EFFICIENCY of WATER USE and TRANSFER in SOUTHERN TAIWAN*

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I. INTRODUCTION

In the past three decades, Taiwan has experienced remarkable economic growth and been noted for its accomplishment to transform a backward agricultural economy into a modern industrial country. During the period of rapid economic development, water resources has been the generator and often the key to that development.

However, under the old-fashioned rules economic growth usually paid little attention to social and environmental values. As a result, as long as the national economic efficiency can be justified, water projects were deemed to be good way of achieving the social objectives. In practice, considerable investments had been made in water resources infrastructure in Taiwan for past decades. Many dams were built during the period of 1950-1980 for public water supply, hydropower, irrigation and flood protection. Nevertheless, Taiwan started to feel the stress between a continuously growing demand for water and the limitations of its existing water resources and the conflicts of various competitive uses of water at the beginning of 1980s.

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Moreover, it was found that a necessarily increasing supply of surface water to meet the future water demand could only be made at very high costs.Not only the lifetime of many existing reservoirs is shortened due to the heavy loads of sediment from the soil erosion, but appropriate locations for constructing new reservoirs are becoming extremely scarce and construction expenditures are skyrocketed.

In addition, over-exploitation of groundwater aquifers in the coastal area of south region in the last decade due to the rapid increase in aquaculture has resulted land subsidence. This over-exploitation of groundwater, resulting in a need to increase surface water to avoid further subsidence. Yet another emergent problem is water pollution, such as eutrophication of reservoirs and pollution of rivers. The degradation of the water quality also resulting in a need to increase water of good quality.

It seems there is no easy solution to the above problems. The construction of infrastructure works can indeed deal with the supply problem partly, but efficient water use also should be considered to alleviate the pressure of water needs. In other words, an efficiency of water use should be induced either through economic incentives or strict regulation and control. Such demand-oriented measures obviously should belong to the responsibility of government. However, to understand the water values in various uses and relative efficiencies among them is considered an important part in adapting changes from supply to demand oriented management. Formulating valid measures to induce a desired utilization of available water resources is thus becoming an efficient strategy for water resources management.

This paper first reviewed the development of water resources in Tai-

wan. Water uses and existing problems were then discussed to obtain a clear background for the research area. The values of water in various kinds of uses, in particular the agricultural and industrial uses, were further considered. After that, the redistribution of water among competing users and uses was analyzed according to the factual situation. Finally, some measures to improve the efficiency of allocation of water supplies and uses were suggested.

II. PHYSICAL BACKGROUNDS

1. Geographical Location and Topography

Taiwan, the Republic of China, includes 86 islands which has total area of 36,000 square kilometers (13,900 miles^2), among them the main island covers 99.6% of whole area. Geographically, Taiwan island is situated in the Pacific Ocean about 150 kilometers off the southern coast of mainland China and lies astride the Tropic of Cancer between 21°45' and 25°56' north latitude. This island has 384 kilometers long from north to south and a maximum width of 144 kilometers in west-to-east. However, the area of Taiwan is not only quite small when compares with other nations, but of which about 74% is classified as mountainous lands and slopelands. Therefore, most of human activities take place in the remaining coastal plains, predominantly on the western side of the island.

On the slopeland watersheds, there are several major natural factors contributing to severe soil erosion, such as heavy and concentrated rainfall, steep topography, young and weak geological formations, and highly erodible

soils. (According to official definition, slopeland is defined as land over 100 meters in elevation or with slopes greater than 5% excluding all lands dedicated to national forest and protection forest.)

2. Precipitation

Taiwan has plenty of water, the average annual rainfall amounts to 2, 500 mm for the whole area, while about 3,000 mm occurs in high mountain region and 1,500 mm for major part of the coastal plains. The island is frequently invaded by typhoons, on the average about three a year, which often bring abundant rainfall. The yearly total of rainfall is as large as 90 billion cubic meters, but it is distributed unevenly in space and time. For example, the rainfall concentrates in the northern part, where the annual average maybe as high as around 6,000 mm in some places. Throughout the year, 78 % of the rainfall is concentrated in the summer from May to October in the whole area, while it even reaches 90% in the southern region. In addition, most of rivers in Taiwan are rather short and steep, and are highly irregular in flows. Therefore, even the fertile coastal plain and moderate temperature are favorable to agriculture the whole year round, water always is a limiting factor, particularly to the southern region.

3. Water Conservancy

Being influenced and constrained by the factors of topography, rainfall and typhoon, the agricultural production of Taiwan is in need of the coordination of flood control works and irrigation and drainage systems. Otherwise, too much of rainfall often causes flood, and too little of it causes drought, which are disadvantageous to agriculture. This is also a common

phenomenon to all tropical countries.

Taiwan has long history of irrigation and flood control, which can be traced back to fourteenth century, but the first large irrigation system was not built until the period of seventeenth century. During this century, the public water supply and hydropower plants were also built. However, after World War II most of efforts were directed to the rehabilitation works. From 1953 to 1984 the government of Republic of China at Taiwan successfully implemented six stages of four-year and one stage of six-year cconomic development plans. The total expenditures amounted to NT$185 billion for water resources development, of which public water supply accounted for 26. 2%, followed by hydropower, flood control, irrigation, water pollution control, industrial water and soil conservation. As for the year of 1988, there were 1,752 km of levees protecting about 438,500 hectares of irrigation and drainage area which represented 50% of total cultivated land, 232 local water supply systems with a capacity of over 7 million CMD to serve more than 16 million people or 82% of total population, and 32 hydropower plants with installed capacity of 2,558,000 kilowatts, which was 15.4% of total power capacity.

4. The Southern Region

In this region, there are, large and small in all, thirty-nine rivers, while the surface of river basin amounts to 10,004 km^2. On the average, the yearly flow is about 17.6 billion cubic meters, of which 91.5% of the amount is occurred during rich water period, but during the dry period the yearly flow is only 1.5 billion cubic meters. As for the usable water, the potentiality of available surface water is around 1.9 billion cubic meters, and the

recharge of ground water is 1.7 billion cubic meters. Therefore, total potentiality of water resource development in this region is 3.6 billion cubic meters per year. However, the amount developed each year during 1980s is about 4.4 billion cubic meters, which has exceeded the limit. In fact, groundwater extraction through private wells in some regions started to exceed the natural recharge in the 1960s due to the rapid increase in water demand, which could not quantitatively and qualitatively be met by surface-water or public water supply. In the southern region, land subsidence problems had emerged in the last decade due to over-exploitation of groundwater for fish ponds. Up to sixty-nine cm of land subsidence were measured in one year at a coastal area, in which 2.4m has been measured in the past decade. Land subsidence of coastal areas in this region has caused serious consequences for flood protection, several recent typhoons, for example, already created substantially considerable damage.

III. INSTITUTIONAL SETTING

1. Water Law

It has been realized that how a country manages its water is related with its water legislation, which may reflect its peculiar cultural, social and political framework. Historically, the ancient Chinese never set up privately owned water right, but focused on that the individual duties in water undertakings should lead to the increase of the public welfare. According to this principle of water equalization, the upper riparians could utilize water without affecting other uses or users.

The current water law implementing in Taiwan was first issued in 1942, the period of R.O.C. government in Chinese Mainland, and the old traditional concepts of water law was kept. There were total of 71 articles in the original law, which implicitly adopted riparian doctrine. It was not until 1955 that this law was first revised. And then in 1963, the fundamental doctrine was completely reviewed and water was regarded as natural resource belonging to the nation, and it is through application and registration can then people acquire the right to use it. Having obtained the right, if one stops using water for two years, his right will be abolished. By way of approving the water right, the government thus has the authority for the distribution of water, especially to protect the priority of the right of using water. In other words, appropriative doctrine has replaced riparian doctrine except the local water use less than one hundred liters per minute was still kept in the domain of riparian doctrine. In addition to the basic change in doctrine, the clauses concerning to multiobjectives of water resources development were added, making a total of 99 articles.

The water law was further amended and issued in 1974, which had a major change in priority of water rights and management of groundwater. Originally, the priority was based upon the time order of water right registration, while the amended law regulates the priority order according to the purpose of water use as follows: (1) domestic, (2) agricultural, (3) industrial, (4) navigation, (5) hydropower, and (6) other uses. In order to strictly control the use of groundwater to mitigate the phenomena of land subsidence and salt water intrusion in coastal area, this amendment specifically bestowed some administrative power upon local government.

Some modifications of the 1974 amendment were made in 1983 to assure domestic and public water use and to meet the increasing demand due to rapid industrialization. The priority of water use was changed as follows: (1) domestic and public water supply, (2) agricultural, (3) hydropower, (4) industrial, (5) navigation, and (6) other uses. Hence water law arranges the order of priority according to all kinds of purpose of water use. As for the same purpose of water use, the order of priority is arranged based on the order of registration, without comparing the amount of benefits produced by each unit of water use. The reason of doing so is to weigh the social consideration more than the economic consideration.

However, the emergence of new social and environmental values and different pattern of water use is forcing to restructure the legal and institutional system, using concepts which are rather different from those of water policy decisions in the past decades. It has been widely recognized that the government should have authority to regulate both existing and new users, the diversion of water among various users, and the allocation of water rights to new users, especially when transferring water from other river basin or region is needed. Therefore, the outmoded concepts should be refined to allow more flexibility and to accommodate the changing conditions. Owning to the conventional riparian doctrine and prior appropriation doctrine can not meet our needs, some people advocate the public trust doctrine. They claim this doctrine provides a philosophy for administering public resources such as water, and it has the potential to form an appropriate water policy to guide decision making about water use and management.

2. Administration

The development and management of water resources are the responsibility of government for a long time. The Ministry of Economic Affairs is designated and authorized to exercise control over the acquisition of water rights, the use of other water resources generated from rivers and the installation and construction of facilities and structures which would affect the function of river channels for passing floods. Other laws concerning the public water supplies is supervised by the Ministry of Interior, and water quality protection is in the charge of the Environmental Protection Administration. Moreover, the management of water for agricultural use is under the control of the Council of Agriculture. Thus a situation has evolved resulting in the need of close coordination of the departmentalized operations under these agencies. An agency, the Water Resources Planning Commission, was formally established in 1964, which started the planning activities in 1955. Therefore, one of this agency's main tasks is the coordination of governmental agencies involved in water resources management.

As in many other countries, legislation and administration of water resources and related issues in Taiwan runs behind real world development, trying to remain status quo even when new problems emerging. Management and utilization of water resources in Taiwan, as mentioned above, are still heavily based upon traditional Chinese views on the relation between individuals and the society as a whole. These concepts worked fine when water is relatively abundant and management is ranged in a local or regional area. Nevertheless, in a highly urbanized and industrialized society, control of the common resources like water becomes a nationwide issues and inter-

ests, because it related to economic development and general social welfare of the country.

It appears that with respect to the administrative system, the above statements and existing issues imply that current system is in a transition phase from traditional administration to reasonable control. That is, water resources not only should be administered but also be efficiently and reasonably allocated and its use should be controlled, based upon a demand-oriented view. Water resources management is still a key for conducing a country toward economic growth and more equal distribution of general welfare, but its role should be adjusted to correspond to our changing world.

IV. WATER USES AND CURRENT ISSUES

1. Water Uses in Southern Region

The total amount of water consumed in Taiwan is about 18.5 billion cubic meters per year, of which 80% is used for agriculture, 11% for domestic uses, and 9% for industry respectively. Water obtained from rivers and streams is 10.8 billion cubic meters, 3.6 billion cubic meters from dams and reservoirs, and 4.1 billion cubic meters by pumping from groundwater. Since water resources is limited, but with rapid growth in population and industry, the key problems for organizations in charge of water resource will be the conservation and reasonable distribution of water.

Southern region is one of the main agricultural regions in Taiwan. At present, there is around 83% of total water (6.2 billion cubic meters per year) in this area is used for agriculture, of which 54% is used for irrigation,

29% for aquaculture, and 1% for livestock farming. This region has plenty of groundwater, therefore irrigation water not only comes from streams and rivers, but from groundwater. Moreover, the entire aquacultural uses of water are drawing from groundwater due to the serious river pollution. But the overdrawing of groundwater has caused the falling of water table and the land subsidence, the strict control of its use will be forced. The existing water resources available to the southern region thus faces a more insufficient situation. It has been suggested that the irrigation method and the facilities for transporting and distributing irrigation water should be improved, so as to save more water for other uses. However, with the large reduction of cultivated land recently, the use of irrigation water seems to be more flexible. Hence other users keenly compete the water which is leftover after the change of cropland.

The percentage of population served by piped water supply of the southern region in 1990 is 82.3%, which is the second highest one, only a little lower than the northern region. But in some places such as Pingtung Prefecture, because of its rich groundwater, people are used to pump groundwater to get their drinking water, the percentage of being served by tap water is only 27.3%.

The area of industrial land in southern region is about 9,000 hectares in 1990, which is larger than any other regions. The amount of water use for industry is 650 million cubic meters per year, of which 25% is supplied by piped water, while the other 75% is mainly from groundwater by self-pumping. During drought seasons, water obtained from both sources is not enough for basic needs, thus the idea of building more dams for in-

creasing tap water and raising the efficiency of water use has been widely accepted.

2. The Problems of Various Water Uses

(1). Agricultural water uses

a. In the past water rights were registered for agricultural use, and water could be used as a free good, water users were often ignoring the concepts of opportunity costs. Thus agricultural sector relatively owned more abundant of water, but other uses were comparatively limited. The competition for acquiring agricultural water by other users hence can not be avoided.

b. The irrigation are a of cultivated land becomes smaller each year due to a massive campaign--the so-called paddy land conversion program--has been introduced in 1984 to induce the farmers to grow other crops instead of rice, but the amount of water used for agriculture hasn't reduced. The reason is during this period, the government didn't map out any plan for saving water at the same time, so the amount of water used in agriculture didn't decrease.

c. Now we don't have measures for rewarding water saving, nor any way to do in dry season, as well as any plan to rearrange priority or alternative in an emergency.

d. Until now we have no any plan of compensation to transferring water from agricultural use, this leads the water redistribution more difficult.

e. The amount of agricultural water has been influenced by the pollution of water discharged from factories, together with the excessive

use of pesticides, fertilizers and the discharges by livestock farming is near 10%. In addition, it is estimated that the agricultural production has reduced from 10% to 30% due to water pollution. Moreover, the power of authority in charge of water use is gradually encroached by the invalid enforcement of regulations applicable to each individual source.

f. The Water Law, an instrument of administration, has not been validly put into practice, e.g. many of those who do not have water rights, while drawing water from rivers; and those who have the water right but do not draw water or overdraw.

g. The total area of cultivated land in Taiwan is about 890,000 hectares, of which 480,000 hectares are paddy fields (340,000 hectares are equipped with facilities of irrigation), and 410,000 hectares are upland farms, but the water fee in irrigation districts was underpriced based on the costs of construction and maintenance. Moreover, this underpriced fee will be completely nullified in 1993. Another problem is thus whether the land beyond the districts should obtain free irrigation water. This problem has to do with the efficiency and equity.

(2). Domestic and public water uses

a. Owing to the long-time favorable treatment (subsidies) to soldiers' families, schools, municipal organizations, and fire-fighting, and underpriced fees, the water company is now in debt for NT$17 billion, this causes the company to be unable to develop new sources and well maintain the existing facilities.

b. In early stage, all the water in the rivers and streams in Taiwan

was registered for agricultural use, so the water left for domestic and public use was very limited; especially in dry season, it was more difficult to get water.

c. Now the water company maintains its business by means of loans, this leads to its inability to replace the old water pipes and other equipments. It is estimated that the leaking amount of water is around 20-30%.

d. The practices of water saving haven't been listed in the regulations or the laws concerned. For instance, in the law of construction, there isn't any regulation about the water saving for toilet use.

(3) Industrial water uses

a. In the past the problem of water supplies hasn't been noted when developing industrial parks, so most of factories acquired their water by drawing groundwater, and most of them didn't have installations for circulative use and retrieval. This caused a serious distortion of economic value in water and even reasonable prices, which are much higher than the existing prices, and haven't yet been accepted by the public.

b. The arbitrary discharges of water from factories caused environmental pollution, which greatly influenced the availability of water resources. The water in some rivers, for example, is seriously polluted, and thus is completely useless.

c. On the one hand, there are no measures favor creating incentives for water-saving; on the other hand, the number of high water-consuming factories rapidly increase.

V. EFFICIENCY OF WATER ALLOCATION AND USE

Allocations of water among competing uses in Taiwan are seldom operated by markets, hence the traditional process of allocation in achieving economic efficiency is highly improbable, if not impossible. In addition to market failures, water misallocations are largely due to inefficient institutions or insitutional failures. Based upon traditional water right systems, the institution tends to view water as free goods, and the possessor of the water right is apt to allocate or use water inefficiently.

General speaking, the factors that affecting the efficiencies of water use and allocation are composed of physical and nonphysical characteristics, and the nature of water redistribution is intimately related to the legal and organizational framework. Although sections II and III have respectively discussed in this respect to some extent, it is well-known that the existing inefficiencies in water use can also be explored through thorough study on water values. Furthermore, as long as water values are relative low in some sectors or uses, water redistributions or transfers will be unavoidable during drought season. However, it also should be emphasized that these economic efficiencies are mainly due to the imperfect systems of law and institution that hamper water transfers.

1. Economic Values of Water in Southern Region

Theoretically, the value of water can be defined as the maximum amount of money that the user is willing to pay to obtain a certain quantity of water at a given time and place. In practice, the procedures for calculat-

ing the values of water are not universally accepted by the economists, and the information on physical and nonphysical attributes of water use and demand is often very inadequate. Nevertheless, the study of water value can help us to understand the nature of water problems and alternative ways of coping with them. By way of case studies, we could explore alternative means for meeting long-run needs of water and resolving various conflicts among competing uses.

In the early stage water resources in the south region of Taiwan were developed mainly for agricultural use, just a little left for domestic and industrial uses, but there hadn't been any dispute among them. However, with the rapid industrial and economic developments which have already surpassed that of agriculture, this region has become a key area in developing industry and demanding water. But owing to the nearly all the water resources in this region have been completely developed, there is no easy way to develop any new sources at acceptable expenditures. Therefore, the best way may be to emphasize the management of water resources, i.e. reallocation and conservation water based on the institutional and/or economic considerations.

In order to compare the relative values of water uses between agriculture and industry in south region, the values of irrigation water and industrial water were estimated by crop budgeting analysis and recycling opportunities method, respectively. The values of irrigation water for different crops are considerably variant, range from 0.36 NT$ per cubic meter water for rice to 35.76 NT$ for tobacco (see Table 1). On the average, the mean value is about 3.18 NT$ per cubic meter of water.

The value of water in industrial use has been considered equating with the internal cost of water recirculation by some economists, e.g. Gibbons (1986). However, the proportion of water reuse to the total quantity of water use in industry at south region was only about 7% (see Table 2). In considering the importance of groundwater and piped water to the industry, an average cost of water uses, which represent piped water, groundwater and recycling water, was used as shown on Table 2. The variations of average costs in different industries were not large, may be due to the fact that the costs of piped water and groundwater were not very variant among industries. Owing to the significant difference between the cost of water and the value of water, it is not plausible to use the above average cost of water as a surrogate of water value. But since the cost of industrial water intake for most industries is low and water use by most of them is self-supplied at present, while the major water use costs may come from the costs of water treatment and waste water discharge in the near future. Therefore, the average cost of water use shown on Table 2 can be viewed as a minimum value of water use, because the degree of recyling will increase when the regulation on water pollution is getting stricter. In practice, Gibbons (1986) has shown that the average cost of recycling rises as the degree of recycling goes up, and the marginal value of water in a specific industrial use thus depends on the current location on the particular recycling cost function of the industrial process.

From the investigation of water values, we could understand how water is currently being used. Besides, we may find that there are large disparities in values among different uses, and the values of water are often con-

trary to the amounts of water consumption. However, any of the individual water values, either on Table 1 or on Table 2, should not be given a special significance, because they simply are evaluated based upon different conditions. In other words, the measurement of various water values may imply different meaning to different people at different times and places. Yet some existing inefficiencies in water use still can be induced from this kind of exploration, since it is a state of economic efficiency only when water resources would be used for those purposes which generate largest benefits for the society as a whole.

2. Water Transfer

Per capita consumption of rice in Taiwan has drastically fallen from over 130 kg per year to less than 70 kg per year for the past decades. This changed situation has induced the government to adjust its old-fashioned food policy by launching a nationwide paddy land conversion program in 1984. The main objectives of this program were to reduce the total production of rice and to raise the rice farmers' income simultaneously.

Some people were concerned about that this program may also be conducive to water conservation, since farmers were to induce to plant other crops, such as maize, sorghum and wheat, instead of planting rice. In fact, the cultivated area of paddy rice in south region has been reduced with more than 25 per cent over the past seven years. Therefore, they argue that the agricultural sector should shift some amounts of irrigation water out to other sectors. But the Irrigation Associations, which practically implement the operation and distribution of irrigation water, do not agree to this argument.

There indeed exists some serious technical problems in transferring water from agricultural sector to other sectors. First of all, if the paddy land conversion were dispersedly occurred, then the leftover water will be very hard to manage though the reduction of rice production can really be made. Only a whole area in the same irrigation system completely changes its crop pattern would contribute to successfully redistribute is leftover water.

Economically, low yields of paddy land should first be converted upland, but the main reason of low yield is often caused by the scarcity of water, hence there aren't much water can be saved. Besides, it is hard to plant crops on salty and sticky soil in dry season, this lower the incentives of conversion. Moreover, the paddy land conversion program is related with the water distribution program, so both programs should be implemented according to the future goals of agricultural policy. At present, the coordination of water distribution and the paddy land conversion programs should be planned from a long-term view has been noted, and the objectives of paddy land conversion thus can be induced. On the other hand, it also has been recognized that the short-term measure and plans regarding each individual conversion district and water transfer should be instituted as soon as possible.

In addition to the above problems, the irrigated area also has been reduced due to the change of economic structure, thus the original amount of water use has to be shifting out and redistributing to other or new uses. But the land that has been changed its use is also fragmentedly distributed, that will cause some disadvantages to the operation of irrigation and the loss of water. It seems it is necessary to engage in case study before the

change so as to prevent the problem of water redistribution from happening again.

Furthermore, the trends of agricultural development hereafter show the difficulty in increasing the area of cultivated land and the investment and development of new water sources are not what we can afford based upon the benefits created by the project. In the future the amount of water needed for irrigation depends on the goals of production level and the systems of crops pattern. But the factors affecting crops pattern are very complicated, so the estimation of the amount of water for irrigation is difficult. Owing to the problem of water redistribution is still not easy to solve, the stress may better lay on the reduction of water loss during transportation and on the water reuse for the time being. Therefore, the improvement of the system of water transportation, the increase of automatic facilities for distributing water, and the extension of irrigation by turns are all the appropriate measures we can adopt now.

Although water transfer is superficially a difficult task, it is actually not, especially during the period of drought. For example, the priority of current water use is in the order of domestic and public water use, agricultural use, power use, industrial use, water transport, and other purposes according to Water Law. But the designed industrial park could urge the authority to change the ranking of priorities based on the existing conditions. This is in fact a way of water transfer from agricultural use to industrial use. Besides, agricultural water use is always the first to be nullified in the droughty time.

VI. STRATEGIES FOR WATER RESOURCE MANAGEMENT

1. Measures for Agricultural Uses

a. Encouraging the rotation of crops for paddy fields.

b. To implement irrigation by turns, which may save one-third to one-half amount of water.

c. To improve and maintain the channels or ducts for transporting water more effectively.

d. To use as much as possible return flow and drained water for raising the rate of water reuse.

e. To implement and subsidize an all-out facilities for the using of recycling water in aquaculture, that'll save 1/3 to 1/2 amount of water.

f. To regulate reasonable amount of water use in aquaculture and install equipments for measuring the water quantity that is drawn from underground, and then request them send the records to the authorities.

g. Severely prohibit overpumping ground water, violators' electricity may be disconnected, if necessary.

h. To study the substitution of sea water for fresh water and raise the fish which can adjust in highly salty water.

i. To map out special areas for developing aquaculture.

2. Measures for Domestic Uses

a. To lay stress on the inspection of water leaking condition. Accord-

ing to the information of water company, about 3% water is lost when it transported from the water source to the company and 15 % from the water source to the company and 15% from the company to each user. Thus the system of water pipes and related equipments should be improved, so as to reduce the rate of loss.

b. To regulate reasonable amount of water consumption and water price. The distribution of water to each person in Taiwan is only about 1/6 of the mean value of the world, this indicates that water supply is relatively limited in Taiwan, so the daily amount of water use per person should not increase yearly with the increasing personal income. It has been estimated that the reasonable amount of water for each person daily is from 380 to 400 liters, while the current water price should be raised.

c. To advocate water-saving type facilities for families. Generally, a typical family in Taiwan used about 70% of daily consumption of water for bathing and toilet, the next is for drinking and clothes washing, and the rest is very little. It has been suggested that if each family uses water-saving type closestool, then the amount of water saved will be up to 40%.

3. Measures of Industrial Uses

a. To set reasonable consumption and prices of water use.

b. To persuade or enforce the firms adopting the circulative use of water.

c. To reduce the amount of water use per unit of production.

d. Before designate and develop industrial park, the required water

resource should be planned ahead.

VII. CONCLUSIONS

The challenge of the present is for us to make the best use of water, but it is greater than ever before because the demand for water is increasing fast while the supply of water is very limited. Water resource plans are not only important public utilities, but also the key to economic development and quality of life. Thus the government should take the responsibilities of development and management, to expand the availability of water resource on the one hand and to strengthen on the management on the other hand.

We are in the transition stage of water resource management, from a supply-oriented process to a demand-oriented process, the outmoded process for determining priorities and distributions for the use of water has become obsolete. People are beginning to realize that how unique and precious water is, and how necessary it is to understand water problems so as to solve them. But we have to emphasize that neither the maximization of water values nor the solution of water problems can be physically achieved by any new technology alone. The ultimate way will be found in more sophisticated management if the existing problems do not change in their nature.

In the southern region of Taiwan, with rapid development in urbanization and industry and, in contrast, the shrinkage of agriculture, parts of paddy fields have been converted to other use. Because of the difficulty in developing new water sources and the keen competition for limited water among different users, what have been distributed already should be trans-

ferred for redistribution in order to increase the emerging public values. Therefore, we should map out appropriate strategies and regulations from the social and economic point of view, in the interests of making the distribution and management of water resources be more rational. As for the problem of water transfer, we consider that water resource management should coordinate with other related policies. Both agricultural and industrial policies are good examples for expression, if we let the market mechanism completely operates in the system of water resource management, then the irrigation water with lower values will flow into other water uses, such as industrial use, with higher values. But this change in water use may in turn affect the goals of agricultural and industrial policies. Based upon our study, we thus have an opinion of considering the technological improvements and water saving the most reliable way to solve problems.

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Table 1. Average consumption and value of irrigation water in southern region

unit: metric ton, NT$ per metric ton

	crop	water consumption per hectare	average value of water
1st crop	rice	18,000	0.56
	tobacco	4,800	29.51
	pulses	3,600	8.33
	vegetables	3,100	13.75
	maize	4,000	5.94
2nd crop	rice	14,600	0.36
	pulses	3,900	10.15
	vegetables	2,300	10.36
	maize	4,000	6.40
winter crop	tobacco	4,200	35.76
	pulses	3,500	5.00
	vegetable	1,900	11.33
	maize	3,800	7.76
long-term crop	sugar cane	9,400	7.95
	betel nuts	8,900	18.46
	bananas	12,000	3.47
	coconuts	8,000	1.34
	mangos	9,500	6.08
	wax apples	15,000	16.74
	average	11,600	3.18

Note : 1. The number of sample points, each point represents a piece of land, is 1105, which covers an area of 391 hectares.

2. Vegetables include 12 different kinds of vegetable.

Table 2. Average consumption and cost of industrial water use and its reuse ratio in southern region

unit: metric ton, NT$ per metric ton

	average consumption of water per year	% of water reuse	average cost of water
food	41,600	4.6	7.6
lumber & furniture	7,200	0.0	5.6
paper & printing	23,100	33.8	6.0
chemical materials	137,200	1.5	6.7
chemical products	8,200	3.2	5.9
plastic products	5,200	5.7	19.2
non-metallic mineral products	23,700	2.4	7.2
basic metal	4,400	4.5	6.5
metal products	12,900	32.9	16.5
average	32,800	7.4	7.7

Note : Total number of sampling firms is 108.

台灣南部地區水的使用及移轉效率

蕭景楷*

摘　　要

本文首先回顧台灣地區水資源的發展概況，其次探討水資源使用的相關問題。接著分析水資源在不同用途下的價值，並特別針對農業和工業的單位用水價值做實證研究。然後依據現況討論水在各種使用者及用途之間，可能的重分配情形。最後，提出一些改進水資源分配及使用效率的建議。

由於水資源計畫不僅是重要的公共設施，而且也攸關我們的經濟發展和生活品質，所以政府在開發及管理上都負有重大責任，除了要增加水資源的供應外，更要加強其管理。在水資源管理問題的本質由供給導向轉爲需求導向之際，我們一方面要改善過去決定用水優先順序及分配的方式，另一方面也要尋求能解決現有問題的管理方式。

在台灣南部地區水資源的研究中，我們發現都會區和工業的快速發展伴隨著農業的日漸萎縮，尤其部份水稻田已轉變爲其他用途；而新水源的開發在實質成本和環境的考量下，變得非常困難。所以，現有的水資源分配狀況，勢必重新加以調整，才能增加全體社會的利益。我們除了應當從社會和經濟觀點，擬訂適當的策略和規範使水資源的分配和管理更合理外，也要考量水資源管理措施和其他相關政策配合的問題。在實際解決現有問題方面，本文認爲技術的改進以及節約用水，可能是較爲可靠的辦法。

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