

IRRIGATION PERFORMANCE AND MANAGEMENT IN TAIWAN

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ABSTRACT

Paddy is the important crop to be grown in Taiwan. There are two paddy may be grown in a year, wherever irrigation water is available. It maintains the self-sufficiency in food-crop products so as to ensure the security of food supplies and raises farmers income in Taiwan for a long time. This paper is to introduce the aspects dealing with irrigation performance and management prevailed in Taiwan. Due to the recent socio-economic changes, the water demand has been increasing with the expansion of industrialization and urbanization. The acquisition of new water supplies for agricultural irrigation has become more difficult and costly. Besides, the existing irrigation water sources face the pressure of competition use of other purposes. Irrigation encompasses social, economic, policy and institutional aspects, such as irrigation science, ecological function, entry into WTO challenges, etc. As a result, a great effort to ensure efficient utilization and sustainable use of irrigation water through improvement in irrigation system and water management is being made and also discussed in this paper.

INTRODUCTION

The climate of Taiwan is comparatively warm, which provides a long growing season and permits diversified cropping. There are two or more crops can be grown in a year, wherever water is available. The average annual rainfall is 2,515 mm. Rainfall is abundant, but its distribution throughout the year is different locally and timely. This uneven annual rainfall is not quite in accordance with the growing seasons of crops. Therefore, irrigation is indispensable for crop production, which depends on the available water sources and adequate irrigation facilities as well as proper management. The total area of Taiwan is about 36,000 km², of which 24% or 8,760 km² are cultivated lands including about 60% of irrigated land and 40% of non-irrigated land. In 1996, the total water used in Taiwan amounted to 18.1 billion m³, of which about 10.2 billion m³ or 56% of the total was used for irrigation as shown in Table 1(WRB,1997). River off-take, reservoir/pond storage water and ground water are the three major water sources to be developed for irrigation. They are operated individually or conjunctively during the irrigation season with various irrigation systems, which can be

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classified as (1) irrigation system directly diverting water from natural stream, (2) irrigation system with a reservoir, (3) irrigation system with irrigation ponds, (4) irrigation system with water supplied from irrigation wells, and (5) irrigation system with two or more of the aforementioned water sources. The total irrigations area in Taiwan is about 456,000 ha in 1997, of which 381,000 ha or 76% are under the jurisdiction of 17 Irrigation Associations (IA) and the rest are managed by private farmers and Taiwan sugar corporation's farmers. These irrigation areas are served by 1,797 irrigation canal systems, 2,000 shallow and deep irrigation wells, and 18 reservoirs (TJIA, 1998).

Table 1. Water use of Taiwan in 1996

Unit: $10^6 m^3$

Area □□□□□□□	North	Central	South	East	Total	(%)
Agricultural water use	2,020	5,557	3,650	2,271	13,498	(74.5)
(1) Irrigation	1,654	4,828	1,548	2,170	10,200	(56.3)
(2) Fish-culture use	353	671	2,025	97	3,146	(17.4)
(3) Livestock use	13	5	77	4	152	(0.80)
Domestic water supply	1,524	619	660	59	2,862	(15.8)
Industrial water use	625	426	663	51	1,765	(9.7)
Total water use	4,170	6,602	4,973	2,380	18,125	(100)

Source : Water Resources Bureau, Ministry of Economic Affairs, 1996

Taiwan had developed irrigation chiefly for rice cultivation for more than 300 years. As paddy rice consumes a large amount of water and water becomes more and more limited in Taiwan, economical and efficient utilization of the limited irrigation water resources is essentially important. For this point of view, water saving irrigation method and high irrigation efficiency management are developed for irrigation. This paper is to introduce the aspects dealing with irrigation performance and management prevailed in Taiwan, and some improvements due to the recent environmental and socio-economic changes.

IRRIGATION DEVELOPMENT HISTORY OF TAIWAN

Since rice is the staple food in Taiwan, irrigation has been essentially developed for rice cultivation. It began in the seventeenth century when immigrants came from mainland China. The early development of the irrigation systems were small scale with purpose mainly for rice production. Most of the irrigation systems were built and managed by the farmers themselves without any assistance from the government. By 1895, a total area of about 350,000 ha had been developed for farm land, of which about 200,000 ha were under irrigation.

During the period from 1896 to 1947, Taiwan was occupied by Japan, a set of

regulations calling for the registration of those private irrigation systems were promulgated by the Japanese government in order to put them under government supervision for well management and maintenance, and 181 public canal cooperatives were founded to take in charge for irrigation operation and management. In the meantime, the government canal cooperatives were also established for operation and management of those canals which were constructed by government. Later on, the Japanese government further reorganized the public canal cooperatives and government canal cooperatives into irrigation cooperatives. In this period, the existing systems were remodelled, consolidated, and enlarged, and a number of new systems such as Tao-yuan Canal, Chia-nan Canal, etc. were constructed. The irrigation area was increased to about 560,000 ha.

After World War II, irrigation development in Taiwan had been carried out in a great efforts since 1945. First of all, rehabilitation of the damaged irrigation systems were the important works to be done, and about 260,000 ha of irrigation area were rehabilitated.

Since 1956, some new development for economical utilization of water resources projects related to irrigation for agricultural production were conducted. The new development projects covered: (1) large-scale irrigation, such as Shih-men Canal irrigation system, Kuan-shan Canal irrigation system, Lu-yeh Canal irrigation system etc., (2) multi-purpose reservoirs, such as Shih-man Dam, Tseng-wen Dam, Min-teh Dam, Pai-ho Dam, etc., (3) ground water development, mainly developed in Yun-lin and Ping-tung area, (4) tidal land and river-bed land reclamation. By 1962, the irrigation area was increased to 676,384 ha, which was the highest record in Taiwan. For the efficient utilization of the existing water resources, rotational irrigation practice, canal lining project, land consolidation projects were implemented.

At present, the total irrigation area managed by 17 IAs is 381,000 ha, the total length of the leading, main, lateral, and sub-lateral canals and farm supplying ditches is 44,466 km (TJIA, 1998). Especially, the length of farm supplying ditches is 30,353 km, or 68% of the total (TJIA, 1998). The average length of supplying ditches per hectare is 80 m.

CROPPING PATTERNS AND TYPICAL FARM-LEVEL IRRIGATION SYSTEMS

Cropping Patterns

Since rice is the predominant crop in Taiwan, it is usually used for the determination of the most common cropping patterns according to the availability of irrigation water. The cropping patterns to be adopted in Taiwan may be classified into seven groups as shown in Fig. 1 (Wen, 1980). Of the total service area of 381,000 ha in the 17 IAs, the double rice-crop area is 261,000 ha, the single rice-crop area, 24,000 ha, the rotation cropping area (including two and three year rotations), 83,000 ha, and the upland crop area, 13,000 ha (TJIA, 1998).

Continuous Irrigation

Taiwan was a barren island in the old day. When immigrants came from mainland China and settled, agricultural activities started and canals were built to convey water from streams for irrigation. During this period, the population was sparse and the water was plentiful, there was no need to restrict water use. The irrigation practice in those days was of the continuous method. Starting with the transplanting of rice, the paddy field is continuously supplied with water of 50 mm to 60 mm in depth through the period of rice plants except weeding, fertilizer application and harvesting. Water is applied day and night flowing into the paddy field at one end and out at the other end without any control. Such practice results in high use of water. In general, the irrigation rate was as low as $330 \text{ ha}/(\text{m}^3/\text{s})$ in most area.

Rotational Irrigation

Due to the rapid growth of population and rapid development of industry in Taiwan after World War II, the use of cultivable lands and existing water resources for irrigation and other purpose is approaching to a limit. To develop new water resources is not only costly but also time consuming. In this respect, an attempt was made to improve the conventional continuous irrigation method in order to reduce the unnecessary waste of irrigation water. A promotion of rotational irrigation was, then, initiated. There are three different methods of rotational irrigation may be done (Chow, 1960 and JCRR, 1968):

- A. Rotation by sections in the main canal,
- B. Rotation by sections in the laterals or sub-laterals,
- C. Rotation by farm ditch.

In case A, the water will be conveyed in turn to different sections of the main canal. In case B, the main canal will have continuous flow while water will be conveyed to the various sections of laterals or sub-laterals successively. In case C, the water flow in the farm ditch will be intermittent while the flow in the main, laterals and sub-laterals will be continuous. In this case, the irrigation water is applied in appropriate quantity at the right time and in proper order so that all paddy fields may get the needed amount of water. In order to facilitate this method of irrigation, the whole area is divided into several rotation areas, and the irrigation systems are to be designed that irrigation water can be simultaneously be delivered into each individual rotation area of about 50 ha, the use of water is rotated in sub-divisions of a rotation area, called "rotation units". For example, a certain rotation area is divided into 4 rotation units, and the rotation interval is 4 days, each rotation unit will get its share of time of irrigation application in proportion to its area (Fig. 2). In the aforementioned three types of rotational irrigation, case A or B is mostly used in drought period, while case C is used in practical irrigation. Experiment had shown that rotational irrigation can achieve a saving of about 20-30% in water without producing any bad effect on rice growth and harvest. By this method, the irrigation rate was increased to $800 \text{ ha}/(\text{m}^3/\text{s})$. Furthermore, rotational irrigation is in favor of plant growth, saves fertilizer eliminate water disputes.

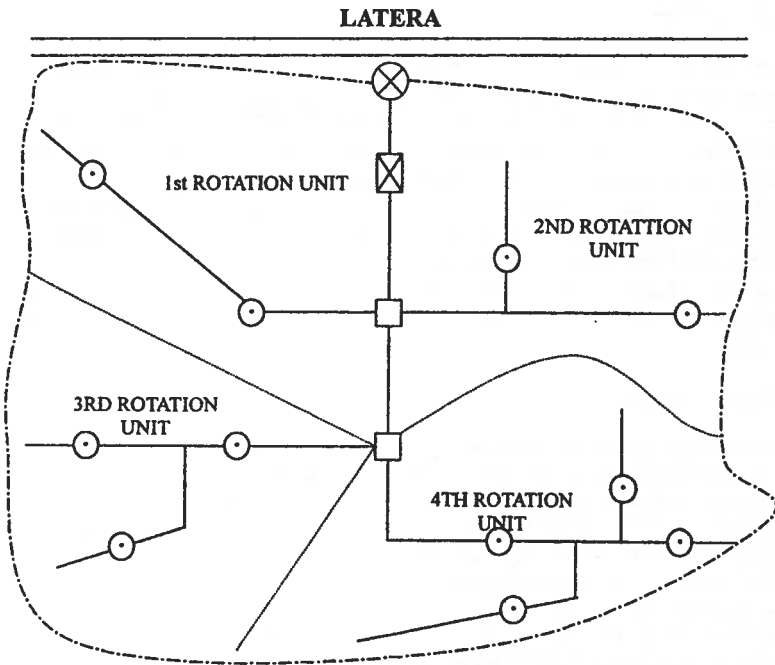
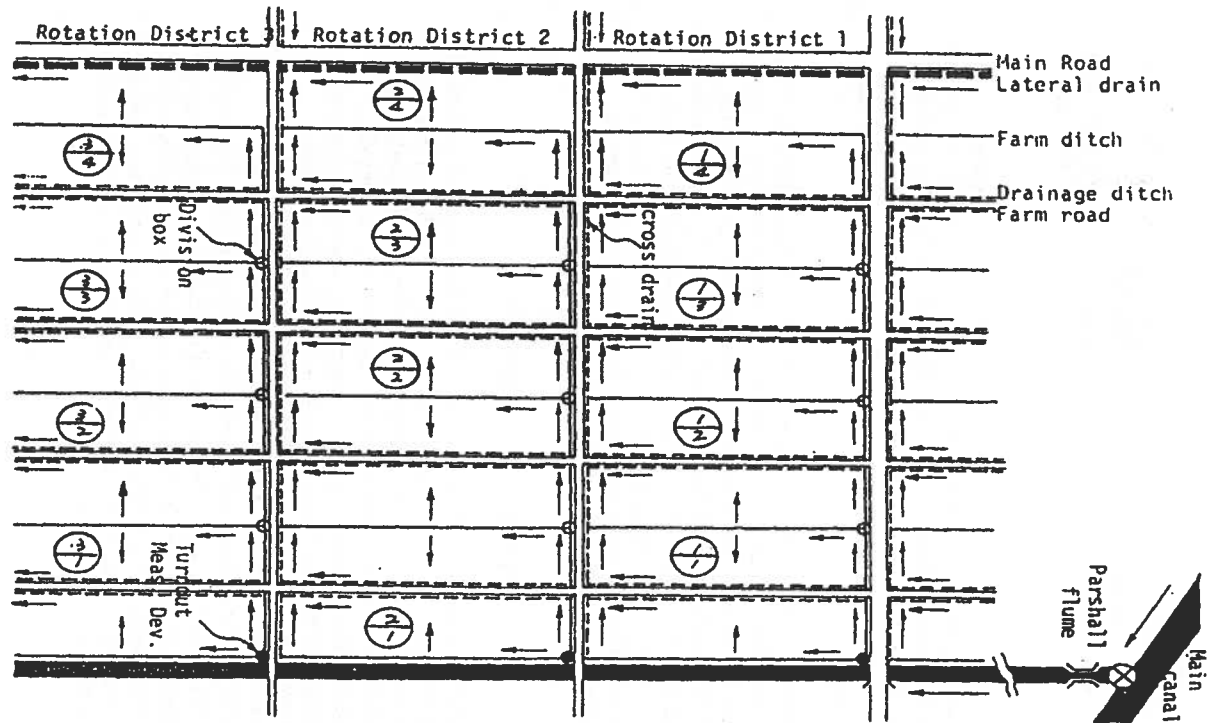


Fig.2. Typical layout of Rotation Area

Land Consolidation-Improved Farm Level Structures

Since land holdings in Taiwan have been very small and fragmental, the irrigation operation and management is inconvenient due to the inadequate and insufficient irrigation and road systems. A land consolidation program was started in 1958 to amalgamate the small and irregular farm plots and consolidate them by exchange and redistribution of farm roads, irrigation and drainage systems were made for better transportation, direct irrigation and effective drainage. A typical rotational area and water distribution system through land consolidation program is shown in Fig. 3.

As to the water distribution on paddy fields with land consolidation, irrigation water flows continuously through the turnout gate and controlled by the measuring devices into the rotation area, and irrigation is rotated among rotation units. In the land consolidation area, each block area of about 10-14 ha is regarded as a rotation unit, and each rotation unit is subdivided in several plots with area of 0.2 ha - 0.4 ha (100-120 m long and 20-40 m wide). Irrigation water is delivered to each plot from the farm supply ditch directly, while in the rotational area without land consolidation, the water is supplied to the plot passing from field to field. Up to 1998, the total completed area is about 380,000 ha.



Remarks: Upper number in the circle -- "Rotational Area"
 Lower number in the circle -- "Rotational Units"

IRRIGATION MANAGEMENT

In order to manage and utilize the irrigation water effectively, the Irrigation Association (IA) is organized by farmers according to water regions. The major functions of IA are construction, improvement and maintenance of irrigation/drainage facilities as well as water management. The total service area of the 17 IAs in Taiwan is 381,000 ha, and the typical organization of IA is shown in Fig. 4.

The IA has a management division at its head office to handle irrigation management policy, water planning and scheduling, and irrigation supervision. In a typical IA, it has local regional management offices, called "working station". The irrigation working station operates and maintains the irrigation system. Besides, some IAs have water source and canal working station to control and supply the water.

Field water distribution planning and execution are the main responsibilities of an irrigation working station. The station supervises and assists five to ten irrigation groups to carry out the water distribution and maintenance work of irrigation groups at the farm level. The irrigation groups are organized by the IA members themselves on the basis of farm-level irrigation systems without salary from the association. A group consists of an area of 50 to 150 ha and several teams, each with 10 to 15 members. The main work of a irrigation group is to maintain irrigation and drainage ditches, to distribute irrigation water, etc.

IRRIGATION OPERATION

Prior to the irrigation season, a preliminary water distribution plan is to be worked out by the management division at the head office according to the government policy, production goals, the existing reservoir/ponds storage and water release, water flows at diversion weirs, other available water sources, past records of irrigation requirements, canal conveyance losses, rotational irrigation intervals, and time of irrigation etc. The prepared plan is handed through regional management offices or directly to the working stations for further study and discussions with irrigation groups, and finalization. The finalized water distribution plan is to be strictly carried out by the working stations. The canal operators of stations are in charge of regulation and controlling water flows along main canal, laterals, and sub-laterals. The irrigation supervision are in charge of water control and measurement at turnout gates on laterals or sub-laterals, and of inspection on farm-level water distribution which are undertaken by irrigation groups in their individual irrigation areas.

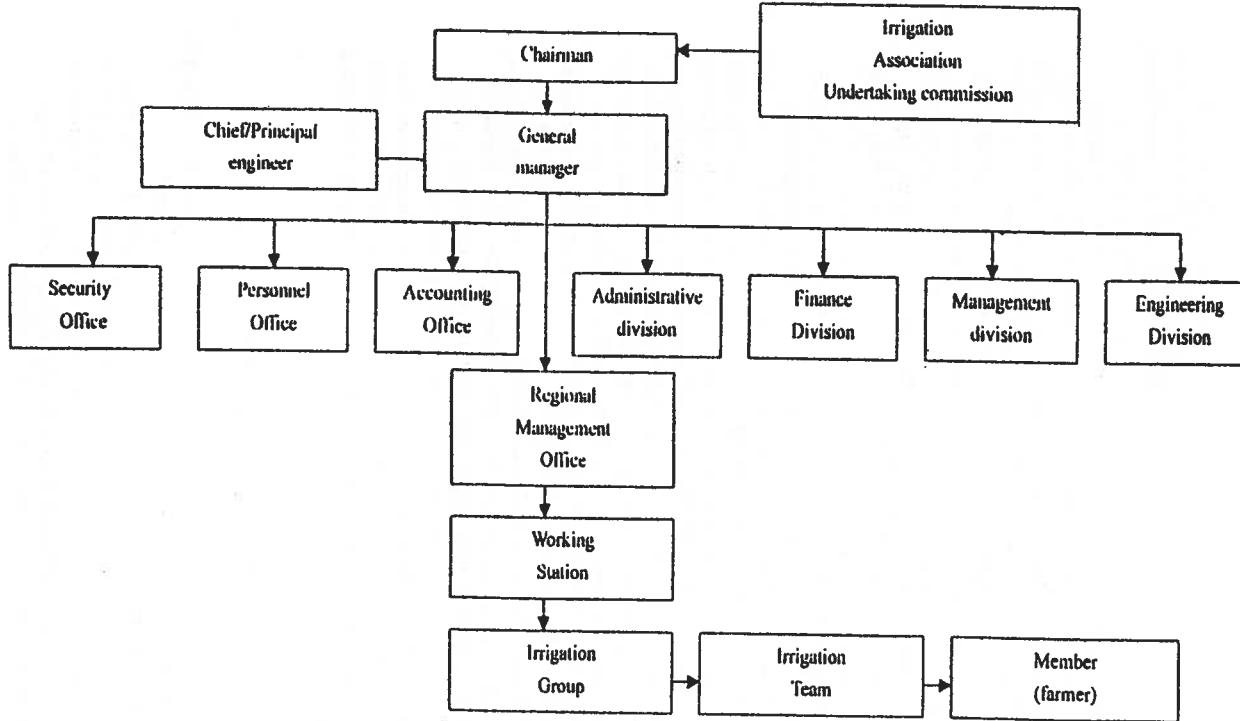


Fig.4. Organization Char of Typical Irrigation Association

PROBLEMS RECENTLY ENCOUNTERED

As rice is the predominant crop in Taiwan in the early stage, paddy is grown wherever possible, so, there had been a surplus crop of rice production year after year. For example, the paddy harvested area was 502,018 ha with an annual brown rice production of 639,000 t in 1945, increased to a high record of 786,343 ha with a maximum production of 2,712,000 t in 1976(COA,1994). Moreover, consumption patterns have been changing with increasing wealth, the average year consumption of rice per person has fallen from 134 kg in 1974 to 59 kg in 1996(DF,1998), in addition, the international price of rice has been low, and there has never been a fixed export market for Taiwan's rice. In order to balance out production and marketing of rice, a paddy diversion program was initiated on 1984 to divert the use of paddy field from the production of rice to alternative crops. The total diversified paddy field (including set-aside field) was from 43,700 crop-ha in 1984, increased to 260,000 crop-ha in 1997(DF,1998). Under this program, theoretically, there should have a large amount quantities of irrigation water to be saved for other use. Actually, about 76% of the irrigation water is river off-take with local and time difference, and has been seriously polluted, which is very difficult to be used by other users. Besides, the diversified paddy field is not concentrated, and irrigation is still needed for those paddy field which has not been diversified, and for the upland crops field, so a certain amount of discharge in canal is necessary for canal conveyance loss. As a result, not only no more water can be saved for other users, but also the irrigation management becomes more complicated. At the present stage of economic growth in Taiwan, water demand has been increasing and the production of additional new water sources has become more costly. No new irrigation projects can be implemented for rice production due to economic feasibility factors. However, in order to maintain paddy field with area of about 350,000 ha for self-sufficiency in food-crop products so as to ensure the security of food supplies and raise farmer's income so as to narrow the income gap between farmers and nonfarm workers, irrigation is still necessary. A certain amount of water is needed to be used for irrigation, but the percentage is decreased year after year. For example, the total amount of irrigation water used in 1996 was about 10.2 billion m³ or 56% of the total water used in Taiwan, which was much lower than the amount of 13.6 billion m³ or 81% in 1971.

MEASURES OF IMPROVEMENT

As mentioned above, due to the recent socio-economic changes, the water demand has increased with the increasing of population and the expansion of industrialization and urbanization. The acquisition of new water supplies for agricultural irrigation has been become more difficult and costly, and growing no more. Besides, the existing irrigation water faces the pressure of competition use of other purposes because of its lower production value per unit use of water. However, irrigation water resources are not only essential for agricultural

production but also maintaining the ecological functions. In order to incorporate with Taiwan's future long-term agricultural policy, and to maintain the paddy field functions, the following measures are made(Tsai,1998).

1. In order to incorporate the dry and wet crops rotation plan, investigation of the existing irrigation water use is needed. Raising the water use efficiency for first paddy in dry season is necessary. The paddy field protection and ecological maintaining is implemented on the ceased cultivation of the second paddy field in wet season.
2. The "Appropriate quantity of irrigation water and dependable water sources investigation and evaluation" project is implemented for establishing the reasonable irrigation water adjustment and utilization.
3. Strengthening improvements in irrigation management and operation techniques, repairing and improving the old existing irrigation system facilities, promoting the water saved pipe-line sprinkler irrigation are the measures for raising the effective use of water resources.
4. Strengthening the monitoring system on the irrigation water quality, implementing management of the water quality monitoring in the heavy(or serious) polluted areas and studying the degradation tendency in general polluted areas are continued to carried out.
5. Automatic remote observing, transmission and processing of irrigation operation data, and system control systems are installed on the major canals for real-time irrigation operation and management.
6. Computer programming application to water distribution plan and irrigation scheduling, and irrigation systems' design are also conducted.
7. The functions and achievements of paddy field on production, living and ecology is investigated and evaluated. The reasonable water use model in different areas and different seasons are established.

CONCLUSIONS

Paddy is the important crop to be grown in Taiwan. It maintains the self-sufficiency in food-crop products so as to ensure the security of food supplies and raises farmer's income and to narrow the income gap between farmers and nonfarmers for a long time. Irrigation plays a very important role for rice production. Due to the recent socio-economic changes, the water demand has been increasing with the expansion of industrialization and urbanization. The acquisition of new water supplies for agricultural irrigation has become more

difficult and costly. Besides, the existing irrigation water sources face the pressure of competition use of other purposes. Irrigation development is no longer merely a problem of engineering. It encompasses social, economic, policy and institutional aspects, such as irrigation science, soil improvement, ecological functions protection, entry into WTO challenges, ect. As a result, a great effort to ensure efficient utilization of the limited irrigation water through the improvement of existing irrigation systems and intensive management should be made.

REFERENCES

1. Wen, Li-jen, 1980, Improvement of Irrigation System and Water Management in Taiwan. Proceeding of ICID, 11th Congress, Grenoble, France.
2. Chow, Lee, 1960. Development of Rotational Irrigation in Taiwan. Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Proc.86 (IR 3,2588):1-12, September.
3. Joint Commission on Rural Reconstruction(JCRR), 1968. Rotational Irrigation Development in Taiwan, Taipei, R.O.C.
4. Taiwan Joint Irrigation Association(TJIA), 1998. FY1997 Data Book of Irrigation Associations, Taichung, Taiwan, R.O.C.
5. Council of Agriculture (COA), 1994. COA General No.8, Taipei, Taiwan, ROC.
6. Water Resources Bureau(WRB), 1997. FY1996 Working Year Book of WRB, Ministry of Economic Affairs, Taipei, Taiwan, R.O.C.
7. Tsai, Ming-hua, 1998, Agricultural Water Conservancy Policy and Application Strategies for the future in Taiwan. Scientific Agriculture Vol. 46 No.1-2, 28-33, January 1998.
8. Department of Food(DF), 1998, Taiwan Food Statistics Book, Taiwan provincial Government, Taipei, Taiwan.