HISTORY OF LARGE SCALE IRRIGATION AND DRAINAGE PROJECTS AND THE GROWTH OF REGIONAL SOCIETIES IN TAIWAN

Yu Chuan Chang¹, Chun-E Kan², Eiji Yamaji³ and Kunihiko Yoshino⁴

ABSTRACT

Taiwan has been facing double exposure on agriculture as developed countries in the Eastern Asia in these days. The performance of large-scale irrigation projects deeply affects the vulnerability and the adapting capacity for local food security. This paper demonstrates the development of irrigated agriculture in Taiwan, and focuses especially on the history of large scale irrigation and drainage projects, critical agricultural issues to which Taiwan has been facing, and challenging cases of cooperation between agricultural sector and industrial sector based on literature review and field survey. The coming global food crisis is not only a result from the increasing world population, but also from the climate change and economic growth. That means the vulnerability of agriculture should be examined, the adapting capacity to climate change will decline and the competition for water, labor and land resources between sectors will become keener due to the economic globalization. In the case of irrigated agriculture, sustainable development strategies must be taken up as well as environmental changes.

Keywords: Taiwan, Irrigation and Drainage, Water management, Agricultural development projects, Infrastructures.

1. INTRODUCTION

The introduction of modern agricultural technologies and policies from Japan is said to have a profound impact on the modernization and development in Taiwan. However, both Taiwan and Japan have been facing double exposure on agriculture as developed countries in the Eastern Asia in these days. The performance of large-scale irrigation project deeply affects the vulnerability and the adapting capacity for local food security.

This paper demonstrates the development of large scale irrigation and drainage projects, critical agricultural issues to which Taiwan has been facing, and challenging cases of cooperation between agricultural sector and industrial sector based on literature review and field survey.

2. IRRIGATION DEVELOPMENT

Being situated in both tropical and subtropical oceanic zones and also in the Asian monsoon region, and with a large ratio of mountainous lands, (Fig. 1), the climates in Taiwan are greatly influenced by the monsoons as well as the land forms.

The average annual rainfall in Taiwan is 2,610 mm, which far exceeds the world average of 650 mm/year. But the water resources management is tough as the

¹ Professor, Hsing Wu University, New Taipei City, Taiwan; E-mail: 096062@mail.hwu.edu.tw
² Professor, National Taiwan University, Taipei 11465, Taiwan;
³ Professor, University of Tokyo, Japan
⁴ Professor, University of Tsukuba, Japan
annual allocated water per capita is only around 1/8 of the world average due to uneven spatial and temporal distribution of rainfall. The sediment yield per unit area of the rivers is about 64 times of the world average (COA, 2001). The development of agriculture is highly depended on the large scale irrigation and drainage projects.

Figure 1 Map of Taiwan Island

The course of irrigation development in Taiwan that has lasted for over 400 years since its inception can be divided into several stages as indicated in Fig. 2 (COA, 2009), which can be summarized below.

2.1 Free development period (before 1895)

The term of “irrigation facilities” was first introduced in Taiwan later during the Dutch colonization of Taiwan (1622 ~ 1661). During the administration period of General Zheng who recovered Taiwan Island from the Dutch (1662~1683), several irrigation projects had been developed including diversion works, ponds and canals to enhance agricultural produces especially rice and sugar for political and military purposes.

As the immigrants from the China mainland to Taiwan increased in 1680s, the private sector began participation in development of irrigation projects, invested by either the singles or the partnerships. By the year of 1895 when the Qing Dynasty handed over the island to the Japanese Government due to loss at war, the total area of paddy fields in Taiwan exceeded about 200,000 ha, of which around 110,000 ha were irrigated by the canal water, which comprised stream flows, rainwater stored in ponds and groundwater. These canals are among others the LiugongCanal at Taipei area in the north, BabaoCanal at Changhua area in the central and CaogongCanal at Kaohsiung area in the south of Taiwan.

Figure 2. The irrigation development stages in Taiwan
Before the Japanese Colonial Period, most hydraulic facilities had been constructed and managed by the private groups. The local government failed to take an active role in managing the hydraulic facilities. They mostly issued permits, or acted as the judge and law enforcer when there was a dispute.

During earlier periods, most Chia-Nan Canal hydraulic facilities were co-set up by villagers. In order to manage these equipment’s, they would either recommend or invite a reservoir supervisor to inspect, repair the canal, distribute water, and water thieves. The people that channeled water would pay the water supervisor with grains of rice. When there was canal damage, they were required to fix it.

2.2 Foundation lying period (1896 – 1945)

To fulfil the development goal of the policy of “Agricultural Taiwan” set forth by the Japanese Government during these years, the public funds were allocated to invest a great deal in the irrigation projects in Taiwan. As long as the colonial administration period a total of 18 reservoirs and regulating storages were constructed, of which the Sun-MoonLake and Wusantou Reservoir were the largest which design by Japanese engineer Mr. Yoichi HATTAR. These two have been among the most famous water resources works even up to date. Both of them are of the off-stream dams storing transbasin flows. The achievements in these construction works showed the practices of sophisticated and comprehensive engineering planning procedures and advanced construction techniques.

Regarding the irrigation projects newly developed by the colonial administration, those of outstanding included the irrigation systems of Liugong and Taoyuan in the north; Houli, Chizipi and Babao in the middle; Chianan, Shizitou and Caogong in the south; and Jiye and Beinan in the east of Taiwan.

Each of the systems served over tens of thousands hectares of farmlands. Additionally, the sugar mills then constructed their own small to medium scale irrigation systems including reservoirs and ponds, by means of their own capitals to irrigate about 30,000 ha of farms at their plantations located in various districts of the island. In 1937, the paddy area in Taiwan reached around 544,000 ha, and produced rice grains of about 1.77 million m. tons, which both were the highest during the Japanese colonization era.

On the other hand, based on the fundamental survey conducted in 1934 the Japanese colonial administration of Taiwan ever formulated an island-wide farmland improvement plan in 1938, which included development of 66 irrigation projects to benefit a total agricultural area of about 506,100 ha. The plan was scheduled to firstly complete 39 significant projects within 11 years. However, due to the outbreak of the 2nd World War (WWII) in the Pacific region in early 1940s, the implementation progresses of these were very slow owing to severe lack of construction materials, machineries and labor. Eventually only three of them were duly completed.

During the colonial period Taiwan’s irrigation system management of centralized approach adopted by the government attributed to the successful implementation of irrigation projects in renewal, improvement and new development. Therefore, with the strong policy support of the government, and applying the modern engineering technologies including application of reinforced concrete in design and construction of irrigation and drainage works, the irrigation project development progressed rapidly and several of large scale modern civil works were completed as mentioned previously. By the end of this era in 1945, due to the Pacific War devastation on the island of Taiwan, the irrigation area reduced to about 486,300 ha, and produced rice grains of about 0.75 million m. tons.
During early Japanese rule, The Office of the Taiwan Governor General continued the operation mode like that of the Qing Dynasty. In July 1901, The Office of the Taiwan Governor General promulgated “Taiwan Public Reservoir/Canal Code” and began active management. All hydraulic facilities of public reservoir canals were ordered to be under direct local government supervision, and data was to be recorded. (Water source, path, and manager etc.) In 1913, The Office of the Taiwan Governor General amended the rules that interested parties of reservoirs and canals (Those who had used water sources and those who had been affiliated with the water source users) were entitled to setup corporate reservoirs/canals. This grouping was bound by laws, and the labor division inside organizations was clarified. Moreover, these corporate reservoirs/canals were entitled to borrow money from the bank.

In 1908, The Office of the Taiwan Governor General promulgated “Government Reservoir/Canal Code”. The government was directly involved in the management of larger hydraulic facilities. The government reservoir/canal assemblies were often managed by Public Works Department Civil Engineering Section Head or authorities. Landowners, tenants or other water source users were all members of the group. As compared to the public reservoir/canal Assembly, the public reservoir/canal assembly was much stricter in its management.

After 1920, government reservoir/canal was reformed into a public reservoir/canal in which the management right was given to the local government. In 1921, The Office of the Taiwan Governor General promulgated “Taiwan Irrigation assembly Regulation” in which the public reservoir/canal assemblies gradually combined into one and changed into irrigation assemblies one by one. They were directly appointed by the governor or local authorities. Inside the group, half of its members are appointed by the government although there was an election team. Resolutions had to be first agreed on by The Office of the Taiwan Governor General before executions were allowed.

2.3 Mature/ Degradation period (from 1946)

At the beginning of Post-War era, in order to restore the island’s staple food production to its pre-war level, the ROC Government in its great efforts of reconstruction of Taiwan’s major infrastructures including irrigation facilities, during the initial stage of about 10 years following recovery of Taiwan, concentrated on among others the major repairs or rehabilitation of the existing irrigation facilities and continuation of the unfinished previous projects suspended due to war affairs. Besides, the Government also implemented in parallel with drastic land reform program based on the “tenants-are-landowners” policy.

From late 1950s till 1960s when the national socioeconomic situations were improved, the Government then initiated implementation of new irrigation projects such as the Douliu Irrigation System at the plain of south of the Jhuoshui River in central Taiwan, and the Shimen and Zenwen Reservoirs respectively in the northern plateau and in the southern plain. The two reservoirs aimed to stabilize the irrigation water supply to the existing Taoyuan and Chianan Irrigation Systems, respectively; and the Shimen reservoir also supplies water to the new Guangfu Irrigation System. While both reservoirs provide with water for the increasing demands of domestic and industrial uses, they also support other purposes such as power generation, flood control and tourism. These new irrigation infrastructures developed then expanded the irrigation area in Taiwan to about 490,000 ha in 1960s.

In addition, the farmland consolidation has been implemented by the Government to better the mostly small-sized and or irregularly shaped farm plots for raising framing
efficiencies and directly drawing irrigation water from sub-tertiary or quaternary canals, as well as to drain excess water directly to tertiary drains since 1960.

The farmland consolidation was a process to consolidate the excessively small and fragment farm parcels mostly less than 1 ha each in adjacent, through exchanges of ownerships and ensuing plot-annexations; and meanwhile irrigation canals, drainage ditches and farm roads were provided altogether in the tertiary units (each size typically about 50 ha) of irrigation systems. The consolidated farm plots each thus would be able to directly draw irrigation water from the adjacent canals and discharge excess water into the bordered drains, while the farming inputs, implements, and outputs or produces would be conveniently accessible.

As new water sources for irrigation as well as other purposes have become increasingly difficult to exploitation or development in the island since 1980s due to constraints of geological and hydrological appropriateness and environmental conservation concerns, there have been little significant irrigation development projects.

To expand irrigation area with water-save methods to the upland farms for increasing local farm produces and ensuring the product quality and hence to improve the farmers’ incomes from farming, since 1983 the government has been providing financial and technical assistance to the farmers who are the owners and cultivators of their upland crop farmlands. Water-save irrigation facilities have been designed and built to best suit to their farmland forms and the crops grown. The facilities included water pipes and pumps as well as appurtenant devices for sprinkling, dripping and micro irrigation systems. As of 2007, a total of 38,420 farm-holders have installed the aforementioned facilities to benefit about 29,247 ha of upland crop farms producing mainly vegetables, tea, grape, pear and tangerine, among others. The benefits achievements included more economic water uses; higher crop yields and greater net returns.

As a result of rapid industrial development and fast urbanization in Taiwan since 1970s, the arable lands including irrigation lands have been converted to non-agricultural purposed lands. Up to the year of 2007, the irrigation area of Taiwan reduced to around 422,168 ha, of which about 382,229 ha were serviced by the existing 17 irrigation associations in all. According to the inventories of the irrigation systems in the year of 2007 compiled by the Joint Irrigation Association of Taiwan, an organization with its members being all the existing irrigation associations, quantities of the main items of facilities, with an overall length of about 46,429 km of irrigation canals and 23,481 km of drainage ditches.

In 1946, the R.O.C. government renamed irrigation Group and Public Reservoir/canal Assembly as Farmland Irrigation Association. The association chairman was elected by the election committee members. This is rather different than that of the Japanese Colonial Period when group leaders were directly appointed by local officials. Both had the same organization structure, however. The following year, Taiwan Province Department of Construction, Water Resources Bureau, and regional farmland irrigation associations were monitored and supervised. In 1948, the government regrouped Irrigation Association into Irrigation Committee in which the members were elected directly by its members. The list also includes the local authorities (Permanent Secretaries) and Irrigation experts (expert commissioners). After the committee selected the chief commissioner and the vice chief commissioner, the names were passed to the Water Resources Bureau for appointment.

After the regrouping, the government had more control over the irrigation committee but in the absence of law enforcement, the irrigation committee was like a
government agency in form but was still generally viewed as a private group. It was neither a public nor a private organization. Difficulties were encountered as a result. In 1956, the government promulgated “Taiwan Province Irrigation Association Organization code”. The 40 irrigation committees in the nation were combined into 26. These irrigation associations were entitled to corporate rights, were allowed to exercise governing rights but did not fall under the jurisdiction of government agencies.

Later on, finance and personnel related problems were frequent occurrences due to corruptions. The government was forced to propose a comprehensive plan intended for irrigation associations in 1975. Member elections were terminated temporarily. The chairman was directly appointed by the provincial government and the irrigation associations were combined into 14 in number. It was not till 1982 was the autonomy of public juridical persons restored. 2 to 3 people were nominated by the government but it was the committee that selected the chairman. After the election system was restored, local factions manipulated the system and tampered with election results. In 1993, The Legislative Yuan passed the amended “The General Guidelines for Irrigation Association Organizations”. As stated in the general guidelines, the chairman and committee members are to be selected by the government. The “committee representative system” was changed into the foundation system”. The following year, irrigation associations in the nation under Ministry of Economic Affairs were relisted as under Agriculture Committee. The chairman was directly appointed by the government to minimize interventions from local factions. The government hoped to change all irrigation associations into public agencies. However, after 2002, the chairman was again elected by committee members. Strictly speaking, irrigation associations were only ostensibly called public agencies.

3. IRRIGATION ASSOCIATION DEVELOPEMENT

3.1 Free development period (before 1895)

There was few irrigation project established by local government. Most of the irrigation organization were organized by private sector.

3.2 Foundation lying period (1896 ~ 1945)

In 1901, “Taiwan Public Reservoir/canal Code” was promulgated and managed actively. In 1908, “Government Reservoir/canal Code” was promulgated and managed by government reservoir/canal assembly. In 1921, “Taiwan Irrigation Assembly Regulation” was promulgated and the reservoir/canal Assembly was renamed Irrigation Assembly.

The large scale irrigation and drainage projects was launched during this period. The most famous one is the Chia-Nan irrigation project. In spite of the construction of irrigation structures, the irrigation association are also reorganized by the government.

In 1919, public reservoir/canal Guantian River Reservoir/canal Assembly was established to construct Chia-An Canal. Dept. Civil Engineering Yamagatayousuke of The Office of the Taiwan Governor General was mainly in charge of Chia-Nan Canal constructions. Hachitayoichi served as the Wushantou Public Works Dept. Head, supervisor, and Public Works Section Head. In 1921, it was renamed “Public Reservoir/canal Chia-Nan Canal Assembly”. A new assembly office was setup on Shiatou Road, Chiayi Street, Chiayi prefecture (present Chiayi City). A branch office (office) was also setup in Tainan Zhou Ting. Hachitayoichi served as the Wushantou branch office head. In 1923, the 19 public reservoirs/canals on Chia-Nan Plain are classified as to administration district and are combined into 6 irrigation assemblies.
including: shinfengchun, shinhua-chun, Sinyingchun, chiayichun, Douliuchun, and Huweichun. "Public Reservoir/canal Chia-Nan Canal Assembly" retained its original name and organization. In 1931, the assembly office was transferred to Tainan Zhou Ting. (Present Tainan City). In 1940, at Tainan Zhou Ting Sing Duan (Present Tainan City), a new office was setup. (Present Chia-Nan Irrigation Association Office Building) (Located at No.25 Yuai Street, Tainan City)

In 1943, the 180 irrigation assemblies and public reservoirs/canals were combined into 50 irrigation assemblies from 1941-1944. "Public Reservoir/canal Chia-Nan Canal Assembly" and the 6 irrigation assemblies including: shinfengchun, shinhua-chun, Sinyingchun, chiayichun, Douliuchun, and Huweichun were combined into Chia-Nan Canal Irrigation Assembly in 1943. The irrigation area increased to about 180,000 hectares.

3.3 Mature/ Degradation period (from 1946)

In 1946, Irrigation Assembly and Public Reservoir/canal assembly were regrouped as Farmland Irrigation Association. In 1948, Irrigation Association was regrouped Irrigation Committee. In 1956, 40 irrigation committees were combined into 26 irrigation associations. In 1975, the chairman was appointed by the government and the irrigation associations were reduced to 14 in number. In 2002, the chairman was elected by members.

In Chia-Nan area, the irrigation organization was regrouped as “Chia-Nan Canal Farmland Irrigation Association” in 1946. In 1947, “Douliu Farmland Irrigation Association” was established. Douliu irrigation area was under its supervision. The irrigation area was reduced to 150,000 hectares. In 1948, it was regrouped as “Chia-Nan Farmland Irrigation Committee”. In 1956, it was regrouped as “Chia-Nan Irrigation Association”. (Till today).

In 1974, the two irrigation associations in Jhushan, and Douliu were combined into “Yunlin Irrigation Association”. The 50-hectare irrigation area of Turbid Main Canal Irrigation System originally under Chia-Nan Irrigation Association was ceded to “Yunlin Irrigation Association”.

In 1975, the government implemented comprehensive irrigation association plans, which were under government supervision. Member election was temporarily called off. The chairman was directly appointed by the provincial government. In 1982, at the end of the government’s comprehensive farmland irrigation plan implementations, “Chia-Nan Irrigation Association” restored autonomous farmer group operation modes. The chairman was elected by members. In 1994, in accordance with amended “General Guidelines for Irrigation Association Organization”, the committee members, and chairman were appointed by the government. In 1995, due to land use changes, the irrigation area of “Chia-Nan Irrigation Association” was reduced to about 48,000 hectares. In 1996, Chia-Nan Irrigation Association Office Building was listed as a historic site in Tainan City. In 2002, in accordance with amended “General Guidelines for Irrigation Association”, the chairman and committee members were directly elected.

4. DOUBLE EXPOSURE CHALLENGE

The “double exposure” refer to the fact that regions, sectors, ecosystems and social groups will be confronted both by the impacts of climate change and by the consequences of globalization (O’Brien et al. 2004). Climate change and economic globalization, occurring simultaneously, will result in new or modified sets of winners and losers. In order to find out the vulnerability of irrigation agriculture under double
exposure in Taiwan, the definition of vulnerability is discussed as a function of adaptive capacity, sensitivity, and exposure (McCarthy et al., 2001).

4.1 Adaptive capacity of climate change

Rice is the staple crop in Taiwan, and until recently, rice cultivation has been central to the agriculture economy and culture. The history of irrigation agriculture almost regards in paddy rice system. Although the irrigated paddy rice possessed a well-infrastructure base and management experience in Taiwan, but the overproduction in rice resulted in abandoned field and transferred crop after 1970s. The development of large scale irrigated project was fallen in a rut. Until 2007, the irrigation area only occupies 40% of paddy field and about 60% of paddy field is still rain-fed paddy and most of the irrigation lands are irrigated mainly under large-scale irrigation and drainage projects (TJIA 2007), where timely and equal distribution of water against the whole command area is prerequisite. Therefore, quality of irrigation and drainage facility is an important measure of relative adaptive capacity of agriculture land, and districts with better facilities are presumed to be better able to adapt to climatic stresses.

It was during the Japanese colonial era that its administrative authorities granted the irrigation organizations in Taiwan the status of public juridical persons so as to delegate them more authority and responsibility, and meanwhile to strengthen their organizational structures and promote their capabilities to carry out the operation and management of increasing irrigation facilities in numbers, scales and technical sophistications as well.

In Taiwan, the collection of water fees is always the major income of Irrigation Associations to provide the service. From the economic viewpoint farmers may not have any incentives to organize an irrigation association under tenant farming or poor marketing condition, so it became difficult as farmers only receive the benefit of crop yield after overproduction in paddy rice. Especially the urbanization after 1970s, the operation of Irrigation Associations in Taiwan has been challenged by the sole purpose of irrigation as the service is provided beforehand.

4.2 The sensitivity of climate change

Taiwan is in the Asia-Pacific monsoon region, the precipitation received in monsoon season is very important for farmers, and the irrigation plans are often promoted in a supply-oriented fashion. If the monsoon arrives too early, too late or is erratic in its intensity, farmers will be adversely affected. Water scarcity becomes the main productivity constraint for Taiwan agriculture. According to the climate pattern analysis of the 40 years (COA, 2008), the rainfall and the length of dry period are dramatically polarizing. Those means the cropping pattern is changing in Taiwan.

Besides, substantial siltation in Taiwanese reservoirs generally results from natural collapse and anthropogenic activities. In addition, with its steep terrain and torrential rains leading to intense transient flows, Taiwan can experience severe sediment problems. Faced with both the increasing difficulty of developing new water resources, and the potential consequence of severe water shortages, it is essential for Taiwan to prolong the utility of existing reservoirs, and to protect the quality of the water supply. On the other hand, due to the global climate warming effect, occurrences of unusual intensity storms or torrential rains have become more evident in recent years, and hence the scales of flooding of farmlands, in addition to urban areas, have become more severe.
4.3 The sensitivity of globalization on rice system

The past three decades have seen a decline in the domestic consumption of rice. Many Taiwanese rice producers have been forced into a practice of crop diversification to boost their income, and to save on the costs required to produce rice at a competitive price, and regional sufficiency or deficiency in rice production has become a serious issue. After the opening up of international markets, local rice producers are in competition with other producers on the international market, and have been required to perform cost saving measures. But it is hard for the small farm. In 2010, the average farm size in Taiwan was 1.09 ha per household (COA, 2008). By this standard, the Taiwanese farmer would originally be categorized as a “peasant”. In the past three decades, however, changes in the nature of “peasants” have been accelerated along with commercialization of rice, and through urbanization. Moreover, young adults migrate from rural to urban contributing to the rapid depopulation and ageing in rural area and leave a landscape of deserted villages and abandoned fields. Until 2008, the harvested area occupies only about 60% of paddy field and about 40% of paddy field is abandoned. Since the abandoned fields always generate at random location, they not only result in fragment landscape but also in low water productivity. Some of irrigation water is drained directly to the downstream without use. The low irrigation water efficiency is always debate by other water sectors, and asks to transfer the irrigation water right to others. The relationship between the abandoned paddy field and the water competition resembles "a vicious circle", which accelerates the collapse of rice system and results in high rate of food imports from international markets. In 2010, Taiwan’s food self-sufficiency rate is only 32%. For food security reason, it is not a good trade in long term.

5. SUSTAINABLE DEVELOPMENT

The worsening of climate change in recent years has brought the hydrological conditions into more extremes, and threatens the water sectors. Especially for irrigated agriculture, the irrigation land is always forced to conduct fallow in order to transfer the water to other sectors, which may introduce the deficit risk shift to irrigation sector and food security problem (Chang, 2007). That is, traditional irrigation practices are no longer capable for the normal operation of water resources distribution, and hence new ideas are needed.

5.1 Diversification of Irrigation Association

The example of Chia-Nan Irrigation Association in southern Taiwan is a successful case of diversification of the activities of the Irrigation Associations. Besides traditional irrigation and drainage, Chia-Nan Irrigation Association also engages in: 1. power generation by setting up a power plant, yet under the condition that water conveyance is not affected, 2. renting the canal network to other sectors for water conveyance, 3. constructing business buildings for commercial use, and 4. establishing water-friendly parks or entertainment parks beside the waterways. The management of sustainable diversification without selling properties by the Chia-Nan Irrigation Association is definitely a model example in Taiwan.

5.2 Improvement of water distribution pattern

The plot with the area of about 0.25 hectare has been the operation unit for water distribution in Taiwan, and the principle of rotational irrigation by distributing water to each plot stepwise is adopted (TJIA 2007). However, instead of the continuous uniform rainfall with long durations, current rainfall occurrences are mostly
concentrated torrential rain. Without the regulation from reservoirs, it is difficult to maintain a constant irrigation flow.

As a result, it is suggested in this article that the "irrigation group", which is consisted by a collection of plots with the total area of 6 hectares (Fig. 3), be considered as the operation unit of irrigation. By keeping the ridges of adjacent plots in the irrigation group connected in a state of continuous irrigation, the operation cost of irrigation management will be significantly reduced.

**Figure 3. Water storage capacity of deep ponding water management**

5.3.1 **Multifunction of paddy field**

a. **Paddy field dam**

The water depth in rice-paddy fields has been 60 mm. Under the concept of "paddy fields are reservoirs", this depth is strongly suggested to be raised with many benefits. In specific, the water depth is suggested to be increased to 250 mm by raising the ridges, and the irrigation practice is regarded as deep-ponding (Fig. 4) (Chang et. al., 2007). With the deep-ponding, the ability to withstand water-shortage is increased more than four times as compared with the conventional irrigation.

In addition, when the idea of deep-ponding is associated with the augmentation of irrigation units, then under the safety range of tolerable flooding, these irrigation units also provide a storage space for the excessive runoff, especially when it is brought in by the concentrated torrential rain. That is, if the ridges were to be raised so that water depth was increased from 60 mm to 250 mm, an equivalent space of 190 mm is ready for water storage.

**Figure 4. Deep-ponding water management**
b. **System of Rice Intensification (SRI)**

In order to meet the growing demand of food, the idea of breeding new species of rice with super-high yield has been started since late 1980’s in many countries of the world. According to the studies in Japan, it was found that high productivity could be achieved by associating species improvement with deep-ponding irrigation management. And a methodology for increasing the productivity of irrigated rice by changing the management of plants, soil, water and nutrients, known as the System of Rice Intensification (SRI), was proposed later in 1983 by Henride Laulanie, based on his experiences in Madagascar. The experimental records of SRI from 36 locations of the world indicate that when compared with conventional irrigation, the application of SRI may result in advantages such as more productivity, less irrigation water consumption, lower production cost, less fertilizers, and better root growth, etc... However, a great deal of labor is needed for running SRI in terms of transplanting, weeding, and water management.

In fact, the practice of SRI is very similar to the field management of Taiwan in the 1970’s. Major activities in Taiwan included reducing rice planting density, alternate irrigation between wet and dry conditions, weeding by plowing, and increasing soil aerations, etc. A study was conducted in the years from 2009 to 2011 regarding the comparison of dense cultivation with deep-ponding and SRI. And the preliminary conclusion was that both techniques were helpful to the increase of rice production, but different in the process. The dense cultivation with deep-ponding has the function of flood detention, and is suitable for larger irrigation scale. SRI, instead, is applied by using the capability of drought endurance, and is suitable for small farm holders.

c. **Reuse of the Return Flow**

Taiwan has transformed from agricultural society into a hi-tech along with diversified agriculture in recent years, and the demand for industry water resources has dramatically increased up to 10% of the total developed water resources. Hence, return flow has been considered as one of the water resources for local industrials.

Agriculture in Taiwan accounts for 70% of the total water resources with 12.24 billion tons, and irrigation for rice paddy takes 10.55 billion tons. However, the actual amount of evapotranspiration is under 50% (Chang et al., 2001). Most irrigated water becomes return flow in the form of surface runoff or subsurface percolation, and is often reused downstream as one major source of irrigation water. As a result, how to make better use of the return flow has become a challenge for the water resources engineers in Taiwan (Chang et al., 2010).

![Return flow recovery system](image)

*Figure 5. Return flow recovery system*
6. CONCLUSIONS

The process of people struggle with water and food could be taken as the epitome of the human history. During those years of adapting clime change, we experience the nature that seems to be readable but hard to be predictable.

The study is not going to present an innovation of water management, but try to find water-wise strategies through the review of the irrigation agriculture in Taiwan which is affected by China, Dutch, Japan and USA in her long term development. As a result of this study, following findings are concluded. 1) Modern technologies have been introduced to Taiwan by many Japanese engineers under huge capital investments from Japan, and many of those technologies and infrastructures have been still used effectively. 2) Some of irrigation water and return water are used as industrial water. 3) Taiwan agriculture has been claimed to considerably reform itself since Taiwan was admitted to WTO. In addition to these, some of problems are clarified, such that the irrigation area decreases annually result in the food policy, and the irrigation water has been polluted during urbanization.

During the past 400 years, irrigated paddy always plays an important role in the area, as the cultivation reserve the water cycle environment bymanaging floods in occasion of storm rainfall, recharging ground water, and keeping water in farmlands. It is critical to find a wise balance between food crisis and rural urbanization in the region.

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