RESPONSIVE STRATEGIES OF AGRICULTURAL WATER SECTOR IN TAIWAN

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ABSTRACT

In addition to increasingly frequent water shortage problems, agricultural water sector is also challenged by environmental issues. The objective of this article is to summarize, as well as propose sustainable strategies for agricultural sector in response to current environmental challenges.

For water shortage problems, which are becoming more and more frequent worldwide including Taiwan, measures for irrigation water, such as extending irrigation periods, decreasing number of irrigation application times, or rotational irrigation, are introduced and discussed. When borrowing or transfer of water among sectors is needed in Taiwan, it is usually from agricultural irrigation water to other sectors in almost all cases. The maintenance of water right, and compensation to farmers for their income loss, are the two major issues. As for environmental changes, the impact of the accession of Taiwan to WTO (World Trade Organization) is discussed specifically in this article, and a management scheme in order to save irrigation water, which could be used for other purposes, is suggested in this article.

FOREWORD

In addition to increasingly frequent water shortage problems, the agricultural water sector is also challenged by environmental issues. In this article, "environment" doesn't only mean natural environment, but also includes political, policy, economical, technological, and societal, etc. The objective of this article is to summarize, as well as propose, sustainable strategies for the agricultural sector in response to current environmental challenges. As a result, three issues will be discussed in this article: 1)water shortage issue, 2)water transfer issue, and 3)the accession of Taiwan to WTO (World Trade Organization) issue.

WATER RESOURCES IN TAIWAN

The average annual rainfall in Taiwan is 2,515 mm, and the total volume reaches 90.5 billion m^3,

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which is approximately 2.7 times of the world average. Although the amount of rainfall sounds plenty, the water resources management is tough as the annual allocated water per capita is only around 1/8 of the world average. In addition, due to the uneven distribution both temporally as well as spatially, the overall summer wet season accounts for 78% of rainfall (nearly 90% on the most severe southern Taiwan) as seen in Figure 1.

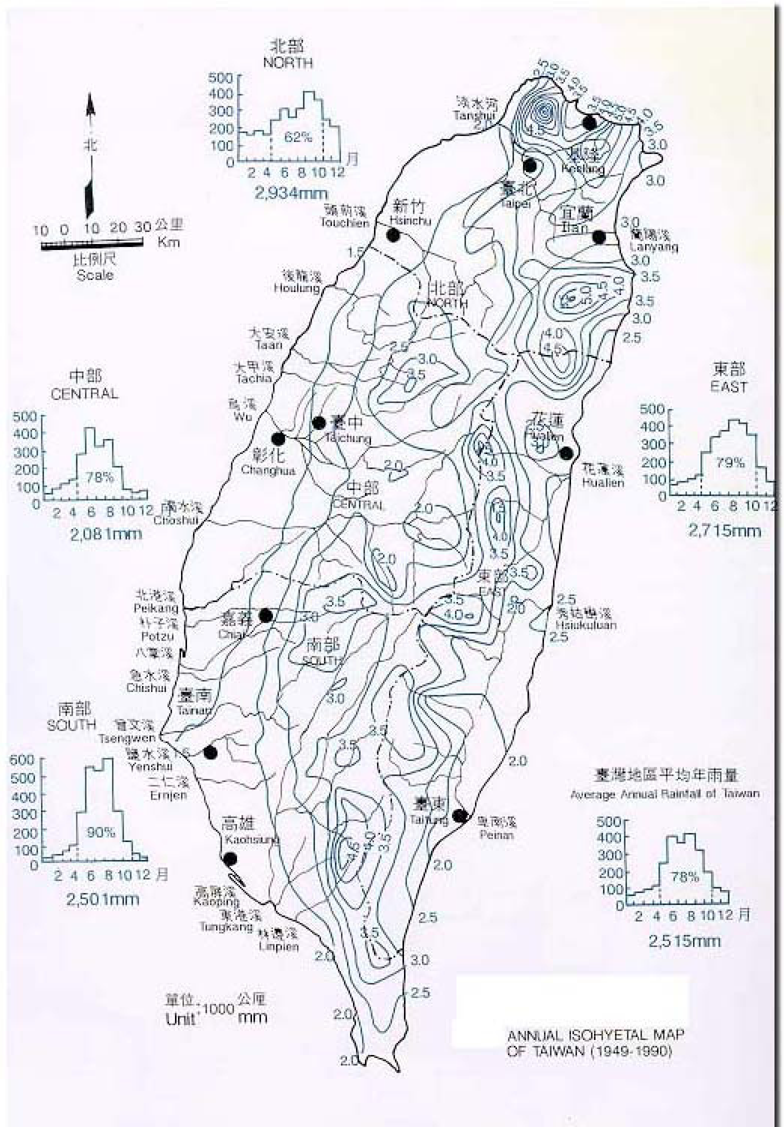

Figure 1. Annual Isohyetal Map of Taiwan

On the demand side, the statistics show that the domestic water has increased from 730 million m^3 in 1976 to 3.53 billion m^3 in 2004, and industrial water from 1.35 to 1.65 billion m^3, while agricultural water has decreased from 15.96 to 12.60 billion m^3, and has been remaining almost stable since 1996. According to WRA (Water Resources Agency), the water-resources authority, the projection of long-term demand with medium growth rate on a five-year interval targeted in year 2021 shows same trend (see Figure 2).

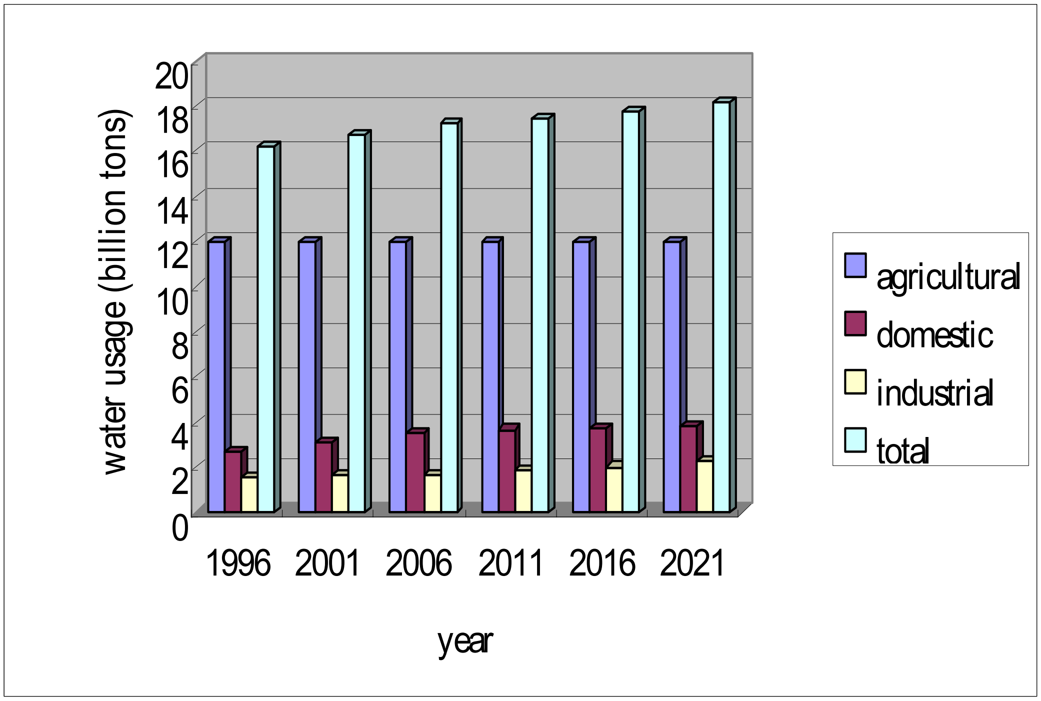

Figure 2. Trends of Water Demand for Various Sectors in Taiwan

WATER SHORTAGE ISSUE

For water shortage problems, which are becoming more and more frequent worldwide including Taiwan, each water use sector has its own priority duty to satisfy itself before seeking borrowing or transfer from other sectors. In this regard, the agricultural sector could have various measures in response to various degrees of water shortage. In this article, measures for irrigation water, such as extending irrigation periods, decreasing number of irrigation application times, or rotational irrigation, will be introduced and discussed.

General Measures for All Sectors Corresponding to Supply-Demand Analysis

From the water resources aspect, the situation of drought or water-shortage occurs when supply is not able to meet demand. The general corresponding response measures may vary according to the degree of drought conditions, i.e., the difference between the amounts of supply and demand, as shown in Figure 3.

In Figure 3, the supply and demand sides are placed on opposite sides. On the left supply side, there are three major water source categories, namely available groundwater, reservoir storage, and river flow. On the right demand side, there are four water use sectors, namely domestic, agricultural, industrial, and environmental. The starting timings to take corresponding measures are based on the difference between supply and demand conditions, and are classified into stages as follows.

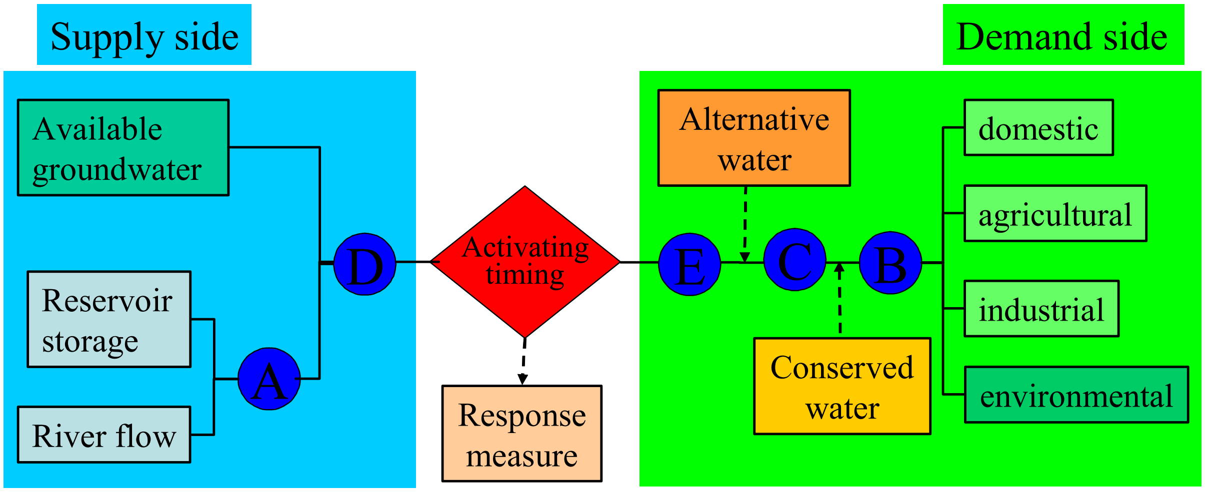

Figure 3. Supply-Demand Analysis for Water Resources Management

Stage 1 When A>B, i.e., reservoir storage and river flow are able to satisfy demand needs, then strict groundwater conservation measure is enforced.

Stage 2 When A<B, the water-saving measure is first activated. Each water-use sector has its own duty to reduce its own demand in order to keep A>C.

Stage 3 When A<C and under the tolerable safe-yield limit, groundwater is introduced for conjunctive use in order to sustain D>C.

Stage 4 When D<C, appropriate measures for different water sectors are activated. For the agricultural sector, fallow or crop change are conducted, while for the domestic and industrial sectors, alternative water sources, such as desalination water, recycled water, or reclaimed water, are introduced, in order to keep D>E.

Stage 5 When D<E, i.e., any or some of the water sectors are not capable of satisfying it or themselves, then transfer among sectors is required.

In practice, there is a similar signal system (Fig. 4, in Chinese) set by the WRA, which comprises five signal lights from blue, green, yellow, orange, to red. The activation of each signal level is based on meteorological (e.g., expected rainfall), hydrological (e.g., inflow rate, or flow level), reservoir stage, or expected demand, etc.

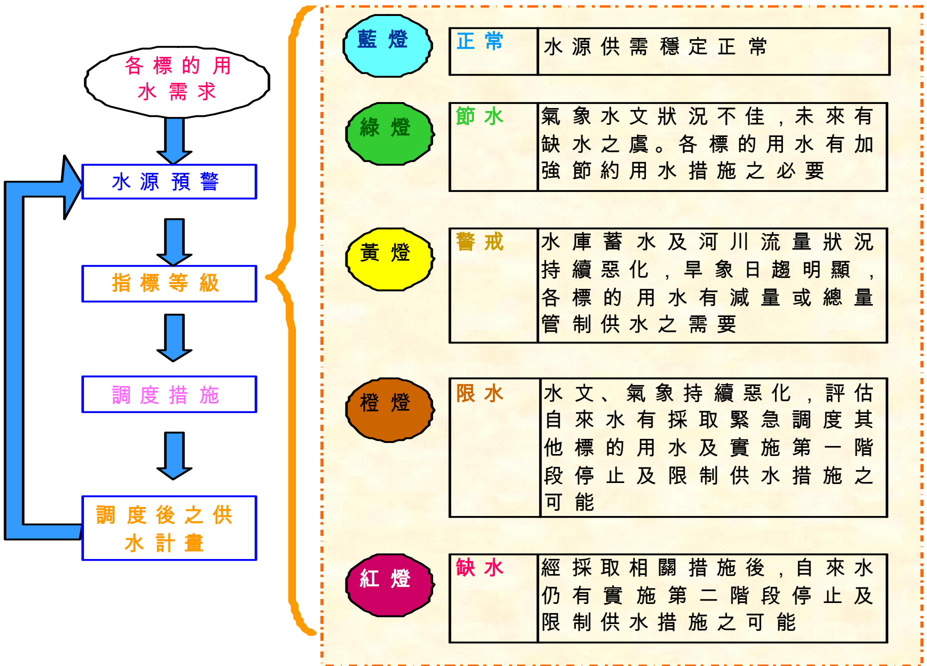

Figure 4. Signal System for Drought in Taiwan

Responsive Strategies for Agricultural Sector during Drought Seasons

Basically, for the agricultural sector there are two main strategies to be applied against drought. One is to extend the irrigation periods, which in effect, is to decrease the number of irrigation application times, and the other is to adopt rotational irrigation.

Extension of Irrigation Periods Although the irrigation periods (as well as the number of irrigation application times) are generally specified in the irrigation plans of Irrigation Associations, crops are often less vulnerable to water shortage conditions. The timing for the next application of irrigation varies with the drought-enduring ranges of crops, and is normally determined by field observation. Or, if the same amount of water is irrigated, with the number of irrigation application times being reduced, a significant amount of water loss could be saved with this practice.

This practice of extending irrigation periods must be carried out in conjunction with other measures or management schemes, such as the improvement of irrigation efficiency, or a recently promoted plan of so called “deep-water” irrigation cultivation technique. In this “deep-water” irrigation cultivation technique, the irrigation water depth is suggested to be increased from 60 mm, which is the current standard for rice cultivation in Taiwan, to 250 mm, and the estimated irrigation period could thus be lengthened up to around 20 days.

Rotational Irrigation Rotational irrigation is a scheduling process among groups of irrigation units, normally implemented to counter water-shortage problem. It is often applied at various levels of irrigation systems. In general, when the amount of irrigation water supply is above 75% and measures are to be taken, rotational irrigation is applied with main canal systems.

When irrigation water supply is between 75 – 50%, rotational irrigation is applied with lateral canal systems. When irrigation water supply is again lowered to between 50 – 25%, rotational irrigation could still be applied, but on tertiary units. When irrigation water supply is further decreased to below 25%, rotational irrigation is not suggested and extensive fallow is applied.

Two examples of Yun-Lin Irrigation Association in central Taiwan are shown below. Figure 5 is the case of rotational irrigation applied in Cho-Kan main canal system, where three irrigation areas by three laterals are involved in the rotational strategy. Figure 6 is the case in a lateral canal system where various groups are organized according to water supply to meet demand conditions.

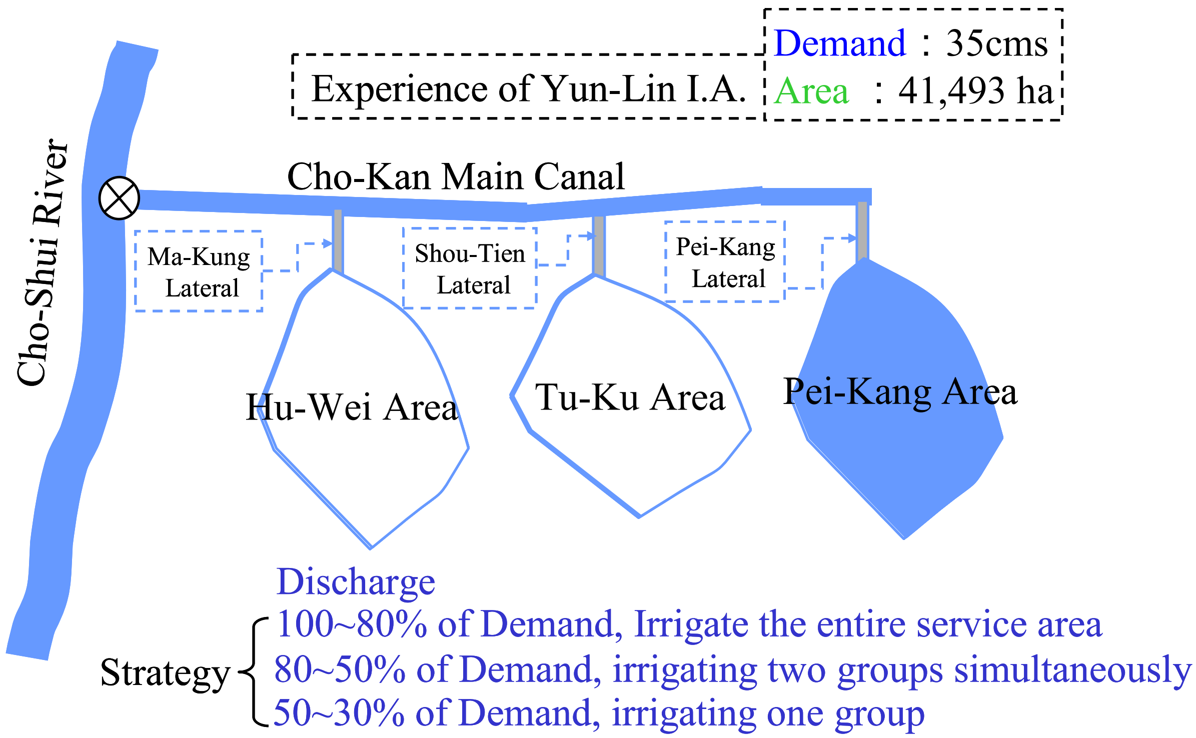

Figure 5. Example of Rotational Irrigation Applied to Main Canal System

WATER TRANSFER ISSUE

When borrowing or transfer of water among sectors is needed in Taiwan, it is usually from agricultural irrigation water to other sectors. The maintenance of water right and compensation to farmers for their income loss are the two major issues.

Most often cases of water transfer in Taiwan are from the agricultural sector to domestic. However, the industrial sector has been facing frequent water shortage problems as well, and similarly, transferring or borrowing from agricultural has become sole and important solution before specific water source intake systems are completed. As a result, it is necessary to setup a water transfer strategy among sectors in order to reach a win-win state.

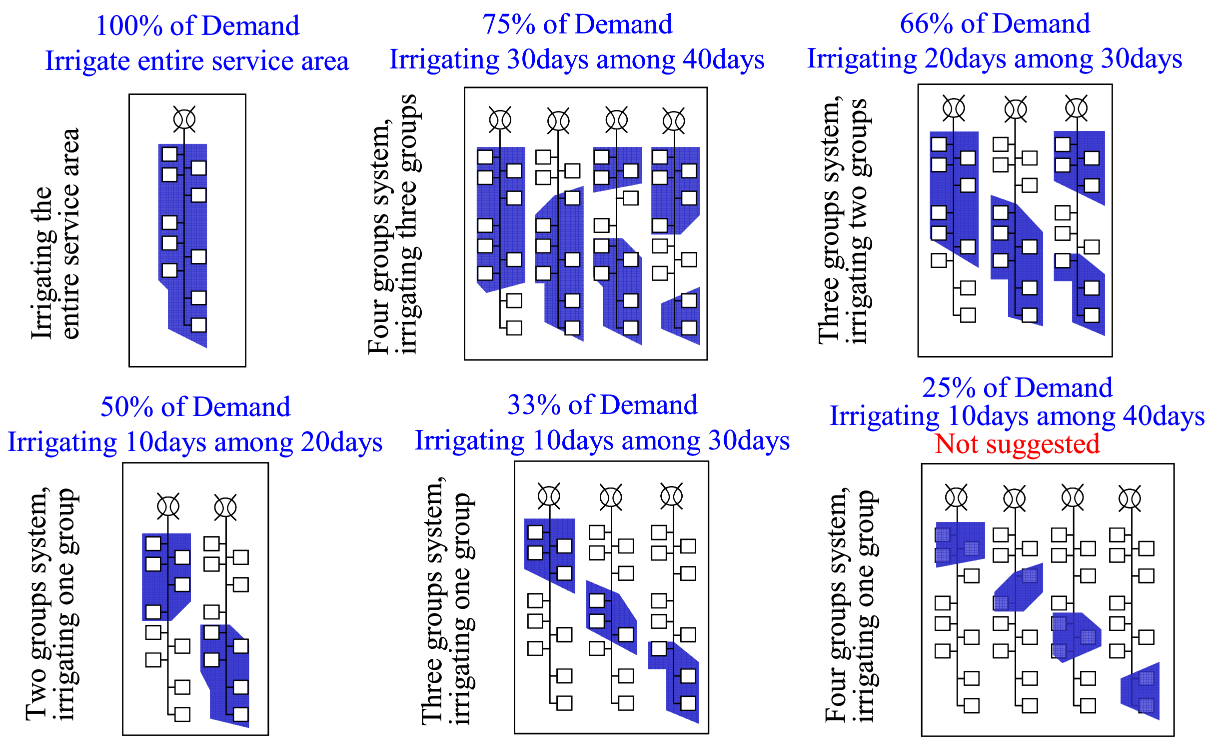

Figure 6. Example of Rotational Irrigation Applied to Lateral Canal System

Discussion on the Appropriateness of Past Transfer Cases

There are three types of transfer (or borrowing) of agricultural water: permanent, partial, and temporary transfers. After reviewing past cases regarding transfer of agricultural water in Taiwan, the following facts can be summarized:

1) Despite the fact that agricultural sector also faces water shortage, it is considered to be transferred whenever needed.

2) There is yet no reasonable compensation for the transfer of limited agricultural water resources.

3) The "value" of agricultural water resources is yet to be established.

4) Agricultural water right is seemingly abolished when frequent transfers are requested.

Basic principles on the aid of agricultural water to other sectors

Based on past experiences of water transfer, the following rules and basic principles are concluded:

First Ranked Domestic Sector During severe drought, the water resources is first re-allocated according to adjusted distribution. The first ranked domestic sector is eligible to transfer water from other lower ranked sectors when the necessary amount of water to sustain life and living needs is not acquired, and agricultural sector is always the one. However, proper compensation is needed as agriculture itself is also damaged from drought.

Second Ranked Agricultural Sector As the second ranked sector, the agricultural water is eligible to request transfer from lower ranked sectors. Although it rarely occurs, it is possible under food shortage conditions. In very few cases, it did happen when agricultural water requested aid from local deep wells of other sectors. However, the aid did not quite follow the priority order, and the compensations were based on negotiations.

Third Ranked Industrial Sector Industrial water ranks third behind domestic and agricultural. Nonetheless, in order to protect industrial development, which has higher production value and is more vulnerable to water shortage, the transfer from agricultural sector often occurs. And most of the cases were proceeded through negotiations with agricultural sector, yet the reasonable compensation for the damage loss of farmers is yet to be determined.

THE ACCESSION OF TAIWAN TO WTO ISSUE

As for environmental changes, the impact of the accession of Taiwan to WTO would be discussed specifically in this article. The World Trade Organization (WTO) is a global international organization dealing with the rules of trade between nations. At its heart are the WTO agreements, negotiated and signed by the bulk of the world's trading nations and ratified in their parliaments. The goal of WTO is to help producers of goods and services, exporters, and importers among its members conduct their business. Taiwan joined WTO in 2002, and under the agreement, 144,270 tons of rice were imported, resulting in a decrease in rice cultivation area through fallowing or crop-change. Thus, this issue raised another question on whether and how irrigation water could be saved. A management scheme in order to save irrigation water which could be used for other purposes is proposed.

Since the accession to the WTO, the cultivation land area of rice in Taiwan has been decreasing as the rice demand is decreased. It is studied and suggested in this article that land fallow and crop-change could be properly practiced on irrigation systems during water-shortage periods, which are commonly the first crop of rice in Taiwan. Under these practices, the agricultural water should be able to be effectively saved, and the non-agricultural demands could be supported without impacting food policies. The pressure of water-resources development could thus be reduced.

The focus of the study area in this article is conducted in Tao-Yuan area (Table 1), which is located in the northern part of Taiwan. The strategies for temporary shift of agricultural water under the conditions of maintaining the re-planting capability of farmland would be assessed.

Table 1. Rice Cultivation Area in Tao-Yuan Irrigation Association

year	crop	planned irrigation area(ha)	actual rice cultivation area(ha)	fallow and crop-change area(ha)	remarks
2000	1st crop	25,964	22,378	3,586	
	2nd crop	25,964	20,911	5,053	
2001	1st crop	25,933	21,742	4,191	
	2nd crop	25,933	20,576	5,357	
2002	1st crop	25,054	19,879	5,175	
	2nd crop	25,054	17,212	7,842	
2003	1st crop	24,749	-	24,749	Irrigation was stopped in 1st crop in accordance with government policy, and actual cultivation area was not surveyed.
	2nd crop	24,749	6,063	18,686	Severe drought
2004	1st crop	24,524	937	23,587	Irrigation stopped
	2nd crop	24,524	6,171	18,353	

Source: Tao-Yuan Irrigation Association

<u>Preparation of Fallow or Crop-change Plans</u>

If the cooperation from the farmers is acquired, it is proposed that in accordance with the promotion of fallow as well as crop-change systems, the planned water-supply in the reservoir areas, especially the Tao-Yuan area in this article, could be theoretically reduced by the unit of check-gate operation. The objective of saving water through fallow as well as crop-change in order to comply with WTO agreement could be reached by conveying it along the irrigation systems to the designated location or facility.

In order to effectively carry out the ideas of the study objectives, the following basic principles are first proposed:

1. Current planting systems should be maintained to avoid complexity,
2. The issue of water-right change should not be involved in order to minimize doubt as well as arguments, and
3. The form of "group fallow" should be promoted in order to effectively save water.

Hence under principle 1, the double-crop fields are suggested in order to maintain current planting system. Under principle 2, rotational fallow by groups are suggested in order not to involve the doubt of water right change. Under principle 3, the lateral ditches as basic units are suggested in order to promote through groups.

In addition, since water resources agencies already have set related moving or transferring response procedures as well as measures for emergency droughts, the ideas in this article should be adopted to constantly support water supply in order to meet the policy of fallow as well as crop-change. Under this principle, water supply from reservoirs is suggested.

In the mean time, associate measures or principles should also be promoted, such as compensation to farmers, respect to management input of irrigation associations, etc. Also, current fallow as well as crop-change is promoted targeting on second crop in consideration of crop yield and quality. However, from the water-resources point of view, first crop is suggested due to wet seasons.

Analysis of water-saving potential by fallow and crop-change in Tao-Yuan area

Year 2004 of Tao-Yuan is chosen as case study when the allocated fallow area in accordance with the WTO regulation of rice import was 11,946 hectares in the first crop and 15,943 hectares in the second crop. Assuming that all the fallow area in Tao-Yuan County was completely applied in the irrigation district of Tao-Yuan Irrigation Association, and further the work stations of associate laterals were set as basic units by taking the on-site operation applicability into consideration, the potential water saving amount can be obtained by accumulating the amounts of distributed water of the corresponding lateral work stations under the priority of lower water distribution weights, which are the water requirements per unit area, unless minor necessary adjustments are needed.

Following the principle, the manage areas of work stations are accumulated in the order from Ta-Lun (laterals #6, 7, and 8-1), Hsin-Po (lateral #9), Tao-Yuan (lateral #1), Hsin-Wu (laterals #12, Keh-Ker-Gang Ditch, and 12-1), Ta-Yuan (laterals #3, 4, and 5), until Kuan-Yin (laterals #10 and 11) work station, in which the accumulated area of 11,959 hectares has reached the first crop fallow requirement of 11,946 hectares. Hence, the corresponding accumulated distribution water of $123.648*10^6$ m^3 is the potential amount of water saved for the first crop (Table 2).

Continuing the procedure, the Ta-Chu (lateral #2) and Tsao-Ta (lateral #8) work stations are selected when the accumulated area of 16,906 hectares is reached beyond the 15,943 hectare second crop fallow area, the corresponding $179.989*10^6$ m^3 is the potential amount of water saved for the second crop.

In other words, assuming that the guided fallow area of both first and second crops of year 2004 in Tao-Yuan area is completely applied in Tao-Yuan Irrigation Association irrigation district, and basing the calculation on the average distributed amount of water of the 2005 irrigation plan of Tao-Yuan Irrigation Association, a total of approximately $300*10^6$ m^3s of water saving potential for the whole year could be expected.

Preparation of fallow or crop-change measures

Furthermore, according to the estimation of water shortage of domestic water supply systems in Taiwan area for the year 2011 as provided by the Water Resources Agency, the medium growth demand in Tao-Yuan area is $1.29*10^6$ m^3 per day while the supply side is $1.10*10^6$ m^3/day, hence, a deficit of $0.19*10^6$ m^3/day should be supported form other sources before water-shortage crisis occurs.

Table 2. Calculation of potential amount of saved water in accordance with fallow in Tao-Yuan area

	1	2	3	4	5	6	7	8
canal	Work station	lateral	Irrigation area (ha)	Area by work station (ha)	Distributed water by canal ($10^6 m^3$)	Water distribution weighting ($10^4 m^3$/ha)	Accumulated area by weighting order	Accumulated potential saved water ($10^6 m^3$)
Tao-Yuan main canal	Tao-Yuan	#1	1,465.0	1,465.0	12.892	0.88(3)	3,979	33.614
	Ta-Chu	#2	2,663.0	2,663.0	27.878	1.05(6)	14,622	151.526
	Ta-Yuan	#3	416.0	1,964	3.793	0.99(5)	9,117	88.824
		#4	983.0		9.105			
		#5	565.0		6.569			
	Ta-Lun	#6	514.0	1,386	4.425	0.80(1)	1,386	11.061
		#7	714.0		5.586			
		#8-1	158.0		1.050			
	Tsao-Ta	#8	2,284.0	2,284.0	28.463	1.25(9)	16,906	179.989
	Hsin-Po	#9	1,128.0	1,128.0	9.661	0.86(2)	2,514	20.722
	Kuan-Yin	#10、11	2,842.0	2,842.0	34.824	1.23(7)	11,959	123.648
	Hsin-Wu	#1	1,675.0	3,174	18.210	0.96(4)	7,153	69.357
		Keh-Ker-Gang Ditch	1,317.0		16.313			
		#12-1	182.0		1.220			
	Hu-Kou	Kuang-Fu ditch	3,784.0	3,784.0	47.004	1.24(8)		
Total				22,155				

Suppose that $0.19*10^6$ m^3/day is needed for 180 days in a crop period, then $34.2*10^6$ m^3 of water is required for each crop. Take the associated planned distribution water amounts for each crop, as well as the administrative coordination in execution practice into consideration, then, various combinations which meet the $34.2*10^6$ m^3 requirement could be determined by further considering the manage areas of work stations as basic fallow unit, one crop per fallow term, and rotational fallow to assist agricultural water. Furthermore, for the applicability of practical execution to minimize the operation disputes as well as to raise the coordination efficiency, it is suggested that the three groups of up-stream, mid-stream, and down-stream are classified. The upstream group includes Tao-Yuan, Ta-Chu, Ta-Yuan, and Ta-Lun work stations, while the mid-stream includes Tsao-Ta, Hsin-Po, and Kuan-Yin work stations, and the down-stream group includes Hsin-Wu and Hu-Kou work stations (Table 3). For each group, the associated amount of saved-water from conducting fallow could meet the requirement, and hence could provide reference for rotation fallow.

CONCLUDING REMARKS

The increase in industrial and domestic water demand due to the development of economy as well as change in industrial structures has put pressure in the agricultural water sector. Moreover, as the development of water resources is becoming difficult, especially after joining

WTO, how to effectively distribute and manage water resources has become an urgent issue in Taiwan.

Although three issues are discussed in this article, problems concerning agricultural water sector are far more sophisticated. And as agricultural water used to account for most part of the water resources in Taiwan, a comprehensive water resources policy and regulations are needed.

Table 3. Suggested rotational fallow groups by work stations in Tao-Yuan area

canal	Work station	lateral	1^{st} crop Lateral intake (10^6m^3)	1^{st} crop Intake subtotal (10^6m^3)	2^{nd} crop Lateral intake (10^6m^3)	2^{nd} crop Intake subtotal (10^6m^3)	Suggested group
Tao-Yuan main canal	Tao-Yuan	#1	8.05	42.60	6.79	37.16	Upstream group
	Ta-Chu	#2	15.64		13.26		
	Ta-Yuan	#3	11.71		10.35		
		#4					
		#5					
	Ta-Lun	#6	7.20		6.77		
		#7					
		#8-1					
	Tsao-Ta	#8	14.99	41.17	13.55	37.25	Mid-stream group
	Hsin-Po	#9	6.08		5.53		
	Kuan-Yin	#10、11	20.09		18.17		
	Hsin-Wu	#1	20.27	45.93	17.16	38.50	Downstream group
		Keh-Ker-Gang Ditch					
		#12-1					
	Hu-Kou	Kuang-Fu ditch	25.66		21.34		
Remarks		Under the basis that $0.19*10^6$ m^3/day is needed for 180 days in a crop period, thus $34.2*10^6$ m^3 of water is required for each crop.					