

# Irrigation Management in Taiwan

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## ABSTRACT

TAIWAN IS LOCATED at the tropic-subtropic zone and crops can be grown throughout the year. Because of a lot of rainfall and uneven distribution, water inundation and drought disasters happen very often and, therefore, irrigation and drainage works are very important in this area. There are seventeen irrigation associations which are organized by farmers themselves in every district in Taiwan; the total area is about  $40 \times 10^4$  ha; the associations carry out the irrigation and drainage works very carefully, but the irrigation and drainage structures are constructed by the government. The business of the associations includes water distribution to the fields, operation and maintenance of irrigation and drainage systems, water resources control, construction of small structures, etc. In order to develop modern technology on management, computerization, remote control, remote sensing and geographic information systems will be used gradually.

## NATURAL ENVIRONMENT WATER RESOURCES AND CROPPING PATTERN IN TAIWAN

### Topography and Rainfall

Taiwan is a long and narrow island, 394 km from south to north and 144 km from east to west, and the total area is about 36,000 km<sup>2</sup>. The Central Mountain runs from north to south and separates the island into eastern and western parts. The highest elevation is about 3,900 m above sea level. The mountain area where the elevation is higher than 1,000 m is about 31.3 percent, the elevation from 1,000 m to 100 m is about 37.2 percent and the area lower than 100 m is about 31.5 percent. There is not much cultivated area in Taiwan (Figure 1). Most rivers in Taiwan, which originated from the Central Mountain, are short and steep. Yearly rainfall is about 2,515 mm with high intensity. Soil erosion is very serious because of a short geologic era. The rainfall distribution is 4,000-5,000 mm in the mountain area and 1,500-2,000 mm in the plains, the percentages of the precipitant are, respectively, 62, 78, 90 in the northern, middle, and southern parts of Taiwan. Most precipitation occurs from May to October (Figure 1).

### Quantity of Runoff Water Resources

There are 21 main, 27 secondary and 81 small rivers in Taiwan. The largest one is the Gao-ping River which is located in the southern part of Taiwan having a drainage area of about 3,275 km<sup>2</sup>. The second one is the Tai-shui River which is located in the northern part of Taiwan, with a drainage area of 2,726 km<sup>2</sup>. The highest discharges in rivers occur in the typhoon season from May to October and the discharges are very small during the drought period from November to April. The average yearly amount of runoff is about  $668 \times 10^8$  m<sup>3</sup> [and only] about 77 percent is utilized in the rainy season and 23 percent in the draught reason. The lowest runoff is only  $340 \times 10^8$  m (Table 1). The flood and drought disasters occur very often, for example, the drought seasons of 1988, 1989, 1993 and 1994 occurred resulting in a serious shortage of water for irrigation and domestic use.

### Reservoir and Groundwater Resources

All 34 reservoirs having a total capacity of  $18 \times 10^9$  m<sup>3</sup> are located in the western part of Taiwan. Yearly utilized water from  $30 \times 10^8$  to  $50 \times 10^8$  m<sup>3</sup> depends on the yearly available water sources. Underground water sources were pumped to compensate for the deficit in surface water sources. The pumped underground water was about  $71 \times 10^8$  m<sup>3</sup> in 1992, but the recharge water was only about  $40 \times 10^8$  m<sup>3</sup> in one year (Table 2). It could be said that the underground water was overpumped, especially in the middle and southern parts of Taiwan, which is shown in Figure 2.

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## Briefing on Agricultural Management in Taiwan

Taiwan is located in the sub-tropical zone where crops can be cultivated throughout the year. The main crop is rice. Since 1960, the demand for foodstuffs has increased rapidly. In order to decrease foreign exchange, the cultivation policy of reducing the rice area and raising the upland crop cultivation was carried out. There has not been any irrigation on upland crops before. Now we have to irrigate upland crops for increasing production. Eight experimental stations of upland crop irrigation were established in 1961, and a lot of experimental data has been collected. And now we are extending upland crop irrigation. There are five crop patterns:

1. Spring rice is cultivated from February to June and autumn rice from July to November which is the traditional cropping pattern found in the middle and northern parts of Taiwan because there is enough water for irrigation.
2. Spring or autumn rice is cultivated once a year in the southeastern part of Taiwan. As there is not enough water to irrigate rice upland crops are cultivated during the rest of the year.
3. Rice twice in three years in the southern part of Taiwan because of lack of water for rice irrigation. The cropping pattern within three years is:  
Sugarcane -- upland crops -- rice -- upland crop -- rice.
4. Rice once within the three years in the same area of item 3 above. The pattern within three years is  
Upland crops -- upland crops or green manure -- rice -- upland crops.
5. A sugar company grows sugarcane throughout the year in the southeastern part of Taiwan with an area about 47,000 ha.

The agricultural structure in Taiwan is as shown in Table 3. The most developed agriculture is in the middle and southern parts of Taiwan [with 76 percent of all]. [From 1985 to 1993 it was decreased 15,610 ha agricultural area and 182,875 persons.] Because of agricultural policy, the area of rice has decreased to 2.1 percent from 1985 to 1993. [From the point of view, the irrigation area have been increased 21,980 ha because of developed upland crops.] There were 121,465 ha of rice area which was changed to plant vegetables, green manure, corn, etc., with 2,189, 10,719, 24,617 ha, respectively. See details in Table 3.

### Planning of Water Resources Development in Taiwan in the Future

It was estimated that in 2001 we need  $150 \times 10^8 \text{ m}^3$  water for agricultural use,  $32 \times 10^8 \text{ m}^3$  for industry and  $23 \times 10^8 \text{ m}^3$  for water supply. The total water resources is about 73 percent of  $213 \times 10^8 \text{ m}^3$  in 2011, expect [keeping] water for agriculture to  $150 \times 10^8 \text{ m}^3$  70 percent, water for industry and domestic use to  $38 \times 10^8 \text{ m}^3$  18 percent,  $25 \times 10^8 \text{ m}^3$  12 percent, respectively. From the present to 2001, the total need of water will increase to  $10 \times 10^8 \text{ m}^3$ , water for industry and domestic use will increase to  $6 \times 10^8 \text{ m}^3$  and  $8 \times 10^8 \text{ m}^3$ , respectively, but water for agriculture will be reduced to  $4 \times 10^8 \text{ m}^3$ . From 2001 to 2011 the total need of water will increase to  $18 \times 10^8 \text{ m}^3$ , water for industry and domestic use will increase to  $8 \times 10^8 \text{ m}^3$  and  $18 \times 10^8 \text{ m}^3$ , respectively, but agriculture water still was  $150 \times 10^8 \text{ m}^3$ . It will build new reservoirs in the future for the shortage of water mentioned above. See details in Table 4.

### ADMINISTRATION OF WATER CONSERVANCY SYSTEM TO RELATE TO AGRICULTURAL WATER CONSERVANCY

The highest water conservancy office is the Ministry of Economics, Executive Yuan. It is divided into two parts as the Water Conservancy Department (WCD) and the Water Resources Planning Commission (WRPC). WCD is for the administration phase, and WRPC carries out the technical phase of water conservancy. Responsibility for agricultural water use rests with the Agriculture Commission, Executive Yuan, for domestic water supply with the Ministry of Interior, Executive Yuan and for industrial water use with the Industry Bureau, Ministry of Economics. The Department of Environment, Executive Yuan is also related to water conservancy in Taiwan. The relations between the offices are shown in Table 5.

The Water Conservancy Bureau (WCB) belongs to the Reconstruction Department in Province; water construction works are carried by the bureau in province, but some works are carried by County and City. Agriculture water

management is carried out by the Irrigation Associations which are organized by the farmers and supervised by the WCB; the details are shown in Table 5.

## **ORGANIZATION OF THE IRRIGATION ASSOCIATION IN TAIWAN**

The Irrigation Association (IA) is organized by farmers themselves and supervised by the WCB. There are seventeen IAs in Taiwan. The farmers selected the representatives and the representatives voted the chairman of the IA. There are 950,340 members of IA with 403,395 ha irrigation area (Figure 2). The service members, staff, etc., of each association are shown in Table 6. The largest IA is Chia-nan Irrigation Association. Irrigation area is about 78,926 ha. One General Manager and one Chief Engineer work under the Chairman. The association has many divisions such as engineering, management and finance division, etc. There are many local irrigation offices under the General Manager and many work stations under each local irrigation office. Four kinds of working stations are established such as water source station, main canal station, forest station and irrigation station. Take Chia-nan Irrigation Association as example: there are 57 work stations, 672 irrigation groups under stations and 5,373 work teams under an irrigation group. There are 198,438 members in the association. The organization of irrigation and drainage systems of Chia-nan Irrigation Association is shown in Figures 3 and 4.

## **TECHNICAL DEVELOPMENT IN AGRICULTURAL IRRIGATION MANAGEMENT**

The main works of the IA are operation and maintenance of irrigation and drainage systems. Earlier, the works in the service area were done with manpower. It had no efficiency to manage the whole system and could not apply the new technology to maintain the systems. Neither was it able to do the complicated works of the staff. Therefore, the university professors and researchers aided them to make technical works and trained the staff. The funds are supported by the National Science Council (NSC), Agriculture Commission, WCB, etc. Most of the projects were taken over by the Agricultural Research Center. In order to make some field experiments, the Hsueh-chia Experimental Station in Chia-nan Irrigation Association and the Chi-ting Irrigation Equipment Test Station in Water Conservancy Bureau were established. Many projects on new technology for irrigation management were completed in the past twenty years. The projects are described below:

### **Upland Crop Irrigation Experiments and Extension Projects**

There has been no irrigation on upland crops in past years. Since the demand of foodstuffs has increased very much, upland cropping has been raised gradually in order to increase the production of foodstuffs. Because of the importance of irrigating upland crops, nine upland crop experimental stations were established. In the beginning, basic data of upland crops such as soil texture, physical and chemical properties of soils, conveyance losses in channels, consumptive use of crops, effective rainfall, irrigation efficiency, etc., were collected. Then the association staff were trained to do extension work. The teaching materials included basic field information, water measurements, irrigation methods and knowledge of maintenance of the irrigation system. At the end of 1992, the training work on surface and sprinkler irrigation was completed. Training farmers for extension was continued from 1993.

In order to extend sprinkler and drop irrigation completely, we need some equipment, such as power unit, pump, pipe line, etc. The government supplies 49 percent of the fund for setting up the irrigation system. There [extended] about 4,000 ha area with 6,157 families; 12,533 farmers were taught to operate and maintain the fields from [1983] to 1993.

### **Computerization in Irrigation Associations**

The computer is a very important tool to manage irrigation and drainage systems. It can save manpower and can be operated with high efficiency; it can be used in computing irrigation water distribution, management in canal systems, irrigation fee collection, data analysis, etc. [There are 35 projects to study computer application in the irrigation associations in Taiwan until 1993. Twenty-two projects were studied the application and thirteen were trained the staff of the irrigation association for computer application.]

### **Automatic Control in Irrigation**

Industry has developed rapidly in recent years. It may change the agriculture-oriented society into an industrial society. Water has to be shared among the three purposes: domestic, industrial and agricultural uses. Therefore, there will be

not enough water for irrigation, especially in the drought period. The problem of resulting quarrels cannot be solved except by measuring exact discharges in canals. So, the remote control method was used. Automatic control of the discharge in irrigation canals [since 1970], and 24 projects have been done before 1993.

### **Remote Sensing Used for Planning in Irrigation Systems**

To utilize land reasonably, factors influencing environmental impact, such as irrigation water adaptation, water quality, soil erosion, animal settlements, environmental change, climatic changes and human power have to be considered. It may be more convenient to collect the data, if we utilize remote sensing technics in the irrigation service area. [There have been sixteen projects planning agriculture land in irrigation associations since 1989.]

### **Application of Geographical Information System**

The technology of the Geographical Information System (GIS) has been used in broad fields in recent years. With the powerful computer capability and huge database this method is excellent for estimating management and for decision making. Before computerization of data analysis in irrigation associations map data were still processed by hand and these map data comprised the most work in irrigation associations, such as land maps, service area maps, etc. Only three projects have been done through GIS before 1993:

1. Study on the order of irrigation in drought periods by GIS.
2. Assist to make a decision on strategy of irrigation management.
3. Study on application of GIS to the service area management.

### **CONCLUSION**

Although yearly rainfall is as high as 2,500 mm in Taiwan it is distributed unevenly. Meanwhile it has steep river slopes. So the utilized runoff water was only 21 percent. Eighty percent of the water resources was for agricultural use. Water used in agriculture was reduced to 70 percent of the total water resources. Irrigation water is managed by farmers themselves. They organized irrigation associations to carry out operation and maintenance in their irrigation and drainage systems. The fund is supported by the government which helps the farmers to supply water to their fields. Irrigation associations are applying modern technology helped by professors and researchers for water management purposes, such as upland crop irrigation, computerization, remote control discharge in irrigation systems, remote sensing used planning irrigation projects, GIS application, etc. But the irrigation associations have a high priority in saving water used in agriculture in the future, especially after carrying out the "General Agreement on Tariffs and Trade." The type of agriculture development will be reformed and the irrigation system and type of water use will be changed.

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Figure 1. Yearly Isohyetel Lines in Taiwan.

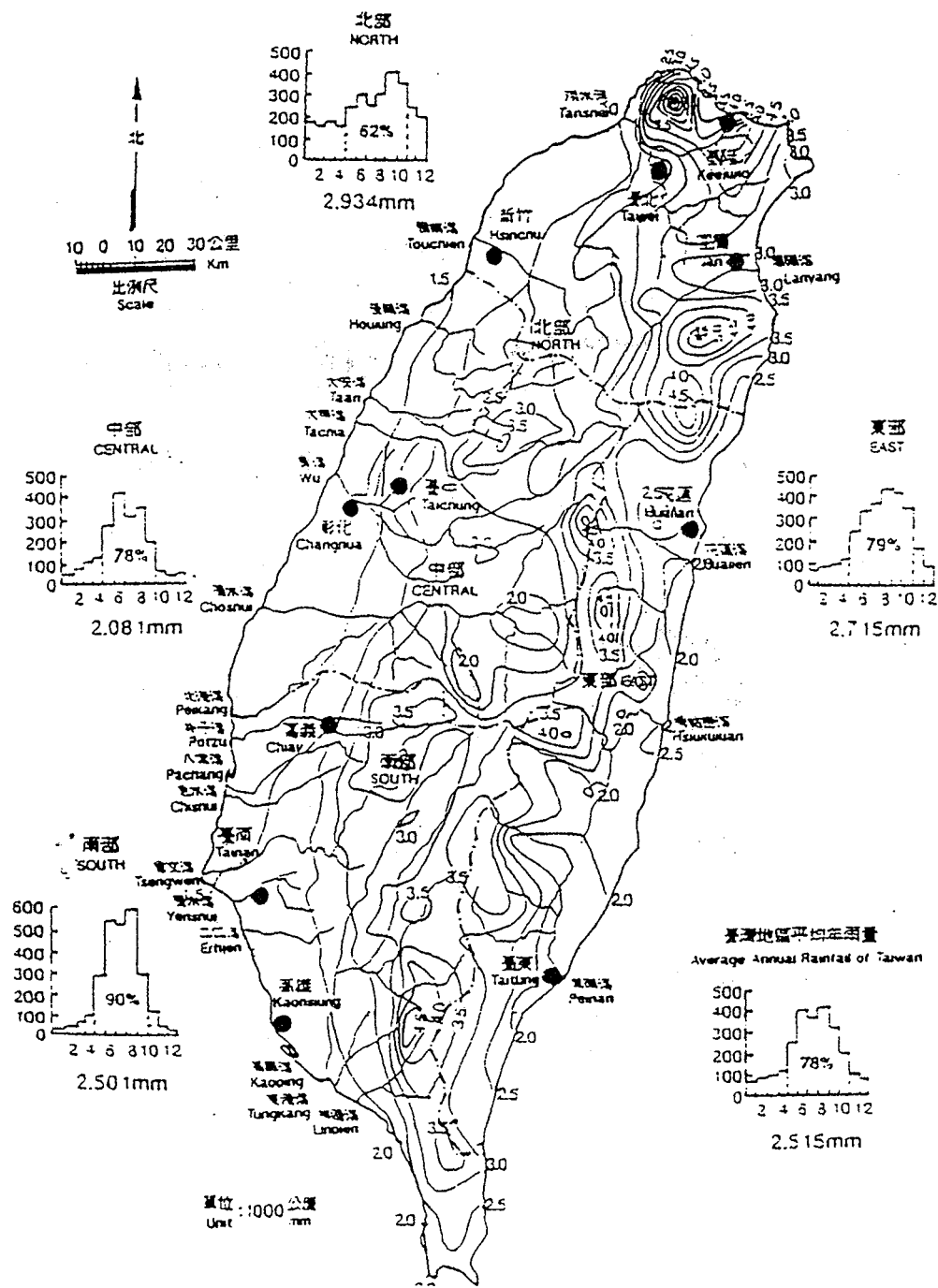


Figure 2. Distribution of Irrigation Associations in Taiwan.

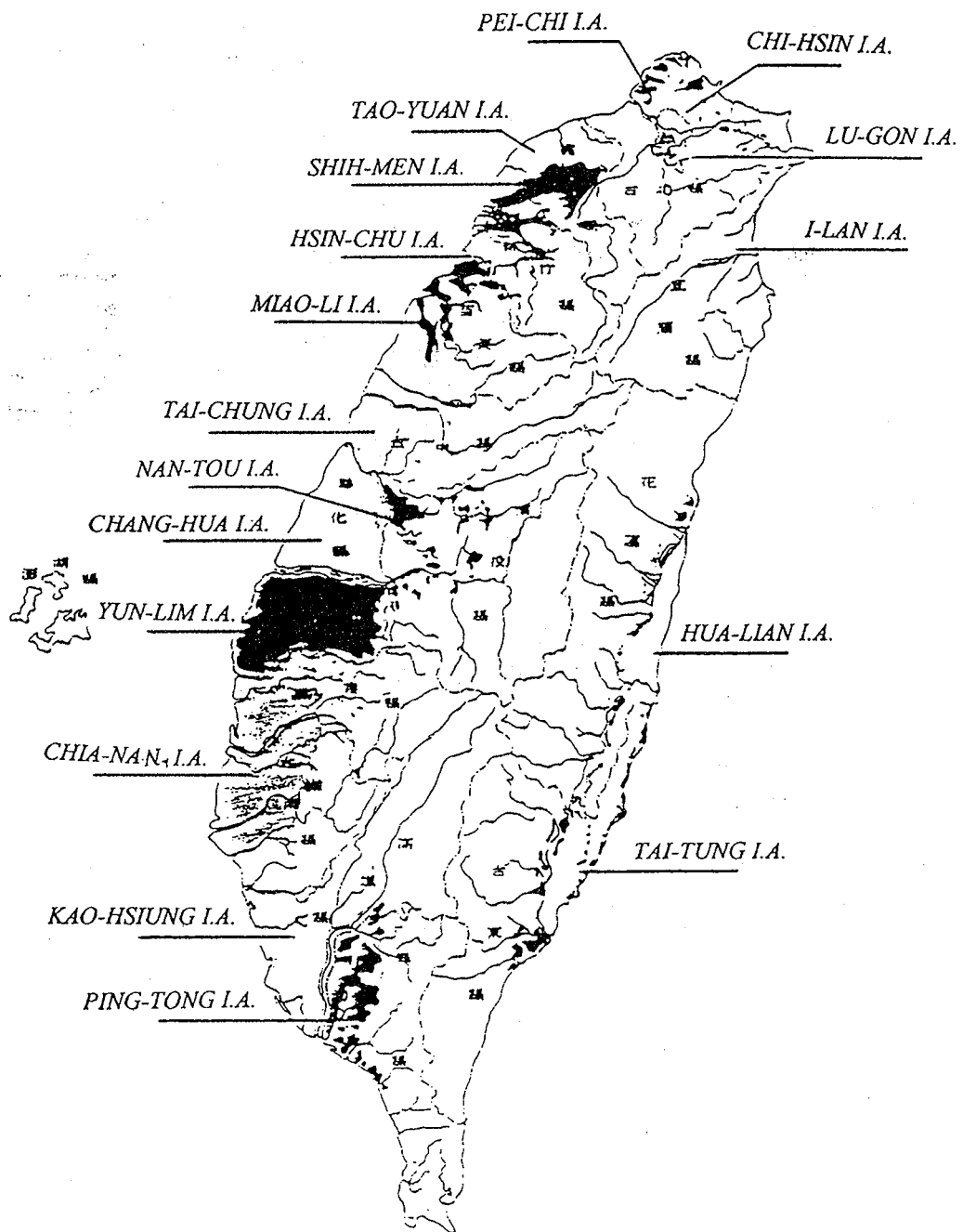


Figure 3. Irrigation Management in Chia-Nan Irrigation Association.

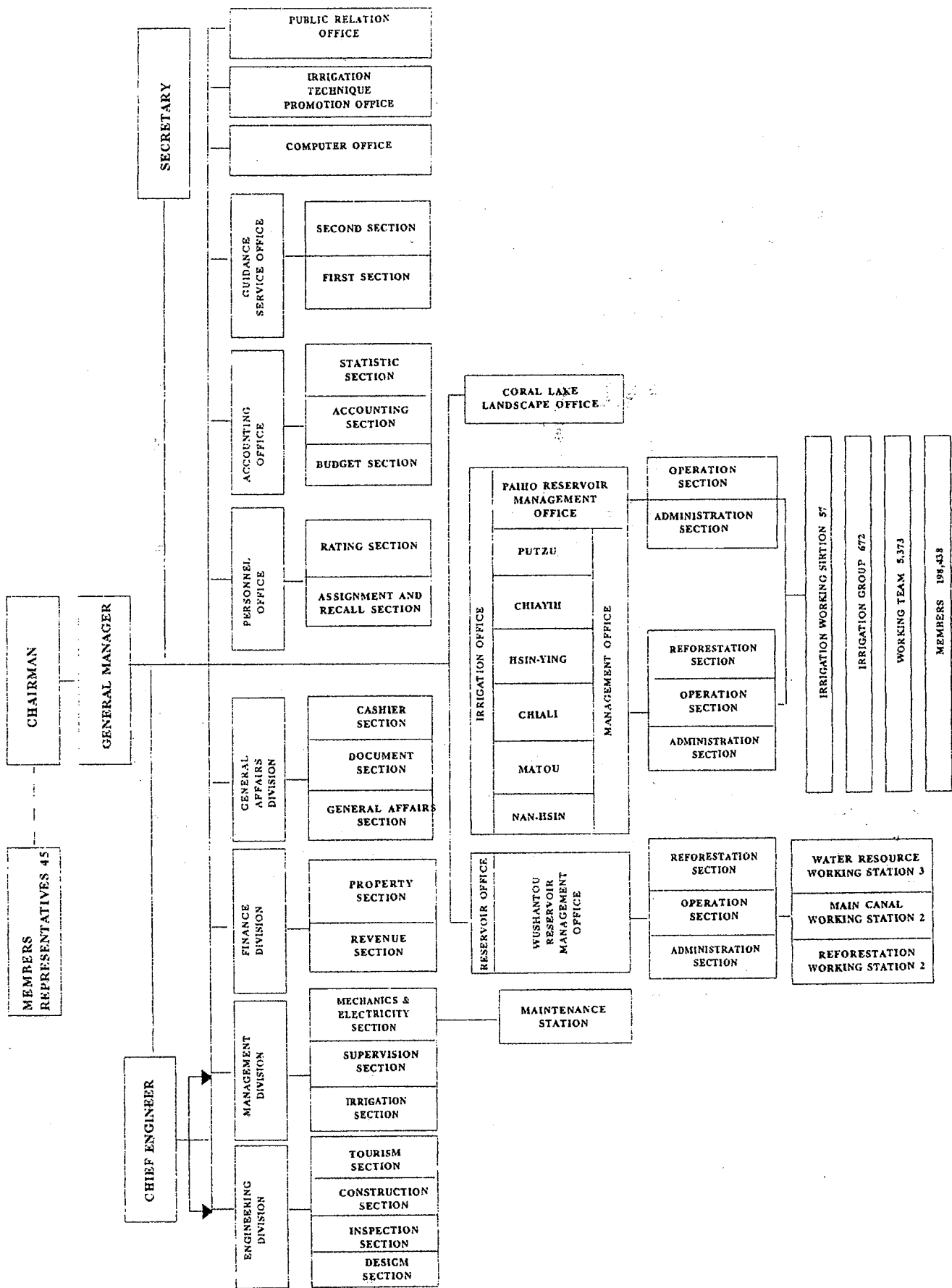






Table 1. Estimation of Surface Water Resources in Taiwan.

units:  $10^8$  m<sup>3</sup>, percent

District	Area km <sup>2</sup>	average			run off (1)		lowest yearly charge(2)	Average (3)	Lower (4)	Lowest (5)
		largest	lowest	yearly	lowest	yearly				
Northern part	7347(20)	10099(63)	6052(37)	16151(100)		9,259	7,305	4,986	3,093	
Middle part	10507(29)	13273(73)	3707(22)	16980(100)		9,704	6,858	5,019	3,572	
Southern part	10004(23)	15574(91)	1609(9)	17179(100)		6,623	3,260	1,920	1,317	
Eastern part	3144(23)	12452(76)	4010(24)	16462(100)		8,495	6,681	5,682	3,883	
Total	36002(100)	51398(77)	15374(23)	66772(100)		34,081	24,104	17,607	11,865	

(1) Average from 1949 to 1990

(2) Lowest discharge: In the district eastern part and I-Lang in 1963, Northern Part in 1954, middle and southern parts in 1980.  
(3), (4) & (5) Over 50 percent, 75 percent and 95 percent Yearly discharge, respectively.

TABLE 2. ESTIMATION OF UNDER-GROUND WATER RESOURCES III (AIWAII).

District	Area km <sup>2</sup>	Location	Area km <sup>2</sup>	%	Recharge by rainfall (10 <sup>8</sup> m <sup>3</sup> )	Pumped in 1992 (10 <sup>8</sup> m <sup>3</sup> )	Remark
Northern part	7,347	Taipei basin, Taoyuan, Chungli table land, Hsinchu along the sea and Lanyang plain	2,410	32.8	4.72	5.37	Land subsidence Taipei basin because of overpumping was happened
Middle part	10,507	Miaoli along the sea, Taichung district and alluvial far along Choshui chi	3,340	31.79	16.14	25.92	
Southern part	10,004	Chanan plain, Pingtung plain	3,650	36.59	16.64	37.97	Land subsidence along the sea
Eastern part	8,144	Hualian, Taitung valley and plain	930	11.42	2.5	2.13	
Total	36,002	9 districts	10,330	28.69	40	71.39	

Table 3. Basic data of agricultural management in Taiwan.

Item	Taipei district	Hsinchu district	Taichung district	Tainan district	Kaohsiung district	Eastern district	Total or average	Difference (1993-1985)
Country or City	Ilan Taipei Keelung	Tao Yuan Hsin-chu Hiao li	Chang-hua Taichung Nan-tou	Yun-Lin Chiayi Tainan	Kaohsiung Pinglung	Hua-lien Taitung		
Total land area (km <sup>3</sup> )	4595	4573	7396	5444	5733	8144	35885	+11.8
Cultivated area (ha)	68768	115222	194845	269731	130225	91587	870378	-15610
Index of cultivated area (96)	15	25	26	50	23	11	25	-0.5
Farmer's family	69537	97554	222349	240667	123455	40133	793695	-3469
Agricultural population	378408	526066	1194437	1086041	670238	204882	4060072	-182875
Agricultural population per ha	5.5	4.6	6.1	4	5.1	2.2	4.58	+0.02
Average cultivated area per family (ha)	0.99	1.18	0.88	1.12	1.05	2.28	1.25	0
Area of paddy rice (96)	52	65	52	62	46	30	51.2	-2.1
Area of upland crop (96)	48	35	48	38	54	70	48.8	+2.1
Double paddy rice field (96)	90	99	96	30	81	96	82	+0.7
Single paddy rice field (96)	10	1	4	70	19	4	18	-0.7
Irrigation by Irrigation association (ha)	24852	93572	89931	139426	39660	22758	410199	+21980
Irrigation by Irrigation association (96)	36.1	81.2	46.2	51.7	30.5	24.8	45.1	+5.1
Paddy rice	35814	74622	100787	166648	60066	27.079	465016	-121465
Vegetable	34255	11788	66828	82544	31500	7499	234414	+2189
Sweet potato	1253	1947	2513	3879	1915	404	11911	-15056
Tee tree	5323	7274	6549	2124	188	1124	22582	-6202
Orange	8	19	4	1	---	4	36	-9257
Peanut	438	592	5101	27478	831	1179	35619	-15038
Green manure	2067	2013	1190	12956	2070	4202	24498	+10719
Citronella	---	---	---	---	---	---	---	-270
Water melon	382	2409	4458	10548	1229	1940	20966	-1807
Wheat	---	---	1402	---	---	---	1402	+385
Sugar cane	---	169	6912	33476	15455	6331	62343	-19479
Cassava	---	15	2	120	460	9	606	+606
Rape	1326	180	501	1734	19	1397	5157	+3655
Flax	---	---	---	---	---	---	---	-2741
Tobacco	---	---	2174	1958	2643	297	7072	-2003
Mushroom	---	69	275	537	59	---	940	+940
Soybean	4	---	46	3765	206	174	4195	-1340
Com	89	1277	5622	52239	4479	13442	77148	+24617
Green bean	---	15	---	557	4	8	584	-571
Peppermint	---	---	---	---	---	---	---	0
Red bean	---	---	8	37	5401	7	5453	-8878
Kenaf	---	---	---	---	---	---	---	0
Banana	25	52	4372	608	5202	245	10504	-139192
Pineapple	15	26	1338	2836	3923	213	8352	-220707
Mulberry	---	46	---	6	13	149	214	-816
Licorice	---	---	---	---	---	---	---	0
Harron	---	---	---	---	---	---	---	0

Source: "Taiwan Agricultural Yearbook (1993 Edition)"

Table 4. Estimation of Water Requirement in each Purpose Use of Water in Taiwan.

Units:  $10^8$  m<sup>3</sup>, %

Year		1981	1990	2001	2011
Water Used for Agriculture	Irrigation	137(37)	121(62)	127(62)	127(60)
	Aquaculture	21(11)	32(16)	22(10)	22(10)
	Animal Husbandry	0.8(37)	1.1(1)	1.4(1)	1.4(1)
	Sub-total	159(85)	154(79)	150(73)	150(70)
Domestic use of water	Public water supply	11(6)	21(11)	30(15)	36(17)
	Private water	3(1)	3(1)	2(1)	2(1)
	Sub-total	14(7)	24(12)	32(16)	38(18)
Industry	Use of water	15(8)	17(9)	23(11)	25(12)
Total		188(100)	195(100)	205(100)	213(100)

Table 5. Main Office and Business Unit of Management on Water Resources.

Functions	Main Office			Business Unit
	Central	Province	Country	
Flood control	Ministry of Economy	Water Conservancy	Water Conservancy Section	--
Tide protection	Ministry of Economy	Water Conservancy	--	--
Regional drainage	Ministry of Economy	Water Conservancy	Water Conservancy Section	--
Reservoir	Ministry of Economy	Water Conservancy	--	Irrigation Association Domestic Water Co.
Water power	Ministry of Economy	--	--	Electric Power Co.
Irrigation	Agriculture Commission	Water Conservancy	Water Conservancy Section	Irrigation Association
Farm drainage	Agriculture Commission	Water Conservancy	Water Conservancy Section	Irrigation Association
City drainage	Ministry of Interior	Residence Bureau	Water Conservancy Section	--
Water supply	Ministry of Interior	Department of Reconstruction	Water Conservancy Section	Domestic Water Co.
Soil erosion	Agriculture Commission	Water Conservancy	Water Conservancy Section	--

Table 6. Irrigation Area and the Number of Members, Staff and Working Station of Irrigation Association in Taiwan.

Item Association	Irrigation Area (ha)	Service district	Staff	Members	Teams	Irrigation groups	Working station	Staff in working station
Two years before	404,517		3,338	950,334	14,123	3,551	261	3,393
One year before	390,577		3,240	943,817	14,126	3,551	264	3,223
Total	403,395		3,153	963,206	13,350	3,525	292	1,331
Taiwan	401,888		3,086	959,543	13,329	3,492	290	1,326
Province	19,069	I-Lan County	126	50,779	502	186	10	56
I-Lan	5,416	Taipei County, Chi-Lung City	32	11,040	353	59	4	13
Pei-Chi	26,083	Taipei County, Tao-Yuan County	209	51,924	2,138	339	13	0
Taur-Yuan	25,648	Taipei, Tao-Yuan, Hsin-Chu County	99	22,781	366	110	7	42
Shih-Men	6,752	Hsin-Chu City, Chu-Pei City, Gon-Lin, Heng-Sang Town, Hsin-Pu, Kong-Si, Chu-Tung Town	56	21,334	120	102	4	22
Hsin-Chu								
Miao-Li	10,059	Miao-Li County, Hsin-Chu County, Hsin-Chu City	86	30,040	602	119	10	39
Tai-Chung	33,022	Miao-Li County, Tai-Chung County, Tai-Chung City	241	90,717	1,071	320	23	127
Nan-Tou	12,577	Nan-Tou County, Tai-Chung County, Chang-Hua County	100	38,625	475	122	9	58
Chang-Hua	46,198	Chang-Hua County, Nan-Tao City, Min-Gin Town	330	143,796	1,290	414	32	182
Yun-Lin	66,384	Yun-Lin, Chia-I, Nan-Tou	546	175,339	1,592	500	54	0
Chia-Nan	78,926	Chia-I, Tai-Nan County and City	658	176,720	2,007	682	73	464
Kou-Hsing	20,186	27 towns in Kao-Hsiung County, City District North to Tainan County ER-Jen Chi east to Ping-Tung County	213	49,653	388	146	16	123
Ping-Tung	25,606	South-Western sea side	224	59,958	1,089	202	18	111
Tai-Tung	13,505	Ping-Tung County	92	17,270	897	110	9	51
Hua-Lian	12,457	Tai-Tung County	74	19,572	439	81	8	38
Taipei City	1,507	Hua-Lian County	67	3,663	21	33	2	5
Chi-Hsin	1,025	Shih-lin, pei-tou, nia-hu, nan-kang, shih-chih Taipei City, Suang Sang, Ta-Shih, Chung-Shang, Wen-Shang Districts and Part of Shih-Lin District and Taipei County, Shih-Tin City.	33	2,445	0	20	0	0
LU-Gon	482		34	1,218	21			