COPING WITH CHANGE: EVOLUTION OF IRRIGATION ORGANIZATION IN TAIWAN

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ABSTRACT

An irrigation system is a common-pool resource whose size or characteristics makes it costly, but not impossible, to exclude potential beneficiaries from obtaining benefits from its use. Especially, when the water supply is scarce and unpredictable, allocation of water is necessary to ensure that water is distributed equitably and used productively. With this concept to share the scarcity of water, development of rotational cropping and irrigation in Taiwan, particularly during the period of 1950s to 1980s had fulfilled its designated contemporary goal of producing adequate food to meet the need of that era with comparatively small amount of water. This achievement might attribute to the technical renovation on water management and heavy investment in the improvement of irrigation facilities. This practice had enabled water controllers to convince water users that the scarcity of water is being distributed equitably to a maximum extent.

Taiwan arguably has some of the best-performing irrigation systems in the world, which have made significant contributions to the country's economic development (Williams 1994; Chen 1997). Prior research suggests that the excellent irrigation performance can be attributed to the design of the country's irrigation institutions. Irrigation in much of Taiwan is governed by seventeen Irrigation Associations (IAs) – parastatal organizations are collectively owned by farmers, supervised by governments at multiple jurisdiction levels, managed by professional managers, led by local politicians chosen by farmers, and supported by a network of Irrigation Groups (IGs).Through IAs, farmers organize collective action for irrigation operation and maintenance (PIM) at the local level. This design combines professional management and government support on the one hand, and farmer participation and self-governance on the other.

Since the early 1980s, Taiwan's irrigation has been facing substantial challenges as agriculture lost its economic importance; the decline of agriculture has come with drastic changes to the country's social-political contours. As a result, irrigation in Taiwan has taken on new features including a dominance of part-time farming, an increasingly heavy reliance on groundwater, and a growing integration of irrigation into the national water management regime; all these have reduced farmers' incentives to engage in self-governing activities for irrigation management. Since 1993, the government has been paying membership fees to the IAs on farmers' behalf. As the irrigation sector is getting more and more reliant on government subsidy, the government feels obliged to impose tighter control to make sure that public money is appropriately spent. However, coordination in actual water delivery in Taiwan is maintained not by a grand plan or a pacemaker, but by an array of

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institutional arrangements that encourage local problem solving on one hand, and local mutual adjustments on the other. Farmers in disparate situations can decide on how much effort they want to put in irrigation management, and their best ways to do it. The flexible institutional arrangements in Taiwan depend on the willingness of a small group of IG leaders who serve as the linkage to connec with farmers.

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 keep fallow in order to transfer the water to other sectors. That is, traditional irrigation practices are no longer capable for the normal operation of water resources distribution, and hence new ideas are needed. The role of the IG has become increasingly important for the coordination with variability on field level. The IAs are surely aware of the situation, and have adopted measures to beef up the support and incentives for the IG leaders. In addition to find the sustainable development of Irrigation Associations, the Irrigation Associations should not confine themselves on the single service of irrigation. Instead, through diversification of the businesses by making better use of the facilities, land assets, and human resources, the financial situation of the Irrigation Associations should be significantly improved.

Keywords : Irrigation association, Self-governance, PIM, Taiwan

1. INTRODUCTION

Taiwan, 142 km in width and 383 km in length, is an island oblong in shape and located in the West Pacific Ocean, east of the Chinese mainland with an area of 35,961 km2. Being situated in both of the tropical and subtropical oceanic zones and also in the Asian monsoon region, and with a large ratio of mountainous lands on the island (Fig. 1), the climates in Taiwan are greatly influenced by the monsoons as well as the land forms.

Subtropical climate characterized by high temperature, heavy precipitation, and violent winds. Annual precipitation over the island averages 2,610 mm, which far exceeds the world average of 650 mm/year. However, the rainfall pattern in Taiwan is mostly concentrated torrential with short duration, and the sediment yield per unit area of the rivers is about 64 times of the world average. The annual availability of water resources from precipitation varies from 60 billion m3 to 120 billion m3, of which about 20 to 25 per cent of them were utilized in the last 10 years. In terms of depth, the annual average precipitation of Taiwan is the third highest in the World~ but per capita precipitation being used is about 4,030 m3/person/year, contrarily this amount is the third lowest compared to the lowest and 2nd lowest of Egypt and India at 951 and 3,795 m3/person/year respectively (Ko, 2002). Uneven distribution of precipitation in space and time, together with the lack of suitable storage dam sites due to weakness in geological land formation coupled the difficulties in water utilization in Taiwan. The precipitation utilization rates in the last ten years varied from 22% to 14%. Of the utilized water resources, only 24 to 28 per cent of them were taken from the existing 41 small reservoirs. The shares of water utilization to the sectors of agriculture, domestic water supply, and industry, in the Year of 2015 for example, are about 71.5%, 17.7% and 11.8% respectively. In the same year, paddy rice irrigation, fishery and animal industrial sub-sectors shares 83, 16 and 1 per cent of the total of agriculture respectively (COA, 2013).

Those features induce the damage of flood and drought is very frequently in Taiwan. The development of agriculture is highly depended on the large scale irrigation and drainage projects. Given the above-mentioned unfavourable precipitation distribution, water shortage for irrigation almost reoccurs once every five to seven years during

the dry season of winter; however, the temperature and soil conditions in Taiwan are in favour of growing two crops of paddy rice wherever and whenever water resources are available. As rice is the staple food of the local inhabitants, traditionally, farmers would grow paddy rice as possible as they could when Taiwan was still in the subsistence agriculture. Non-rice crops might be grown after harvesting irrigated paddy at the beginning of dry season. Those non-rice crops, which consumed much less water than paddy, would absorb the residual moisture in the soil after irrigation for germination; then they would grow in the semi rain-fed condition. Once or twice of irrigations depending upon water availability would be given to upland crops. When water resources are sufficiently for growing paddy rice, farmers would grow rice; otherwise the upland crops would be their second choice. This rotational and diversified cropping pattern has prevailed for hundreds years in Taiwan. There were some cases, when upland crops could not receive sufficient water from irrigation or rainfalls, they would produce lower yield or even being suffered from damages. Farmers practicing this kind of rotational or diversified cropping were usually aware of the existence of risk; however, through their long-term trial-and-errors process, they eventually would gam sufficient experiences to undertake the most profitable diversified cropping in the long run.

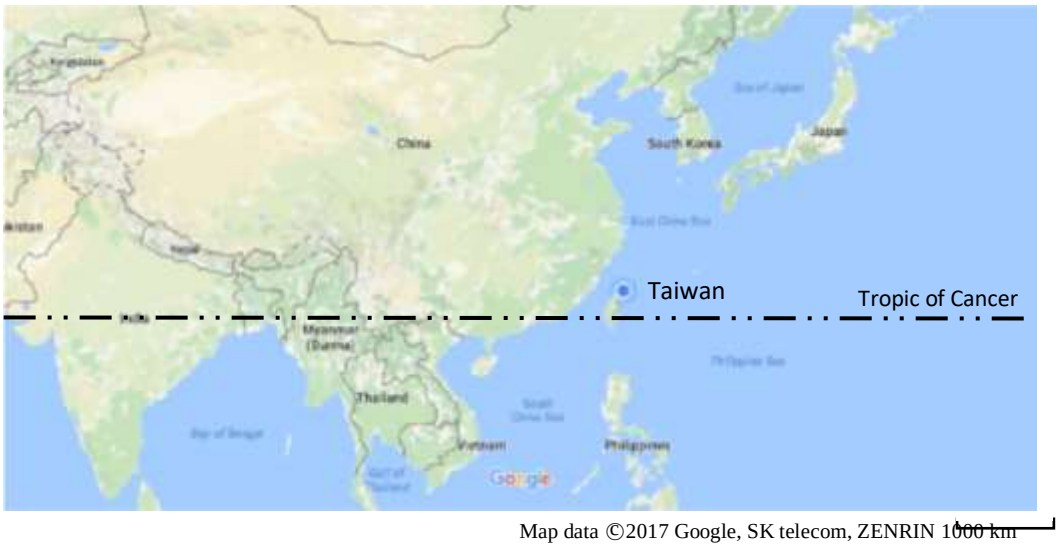

Figure 1. Map of Taiwan

The island of Taiwan, formerly known as Formosa, was inhabited by Taiwanese aborigines before the 17th century, when Dutch and Spanish colonies opened the island to mass Han immigration. After a brief rule by the Kingdom of Tungning, the island was annexed by the Qing dynasty, the last dynasty of China. The Qing ceded Taiwan to Japan in 1895 after the Sino-Japanese War. Following the end of World War II in Asia in 1945, the Republic of China took control of Taiwan. According to the historical data, the course of irrigation development in Taiwan that has lasted for over 400 years since its inception can be divided into two stages as indicated in Fig. 2 (COA, 2009), which can be summarized below.

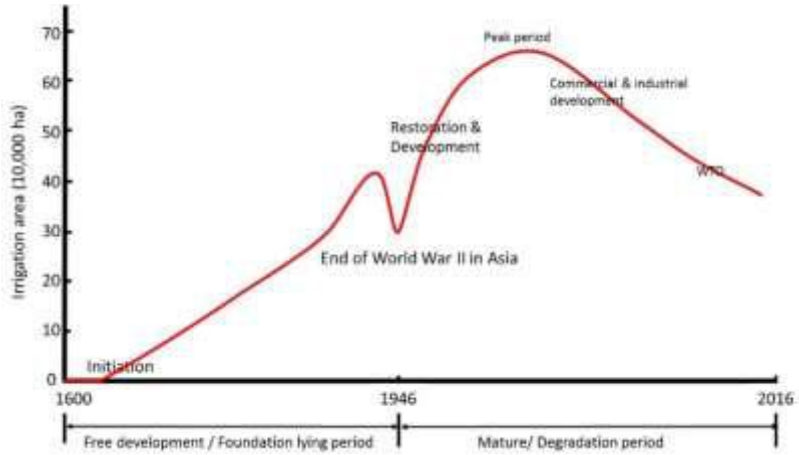

Figure 2. The irrigation development stages in Taiwan

a. Free development / Foundation laying period (before 1945)

There were few irrigation projects established before 1680s. Most of the irrigation organization were organized by private sector. Because of severe financial constraint, few significant irrigation works were developed in the beginning of this period. As the immigrants from the Mainland China to Taiwan increased in 1680s, the private sector began participation in development of irrigation projects, invested by either the singles or the partnerships. At that time, most irrigation facilities had been constructed and managed by the private irrigation groups, and in order to manage these equipment, they would either recommend or invite a reservoir supervisor to inspect, repair the canal, distribute water, and water thieves. Instead of taking an active role in managing the irrigation facilities the government authority merely played the role of issuing permits (canal licenses, admonitions, and seals) or acted as the judge and law enforcer when there was a dispute.

Until the end of 1894, 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 sources included stream flows, rainwater stored in ponds and groundwater abstracted from wells. The irrigation systems were developed and operated totally by the water users, i.e. a real and whole participatory irrigation management (PIM). The people that channelled water would pay the water supervisor with grains of rice. When there was canal damage, they were required to fix it. These irrigated areas were ever supplied water from several canals, which were then expanded and upgraded afterwards till nowadays and hence still exist presently. These canals are among others the Liugong Canal at Taipei area in the north, Babao Canal at Changhua area in the central and Caogong Canal at Kaohsiung area in the south of Taiwan.

As a showpiece “model colony” of Imperial Japan since 1895, the Office of the Governor-General of Taiwan had made much effort to improve the island's agriculture, industry and public works. After adopting mass rice production as the policy for foreign exchange earnings or savings, and food self-sufficiency or food security in 1908, the Government of Japan became involved deeply in the development and management of irrigation systems. Since then, irrigation development and operation has never got rid of Government's different levels of control. From 1901 to 1921, the private irrigation groups were integrated into the Public Irrigation Assemblies and controlled by the government authority through series of government regulations. On the other hand, the large scale irrigation and

drainage projects were launched by government in the same time. 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. Until the end of 1944, the 180 Private Irrigation Groups and public reservoirs/canals were combined into 50 Irrigation Assemblies when the irrigation area increased to about 370,000 hectares.

b. Mature/ Degradation period (from 1946)

Following the end of World War II in Asia, in 1946, 50 Irrigation Assemblies were renamed as Farmland Irrigation Association by present government who take over the management from Japanese. The government authority only played as a moderator or a supervisor in the beginning of this period. Instead of designating by government officials during Japanese colonial period, the association chairman was elected by the election committee members in this period. In 1948, the government regrouped Irrigation Association into Irrigation Committee which made the irrigation institution can be easier to be controlled by the government. However, due to 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. In 1956, 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.

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. 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 16 in number. It was not till 1982 was the autonomy of public juridical persons restored and the irrigation associations were separated into 17 in number. After the election system was restored, local factions manipulated the system and tampered with election results. Based on the food security reason at that time,the government started to take on an increasingly heavy role in irrigation management. Since 1993, the government has been paying membership fees to the IAs on farmers' behalf, and the chairman and committee members were amended 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.

Up to the year of 2015, the irrigation area of Taiwan reduced to around 387,346 ha, of which about 368,576 ha were serviced by the existing 17 irrigation associations in all. According to the inventories of the irrigation systems in the year of 2015 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 44,061 km of irrigation canals and 25,604 km of drainage ditches.

2. INSTITUTION AND ORGANIZATION OF IRRIGATION ASSOCIATION

Taiwan's irrigation systems used to be reportedly amongthe most effective in the world. In a study comparingthe water delivery efficiency in different rice-growingsystems in Asia, Levine (1977) estimated that thebasic water requirement per crop in Taiwan was 1,000mm, as compared to 2,500 mm in the Philippines and1,400 mm in Malaysia. In the Tou Liu system inTaiwan (currently part of the Yunlin IrrigationAssociation), the requirement was even as low as 650mm. The effectiveness, however, is not confined tothe high levels of efficiency in water delivery. Waterdelivery and distribution in Taiwan's irrigation systemsare generally organized in an orderly manner,and the physical structures are kept in relatively goodcondition.

2.1 Organizational structure of irrigation association

In general, an irrigation system consists of diversion works, conveyance canal and distribution system in Taiwan. Owing to the large commanding area, conveyance as well as distribution of water and irrigation work must be separated so that the system can be managed clearly defined. Fig. 3 shows the division of an irrigation and drainage system and its management. As of a small system, it can be simplified according to actual need.

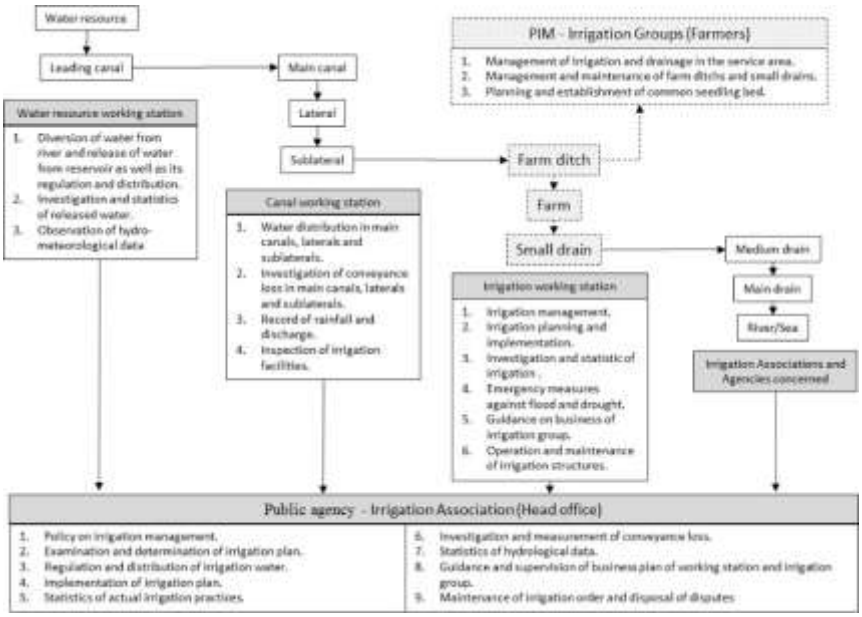

Figure 3. Division of Irrigation and Drainage System and its management

Division of irrigation area varies with irrigation methods. In general, a conveyance system (lateral or sub-lateral) is considered as a division unit, or, the system is divided into several division of area depends on the canal capacity of the conveyance and distribution system, discharge of water source, soil permeability, and growth stage of paddy, so sizes among areas are widely different.

2.2 Adopts environment & socioeconomic change through rotational cropping pattern and irrigation

Scarcity of resources does not cause problem more serious than inequity in distributing such resources to the public. With this concept to share the scarcity of

water, development of rotational cropping and irrigation in Taiwan, particularly during the period of 1950s to 1980s had fulfilled its designated contemporary goal of producing adequate food to meet the need of that era with comparatively small amount of water. This achievement might attribute to the technical renovation on water management and heavy investment in the improvement of irrigation facilities. Contemplatively, this practice had enabled water controllers to convince water users that the scarcity of water is being distributed equitably to a maximum extent so that the use of water in the field could maintain orderly, of which might ascribe equally or even more than the technical amelioration and heavy investment to the success and sustainability of water management.

a. Practice of rotational irrigation

In general, water delivery for irrigation in Taiwan is not based on the demand of individual farmers. Irrigation usually follows a precise schedule recognizing farmer needs. The method is called rotational irrigation. Rotational irrigation is an intermittent application of irrigation water at a regular time interval and with specified water depths. The amount of water applied to each cycle of the rotation is based on the actual need of crop's consumptive use and irrigation requirement according to the different growth stages of paddy. This method will result in one or two days without water standing on the field. It permits a periodical aeration of the root zone, which is considered to be beneficial to a better growth and production of paddy rice.

This concept and practice in Taiwan had already prevailed about two hundred years ago. Especially after the restoration of Taiwan in from 1945, systematic research on water application methods for paddy rice was conducted in the Chianan Irrigation Association. Information from these experiments coupled with actual demonstration experiences in the new canal system gave confidence to the irrigation engineers to develop the specifics of "Rotational Irrigation." It has been rapidly displaced the conventional continuous irrigation. The above-mentioned experiments and demonstrations found that the rotational irrigation compared to the conventional irrigation has the following advantages. They are:

- Rotational irrigation has shown to achieve water saving by 20-25 percent as compared with conventional continuous irrigation in the long-term.
- Most cases indicate a higher yield with rotational irrigation.
- Rotational irrigation decreases irrigation disputes and helps the development of cooperative atmosphere and order in the practicing irrigation in the rural areas.
- Rotational irrigation encourages the use of the common irrigator, by which the farming time on irrigation by individual farmer can be saved resulting in farming efficiency.

As for rotational irrigation, the area should be divided into rotation blocks and rotation units according to the irrigation system and in considering the natural boundaries such as farm roads, waterways and other ground implements. In general, an area of rotation block shall be of about 50 ha. The rotation block, based on the distribution system, is subdivided into several (4-6) rotation units, each of about 10 ha in size. The rotation unit is the basic unit for rotational irrigation. Water distributed into rotation block shall be properly rotated at a certain interval among the rotation units, the rotation process shall be repeated all over again.

Division according to rotation block and unit in a land consolidation area is show in Fig.4b, while the division of an irrigation system is shown in Fig. 4a.

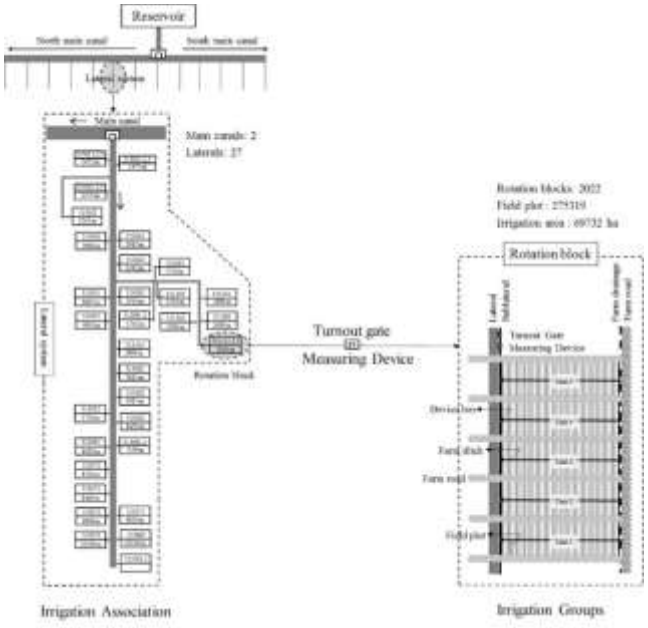

Figure 4. Division of Irrigation system and rotation block

b. Practice of rotational cropping pattern

One of the most sophisticated rotational cropping patterns designed in Asia is located in the Chia-nan Irrigation system situated in the south of Taiwan. This amount of rainfall should have been sufficient to grow two crops of paddy annually. Unfortunately, the about 91 per cent of annual run-off concentrates in the raining season from May to September each year, and the geological condition is neither in favour to build water storage facilities. As a result, the developed water resources were only sufficient to grow one crop of paddy rice in the monsoon season in the one-third of the total newly developed area. Consequently, a "three-year rotational cropping pattern" was developed and practiced.

The preliminary rotational cropping pattern was firstly operated in 1927 during Japanese colonization. After the end of World War II in Asia since 1945, more water resources were developed to produce more rice to meet the increase in populations. As of the now there are six kinds of cropping pattern prevailing in Taiwan. They are:

- Double Paddy Cropping Pattern: rice grows in the both wet and dry seasons each year.
- Single Paddy Cropping pattern: rice grows only in wet season each year.
- Two Paddy Rice Crops Each Two Years Pattern: rice grows in wet season in the first year and another rice crop grows in dry season the next year.
- One Rice Crops in Three Years: rice grows in the wet season once out of three years.
- Two Rice Crops in Three Years: rice grows only in wet seasons twice out of three year; and sugarcane or upland crops during the remainder of three years.
- Modified Two Rice Crops in Three Years: rice grows once in wet season and other in the dry season of another year out of three years.

For enabling the irrigation schemes to carry out "Three-Year-Rotational Cropping Pattern", the entire newly developed irrigation areas were divided into 150-hectare unit each, namely rotational cropping unit; each unit is further subdivided into three

sub-rotational units with 50 hectares each. Three major crops, namely paddy rice, upland crops, and sugarcane were grown in each sub-unit by tum within three years as a rotational cycle. The layout of irrigation and drainage canal either on-farm or off-farm system was so designed to fit the practice of the rotational cropping. In this connection, each rotational unit with three sub-units has their own individual off-take gates. In particular, for the design of irrigation system, among all rotation units or sub-units, canals in different units would never be connected or mixed among them.

As above-mentioned, for instance, when one of the three sub-units would receive water sufficient for producing one crop of paddy rice in the summer; the second sub-unit would be given irrigation water only in the dry season of winter or spring for the need of growing sugarcane; while the third sub-unit, growing miscellaneous crops, would receive only the surplus water whenever is available, or frequently no irrigation at all. The next year, the second sub-unit would be given water to grow rice; the third to grow sugarcane and the first to grow miscellaneous crops, and so on. Thus the differential water supply is applied to the three sub-units on a three-year rotation basis.

To ensure the success of rotation cropping, farmers' irrigation groups and sub-groups were organized according to their units and sub-units. The main task of the organization includes: a leader for each group would be elected through common election for a three-year service term; and three sub-group leaders would be assigned by the elected group leader. The responsibility of group leader would mainly serve as the followings:

- Conducting fixed term and temporary group meetings for discussing irrigation and cropping schedule related affairs;
- Conveying farmers' view regarding irrigation, cropping pattern, water fee and matters relevant to the system controllers i.e. the irrigation association;
- Conveying the message from the irrigation association to the farmer; and
- Other relevant matters entrusted by the Government or the irrigation Association

In the early stage of the implementation of rotational cropping pattern, the willingness of farmers to follow was not encouraging. The Government had provided a strong support and intervention to make sure the success of rotational cropping pattern. For the most cost effective the use of water at that time, the Government usually gave the first priority to paddy rice, the second to sugarcane, then upland crops the third. It has taken about six years on trial-and-error approach to make the arrangement of rotation cropping pattern to be mature.

3. PARTICIPATORY IRRIGATION MANAGEMENT (PIM)

3.1 Needs of PIM

In the implementation of water distribution in an irrigation system duties and functions between canal water distribution and farm irrigation should be separated to avoid discrepancies in irrigation time and irrigation implementation which may cause uneven water distribution. Only in a small system can both be served concurrently by the management technicians. Canal water distribution should be carried out by the canal working station or canal management technicians, while irrigation area (rotation unit) should be managed by irrigation working station or irrigation management technicians. Common irrigator may be employed for each rotation unit. In case there is no common irrigator, it may be operated by the irrigation group (PIM). Farm practices can be done by the common irrigator or the member farmer themselves in accordance with the irrigation schedule.

Rotation block and unit are the end system for water distribution. In general, irrigation water in the rotation block is properly rotated with a certain irrigation interval among the rotation units. Except that the turnout gates of rotation blocks are regulated and farm irrigation practices in rotation units supervised by the management technicians of the irrigation associations, water management in rotation blocks currently adopted in Taiwan are of following system:

a. Implementation of common irrigation system by hiring common irrigators

Inside a rotation block (about 50 ha), one or two common irrigators may be hired by the members within the block. After practical training in water distribution, they will be responsible for execution of water distribution in the rotation block according to the irrigation plan. The advantages and disadvantages of this system are as follows:
Advantages:

- Entrusting execution of water distribution to common irrigators may save labour of farmers so that they may have enough time to develop other side jobs.
- Each farm plot can be irrigated evenly with the skill of common irrigators, no matter how different are the water sources.
- Water distribution done by common irrigators may reduce meaningless disputes.
- Common irrigators may also take charge of the maintenance of farm ditches during his spare time to save labour for maintenance.
- Common irrigators may gradually be transformed into specialists by experience and training with the ability to raise the standard of irrigation and also promote the following cropping system in (1) Establishing common seedling bed, and (2) implementing joint-operation; furthermore, in facilitating joint cultivation, joint pest and insect control, cooperative farm machinery, and cooperative production and marketing on the basis of rotation block. This is most idea method in promoting rotational irrigation.

Disadvantages:

Although labor can be saved, farmer must pay the cost for common irrigators. If the farmers have no other side job, this cost will become a burden to them.

b. Water distribution by member farmers on duty in turn

This method is suitable for the rotation block where there are surplus labors or cultivated area of each farmer is large. The irrigation group will arrange the time for its members to go on duty in turn according to the size of farmers' land. Water distribution in a rotation unit shall be operated by the members outside the unit, even it is its turn.

Advantages:

- Farmers need not pay the cost for common irrigators.
- Farmers' surplus labour can be adequately utilized.
- It may help farmers thoroughly understand the operation of water distribution and promote their experience.

Disadvantages:

- It is easy to be discontinued if the farmer member in turn cannot go on duty.
- Operation of water distribution by farmers may not be as fair and skilful as that done by a common irrigator.
- The irrigation group leader needs to supervise at all times and places.

- Changing shifts wastes time for coming and going.
- Size of cultivated land of farmers are different, accurate calculation and just allocation of work are difficult.
- It is difficult to implement this system in an area where water is abundant.

c. Water application by member farmers themselves during their turns
This is similar to the operation of continuous irrigation. Member farmers irrigate their farms by themselves according to the irrigation schedule.

Advantages:

- Farmers need not pay the cost for common irrigators.
- Farmers may do some of his field work while on duty.
- It can be done by women, elders or children in the daytime

Disadvantages:

- Unauthorized water use may easily occur.
- Uneven application of irrigation water may occur when the discharge from the water source varies.
- Farm ditched have to be protected and maintained by free labors.
- Irrigation of farm plot should be done and handed over according to schedule.
- It wastes time and labor foe farmers to go back and forth between his own farm and the operation spot.
- Irrigation may not be specialized and farmers are difficult to take up some side job.

3.2 PIM Approach

A major feature of Taiwan's irrigation institutions is that they provide arenas and logistic support for problem solving by farmers at the field level. Farmers are organized into self-organized Irrigation Groups (IGs), which are responsible for irrigation operation and maintenance (O&M) in the field. Farmers in an IG elect an IG leader, who is given the mandate to coordinate and liaise with the IG members concerning O&M activities. In some IGs, water guards are hired to help on water allocation and minor maintenance works. A major feature of the IGs is that they are organized on the basis of hydraulic boundaries. For example, in Taoyuan areas where a large number of ponds were in place for water storage, the IGs there are organized in accordance with the areas irrigated by individual ponds. In areas irrigated by water from reservoirs such as the Chianan areas, an IG usually includes irrigators served by the same sub-lateral. By matching the boundaries of the IGs with hydraulic areas, the task of irrigation management is effectively compartmentalized into subtasks; more importantly, farmers in each IG are in effect assigned to coordinate among themselves with reference to the management of the subtask. That farmers at the local level are allowed to work out solutions to cope with the "localized" irrigation problems enables better utilization of local information. The IG arrangements, by nature of its proximity to local community, can effectively draw upon social capital that has already been developed in local community to attain coordination in the O&M processes (Lam, 1996, 2004, 2016).

Coordination at the sub-lateral level with the IG as the basic problem-solving unit by itself is inadequate. Some of relative researchers have found that allowing a small number of random links developed between individuals can provide the glue that drastically shortens the social distance between individuals belonging to different communities. In irrigation management, cross-community coordination is very importance to irrigation efficiency. There are two institutional arrangements are

implemented to connect the clustered groups (IGs) in Taiwan. The first is the irrigation plans worked out by Irrigation Associations (IAs) every year as the blueprint for water delivery. The plans are made mainly based upon the geological and topographical conditions of farmers' fields and expected cropping patterns, with minor adjustments made every year to take into account the changes in the size of irrigated areas and possible changes in land use. While the plans are so meticulous that even the exact amount of water allocated to a particular patch is specified, they are frequently not strictly followed in actual water distribution. In fact in systems where the major source of water is rivers and creeks, irrigation plans are made but seldom used. Yet these irrigation plans do serve a very important coordination function. The amounts of water to particular field as specified in these plans are considered farmers' entitlement of water. They serve as the yardstick around which adjustments be made. So disparate IGs have a rough idea about the overall picture of how water should be distributed, which could impose the bounds within which the IGs can make mutual adjustments. In a way these plans provide a mental map for farmers to engage in mutual adjustments.

Second, random links are applied to provide bridges linking up the IGs and the working stations. The working stations hold regular IG leaders meetings twice a year, usually scheduled for the time right before irrigation starts. Other than these regular meetings, ad hoc meetings will be held to cope with emergencies. Whether these meetings can provide an effective communication for decision making and deliberation has been subject to question. Anyone who has observed these meetings would note that they are more like social gatherings and largely dominated by IA officials. Despite of the attendance rate is always low, these meetings still serve the important function of weak ties linking up the IGs. Other than meetings, IG leaders are engaged in activities of several kinds organized by the IAs. For example, every year an irrigation festival is organized at which some "model IG leaders" will be given awards; also an IG leader is entitled to an "overseas field trip" during his term of service to explore his knowledge. All these seemingly trivial and irrelevant activities help sustain the connection among the IG leaders. Random links are also built in by rotating working station staffs from time to time. A major characteristic of the IAs is that, through a network of working stations, the IA staffs are stationed in the field for a relatively long period of time so that they are made embedded in the communities they serve. Unlike in South Asian countries where irrigation officials are often posted to particular positions for a short period of time, IA staff usually spend a prolonged period of time in a station. The prolonged stay, however, is not like that in Japan where the small size of Farmland Improvement Associations has basically locked in irrigation staff to a particular locale for their careers. The IA staff usually have a number of postings during their careers. The infrequent yet regular movement of staff helps creating links between officials and farmers across communities.

Coordination in actual water delivery in Taiwan is maintained not by a grand plan or a pacemaker, but by an array of institutional arrangements that encourage local problem solving on one hand, and local mutual adjustments on the other. While such a mode of coordination seems not forceful, and certainly does not fit neatly with the engineering image of orderly water allocation, it is tremendously flexible and robust. It allows farmers in disparate situations to decide on how much effort they want to put in irrigation management, and their best ways to do it. The flexibility of the institutions can cope with the low incentive mode of agriculture on one hand, and retain a certain level of vibrancy in irrigation management on the other. The viability of the flexible institutional arrangements in Taiwan depends on the willingness of a small group of IG leaders who serve as the bridges connecting up farmers. Although many IGs are no longer as active as before, the role of the IG leaders has become increasingly important for the purpose of coordination. The IAs are surely aware of the situation, and have adopted measures to beef up the support and incentives for the IG leaders.

4. CHALLENGES

In the 1950s and the 1960s, the Taiwanese government adopted policies to tax the agricultural sector to help launch industrialization. By a series of exploitative measures such as barter of fertilizer for rice and compulsory rice purchases, the government was able to extract surplus out of agriculture to support industrialization by providing affordable food and necessary financial transfers to the industrial sector. By the late 1970s, Taiwan's industry took off. Ironically, the efficiency of the agriculture sector has made the sector particularly vulnerable to the process of industrialization. While agriculture lost its economic viability, the cross-sector reallocation of resources issues occur in Taiwan.

For food security reason, the government has maintained a grain reserve that is sufficient for the population consumption for 3 months. More importantly, the government has promulgated strict zoning laws, restricting changes of land use of paddy fields to maintain the agricultural potential. However, the government has also provided a variety of subsidy programs for the compensation of the farmer, including guaranteed procurement of grains at preferential prices, subsidies for fallowing, and substantial rural infrastructure projects. As the vibrancy of irrigation infrastructure is essential to the maintenance of agricultural potential, the government has been subsidizing the irrigation sector quite substantially. Other than the food security concern, another aspect of the political economy of agricultural policy in Taiwan concerns with votes and elections. The rural populace in Taiwan constitutes a substantial voting block that no political parties in the country could afford to ignore. As of 2016, the 17 IAs in Taiwan have a total membership of more than 1.56 million (TJIA, 2016). Assuming that each member household has four people eligible to vote, the IAs can influence almost 6 million votes. Unlike in many other Asian countries, Taiwan's rural populace is highly organized, an unintended consequence of the government's effort to control the rural population through a network of semi-governmental organizations, including the IAs. When the interest of these organized groups is challenged, they won't hesitate to defend themselves.

However, if the agricultural sector had been able to diversify production, the government's food and agricultural policies would not have affected agriculture too adversely. Unfortunately, the structure of Taiwan's agriculture is not helpful to diversification or change. A major problem is the small landholding size, which is largely a result of the land reforms so successfully implemented in the early 1950s. Since 1990, the average landholding size of farm households in Taiwan has been less than 1 hectare. The small landholding size does not allow effective use of machines and, more importantly, renders infrastructure investment uneconomical. Farmers simply cannot make a living on farming. As farming turns unprofitable, farmers in other countries might well sell their farmlands and move to cities. Taiwanese farmers, however, are generally unwilling to do so. Farmers' bond of land might explain part of the situation, but material incentive might be a more important factor. Many farmers expect that someday their lands might be rezoned, which would mean a substantial increase in land value. For farmers who derive a major part of income from non-farm activities, they could afford keeping the lands and wait.

The political economy of agriculture as described has impact on irrigation management at two levels (Lam, 2016). At the field level, farmers face little incentive to engage in irrigation management. Unlike in good old days when irrigation water very much determined farmers' income, and so farmers had strong incentives to get involved in irrigation operation and maintenance (O&M), farming nowadays is considered a supplementary economic activity which, in some circumstances, is not even for profit-making but simply for keeping the lands cultivable. Such a low-

incentive mode of agriculture poses serious challenges to Taiwanese irrigation management which is grounded upon farmers' participation and farmer-government synergy.

At the sectoral level, the change has posed to the government the difficult question of how to restructure its relationship with the irrigation sector. Given that farmers are trapped in agriculture by government policies and do not have much incentive to invest in irrigation maintenance and operation, the government finds itself taking on an increasingly heavy role in irrigation management (TJIA, 2003). Since 1993, the government has been paying membership fees to the IAs on farmers' behalf, in addition to the large infrastructure maintenance subsidy that also comes out of the government budget. As the irrigation sector is getting more and more reliant on government subsidy, the government feels obliged to impose tighter control to make sure that public monies are appropriately spent. Interestingly, that the government has put in increasing amounts of resources in the irrigation sector does not mean that all the IAs are facing financial difficulties. The IAs that are located near urban areas have in fact been accumulating much wealth through the sales of lands and properties that ceased to serve irrigation purposes (AERC, 2001). Because farmers are no longer enthusiastic about getting involved in irrigation management and hence the operation of the IAs, the government finds herself taking on the role of the monitor to prevent the IAs from turning into some private clubs of IA staffs and local politicians who control the IAs.

Despite the government's intention to tighten control, putting effective control in place is no easy task (CAEA, 1995). First, the IAs are formed and owned by farmers. It is not clear as to how the government could square the concept of private property with the process of nationalizing the IAs. Second, how to manage the IA staff is another thorny issue. Currently the IA staff do not have the civil servant status; in fact, the majority of the older generations of the staff have received only limited formal education. Third, the IAs are important political mobilization machines. Politicians who have a strong hold in these organizations are unlikely to give in easily.

Another dimension of the challenge at the sectoral level is concerned about water resource allocation and utilization across sectors. As agriculture is no longer a major economic activity, many people argue that water rights should be reconsidered so that more water could be diverted to domestic and industrial uses. To irrigation officials and the IAs, they need to address two issues. First, they need to provide justifications for their defence of their water rights. Second, they need to come up with policy recommendations that allow effective utilization and flexible allocation of water across sectors. The challenges at both the operational and sectoral levels have impact on the operation and management of irrigation systems in Taiwan.

5. RECOMMENDATIONS

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 (Y.C. 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.

In addition to find the sustainable development of Irrigation Associations, the Irrigation Associations should not confine themselves on the single service of irrigation. Instead, through diversification of the businesses by making better use of the facilities, land assets, and human resources, the financial situation of the Irrigation

Associations should be significantly improved. The example of Chia-Nan Irrigation Association in southern Taiwan is a successful case. 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.

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