STUDY ON IRRIGATION MANAGEMENT STRATEGIES FOR DROUGHT IN TAIWAN

ETUDE SUR LES STRATEGIES DE LA GESTION D'IRRIGATION CONTRE LA SECHERESSE A TAIWAN

Gwo-Hsing Yu[1], Wei-Taw Lin[2] and Chii-Reid Wu[3]

ABSTRACT

Taiwan is located in Asian monsoon region suitable for growing paddy rice with an annual total rainfall highly exceeding irrigation water requirement for paddy. Flexible farming systems and efficient water uses will not only produce bumper rice crop but will also help in sustaining the ecology. Besides, as the domestic and international data show, drought has become more frequent in recent years caused by climate change. As the largest consumer of water resources (around 70%) in Taiwan, agricultural water has to be shifted to supplement the deficits of domestic and industrial water demands during drought events. Thus, positive planning of suitable strategies of irrigation management during drought events is necessary to ensure the greatest benefit of water resources usage.

The article analyzes the current development status and the bottleneck of irrigation affairs in Taiwan, trying to integrate the needs of national food production and the efficiency of entire water resources. Six constructive suggestions for the government and the irrigation associations to develop water conservation strategies during drought events were made: 1) investing the irrigation infrastructures and establishing the modern control system; 2) assisting farmers to adopt the modern water-save irrigation facilities; 3) setting up flexible farming patterns upon local water resources; 4) formulating rotational irrigation program for fallow areas; 5) promoting the capacity for water transfer during drought events by comprehensive scientific technologies and 6) considering the seasonal rainfall to adjust the irrigation area for the first and secondary rice-crop periods. Besides, the government should continually assist the irrigation associations to maintain the existing irrigation management measures, such as irrigation water resources and facilities protection, water quality and quantity monitoring,

1 Director, Water Resources Management and Policy Research Center; Professor, Water Resources and Environmental Eng. Dept., Tamkang University, Tamsui, New Taipei City 25137, Taiwan, E-mail:e133@mail.tku.edu.tw

2 Deputy Director, Water Resources Management and Policy Research Center, Tamkang University, Tamsui, New Taipei City 25137, Taiwan, E-mail:lwt@mail.tku.edu.tw

3 Section head, Agricultural Water Resources Section, Water Resources Management and Policy Research Center, Tamkang University, Tamsui, New Taipei City 25137, Taiwan, E-mail: wcr@water.tku.edu.tw

and human resource training and promotion, etc., to establish a better environment for water conservation measures promotion.

Keywords: *Irrigation, Management, Drought Events*

RESUME

Taiwan est situé dans la région de la mousson asiatique, approprié pour la culture de riz paddy avec une précipitation annuelle totale dépassant fortement les besoins en eau d'irrigation pour le riz paddy. Les systèmes agricoles flexibles et l'utilisation efficace de l'eau n'aidera pas seulement à produire des cultures de riz exceptionnelles, mais également à maintenir l'écologie. Par ailleurs, comme le montrent les données nationales et internationales, la sécheresse est devenue plus fréquente ces dernières années, provoquée par le changement climatique. Comme le plus grand consommateur des ressources en eau (environ 70%) à Taiwan, l'eau agricole doit être déplacée afin de compléter les déficits de la demande en eau domestique et industrielle au cours des épisodes de sécheresse. Ainsi, la planification positive de stratégies appropriées de gestion de l'irrigation au cours des épisodes de sécheresse est nécessaire pour assurer le plus grand bénéfice de l'utilisation des ressources en eau.

L'article analyse l'état de développement actuel et le goulot d'étranglement des affaires d'irrigation à Taïwan, en essayant d'intégrer les besoins de la production alimentaire nationale et de l'efficacité des ressources en eau tout entier. Six suggestions constructives pour le gouvernement et les associations d'irrigation pour développer des stratégies de conservation de l'eau au cours des épisodes de sécheresse ont été faites:

1) *investir les infrastructures d'irrigation et d'établir le système de contrôle moderne;*
2) *aider les agriculteurs à adopter les équipements modernes d'irrigation pour économiser l'eau,*
3) *mise en place de schémas agricoles flexibles sur les ressources en eau locales;*
4) *la formulation du programme d'irrigation de rotation pour les zones en jachère;*
5) *la promotion de la capacité de transfert d'eau au cours des épisodes de sécheresse à l'aide des technologies scientifiques, et*
6) *compte tenu de la précipitation saisonnière pour ajuster la zone d'irrigation pour les périodes premières et secondaires de la culture de riz.*

Par ailleurs, le gouvernement devrait continuellement aider les associations d'irrigation pour maintenir les mesures existantes de gestion d'irrigation, comme les ressources en eau d'irrigation et de protection des installations, la qualité de l'eau et le surveillance de la quantité, et la formation des ressources humaines et la promotion, etc., afin d'établir un meilleur environnement pour la promotion de mesures de conservation d'eau.

Mots clés: *Irrigation, gestion des épisodes de sécheresse.*

1. INTRODUCTION

Taiwan is located in the Asian monsoon region and regarded as a country with an abundant rainfall suitable to plant paddy rice. With flexible irrigation practices and effective water

management plan, it can not only produce adequate amounts of food but even help maintaining the ecology and living environments. This causes a real benefit for the country to adapt to the impact of climate changes.

The hydrologic statistical data indicate that in the recent years, the phenomena of climate variability are intensified around the world. In Taiwan also, water shortages and droughts occurred in the past few years. As a result, there were nearly 150,000 hectares of farmland, which went without irrigation and about 600 million m^3 of irrigation water was transferred for supporting water usage in domestic and industrial sectors. In addition, Morakot Typhoon attacked southern Taiwan on August 7th, 2009, brought 3,000 mm of rainfall within three days, and caused an unprecedented flood disaster. After that, around 90 million m^3 sediment was accumulated in Tseng-Wen Reservoir, and this is the primary reason to cause drought and water shortages in the southern Taiwan in the first half of 2010. Therefore, the drought event becomes a serious issue for the water consumption in various sectors in the future.

2. CONDITIONS OF AGRICULTURAL WATER RESOURCE IN TAIWAN

(i) Agricultural water resources

The geographical location of Taiwan is in the East Asian monsoon region, and the amount of rainfall during the wet and dry seasons is quite different. The water resources are highly dependent on rainfall brought by typhoons in summer. During the dry season, farmers mainly rely on the construction of water storage facilities to preserve the rainfall during the wet season. The current consumptions of agricultural water and agricultural irrigation are occupied by 71% and 62% of total water requirements (11 billion m^3) respectively (Figure 1).

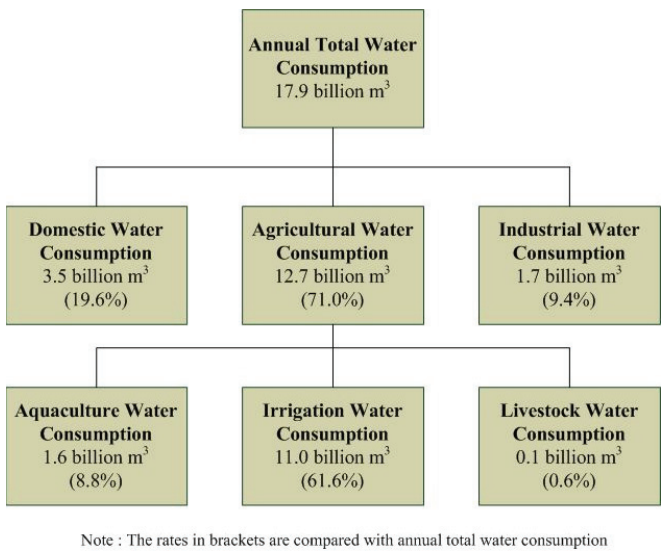

Fig. 1. The quantity of water consumption in various sectors (Cited from: Water Annual Statistics, Taiwan, 1999~2008)

(ii) Current status of agricultural water consumption

The accelerating population growth and economy development results in an increase of industrial water consumption and public water supply. On the contrary, the agricultural water consumption is reduced year by year. The agricultural water consumption in Taiwan is still dominating the water resource utilization. Apparently, the shortage tolerance of agricultural water is much higher than domestic and industrial water. In the event of insufficient water supply in domestic or industrial sector, the Irrigation Associations will take turn in implementing irrigation and water conservation measures, or even leave the land fallow without irrigation. However, under considerations of food security and the principle of rights between the Irrigation Association and farmers, the communication platform for water resource deployment is necessary. In the previous experiences of drought events or water shortage conditions in domestic and industrial sector, the agricultural administration departments were generally able to cooperate and respond quickly to water arrangement. Figure 2 indicates the water consumption trend in Taiwan in various sectors. The agricultural water consumption is influenced by the changes of rainfall, and it is quite different in comparison to domestic and industrial water that tend to grow steadily.

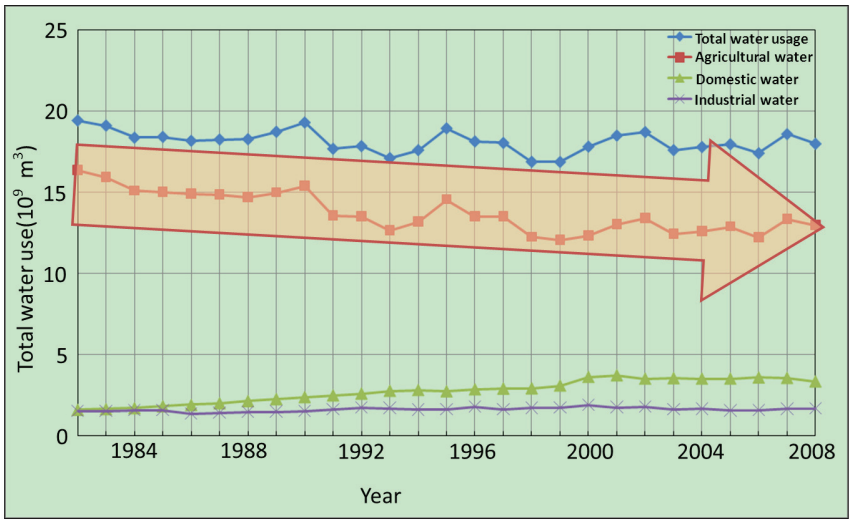

Fig. 2. The trend of water consumption in various sectors

3. CHARACTERISTICS AND POLICY PLANNING OF AGRICULTURAL WATER

(i) Seasonal characteristic of agricultural irrigation water

There are four seasons in a year in Taiwan, and the rainfall varies greatly in different seasons. The ratio of rainfall in wet season (June to November) and dry season (December to May in the following year) is approximately 7:3 at the northern regions, but is as high as 9:1 at the southern regions. Therefore, the agricultural irrigation water supply is actually often insufficient during the dry season. Such a phenomenon is shown in Figure 3.

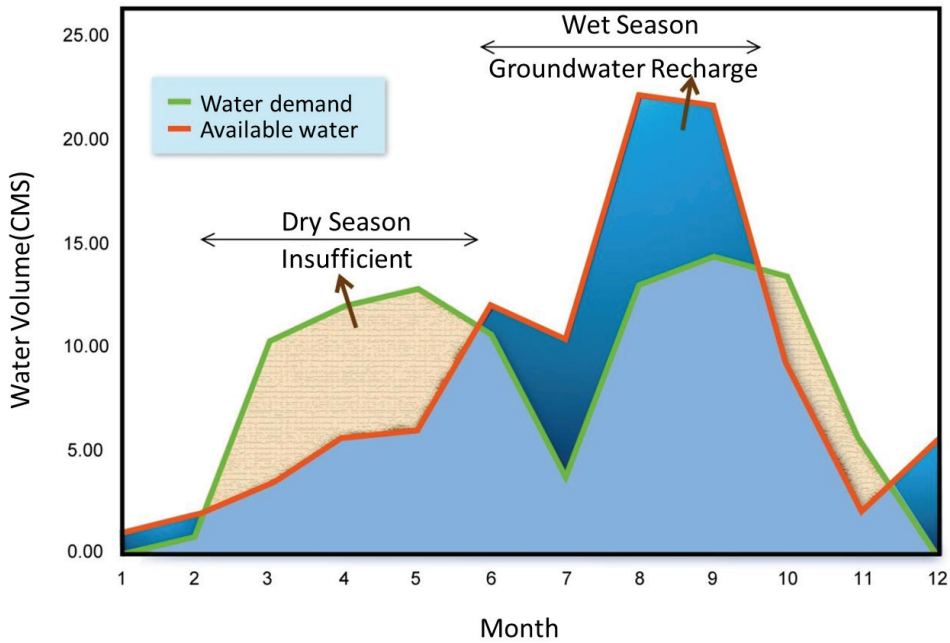

Fig. 3. The seasonal characteristic of agricultural water demand and available water

(ii) Spatial characteristic of agricultural irrigation water

The water shortage regions in Taiwan are predominated in Shimen Reservoir in the north, and Tseng-Wen Reservoir and Wusantou Reservoir in the south (these three reservoirs were initially built for irrigation purpose). However, these areas are densely populated due to the presence of Science Parks, and 0.94 billion m^3 of agriculture water was transferred to domestic and industrial water consumption. Only about 1.28 billion m^3 are left to meet irrigation water requirements (Table 1), but the areas needing irrigation are around 116,000 hectares, to supply to the 3 Irrigation Associations at Taoyuan, Shimen and Chianan. An average of 11,200 m^3 of irrigation water is used per hectare annually (largely lower than an average of 30,000 m^3 of water). Therefore, these areas have no more agricultural water for deployment.

Among the current 17 Irrigation Associations in Taiwan, the annual irrigation water in four of them at the eastern regions (Ilan, Hualien and Taitung) and the northern regions (Peikee) that rely on cited irrigation is generally sufficient. There is 3.5 billion m^3 of irrigation water to cover an irrigated area of 50,742 hectares. This means that 68,900 m^3 irrigation water is available per hectare that is more than double the average amount of 30,000 m^3. However, due to difficulty to find new water sources for current industrial development, if the irrigation water amount is relatively abundant in these areas, there is still space for reviewing the backup transference.

Table 1. The reduction of irrigation water rights in Taiwan reservoirs

Reservoir	Constructed year	Original water rights (billion m^3)	Transferred to domestic and industry (billion m^3)	Remain irrigation water rights (billion m^3)	Present irrigation area (hectares)
Shimen	1964	0.783	0.40	0.383	36,806
Tseng-Wen & Wusantou	1974	1.440	0.54	0.900	79,458
Total		2.223	0.94	1.283	116,264

(Source: Water Annual Statistics, Taiwan)

(iii) Strategic planning of agricultural water resources

Since the 1980s, following the gradual advancement of agricultural society into industrial society, there was a significant increase in domestic and industrial water consumptions. When the total agricultural water requirements reached 16.3 billion m^3, the government formulate the policy not to increase the agricultural water requirement and approve the "Agricultural Water Consumption Goal and Total Inventory Report" in 2000. With regard to agricultural water demand assessment, under normal hydrology circumstances, an upper limit of "high water consumption benchmark" (high level) is indicated as 14.77 billion m^3 to meet the irrigation water demand and meanwhile to maintain three multiple functions among productivity, livelihood and ecology. In the event of abnormal hydrological conditions such as insufficient rainfall, it would follow the "low water consumption benchmark" (low level) of 12.22 billion m^3 as a norm (estimated by farmland fallow practice at 13%, and water shortage condition at 8%). This is evaluated and regulated by the agricultural departments (Table 2).

Table 2. The total inventory and the consumption goal of irrigation water

Sectors/ Ranks	Irrigation (billion m^3)	Aquaculture (billion m^3)	Livestock (billion m^3)	Total (billion m^3)	Notes
High level	13.186	1.472	0.116	14.774	Irrigation in normal
Middle level	12.221	1.472	0.116	13.809	Water shortage at 8%
Low level	10.632	1.472	0.116	12.220	Fallow at 13% and water shortage at 8%

(Source: Agricultural Water Consumption Goal and Total Inventory Report, Taiwan, 2000)

4. STRATEGIES OF IRRIGATION MANAGEMENT FOR DROUGHT EVENTS

(i) Strengthening and improving the irrigation canals and other facilities, and setting up modern control systems

Over the past years, the Council of Agriculture has continued to help strengthen the Irrigation Associations in updating and improving the current irrigation facilities under the annual plan. This includes updating and improving 70,000 kilometers of irrigation canals and 180,000 units of hydraulic structures, which is estimated to reduce 1.5 billion m^3 of water seepage volume each year. In addition, as to the important water irrigation structures and management operation facilities, it was through modernization by the automatic remote transmission system to effectively control the water amount, to prevent water loss through water distribution, and to ensure of waterway safety.

(ii) Guiding farmers to adopt the modernized water-saving spray and drip irrigation measures

As far as water-saving of agricultural irrigation and the improvement of water-use efficiency are concerned, since 1983, the Council of Agriculture has actively promoted and encouraged farmers to adopt the pipeline irrigation method with the benefits of water saving and automation, and help farmers to implement the spray irrigation, micro-sprinkling irrigation, perforated pipeline irrigation and drip irrigation. Till 2009, it has subsidized a total of about 30,000 hectares of farmlands, capable of saving 200 million m^3 of water each year on preliminary assessment. This is able to improve agricultural water shortage phenomenon during drought period.

(iii) Postponing the date of cropping first crop paddy in conjunction with water conditions before implementing the irrigation

In Taiwan, difficult task of first crop paddy has to be done in the dry season, including land preparation and paddy transplanting, and this needs large water requirement, but many farmland often have to be stopped cropping under water shortage. In view of this, farmers are suggested to postpone the date of first crop paddy depending on the water conditions in that year, maybe twenty days or two weeks later in order to gain a longer decision time. After the adjustment, the first crop paddy can still be harvested in June and before the end of July. This should be able to lower the impact on crop growth and yields. As to areas with the highest frequency of irrigation stoppage, the adjustment of cropping time of first crop paddy is shown in Figure 4.

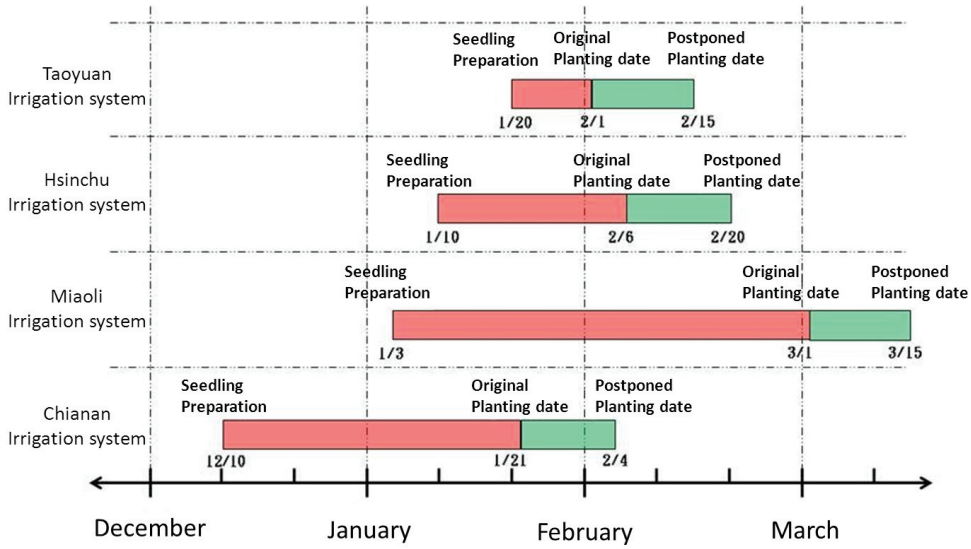

Fig. 4. Postponing the planting date of first season paddy rice

(iv) Announcing the irrigation stoppage areas, and implementing the regional irrigation stoppage rotation plan

In the past 10 years, due to insufficient domestic and industrial water supplies and the coincidence of water shortage during droughts, the continual irrigation stoppage in farmlands at Taoyuan, Hsinchu and other regions was brought up concerns on ecological environment deterioration. To avoid that large areas of farmlands are forced to stop cropping happened in the previous drought events and water shortages and to save public money, it is feasible to pre-set and announces the water irrigation stoppage regions in advance and adopts rotation approach among these regions in the future. Water stoppage can be implemented according to the pre-planned regional areas depending on the water shortage severity in domestic and industrial sector at that time, and be carried out in accordance with annual rotation manner to avoid geographical and environmental impacts.

(v) Improving irrigation facilities using scientific technologies to conserve the domestic and industrial water supplies

According to Article 22 of Water Act in Taiwan, for the people who obtain water through the surplus water amount saved from using the scientific technological method or equipment, adopted by the Irrigation Associations for intake, use or distribute the water, should pay the costs of improvement. The current feasible measures are listed as follows:

A. To save the water from night irrigation: In Changhua and Yunlin regions, the reliance on river water sources for irrigation is calculated to exceed 2 billion m^3 each year, but no irrigation water is used during night time. Hence, it is feasible to plan building water storage facilities to save between 100 million and 300 million m^3 of water for backup uses.

B. Developing agricultural recycled water: To collect the irrigation recycled water by engineering means at farmland's downstream drainage sites can be used in localized areas with water shortages.

(vi) Regulating the first or second crop paddy planting area depending on seasonal rainfall

A. Conserving agricultural water during the dry seasons: Reducing the planting area of first crop paddy and increasing the planting area of second crop paddy are to ensure food productivity.

B. Reducing the agricultural irrigation water demand: Reducing the planting area of first crop paddy and policies set-up are all to encourage upland crops cultivation that consumes less water.

C. Planning the incentive policies to encourage planting second crop paddy: Policies set-up of the planting with second crop paddy is encouraged for maintenance of the agricultural food security and stabilization of the food prices.

5. CONCLUSIONS

With the increasing frequency of extreme weather and in the face of the dual pressure of unstable water resource supplies and continuous growth of water consumption in various sectors, the relevant irrigation departments should actively improve the irrigation management for drought events. Currently, total agricultural water amount in Taiwan is going downward after coordinating the paddy planting area, regulation of the regional water resources and other facts, and the actual annual irrigation water requirements changes year by year following the hydrological conditions. In Taiwan, annual irrigation water consumption accounts for about 62.5% of total water requirements, and this is fairly close to that in the neighboring industrialized country of Japan where treats paddy as the staple crop. At meanwhile, the excessive use of irrigation water during the wet season is still able to preserve the three multiple functions of the paddy fields. These characteristics of water usage are significantly different to that of domestic or the industrial water uses. The government should continue to counsel all Irrigation Associations to preserve water intake on the existing water sources, to protect the water quality effectively, and strengthen personnel training for the implementation of various water saving measures to mitigate the drought.

REFERENCES

IFPRI, 2009, Climate Change: Impact On Agriculture And Costs Of Adaptation, International Food Policy Research Institute.

Pacific Institute, 2009, The World's Water: 2008-2009.

FAO, 2002, World Agriculture: Towards 2015/2030 Summary Report, Food and Agriculture Organization of the United Nations.

UNEP, 2002, UNEP in 2002: Environment for Development, United Nations Environmental Program.

USGS, 2000, Estimated Use of Water in United States in 2000.

Gwo-Hsing Yu, 2010, Policy Meeting of Agricultural Adaptation for Climate Change, Issue One: Climate Change Adaption Strategies for Taiwan Agricultural Resource and environment, Sub theme: Adaption Strategies for Water Resource Management, Council of Agriculture, Executive Yuan. (In Chinese)

Wei-Taw Lin, 2009, Review of Irrigation Water Supporting the Industrial Development in Case Study, Journal of Farmland Irrigation (55). (In Chinese)

Wei-Taw Lin, 2009, The Promotion and Application of Automatic Monitoring of Water Conservancy Facilities in the Disaster Prevention, Journal of Farmland Irrigation (55). (In Chinese)

Chii-Reid Wu, 2009, Assessment of Reasonable Necessary to Maintain the Production, Living and Ecology Functions of Water, Agricultural Water Projects Conference. (In Chinese)

Wei-Taw Lin, 2008, Study on Agricultural strategies for drought, Taiwan Agricultural Engineering Conference. (In Chinese)

Wei-Taw Lin, 2007, New Generation of Irrigation Management Strategies, Journal of Farmland Irrigation (54). (In Chinese)

Water Resources Agency, Ministry of Economic Affairs, Water Annual Statistics (1999~2008). (In Chinese)