Hsinchu	1.3	0.5	1.9	10	3.0	-	3.0	16
Miaoli	3.0	2.7	5.7	27	1.1	0.4	1.4	7
Taichung	1.4	2.5	3.9	11	1.8	4.6	6.5	18
Nantou	0.2	0.3	0.4	3	0.8	0.5	1.3	7
Changhua	3.6	11.7	15.3	28	.9	24.0	24.9	46
Yunlin	-	-	-	-	6.4	21.1	27.5	44
Chiayi	14.6	0.6	15.2	73	12.9	22.9	35.8	78
Tainan	10.8	7.2	18.0	83	23.2	18.2	41.5	82
Kaohsiung	-	-	-	-	2.9	7.2	10.1	36
Pingtung	-	-	-	-	4.8	15.7	20.5	51
Taitung	4.3	1.7	6.0	52	5.5	0.4	5.8	49
Hualien	2.0	4.4	6.4	44	2.4	6.0	8.4	59
Total	46.5	40.2	86.8	-	78.5	122.4	200.9	-

Note: rel = relative; Council of Agriculture 1986.

Competition with imported crops. Large quantities of corn, sorghum, and soybean were imported in 1985 (see Table 5). Their prices are much less than the locally produced crops. Government is considering methods to increase crop yields, and developing new and suitable farm machines to reduce production costs, minimize the price difference, and help the small farm economy.

Income disparity between farm families and non-farm families. The widening income disparity between farm and non-farm families has encouraged the rapid outflow of agricultural labor to the industrial and commercial sectors resulting in a shortage of farm labor, high farm wages, increased cost of production, depressed farm income to subsistence level, and low return on agricultural investment is low. In recent years, the disparity between the two families-type was narrowed to 30 per cent through government efforts.

Some technical problems. Mechanization for corn, sorghum, soybean, and peanuts is far behind that of rice. Farmers lack machines for harvesting diversified crops. Through cooperative efforts, government research institutes and farm machine companies have developed new types of sorghum combines and corn ear-harvesters. Varieties and cultural techniques of diversified crops should be improved to adapt to new conditions, especially rainy season.

Improvement Measures for Feed and Horticultural Crops

Measures to improve feed crops include: a) guiding farmers to establish entrusted machine farming centers for production of feed crops; b) promoting labor-saving cultivation methods without land preparation for planting other crops after harvesting rice; c) guiding farmers to adopt group farming without any change in land ownership within the family farming system; and d) guaranteeing the prices of locally produced corn, sorghum, and soybean.

Measures to improve horticultural and special crops include: a) improving varieties of new heat and pest resistant crops; b) strengthening research and experiment activities to improve cultivation techniques; c) promoting extension, adjusting the harvest season, or increasing the output of fruits; d) promoting research development on protective horticultural cultivation; and e) establishing vegetable-specialized areas with emphasis on summer.

IMPROVEMENT OF IRRIGATION SYSTEMS

General Description

In the past 20 years, development has focused on the economic use of water resources in relation to agricultural production. The development covered large-scale irrigation, multi-purpose reservoirs, ground water development, tidal land reclamation, and waste land reclamation. Rotational irrigation, canal lining, and land consolidation projects. Automatic remote control systems were installed and tested on several major canals for release, rating, and recording flows. Computer programming was applied to water distribution planning. Mechanized transplanting of rice was possible with better coordinated water distribution. Installation of water measurement and recording facilities at major headworks and canals was nearly completed. On the other hand, experiments and extension of dry-farm crop irrigation were undertaken. Drainage improvement was also conducted.

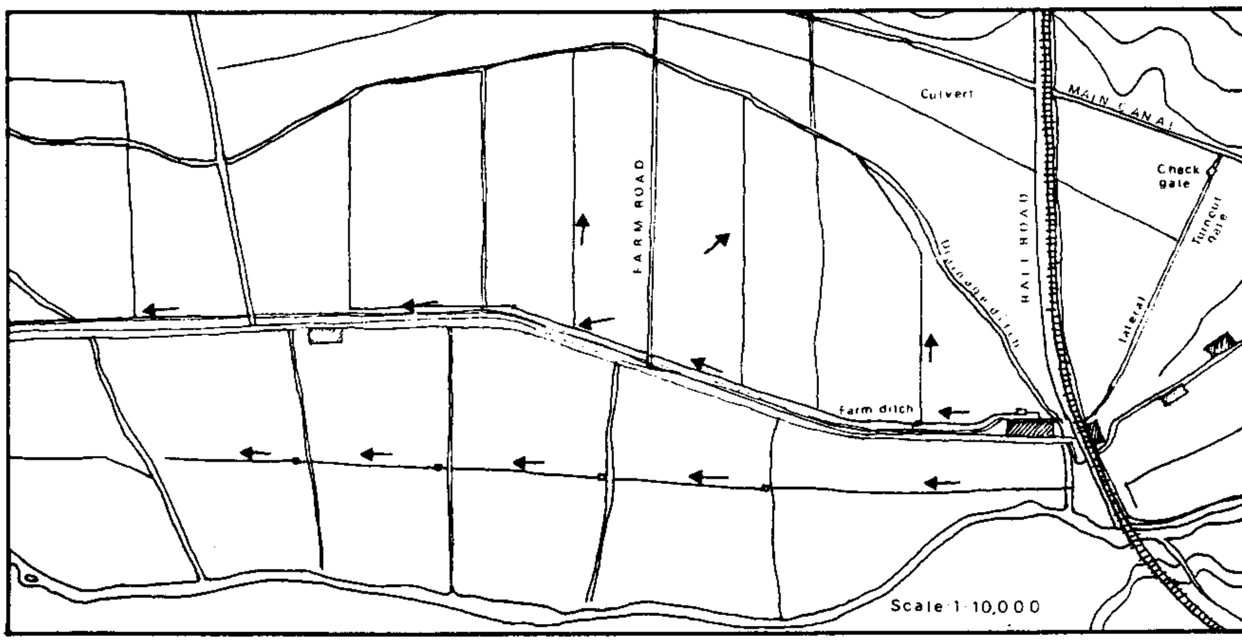
At present there are 18 reservoirs and 1,912 main canals taking water from rivers for irrigation. The total length of the main and lateral and sub-lateral canals is 15,811 km. The average length of supply ditches per hectare is about 57 meters. In addition to irrigation systems using surface water sources, there are 10,370 wells including 1,869 deep wells, most of which are used for supplementary irrigation (L.J. Wen 1981a).

Rotational Irrigation

A rotational system of water issue to farmers in appropriate quantity of water at the right time and in proper order has been adopted for rice cultivation. It is also applicable to other crops, but is different in quantity, time, and method of field irrigation. To facilitate this method of irrigation, the irrigation system has been improved so that irrigation water can be simultaneously delivered into each individual rotation area of about 50 ha. Each rotation area is subdivided into four or five rotation units, about 10 ha each in size. Every rotation area is provided with one turnout gate, one measuring device, and several division boxes. Water flowing through the turnout is measured and rotated among the rotation units with the amount of water and interval of irrigation adjusted according to the actual rotation unit size, soil and crop conditions, effective rainfall and conveyance losses (L.J. Wen 1977 and 1981a).

Continuous irrigation may be applied to rice cultivation but it will cause water-logging which harms other crops. However, rotational irrigation favors plant growth, saves fertilizer, reduces water disputes, and saves labor especially during drought. Since the rotational irrigation practice was initiated in 1956, more than 126,000 ha of paddy fields have been improved. A layout of a rotational irrigation system is shown in Figure 4.

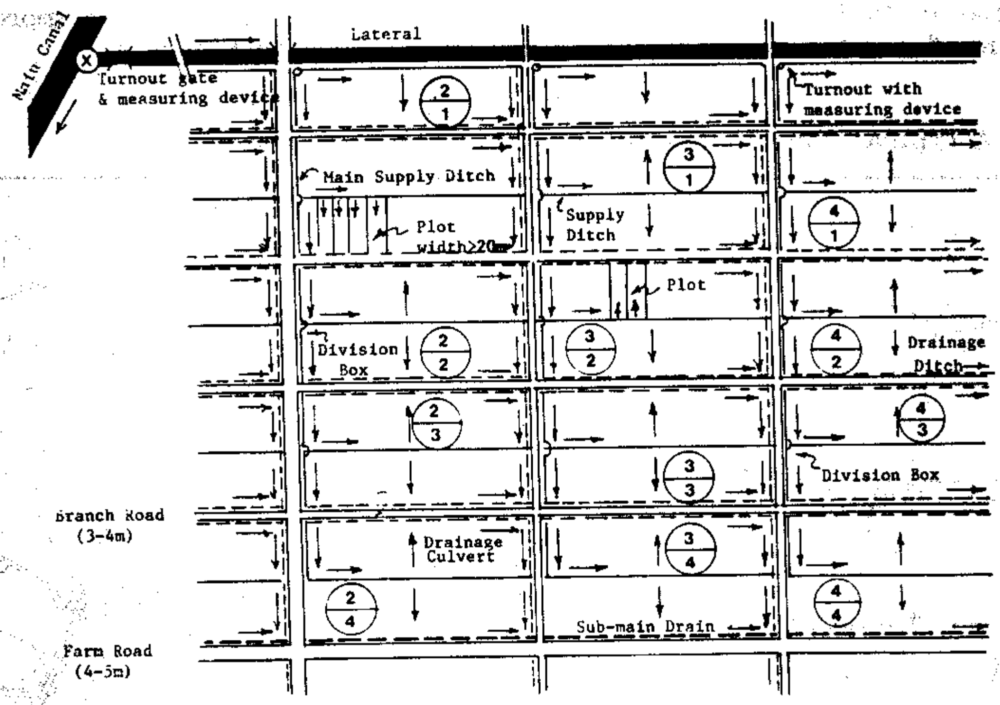
Figure 4. A typical layout of a rotational irrigation system.



Land Consolidation

Since a land consolidation program was initiated in Taiwan in 1961, some 250,000 ha of farm lands, about 80 per cent of which is paddy fields, have been consolidated. Paddy fields were readjusted into rectangular blocks surrounded by farm roads 3-5 meters wide, to facilitate transportation. Each block is about 500-600 meters long and 200-240 meters wide. In a typical layout of farm-level irrigation systems, each farm supply ditch runs in the middle, parallel to the long edge of the block and delivers water to both side plots, each a rectangular shape of 100-120 meters long and 20-40 meters wide depending on local conditions of soil, topography, size of land holding, and farm mechanization. Farm drainage ditches are usually built on both sides of the farm road. In case the topography does not permit a desirable layout, the drainage ditch may be located in the middle of the block and the supply ditch on both sides of the farm road so that the drainage ditch runs lower and the supply ditch higher in order to minimize land levelling costs. As a rule, supply and drainage ditches are at right-angles to contours to reduce the cross-sectional area of water flow, minimizing construction costs. Consequently, supply and drainage ditches are arranged along the short edge of each plot and the main supply ditches along the long edge of the plot to connect the lateral or sub-lateral and supply ditches. A typical layout of land consolidation is illustrated in Figure 5 (L.J. Wen 1977 and 1981a).

Figure 5. Typical layout of water distribution system for land consolidation in Taiwan (upper number = rotation area; lower number = rotation unit).



In land consolidation, consideration is given to separating supply ditches from drainage ditches; direct irrigation for free water management; easy access to each plot; suitability of water reuse; minimum space for farm roads, canals, ditches, and earth dikes in paddies; minimum earth work for levelling by adjusting the alignments and elevations of supply and drainage ditches; and conditions of the downstream drainage channels. Irrigation water can be freely delivered into each plot directly from the supply ditch (without passing from field to field), and the controlled border or furrow method can easily accommodate diversified cropping. For rotational irrigation, each block of about 10-14 ha may be regarded as a rotation unit, and 4-5 units along a main supply ditch form a rotation area. Water flowing continuously through the turnout gate into the rotation area is properly rotated among the units. When water supply is limited, especially during drought, intermittent irrigation may be adopted by rotating water delivery among units. After land consolidation, the farm land will have good irrigation and drainage conditions for rice cultivation and diversified cropping.

CROP IRRIGATION EXPERIMENTS

Historical Review

The actual irrigation requirements of various upland crops in Taiwan were not known to most irrigation and agricultural personnel in Taiwan before

1961. From 1961 to 1963, the first irrigation experimental project under the technical and financial support of the Joint Commission on Rural Reconstruction (JCRR) was carried out at Hsuechia of the Chianan Irrigation Association in southern Taiwan. In 1963, an island-wide irrigation experiment and demonstration project on trial basis was started by the Taiwan Provincial Water Conservancy Bureau (PWCB) with assistance of JCRR the Provincial Department of Agriculture and Forestry, Agricultural Engineering Research Center, the National Taiwan University, local irrigation associations and district agricultural improvement stations. The Agricultural Research Institute, Sugarcane Research Institute, and district agricultural improvement stations were also conducting research and experiments on crop improvement, cropping systems and irrigation. The basic studies on irrigation may be grouped into three categories: experiments on water requirements, adaptation tests on cropping patterns, and experiments on irrigation methods.

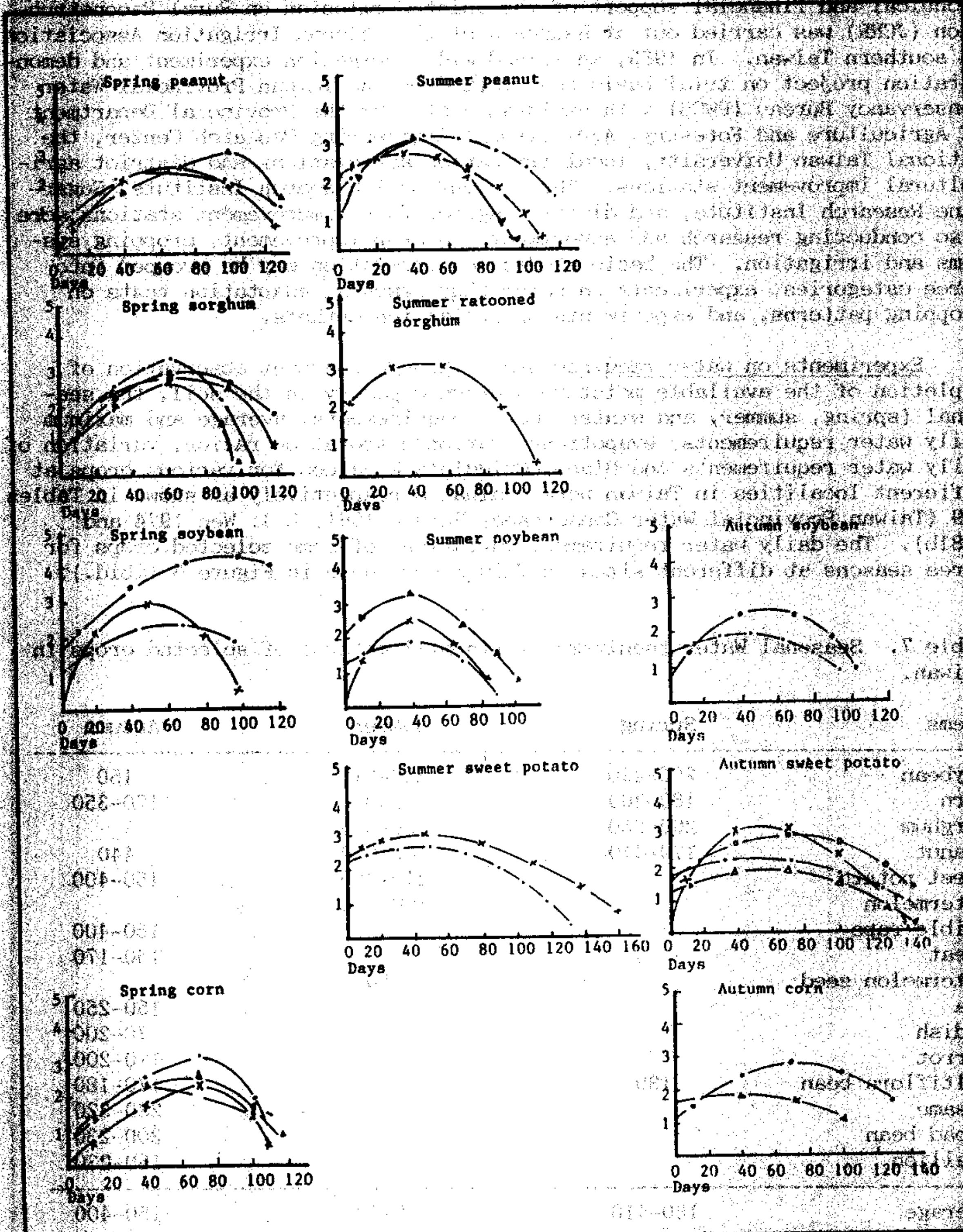
Experiments on water requirements. Through constant observation of depletion of the available moisture storage capacity in the soil, the seasonal (spring, summer, and winter) water requirements, average and maximum daily water requirements, evapotranspiration/evaporation ratios, variation of daily water requirements and Blaney-Criddle's K values for various crops at different localities in Taiwan were evaluated respectively as shown in Tables 7-9 (Taiwan Provincial Water Conservancy Bureau 1961; L.J. Wen 1974 and 1981b). The daily water requirement variations of some selected crops for three seasons at different sites in Taiwan are shown in Figure 6 (ibid.).

Table 7. Seasonal Water requirements (in millimeters) of selected crops in Taiwan.

Items	Spring	Summer	Autumn
Soybean	200-440	230-310	150
Corn	160-300	250	170-350
Sorghum	200-350	250-370	
Peanut	170-410	160-300	440
Sweet potato		210-380	150-400
Watermelon		180-200	
Edible rape			150-400
Wheat			160-170
Watermelon seed		150	
Pea			150-250
Radish			70-200
Carrot			170-200
Multiflora bean	130		170-180
Sesame			280-320
Broad bean			200-230
Scallion			160-230
Average	160-410	160-380	150-400

Taiwan Water Conservancy Bureau 1966.

Figure 8. Daily water requirements (DWR) for selected crops in Taiwan.



Days = accumulated number of days for plant growth; x = Miaoli, northern; . = Changhua, central; o = Kangshan, southern; = Juishui, eastern Taiwan.

Table 8. Maximum and average daily water requirements (WR; in millimeters) of selected crops in Taiwan (1964-70).

Location	Season	Crop	Max WR	Avg WR
Northern Taiwan				
Shihmen	Spring	corn	5.3	2.8
		peanut	4.6	2.6
		sorghum	5.4	2.9
	Summer	ratooned sorghum	4.6	3.0
		soybean	4.7	3.2
		sweet potato	5.9	3.0
	Autumn	broad bean	2.9	2.0
Miaoli	Spring	corn	2.6	1.9
		peanut	3.6	1.9
		sorghum	5.0	2.0
	Summer	ratooned sorghum	3.9	2.2
		watermelon	3.8	2.3
	Autumn	sweet potato	4.2	2.0
		scallion	3.0	1.8
Central Taiwan				
Changhua	Spring	corn	5.5	2.2
		peanut	3.6	2.2
		sorghum	3.5	2.3
		soybean	3.0	2.0
	Summer	soybean	4.9	2.8
		sweet potato	4.8	2.5
	Autumn	wheat	1.8	1.6
Southern Taiwan				
Kangshan	Spring	corn	3.4	2.5
		peanut	5.7	3.1
		sorghum	3.7	2.6
		soybean	6.0	3.0
	Autumn	corn	3.1	2.3
		soybean	3.0	2.3
		sweet potato	3.3	2.4
Eastern Taiwan				
Juishui	Spring	peanut	3.3	2.0
		sorghum	3.1	2.0
	Summer	peanut	3.7	2.5
		soybean	4.1	2.6
	Autumn	sweet potato	4.3	1.6
		spring pea	2.6	1.7
		corn	2.8	2.9

Taiwan Provincial Water Conservancy Bureau 1961.

Table 9. Daily water requirements, evapotranspiration-evaporation ratios, and Blaney-Criddle's K values for different months in Taiwan, 1964-70.

Location	Crop	Value	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Planted period
Central Taiwan (Shihmen)	Corn	U				2.12	4.03	3.93	3.08						Early Apr.-Mid. July
		C				0.72	1.22	1.47	0.71						
		K				1.15	0.69	0.64	0.41						
	Peanut	U			2.05	3.44	2.38	3.11	1.81						Mid. Mar.-Late July
		C			1.47	1.18	0.76	0.82	0.54						
		K			0.60	0.68	0.41	0.54	0.38						
	Sorghum	U				1.53	4.02	4.21	2.95						Early Apr.-Late July
		C				0.71	1.22	1.33	0.67						
		K				0.30	0.69	0.68	0.46						
	Ratooned Sorghum	U								2.17	3.47	4.10	1.72		Early Aug.-Mid. Nov.
		C								0.63	0.90	1.39	0.72		
		K								0.35	0.63	0.72	0.45		
	Soybean	U			0.90	3.13	1.67	1.81		2.74	3.84	4.01	2.11		Early Mar.-Late June Early Aug.-Mid. Nov.
		C			0.19	0.60	1.06	0.29		0.45	0.70	0.84	0.47		
		K			0.19	0.60	1.06	0.29		0.45	0.70	0.84	0.46		
	Sweet-potato	U						2.06	3.63	4.15	4.10	2.81	1.83		Early June-Early Nov.
		C						0.49	0.56	0.70	0.79	0.62	0.41		
		K						0.49	0.56	0.70	0.79	0.61	0.40		
	Broad-bean	U	2.89	2.35	1.28								1.25	2.52	Early Nov.-Early Mar.
		C	0.75	0.64	0.46								0.87	0.64	
		K	0.75	0.64	0.46								0.87	0.64	
Northern Taiwan (Miaoli)	Corn	U			0.67	1.42	2.55	1.67							Mid. Mar.-Late June
		C			0.18	0.45	0.48	0.23							
		K			0.15	0.28	0.43	0.17							
	Peanut	U			0.99	2.45	2.84	1.96	1.62	2.48	2.48	1.27	0.75		Early Mar.-Mid. July Late July-Late Nov.
		C			0.39	0.70	0.60	0.47	0.16	0.34	0.57	0.25	0.09		
		K			0.23	0.49	0.50	0.33	0.08	0.25	0.42	0.17	0.07		
	Sorghum	U				0.78	2.78	3.88	2.66	0.74					Early Apr.-Mid. Aug.
		C				0.29	0.53	0.70	0.40	0.24					
		K				0.20	0.42	0.49	0.42	0.16					
	Ratooned Sorghum	U								1.85	3.97	2.84	1.73		Mid. Aug.-Late Nov.
		C								0.48	0.66	0.52	0.54		
		K								0.38	0.75	0.65	0.35		
	Soybean	U			1.00	1.99	3.14	2.30	1.90	1.37	2.77	1.78	1.21		Mid. Mar.-Early July
		C			0.48	0.60	0.59	0.57	0.53	0.34	0.69	0.61	0.50		
		K			0.08	0.38	0.56	0.38	0.06	0.18	0.54	0.42	0.13		
	Sweet-potato	U	1.12	0.95							2.71	2.93	2.85	1.54	Mid. Sept.-Mid. Feb.
		C	0.46	0.28							0.50	0.62	0.81	0.76	
		K	0.29	0.32							0.50	0.73	0.66	0.45	
	Water-melon	U							3.58	2.71	1.51				Early July-Early Sept.
		C							0.32	0.54	0.52				
		K							0.40	0.45	0.38				
	Scallion	U	1.20	1.37	2.53	0.80								0.27	Late Dec.-Early Apr.
		C	1.22	0.71	0.86	0.25								1.18	
		K	0.35	0.40	0.60	0.17								0.08	

Table 9 (cont).

Central Taiwan (Changhua)	Corn	U			1.73	2.52	3.72	1.84							Early Mar.-Mid. June
		C			0.50	0.69	0.82	0.43							
		K			0.36	0.49	0.56	0.32							
	Peanut	U			1.57	2.24	2.96	2.07							Early Mar.-Late June
		C			0.47	0.60	0.75	0.58							
		K			0.37	0.53	0.49	0.32							
	Sorghum	U			1.64	2.55	3.45	1.59							Late Mar.-Late June
		C			0.41	0.70	0.75	0.59							
		K			0.56	0.58	0.71	0.35							
	Soybean	U	1.47		1.46	1.31	2.47	1.33	2.08	3.17	2.96	1.51	1.84	1.66	Early Mar.-Mid. June Early July-Late Sept. Early Oct.-Mid. Jan.
		C	0.36		0.51	0.49	0.65	0.48	0.42	0.59	0.60	0.32	0.46	0.65	
		K	0.36		0.79	0.38	0.50	0.39	0.29	0.48	0.35	0.31	0.47	0.65	
	Sweet-potato	U	1.33	1.05				1.52	3.48	3.27	3.10	2.24	2.11	1.68	Mid. June-Early Oct. Mid. Oct.-Late Feb.
		C	0.58	0.59				0.25	0.70	0.70	0.48	0.46	0.59	0.62	
		K	0.72	0.63				0.27	0.61	0.57	0.48	0.37	0.45	0.59	
	Wheat	U	1.38	0.97								1.32	1.66	1.58	Late Oct.-Early Feb.
		C	0.48	0.32								0.35	0.51	0.61	
		K	0.43	0.34								0.24	0.39	0.52	
	Radish	U	2.19	1.45										1.20	Early Dec.-Mid. Feb.
		C	0.95	0.81										0.65	
		K	0.63	0.66											
Southern Taiwan (Kangshan)	Corn	U	2.17	1.35	1.51	1.71	1.58					1.82	2.34	2.98	Early Feb.-Mid. May Mid. Oct.-Early Feb.
		C	0.75	0.76	0.61	0.89	0.31					0.35	0.77	0.97	
		K	0.75	0.46	0.53	0.63	0.26					0.37	0.60	0.80	
	Peanut	U		2.27	2.62	4.75	5.01	4.45							Mid. Feb.-Mid. June
		C		1.32	0.91	1.18	1.23	1.33							
		K		0.53	0.56	0.91	0.89	0.60							
	Sorghum	U		1.81	2.33	3.00	1.73								Mid. Feb.-Late May
		C		0.36	0.51	0.80	0.46								
		K		0.29	0.50	0.60	0.39								
	Soybean	U	1.62	2.58	3.17	3.89	2.74					1.82	2.35	2.98	Mid. Feb.-Late May Early Oct.-Mid. Jan.
		C	0.84	0.60	0.56	0.74	0.75					0.29	0.54	0.68	
		K	0.54	0.35	0.46	0.63	0.37					0.36	0.81	0.95	
	Sweet-potato	U	2.41	1.77								2.23	2.64	2.50	Mid. Oct.-Mid. Feb.
		C	0.93	0.82								0.49	0.74	1.02	
		K	0.66	0.50								0.45	0.56	0.75	
Eastern Taiwan (Juishui)	Peanut	U		1.05	2.56	2.66	2.02	0.93	2.67	3.72	1.57	1.04			Mid. Feb.-Mid. June Mid. July-Mid. Oct.
		C		0.51	0.64	0.73	0.78	0.50	0.52	0.69	0.72	0.40			
		K		0.20	0.55	0.42	0.34	0.16	0.39	0.51	0.41	0.20			
	Sorghum	U			1.20	1.90	2.77	1.57							Mid. Mar.-Mid. June
		C			0.51	0.65	0.92	0.56							
		K			0.26	0.36	0.48	0.27							
	Soybean	U						1.88	3.02	3.47	2.51				Early June-Late Sept.
		C						0.16	0.47	0.74	0.68	0.85			
		K						0.22	0.53	0.58	0.36				
	Sweet-potato	U	1.52	1.11								1.09	1.87	2.06	Late Oct.-Mid. Feb.
		C	0.78	0.62								0.58	0.82	1.04	
		K	0.41	0.20								0.23	0.39	0.44	
	Pea	U	2.24	1.58									1.56	1.76	Early Nov.-Late Feb.
		C	1.06	0.64									0.73	1.11	
		K	0.52	0.32									0.38	0.46	
	Corn	U	1.35	0.98	1.35	2.40	2.66	1.52				1.54	1.79	1.92	Early Mar.-Late June Mid. Oct.-Late Feb.
		C	0.85	0.56	0.44	0.71	0.77	0.61					0.80	0.82	
		K	0.33	0.26	0.31	0.37	0.39	0.15				0.29	0.40	0.37	

U = Daily water requirement (mm); C = evapotranspiration-evaporation ratio; K = Blany-Criddle K value. Source: Taiwan Provincial Water Conservancy Bureau 1961.

Tables 10 and 11 (L.J. Wen 1981b; Joint Commission on Rural Reconstruction n.d.) show the evapotranspiration/evaporation ratios and monthly water requirements, and Blaney-Criddle's K values, respectively, of sugarcane in southern Taiwan.

Table 10. Average raised A pan evaporation (E), transpiration (T), and evapotranspiration (ET) rates in millimeters, and evapotranspiration/pan evaporation ratios (PR) of sugarcane in Taiwan (1963-66).

		Clay loam		Sandy soil		Clay loam		Sandy soil	
Month	E	T	PR	T	PR	ET	PR	ET	PR
Feb	107.0	42.1	0.39	112.7	1.05	50.3	0.47	112.0	1.05
Mar	131.4	42.9	0.33	80.4	0.61	56.0	0.43	82.8	0.63
Apr	135.1	49.3	0.37	80.1	0.59	57.6	0.43	80.2	0.59
May	182.3	104.6	0.57	135.8	0.75	158.0	0.87	187.6	1.03
Jun	136.4	139.5	1.02	155.5	1.14	222.1	1.63	242.6	1.78
Jul	148.7	148.2	1.00	162.6	1.09	207.0	1.39	245.1	1.65
Aug	158.3	150.4	0.95	172.2	1.09	169.7	1.07	200.6	1.27
Sep	134.5	152.8	1.14	168.1	1.25	180.1	1.34	195.7	1.46
Oct	121.7	144.0	1.18	147.2	1.21	134.2	1.10	161.6	1.33
Nov	91.2	126.0	1.38	144.0	1.58	112.9	1.24	180.8	1.98
Dec	70.6	74.8	1.06	78.1	1.11	68.8	0.98	98.7	1.40
Tot	1417.2	1174.6		1436.7		1416.7		1787.5	
Avg			0.83		1.01		1.00		1.26

Taiwan Sugarcane Research Institute 1968.

Table 11. Monthly water requirements (WR; evapotranspiration in millimeters) and Blaney-Criddle's K values of sugarcane in Taiwan (clay loam soil).

Month	Mean temp (°C)	Daytime hrs (%)	Factor	WR	K value
Feb	18.2	7.18	118.1	50.3	0.43
Mar	20.7	8.40	147.8	56.0	0.38
Apr	24.6	8.57	166.0	57.6	0.35
May	26.5	9.22	186.6	158.0	0.85
Jun	27.0	9.13	186.9	222.1	1.19
Jul	27.7	9.35	194.4	207.0	1.06
Aug	27.8	9.03	188.1	169.7	0.90
Sep	26.6	8.31	168.6	180.1	1.07
Oct	24.8	8.13	158.2	134.2	0.85
Nov	22.2	7.48	136.7	112.9	0.83
Dec	19.0	7.52	126.4	68.8	0.54
Total			1,777.8	1,416.7	0.80

Joint Commission on Rural Reconstruction n.d.

Adaptation Tests on Cropping Patterns

Tests on the frequency of irrigation were conducted in 1963-64. The results of one experimental application of irrigation at the critical stage for selected crops at different localities showed that there was production increase ranging from 21-228 per cent (Table 13).

Table 12. Experiments on one application of irrigation at the critical stages of plant growth in Taiwan (1963-1964).

Crop	Critical Stage	Season	Days after planting	Irrigation (mm)	Per cent increase
Sweet potato	Rapid root expansion	Autumn	60	60	21
Peanut	Flowering to pod expansion	Spring	50	50	68
		Autumn	75	50	32
Soybean	Flowering to initial pod	Spring	60	50	114
	growth stage	Autumn	55	50	26
Corn	Silking to filling	Spring	60	50	228
		Autumn	60	50	52
Wheat	Young panicle to heading	Autumn	45	50	48

Chinese Institute of Civil and Hydraulic Engineering 1985.

Through precise soil, water, plant, and fertilizer management jointly established by irrigation and agricultural personnel at the standard plots of each station, the varied requirements, yield, and cost figures of different crops were closely recorded for overall evaluation of the recommended crop rotation systems. Results revealed that an increase of production by irrigation might exceed 500 per cent (Table 13; ibid.). As far as the total net income is concerned, it may not be profitable to irrigate fields frequently.

As for cropping systems, the total net incomes of different cropping patterns tested in recent years in the irrigated double-rice fields of southern Taiwan are shown as an example in Table 14 (Chih-Kang Chao 1985). It can therefore be concluded that vegetables are more profitable than other crops. In North and East Taiwan, corn-rice, peanuts-rice, sorghum-rice and rice-peanuts are suitable for double rice cropping. Considering the high unit yield of the first rice crop in central and southern Taiwan, the feasible alternative cropping patterns for these areas will be rice-short duration crops-corn, and rice-short duration crops garlic. The short duration crops include green manure crops, vegetables, melons, mungbean, vegetable soybean and early maturing soybean (ibid.).

Table 13. Production increase by irrigation for various crops in Taiwan.

Crop	Critical Stage	Season	Time and Quantity of irrigation	Production increase (%)
Sweetpotato	Rapid root expansion stage	Autumn	60 days after planting 60 mm one application	21
Peanut	Flowering Stage to pod expansion stage	Spring	50 days after seeding 50 mm one application	68
		Autumn	75 days after seeding 50 mm one application	32
Soybean	Flowering stage to initial pod growth stage	Spring	60 days after seeding 50 mm one application	114
		Autumn	55 days after seeding 50 mm one application	26
Corn	Silking stage to filling stage	Spring	60 days after seeding 50 mm one application	228
		Autumn	60 days after seeding 50 mm one application	52
Wheat	Young panicle stage to heading stage	Autumn	45 days after seeding 50 mm one application	48

Source: Irrigation and Drainage, Chinese Institute of Civil and Hydraulic Engineering, 1985

Table 14. Total net income (in US$/hectare) and unit yield (MT/hectare; in parentheses) of different cropping patterns tested in irrigated single-rice fields at Mei-Nung, Kaoshiung, Taiwan, 1984.

1st crop	2nd crop	3rd crop	Net income	Index
Rice (5.92)	Vegetables (22.0)	Corn (5.57)	9,020	298
Rice (6.22)	Soybean (2.96)	Corn (5.69)	2,980	98
Soybean (1.91)	Rice (4.74)	Same red bean (2.83)	1,374	45
Rice (6.38)	Rice (4.83)	Same red bean (2.95)	3,027	100

Council of Agriculture 1985a.

Experiments on Irrigation Methods

Observations on advancement and penetration of irrigation water over the fields were made for furrow, border, and corrugation methods. The converted water depth required for various irrigation streams to cover different field lengths up to 100 meters were higher than needed. Nomographs for determining the stream sizes, run length, and cutback time of border and furrow irrigation for various crops and soil properties have been identified for Taiwan (National Taiwan University 1976; Taiwan Provincial Water Conservancy Bureau 1980). Data on water depths and stream sizes of border and furrow irrigation for corn, sorghum, peanuts, and sweat potatoes on different soils with and without machine plowing are shown in Tables 15 and 16 (ibid. 1976).

Table 15. Factors affecting border irrigation for given applications (in millimeters), unit discharge rates (in liters per second/meter for plots approximately 10 meters between borders), and cutbacks (per cent).

Soil types	Plowing	Crop	Application	Discharge	Cutback
Sandy loam	Animal	Peanut	80	0.30	80
Silty loam	Animal	Peanut	85	0.35	80
Sandy loam	Animal	Corn, sorghum	75	0.30	80
Silty loam	Animal	Corn, sorghum	80	0.33	80
Loam	Animal	Corn, sorghum	78	0.32	80
Sandy loam	Animal	Prepared land	100	0.40	90
Silty loam	Animal	Prepared land	90	0.35	90
Loam	Tractor	Corn, sorghum	90	0.42	90
Loam	Power tiller	Corn, sorghum	81	0.40	90
Loam	Tractor	Prepared land	110	0.60	90
Loam	Power tiller	Prepared land	105	0.50	90

National Taiwan University and Joint Commission on Rural Reconstruction 1976.

Data on irrigation efficiency of border and furrow irrigation for some crops in the Wushantou reservoir irrigation area in southern Taiwan are listed in Table 17 for reference (ibid. 1980).

Table 16. Factors affecting furrow irrigation of sweet potato for given applications (in millimeters), unit discharge rates (in liters per second/meter), and cutbacks (per cent).

Soil types	Plowing	Application	Discharge	Cutback
Sandy loam	Animal	60	3.0	80
Silty loam	Animal	60	3.5	80
Silty clay	Animal	60	4.0	80
Sandy loam	Machine	80	7.0	80
Sandy loam	Power tiller/animal for furrows	70	6.0	80

Table 17. Experimental data related to irrigation application efficiency in the Wushantou irrigated area, Taiwan.

Crops	Irrigation method	Land preparation	Farm length (meters)	Water depth (millimeters) planned	Water depth (millimeters) actual	Irrigation efficiency (per cent)
Garlic	border	excellent	116.0	34	62.9	54.1
"	"	good	117.5	34	62.9	54.3
"	"	"	136.5	34	43.9	77.4
"	"	excellent	114.0	34	54.4	62.5
Sugarcane	furrow	inferior	97.0	51	63.9	79.8
" "	"	excellent	70.0	51	29.0	100.0
Corn	corrugation	good	70.5	45	58.5	76.9
"	border	excellent	100.0	45	82.0	54.9
Barley	"	inferior	143.0	45	91.8	49.0
Sweet potato	furrow	"	71.0	45	81.2	55.4
" "	"	"	26.0	45	52.1	86.4
" "	"	"	117.0	45	49.2	91.5
" "	"	excellent	90.0	45	31.4	100.0
" "	"	inferior	97.0	45	63.9	70.4
" "	"	"	100.0	45	77.6	58.0
" "	"	good	120.0	45	96.6	46.6
" "	"	"	90.0	45	58.9	76.4
" "	"	"	100.8	43	77.0	58.4
" "	"	inferior	100.8	45	56.4	79.8
" "	"	good	88.0	45	59.8	75.3
" "	"	"	100.8	45	49.5	90.9
" "	"	"	100.8	45	51.7	87.0
" "	"	excellent	145.0	45	30.4	100.0
" "	"	"	158.0	45	49.5	90.9
" "	"	"	51.0	45	24.2	100.0
" "	"	"	51.0	45	37.9	100.0
" "	"	inferior	114.5	42	96.3	46.7
" "	"	good	100.0	45	79.8	56.4
" "	"	excellent	160.0	45	45.6	98.7

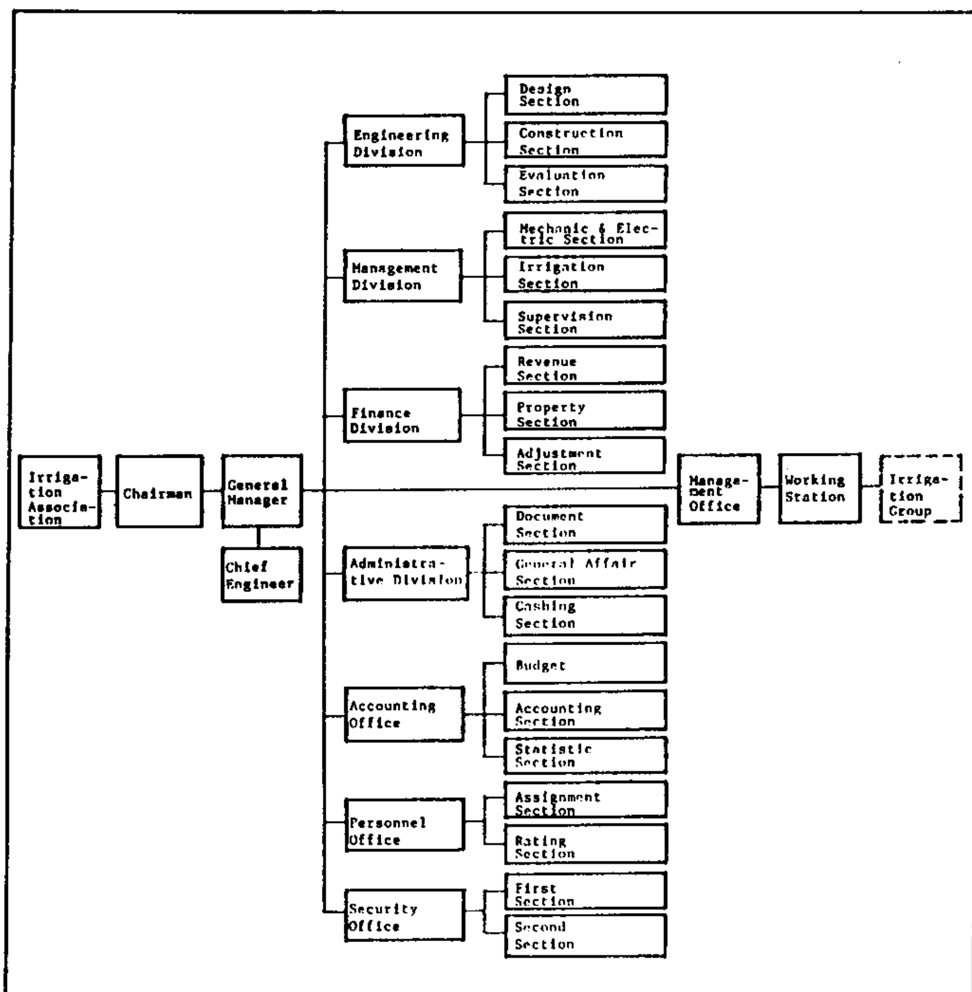
Final report of upland crop irrigation experiments at Hsue-chia Station, 1976

Experiments on different methods of sprinkler and drip irrigation have also been carried out. A simple low cost vinyl-perforated-pipe sprinkler irrigation method was recommended for practical application (Council of Agriculture 1982). For drainage especially in the rainy season, a method of crop production on raised beds with furrows has been developed.

IRRIGATION ASSOCIATIONS

Irrigation associations are corporate bodies organized by farmers to improve facilities, construct new irrigation works, and supply water to farm lands in their designated service areas. They also assist the government to plan and develop new large irrigation projects. At present, there are 17 irrigation associations; the largest is the Chianan Irrigation Association covering about 82,000 ha in the southern part of the island, and the smallest is the Liukung Irrigation Association covering only 279 ha. The organizational setup of a typical irrigation association is shown in Figure 7.

Figure 7. Organization chart of typical irrigation association.



The total service area of the 17 irrigation associations in 1985 was about 390,000 ha as shown in Table 18 (Taiwan Provincial Department of Agriculture and Forestry 1986).

Table 18. Service areas (ha) of irrigation associations, 1985.

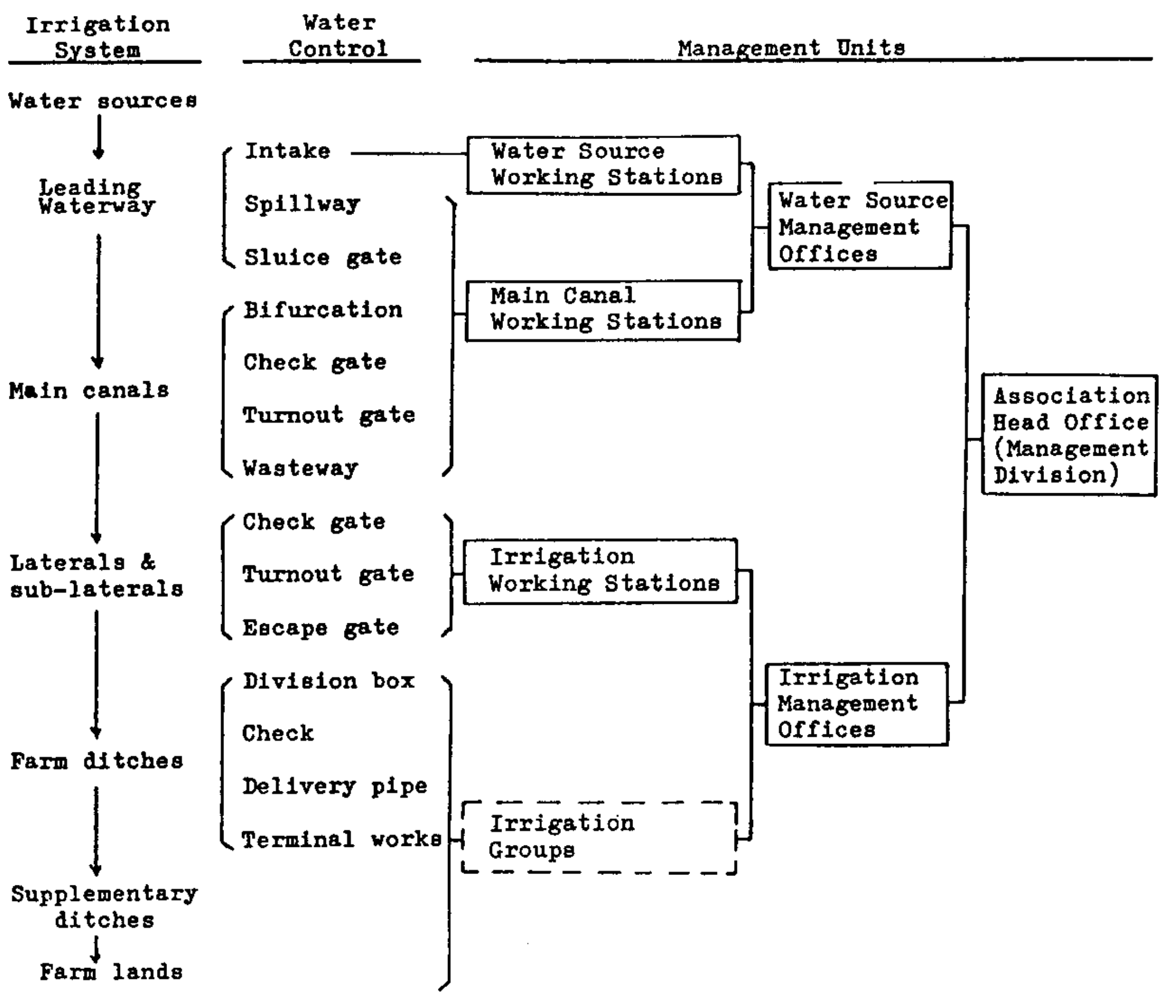
Irrigation association	Total	Double rice crop annually	Single rice crop annually	Cropping rotation	Dryland
Taiwan Province	383,908	255,831	27,036	84,115	16,926
Ilan	19,399	18,608	462	-	329
Peichi	5,457	4,498	959	-	-
Taoyuan	27,756	27,756	-	-	-
Shihmen	13,164	13,164	-	-	-
Hsinchu	7,086	7,086	-	-	-
Miaoli	10,007	9,870	-	-	137
Taichung	33,816	32,757	-	-	1,059
Nantou	12,688	11,509	1,179	-	-
Changhua	47,179	43,776	1,050	2,353	-
Yunlin	62,043	15,016	6,435	40,592	-
Chianan	81,523	24,666	9,867	38,496	8,494
Kaoshiung	19,470	11,938	3,927	2,674	931
Pingtung	21,880	14,257	2,238	-	5,385
Taitung	10,851	9,726	919	-	206
Hualien	11,589	11,204	-	-	385
Taipei City	1,515	1,346	-	-	169
Chihsin	1,236	1,236	-	-	-
Liukung	279	110	-	-	169
Total	385,423	164,852	19,944	79,088	12,318

Note: The above figures do not include about 31,500 ha of private canal systems and about 43,000 ha of the Taiwan Sugar Corporation's farmers. Taiwan Provincial Dept. of Agriculture and Forestry 1986.

Management System

The irrigation association has a management division at its head office to handle irrigation management policy, water planning, and statistical studies on water sources and irrigation requirements. In a typical irrigation association, the management division has local water source and regional irrigation management offices. The former may have some water source and main canal working stations for water control and supply; the latter has a number of irrigation working stations to operate and maintain the irrigation system. The water management system of a typical irrigation association is shown in Figure 8.

Figure 8. Management system of a typical irrigation association.



Remarks: In a small irrigation association there may be no water source management offices, and the irrigation working stations may take responsibility for the water source and main canal working stations.

Irrigation Group

The irrigation groups are organized by association members themselves on the basis of farm-level irrigation systems. A group covers an area of 50-150 ha and consists of several teams, each with 10-15 members who maintain irrigation and drainage ditches, distribute water, establish common seed-beds for members, and help the working station collect membership fees. The group has a chief and the team has a leader through election. They receive no salary. Group meetings are held to discuss irrigation plans at least twice a year with the farmers' association participating and the district agricultural improvement station providing technical guidance.

IRRIGATION OPERATION AND MAINTENANCE

Prior to the irrigation season, a guideline is worked out by the management division at the head office according to government policy, production targets, existing reservoir storage and water release, water flows, past irrigation requirements, canal conveyance losses, rotational intervals, and time of irrigation. These irrigation working stations conduct discussions with irrigation groups to work out detailed irrigation plans. The detailed plans prepared by working stations are submitted to the head office for review and compilation of an annual overall irrigation plan.

The approved water distribution plan has to be strictly carried out by the working stations. Stations are in charge of regulating and controlling water flows along the main canal, laterals, and sub-laterals. The irrigation supervisors are in charge of water control and measurement at turnout gates on laterals or sub-laterals, and of inspections on farm-level water distribution which are undertaken by irrigation groups. One irrigation supervisor usually takes care of 300-500 ha covering 6-10 rotation areas. Within a rotation area, one or two irrigators may be hired by the group to distribute water and maintain farm ditches. Measurement of water actually used in the system from source to individual farm turnout benefits future planning.

To ensure adequate service to farmers, irrigation and drainage systems must be maintained in good operating condition. In general, damage is due to flood and human destruction. The irrigation association pays more attention to maintenance than to construction, and to prevention than to repair. Routine patrolling and inspections are important. For instance, the canal operators frequently inspect headworks, main canals, laterals, sub-laterals, and related structures, and irrigation supervisors inspect turnout gates, farm ditches, checks, and division boxes originally built by the association. Maintenance and repair work may be classified as routine maintenance, annual maintenance, or emergency repairs. Routine maintenance covers minor repairs discovered by irrigation supervisors or group members during routine work. Annual maintenance check up is usually during the non-irrigation season.

IRRIGATION FINANCING

Collecting membership fees, financing projects, setting up the Joint Irrigation Fund and other revenues are important financing features of an irrigation association. The annual budget of an irrigation association is drawn up to meet administrative expenses, engineering construction, maintenance and damage repairs. The main revenue comes from membership fees, construction fees for particular engineering projects, and government subsidies.

Membership Fees

The annual revenue of an irrigation association mainly comes from membership fees which are collected in cash from the direct beneficiaries to cover operation and maintenance costs. Government has set up a maximum limit of monetary value equivalent to 300 kilograms (kg) and a minimum limit of 20 kg of rice per hectare per year.

Construction Fees

Construction fees are collected according to the capital cost, interest of each loan project, benefits obtained, and repayment ability of farmers. For improvement or new projects, the cost is financed partly by a grant and partly by a loan, either from government or monetary agencies. The proportion of grant to loan depends on the financial conditions of the association and the source of funds. The grant is usually 60-90 per cent of the total cost. The term varies from 3-10 years; interest is from 6-12 per cent per annum. Collection starts from the second year after the land is benefited.

Joint Irrigation Fund

Established for mutual cooperation among associations, its main source of money is the associations' yearly contribution. A goal of 500 million New Taiwan Dollars (approximately US$11 million) was achieved, and deposited in a special account from which loans are made at 6 per cent interest per annum for emergency projects, restoration projects, and project improvement.

Other Revenues

An association may also collect fees for leasing structures and supplying surplus water. New members in a new project or irrigation extension area as a result of improvement also pay for the engineering cost by proportion. Revenue and expenditure of 17 associations in 1985 is shown in Table 19.

Table 19. Total income and expenditure (in million New Taiwan dollars) of 17 irrigation associations in FY 1984 (NT$1.00 = US$36.60).

	Million NT$	Per cent
Total Income	3,841.47	100.00
Membership fee	1,806.27	47.02
Property income, use of structures and surplus water	295.05	7.68
Interest and rental	555.23	14.45
Property sale	750.18	19.53
Fines and compensation	4.41	0.12
Government subsidies, loan repayments and others	430.33	11.20
Total Expenditure	2,899.59	100.00
Engineering construction	763.14	26.32
Irrigation operations & maintenance	531.84	18.34
Salary and administrative expenses	1,427.11	49.22
Interest	.74	0.03
Property sale	51.37	1.77
Contribution	7.61	0.26
Others	117.79	4.06

Taiwan Joint Irrigation Association 1986.

CONCLUSIONS AND RECOMMENDATIONS

In monsoon Asia, geographical and climatic conditions profoundly influence agriculture. This influence on rice fields includes:

1. Rice fields are equipped with irrigation systems which usually have a long history of improvements with enormous investments (Kejuro Nagata 1984; Mao-Sen Chen 1976).

2. Because rice survives inundation for as long as three days, paddy fields regulate flood peaks of rivers with a large flood detention capacity perhaps several times more than the total flood storage capacity of the existing reservoirs (Ibid.; Toshio Yahata 1984; L.J. Wen 1981c).

3. Paddy fields have the function of groundwater recharge which is important especially in coastal areas where withdrawal of groundwater causes land subsidence (Mao-Sen Chen 1976; Toshio Yahata 1984).

4. Paddy fields protect the environment. They conserve soil and water, and chemically maintain the productivity of land (ibid.).

Many factors have led to a shift away from rice: increasing yields and cultivated area of rice, decreasing consumption due to changes in market demand for farm products at home and abroad, and a surplus rice production across Asia with a consequent decline in rice prices. Farmers seek to diversify their production and income sources. But they face problems in growing non-rice crops on irrigated paddies essentially used for rice production.

Farm improvement has to be carried out continuously for production of diversified crops in paddy fields. It includes not only irrigation and drainage engineering works but soil and water management. Modernized farm improvement work has the following prerequisites (L.J. Wen 1981c):

1. Farm land with high productivity for growing rice and other crops. Land with high productivity or high yield per unit area must be in good condition for plant growth. It must be favorable for plant root systems and photosynthesis with the following conditions.

2. Guarantee of adequate and timely irrigation and water management. Rice cultivation permits continuous irrigation with water flowing from parcel to parcel in paddy fields. This method is not applicable to diversified cropping. The density of farm irrigation supply ditches must be increased to a certain extent. Pipe irrigation may be ideal but expensive both in initial and operational costs. It is suggested that irrigation systems at farm level be improved through rotational irrigation and land consolidation.

3. Soil management and improvement. Physical properties such as depth of soil layers, texture, permeability, porosity and water holding capacity, and chemical properties such as pH values and fertilities are closely related. For instance, soils may be improved by mixing rice husks or chemical compounds or others for different purposes.

4. Good surface and subsurface drainage for free conversion from rice to other crops and vice versa. Drainage is even more important than irrigation for diversified cropping in paddy fields, especially in low areas and in wet seasons. Drainage systems must be separated from irrigation ones. Because subsurface drainage with tile drains is expensive, surface drainage with open ditches must be tried first, incorporating cultural practices such as raised beds with furrows. If subsurface drainage is required, rice husks may be used for tile drains. This is inexpensive and applicable in many places.

5. Facilitating farm operations. Farm operations including field water applications and cultural practices for diversified cropping need more labor than rice farming. High working efficiency of mechanized group farming is required for diversified cropping to reduce farming costs, especially when labor is short. Paddy fields should be improved for farm mechanization with tractors, power tillers, high pressure sprayers, harvesters, and portable irrigation pumps. The following should be kept in mind: a) Land readjustments must make farm parcels as large as possible for joint farming and, if necessary, irregular foot paths must be removed; b) farm roads, supply ditches, and drainage ditches must be properly located to enable efficiency in mechanized farming and water management; c) farm roads must be sufficiently wide and in good condition for transportation of farm products, machines and other materials; d) the length and the width of each farm parcel must be suitable not only for irrigation application but for machine operations; e) soils must have sufficient depths and good drainage conditions for plant growth and machine operations; and f) land and farm road slopes must be improved for transportation of farm machines, especially in hillside farming.

6. Productivity must be stabilized. Special attention must be given to: a) Flood and erosion control (river levees, sea dikes, and regional drainage systems should be properly improved and maintained); b) wind erosion control (windbreaks are necessary especially in coastal areas where monsoon winds are strong); c) strict control on withdrawal of groundwater is necessary to prevent subsidence, especially in coastal areas; d) watershed management and soil conservation are also important in protecting farmlands from being eroded or buried; and e) strict control of air and water pollution is necessary to protecting precious soils and irrigation water.

In addition to these farm improvements, researches and experiments on adaptability of crops, crops improvement, optimal cropping patterns, crop water requirements, irrigation methods, improvement of farm machines as well as low-cost farming practices have to be conducted. Studies on stabilizing prices of crops, production and marketing plans, strengthening farmers' organizations, and farmer incentives are also a pre-requisite to increasing production (Kunio Takase 1973).

In conclusion, the writer cites some research suggestions of Lee, which although made in 1975 are still considered important:

1. To understand differences between types of products and between technological characteristics in the land use of crops, a farm economy survey and research should be carried out on climate and soil requirements and on the input-output relationship of the grain and non-grain crops and livestock.

2. Long-term projections for national food consumption are needed to understand the variety and future pattern of crops and livestock requirements. This study will throw light on the economic considerations of an efficient cropping system.

3. The farmers' response to price changes affecting non-grain crops should be surveyed. This will clarify the feasibility of resource allocation.

4. Research on the domestic and regional production of crops and livestock should be undertaken from the viewpoint of comparative economic advantage.

5. Farmers' organizations for extending new technology, breeding new varieties, and for protecting from natural risks will be important for promoting agricultural diversification. Analysis of the impact of farmers' organizations will also be useful.

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