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IRRIGATION SYSTEMS IN TAIWAN: MANAGEMENT OF A DECENTRALIZED PUBLIC ENTERPRISE

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Irrigation Systems in Taiwan: Management of a
Decentralized Public Enterprise*

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INTRODUCTION

The use of irrigation, particularly in Asia, is centuries old. Irrigation systems were built in India as early as the second century A.D. and irrigation development was given major emphasis in British India during the nineteenth and early twentieth centuries [Ministry of Irrigation and Power, 1972, pp. 60-82]. In Japan, emphasis on irrigation dates back to the Tokugawa Era (1603-1867) [Fukuda, 1973]. In Taiwan, the first large irrigation system was built during the period 1680-1719 [Ko and Levine, 1972]. One can find similar long experiences with irrigation in many other countries of Asia [Takase and Kano, 1969].

Despite this long history of irrigation, only a few countries have evolved designs of irrigation systems and the management principles and techniques that result in efficient water use. Japan and Taiwan are undoubtedly the most

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advanced in these respects, followed probably by Korea. The People's Republic of China may rank high in efficiency, but insufficient information is available to make any firm judgments. Throughout the rest of Asia efficiency in canal irrigation systems water use is quite low.

Our concern is with surface or canal irrigation systems, typically constructed and operated by public agencies, in which water is provided to a given area of land from a combination of stream flow and reservoir storage. The area irrigated can involve numerous farms and an even larger number of fields.

In an ideal situation, water would be allocated efficiently in an irrigation system when the value of the marginal value product of water in each use is equal to the marginal scarcity value (shadow price) of the water in the system, net of distributions costs. Alternative mechanisms could be employed to achieve optimal water allocation. One mechanism would be to change the marginal scarcity value of water in the system for each type of use. The other mechanism would be to allocate to each user of water the optimal quantity, where the actual price paid by users could be less than or equal to the marginal scarcity value of water in the system. If the users paid less than the shadow price of water, they would be capturing part of the economic rent associated with irrigation.

In an irrigation system with storage (reservoir) capacity, the manager of the system must be concerned with the allocation of water among farms, among crops, and between crop seasons, or even crop years. The supply of water in any particular crop season may not be treated as fixed because water might be carried over from one crop season to the next. The calculation of the optimal distribution of water is a problem in intertemporal allocation.

The efficiency of an irrigation system can be increased through either (a) improving the management of the system or (b) improving the physical design of the system. Both types of improvements may be desirable. However, there may be some degree of substitution between management and design dimensions of a system.

A great deal has been written about the importance of increasing the efficiency of water use in irrigation in Asia, particularly with respect to canal irrigation systems [Asian Development Bank, 1969 and 1973; International Rice Research Institute, 1973; Ministry of Irrigation and Power, 1972; Seminar on Economics of Rice Production in the Philippines, 1969]. Improved efficiency in water use is judged to be an important source of growth in agricultural output and productivity and is of particular importance in most countries of Asia, where land is a scarce factor of production. There are compelling reasons to economize on or increase the productivity of land relative to the more abundant factors, most notably labor. Expanding the irrigated area and improving the efficiency of water use are two ways of increasing land productivity which, as yet, have not proven to be simple matters.

It is being increasingly recognized that efficient canal irrigation systems are very complex entities involving interrelationships among economic, technical, and administrative factors. A recent publication summarizes well the complexities involved:

If the irrigation system is to be effective, the farmer must be able to depend on getting the water when he needs it. This requires an administrative mechanism that can build and maintain physical structures for providing water--dams, canals, ditches, and pumping systems. At the same time, it requires a mechanism to insure fair allocation and efficient use of water among farmers. Maintenance

of the physical structures can be confused with management of the system because these two tasks often merge in the hands of one individual (e.g., the ditchtender). Thus the ways in which the tasks differ, and the different talents they require, often go unnoticed.

One prerequisite for sound management of an irrigation system is a set of procedures for keeping continuously informed about the farmer's situation, and for making judgments, not only about his needs, but even about his preferences. Representing the farmer's interests in water management decisions calls for an ingenuity that is not yet in evidence in the management of many irrigation systems. Some administrative functions performed by government or professional bodies also require reciprocal cooperation and action from the farmer. Where these responses are essential to management success, there is a need to find policies and mechanisms of the administrative body which would help to secure them.

Good water management, and especially good management of irrigation projects, requires a balance of at least four kinds of inputs: physical facilities, inputs of scientific and technical knowledge, management inputs, and inputs of current information and data. It is wasteful to make investments in ways that put some of these factors far ahead or far behind the others. What steps can be taken to analyze systems to see how well these ingredients are balanced, and to identify and correct points of imbalance? Development of human resources is clearly an issue here . . . [International Rice Research Institute, 1973, pp. v and vii].

This paper attempts to describe the operation of canal irrigation systems in Taiwan, judged by many people to be quite efficient with respect to water use. The focus will be on how economic, technical, and administrative factors

have been incorporated into the management of these irrigation systems to yield a high level of efficiency of water use. The factors judged to be important have been distilled from available literature. No attempt has been made to empirically evaluate the relative importance of each of these factors or the precise way in which they are handled. These are subjects for future work. Nor is it feasible in this paper to compare the operation of irrigation systems in Taiwan with those in other countries. By implication, however, all of the factors critical to successful management of an irrigation system discussed for Taiwan are not present in full measure in most other countries.

An examination of management of irrigation systems in Taiwan reveals four factors that seem to contribute strongly to efficient management of the systems. These factors, which are different from what one finds in most other countries of Asia, seem to be highly interrelated, making it difficult to evaluate the contribution of one in isolation from the contributions of the others.

First, in order to increase agricultural production Taiwan has recognized water as a scarce factor of production to be used as efficiently as possible. Second, the national government of Taiwan has evolved a basis for centralized planning of irrigation investments and, at the same time, decentralized management of the systems. This was true until 1975. During 1975 the National Government took several steps which appear to restrict the degree of decentralization in the management of irrigation systems. Our concern in this paper is with the development of irrigation systems in Taiwan up to 1975. Planning of new investments by the central authorities was important to ensure rational allocations of resources among all categories of development expenditures. However, the management of irrigation systems was devolved into the hands of those who directly benefited from irrigation. The mechanism used was the cooperative irrigation association. Users of water have participated in the planning and management of irrigation systems. Third, within the irrigation

associations information systems were developed which permitted the exchange of agronomic and engineering information between users of the water and the managers of the system. These information systems were and still are especially important because water is administratively allocated to users based on some calculation of the scarcity value of water; prices actually charged do not play a major role in allocating water among users. The information systems also facilitated continued improvements in the physical design of irrigation systems and in the agricultural production technologies used by farmers. Fourth, the irrigation associations employ systems of incentives for both managers of irrigation systems and users of water which appear to be compatible with the efficient use of water.

CLEAR AND EFFECTIVE POLICY TO INCREASE AGRICULTURAL OUTPUT

One of the essential principles which contributes to efficient irrigation systems as well as to rapid growth in agricultural output is a clear and effective set of policies that place high priority on agricultural development and that recognize water as a scarce factor of production. Historically, in many countries of Asia either strong emphasis on agricultural development was lacking or, if agriculture was emphasized, water was not visualized as a scarce factor. Levine and Wickham [1975] point out that a great deal of the irrigation in Asia was developed to provide supplemental water during the wet season at which time expected rainfall is almost equal to total crop requirements, but is unevenly distributed throughout the growing season. In this approach to irrigation, water is not viewed as a scarce factor to be managed intensively.

Taiwan has emphasized agricultural development and has treated water as a scarce factor of production, at least since about 1920. The early impetus for these policies came from Japan, ruler of Taiwan from 1895 to the end of World War II. Japan's long-run strategy was to supply the Japanese market by developing Taiwan's agriculture. Heavy emphasis was placed on increasing the production of sugarcane and rice [Ho, 1971]. During the first two decades of the twentieth century there was a decline in the rate of growth in rice production in Japan while demand for rice continued to grow rapidly. This resulted in rapidly rising rice prices and the rice riot of 1918. The Japanese government adopted a policy to develop Taiwan into a major exporter of rice. (Sugarcane production was also emphasized to meet Japan's import needs and to free foreign exchange for industrial development.)

The Japanese strategy to increase rice exports from Taiwan relied on two basic policies. One set of policies was highly exploitative. It reduced the incomes of Taiwan farmers through heavy taxation and forced Taiwanese to

substitute sweet potatoes and other "inferior" foods for rice in their diets. The other set of policies was directed at increasing agricultural productivity through programs of investment in irrigation and water control, research and extension to diffuse high-yielding Japanese rice varieties adapted to local conditions in Taiwan, and institutional development to support the development of a more productive agriculture. These efforts yielded a tremendous surplus of rice for the Japanese market [Hayami and Ruttan, 1970, pp. 570-571].

T. H. Lee [1971] has described the period 1895-1930 as one in which the economic and social basis for future agricultural growth was established by relying heavily on strong measures of force rather than on economic incentives:

Development programs emphasized both material input as well as institutional organization. Emphasis was placed on heavy investment in infrastructure, such as communications, transportation, harbors, power, education, general public health, flood control, and irrigation Institutional and organizational reforms were imposed on the administrative system, land tenure system, monetary and fiscal system, and farmers' associations.

Irrigation came under government control in 1901. Before that date, irrigation projects consisted largely of repairing damaged canals, but now expansion of paddy land and protection from the hazard of drought were the main goals of the program. Institutional roles underwent significant changes in this period with the creation of the landlord class They were convinced that agricultural improvement was to their benefit under the new land-tenure system and land-tax payment. They were encouraged to direct villagers to adopt new seed varieties and better cultivation methods The farmers' positive response to new technology, in this period, was pervasive, largely

because of the influence of the landlord class and the government.

The profitability of the new technology, however, was not broadly recognized by cultivators until 1922, when the new variety of Pon-lai rice appeared and previous investment in agriculture began to show results. The process of altering the old cultivation methods and the extension of the use of the new varieties . . . was not characterized by persuasion, but rather by government enforcement. Police stayed in the local communities and effectively [emphasis added] participated in agricultural extension services [pp. 39-42].

The period 1931-40 saw a continuation of basic developments--infrastructural, technological, and institutional--but with one major difference: the activities of Taiwanese farmers were guided more by economic incentives than by force [Lee, 1971, pp. 42-43].

In the post-World War II period, agriculture development was concerned with the recovery and rehabilitation of agriculture from the damage and neglect which occurred during World War II, and with the sustained growth of agricultural output at rapid rates beyond the period of recovery. The government of Taiwan recognized that rapid agricultural development was essential to create a domestic surplus and the foreign exchange earnings required to finance industrial development. Strong emphasis was given to the development of infrastructure, including irrigation and water control, institutions, technology, and economic incentives. And, this emphasis did create large amounts of resources for industrial development. Taiwan also benefited from large amounts of foreign aid from the United States. It is significant that this aid did not seem to lessen Taiwan's efforts to mobilize domestic resources for development [Lee and Hsieh, 1971].

Ko and Levine [1972] state that in 1895 there were 107,716 hectares of land in Taiwan irrigated by canals and ponds. During the next 50 years the irrigated area was expanded to 561,999 hectares. In recent years there have been 540,000 hectares of irrigated land, accounting for about 60 percent of the total cultivated area.

In the case of Taiwan, there have existed since 1895, and especially since 1920, clear policies to increase agricultural output in which water was recognized as an important and scarce factor. Further, the development of irrigation and control of water were necessary to exploit the output potential of high-yielding, fertilizer-responsive varieties of rice and other crops [Ishikawa, 1967, pp. 108-109]. These policies were not mere pronouncements by governments. Rather, they were policies which were implemented with considerable vigor. There was a clear recognition by all levels of government in both Japan and Taiwan that investments on a broad front were necessary to increase agricultural productivity and to generate a surplus to finance industrial development [Falcon, 1974].

CENTRALIZATION OF PLANNING AND DECENTRALIZATION OF OPERATIONS OF IRRIGATION

It may be important to distinguish between the optimum level of centralization in decision-making for planning of investments in irrigation systems and the optimum level for operating a system. In many countries of Asia, government agencies responsible for planning new investments in irrigation systems also have the responsibility for operating these systems. The skills required and criteria used for planning and constructing new systems are not necessarily those needed to operate a system efficiently. Levine and Wickham [1975] make this same point with respect to the distinction between operation and maintenance of a system. The distinction between the two functions in terms of skills and criteria is not always recognized.

Explicit recognition of the need for centralized planning but decentralized management of irrigation systems has evolved in Taiwan. This is reflected in the national laws governing the use of water and the assignment of legal responsibilities for different functions. The national water law is fairly comprehensive covering most relevant aspects of water resource use for all purposes. A detailed description of the law is contained in Water Law of the Republic of China, promulgated by the Chinese National Government on July 7, 1942 as amended on November 29, 1963 and promulgated on December 10, 1963. The law governs the control and utilization of surface or ground water with respect to flood control, tide control, irrigation, drainage, leaching of injurious salts, soil conservation, storage of water, water supply for human and industrial consumption, harbor construction, water transportation, and development of hydroelectric power.

The law stipulates which agencies of government, referred to as water conservancy agencies, have responsibilities for planning, development, or regulation of water use. These agencies are specified at the central, provincial, and

municipal levels of government. The law also defines water rights; i.e., the legal rights that persons individually or collectively have to the use of surface or ground water. As part of the water rights, priority is assigned to various uses of water. These priority uses, in descending order of importance, are domestic use and public water supply; agricultural use; power; industrial use; water transport; and other purposes. It is not clear that the ranking of priorities for water use correspond to a ranking of the marginal value products for water in these different uses. For example, the rapid growth of industrialization in Taiwan may have resulted in the marginal productivity of water for power and industrial use being higher than the marginal productivity in agriculture. Provision is also made for the transfer of water rights among individuals and organizations, private or governmental. With the growth of urban areas and industrialization, water has been transferred from agriculture to human, industrial, and power uses.

Procedures are also specified for the development of water utilization or conservation projects, protection and maintenance of water structures, and assessment of penalties for violations of the water law.

The national water law provides a basis for the central, provincial, and municipal governments to plan the development of water resources in Taiwan with respect to all uses of water resources. Theoretically, at least, this form of centralized or governmental control over the development and use of water resources should yield results consistent with national economic and social objectives. And, we suspect, there is in practice a reasonably high degree of performance.

With respect to irrigation, and possibly other uses of water as well, the national water law provides for the management of irrigation systems to be conducted by autonomous local organizations in the form of irrigation associations. In addition to the national water law there are separate regulations

governing the establishment and operation of irrigation associations.

(General Rules Governing the Organization of Irrigation Associations, promulgated by Presidential decree, July 2, 1965; revised and promulgated by Presidential decree, February 9, 1970, unofficial translation). These associations are self-governing, corporate bodies organized by users of water for construction and operation of irrigation facilities. The associations are cooperative in nature and are operated by those who use water for their own benefit. In the late 1960's there were 26 such associations in Taiwan covering 464,872 hectares of irrigated farm land [Takase and Kano, 1969, p. 537].

The concept of cooperative irrigation associations was developed in Japan and introduced into Taiwan during the period of Japanese rule. In Japan, the Irrigation Association Law was passed in 1899. This law, together with the Land Improvement Law of 1949, provided the basis for farmers' organizations engaging in the construction, operation, and maintenance of irrigation facilities [Fukuda, 1973, p. 205].

Either a group of farmers or the government may take the initiative in establishing an irrigation association. Proposed irrigation projects must be approved by appropriate governmental agencies. Once established, the responsibilities of the association include construction, improvement, operation, and maintenance of irrigation projects; prevention of damage to facilities; financing; study and further development of systems; and the performance of any other duties entrusted by appropriate authorities under law.

The members of an irrigation association are entitled to irrigation water and other benefits and are required to pay fees and perform certain duties for the association. Noncompliance of a member with the obligations imposed on him by laws and regulations can lead to a suspension of rights to water and other benefits.

While members of the irrigation association are entitled to receive water, this does not mean that each member receives all the water he desires in any given crop season or that he receives it in all crop seasons. Clearly, when there is not enough water in the system to meet total needs and the water available is allocated efficiently, some users will receive only a part of the water they desire and some producers will not receive any water in certain years. But, as discussed in the next section, users know the quantity of water they will receive before planting decisions are made.

The government has borne part of the construction costs of irrigation systems, as much as 50 percent in some instances. The remainder of the construction costs and the operating expenses of a system are paid for by the membership of the irrigation association. Usually, separate schedules of fees exist for construction and engineering costs, and for operating costs. The fees are based on the approximate amount of water used.

It is not clear how well the water fees reflect the scarcity value of water in the system or how the fees are actually set. This is an important topic for which more research is needed. Are the special fees covering construction and engineering costs set to cover the full cost of these activities incurred by the irrigation? Are the regular fees, which supposedly cover the operating costs of the system, based on average or marginal operating costs?

The association membership elects a general assembly which has the responsibility for formulating the policies and operating rules. The policies and directives of the general assembly are carried out by the staff of the association. Staff members may be either hired by the association or appointed by an appropriate government agency, depending on the functions to be performed and skills required. Even employees appointed by a government agency are responsible, in large measure, to the governing body of the association.

INTEGRATION OF AGRONOMIC AND ENGINEERING INFORMATION
INTO MANAGEMENT OF IRRIGATION SYSTEMS

One outstanding characteristic of irrigation associations in Taiwan is an information exchange system between water users and managers of the system. The formal handling of information is important not only to the management of a system of a given physical design, but also to improving efficiency of water use through changing the design of systems. The design and management of irrigation systems have an influence upon each other. According to Levine and Wickham [1975]:

Management must be organized around the physical components of a system, which are specified by design. Certain management practices are precluded by some design choices while others are favored. Rotational irrigation at the turnout cannot be practiced if farm ditches are not provided in the design. Management's influence on design is less obvious but equally important. Shortcomings commonly attributed to poor design can sometimes be alleviated by intensive and dedicated system management No design can be considered ideal in a permanent sense, and an evolving management program is necessary to continually bring out the fullest potential of a system, and to identify appropriate changes in the physical system. Evaluations of different management priorities in existing systems will also provide excellent information to serve as a base for design choices for future systems.
[p. 3].

Irrigation associations have developed the capacity to integrate information and technology concerning crop production and engineering design into the management practices used in distributing water. Mechanisms have been devised which facilitate the flow of information between farmers and system managers on a timely basis. These informational mechanisms contribute to an efficient

allocation of water and reduce the uncertainty of the availability of water to farmers.

It was recognized some time ago, probably in the 1920's or earlier, that a high degree of certainty of water supply to farmers could lead to more efficient use of water in rice production. Increased certainty of water supply to farmers involves both the amount of water supplied and the time during the growing season when it is received.

The need for a high degree of control can be traced to the particular nature of the water response function for rice. More detailed discussions of the water response function for rice are reported by Barker [1970] and Reyes [1973]. A typical function is illustrated in figure 1.

The shape of the water response function can result in sharply asymmetrical effects on rice yields of given absolute changes in the level of water application about some given level such as W_0 . If farmers face uncertainty in the amount of water they will receive in any time period, they will tend to apply water at some rate higher than W_0 in order to minimize losses in yields. They can do this by permitting a greater depth of standing water in the rice fields, i.e., by maintaining an in-field reserve of water. We are ignoring the beneficial effect that deeper water has in the control of weeds. To the extent that the total supply of water available in an irrigation system is limited, excessive use of water by some farmers will result in reduced availability to others. Such a situation will not lead to the optimum allocation of water throughout the irrigation system.

Farmers will try to get as much water as possible if the variance in their water supply is large. They may try to obtain an average amount of water which may exceed the level of W_2 in figure 1 in order to minimize the risk of operating to the left of W_0 . Thus, the larger the degree of uncertainty in the supply of

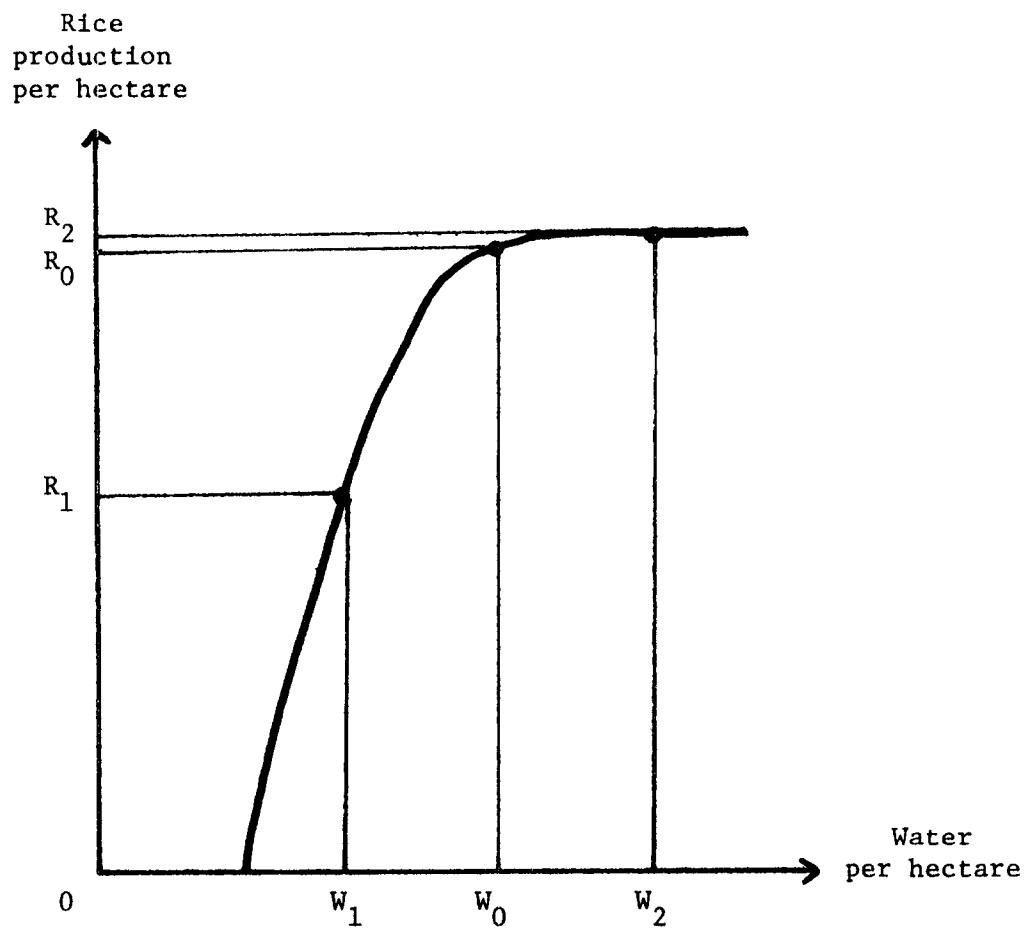


Fig. 1. Water response function for rice.

water, the more farmers will use on average. Conversely, reducing the variance in water availability can reduce the average amount of water used per hectare of land without necessarily reducing the output per hectare.

Information developed about the nature of the water response function for rice provided convincing evidence that reducing the variance in the amount of water to farmers could increase the total area irrigated from a given total supply of water. This information was used to modify the physical design of irrigation systems and management practices used to deliver water to farmers.

There was also another important set of new information which had a profound impact on the design and management of irrigation systems and the efficiency of water use. This was the discovery through experimentation that rice did not require a continuous stand of water during the growing season and that a continuous flow of water through the rice fields is not necessary. As a result of this information, the rotational system of irrigation which led to a large increase in efficiency of water use within each irrigation system was developed and the design of the systems was modified to provide controlled delivery of water to individual farms and fields. A larger area could be irrigated without increasing the water supply [Vandermeer, 1968; Joint Commission on Rural Reconstruction, 1968; Tsui-Yuan, 1965].

In a system of rotational irrigation each farmer receives water at regular intervals, for example once every five days. The amount of water received and the length of the rotation interval are sufficient to provide the necessary amount of water for maximizing the yield response of the farmer's crops but not in excess of that amount. The delivery of water and the length of the rotation interval are based on the requirements during different parts of the growing season. These requirements will depend on the requirements of the plants, amount of rainfall, nature of the soil with respect to its ability to hold water, etc.

Another form of rotational irrigation deals with distribution of water among farmers when the supply of water is regularly insufficient to irrigate all the land in a system. In this situation the whole system may be divided into several large parts, each part taking its turn receiving water from one crop season to another or from one year to another.

Increasing the certainty of water supply to individual farmers and adopting the system of rotational irrigation have greatly reduced one type of externality common to most irrigation systems, the stealing of water [Vandermeer, 1971]. Increasing the certainty with which individual farmers receive water when needed reduces the incentive to steal, since an individual farmer can rely on the system to provide the water he needs. Rotational irrigation also makes it more difficult for farmers to steal water since it is no longer continuously available in the ditches serving their fields.

Related to the two developments in irrigation just discussed was the evolution of an information system which permits managers of systems and users of water to exchange information about water needs and availabilities, and to evolve water use plans which result in technically efficient utilization of the available water. In its simplest form, farmers announce their water needs to the irrigation association prior to planting their crops. The irrigation association estimates the amount of water available for irrigation from reservoir storage, stream flow, and ground water at the start of a crop season. If the total amount of water is insufficient to irrigate all the land in a system, the allocations to individual farmers are such as to achieve the most efficient use of water for each hectare actually irrigated.

At times, the initial estimate of water availability and the estimated irrigated acreage are too high. This may be due, for example, to below normal rainfall during the period of irrigation, which reduces both the amount of water available to the system through stream flow and increases the amount of

irrigation water needed by farmers to compensate for lower rainfall. In such situations, a new set of calculations is performed based on the two-way flow of information between system managers and farmers, resulting in a new allocation plan designed to maximize rice production from the available water supply.

The available literature does not indicate the precise basis used to determine how much water each user receives during each crop season. In the simple case, where only one crop such as rice is grown, it is not clear whether each user gets the same amount of water regardless of the size of each farm or whether water is allocated among farms in proportion to farm size. This would not be an important problem if all farms were about the same size. But this is typically not the case. This issue needs further investigation.

The actual allocation procedure is much more complex than the simplified example just presented. Farmers usually grow several crops with varying needs for water. The irrigation association has to take into account the water needs of these different crops. Furthermore, the cropping patterns utilized by farmers are based heavily on the way the irrigation association allocates water. However, rice is usually considered the primary crop and has a priority claim on available water.

The information system internal to the irrigation association seems to have led to an efficient allocation of water supplies in situations where the agricultural technology and the physical design of the systems are stable. But the information system also played an important role in facilitating dynamic change in the irrigation systems with respect to the introduction of new agricultural technology and the redesign of physical features of the water distribution facilities.

Taiwan has a well-developed system of agricultural research and extension capable of developing viable new agricultural technologies and demonstrating their use under farm conditions. In other words, new technologies can be delivered from research stations directly to farmers. In irrigated areas, farmers who are members of irrigation associations are also members of, or have direct access to, organizations concerned with the dissemination of new agricultural technologies or new production inputs. If farmers individually or collectively decide to use new technologies or inputs and these require different patterns of water use than the old ones, this information can be transmitted to the managers of irrigation systems. The irrigation managers then calculate new water delivery plans. Through the interaction between farmers and the managers of the irrigation systems, irrigation bottlenecks to the adoption of new technologies are minimized.

This same information mechanism is used to change the physical structure of irrigation systems. These changes may involve substantial investments by the irrigation association. They can include expansion of water storage capacity, extension of the area receiving water from the system, and redesign and improvement of the existing water delivery system. Information concerning changes in the irrigation potential of a system is conveyed to farmers who use this information to decide, through their elected representatives in the irrigation association, whether or not to carry out suggested improvements. If such improvements are made, desired changes in cropping patterns can be communicated to managers of the system. A new water delivery plan can be evolved through an iterative exchange of information between farmers and the managers of the irrigation systems.

INCENTIVES

We have indicated that the management of irrigation systems in Taiwan appears to be responsive to the water needs of farmers, to changes in agricultural technology, as well as making improvements in the physical performance of the systems. These characteristics of Taiwan's (and a few other countries') irrigation systems stand in sharp contrast with what one finds in most other countries of Asia. What accounts for these sharp differences?

A distinctive feature of Taiwan's irrigation is that the systems are essentially owned and managed by the farmer-users of the water. Thus, the managers of the irrigation systems work for the farmers. The irrigation associations, which are farmer cooperatives, can hire or fire managers, depending upon their performance. Even where some members of management are appointed by government, they are expected to be responsive to the needs and desires of the members of the irrigation association.

The relationship between management of irrigation systems and the farmer-users found in Taiwan is markedly different from that which exists in many other countries. In most countries the irrigation systems are built and managed by the national or state (provincial) governments. The appropriate government unit hires and (rarely) fires management. The farmers who use or wish to use the irrigation water have little direct control over the performance of the managers. This weak linkage between management and farmers can and does lead to inefficient distribution of water and makes it difficult to adjust water distribution to changes in technology or to changes in the design of the systems which otherwise might be implemented to improve their efficiency.

In the case of Taiwan, the rewards to management are determined by the elected representatives of the members of irrigation associations. And, there is evidence that irrigation associations do reward good management and penalize poor management. The reward structure includes financial returns to management,

promotions, and non-monetary recognitions such as prizes. In contrast, systems where management is divorced from the users of water have incentive structures for management which are usually not linked, or are linked weakly, to the operating efficiency of the irrigation system.

Emphasis on personnel efficiency and rewards is explicit. Irrigation associations are encouraged to have well-established personnel policies which provide job security, adequate financial rewards, and attractive retirement programs. Employees are also provided with considerable amounts of training to help them master the technical and managerial tasks they are expected to perform, as well as to understand the water needs of farmers [Tsui-Yuan, 1965].

Part of the incentive structure consists of a variety of contests in which employees of irrigation associations participate. These contests involve both financial and non-financial rewards, and are interestingly symmetric in their reward structure. An example of grade evaluation and rewards is as follows [Joint Commission on Rural Reconstruction, 1968]:

Grade Evaluation and Prize and Punishment

<u>Points</u>	<u>Grade</u>	<u>Action</u>
Above 80	A	Award of prize in document, money, or souvenir
70-79	B	Award of prize in money or souvenir
60-69	C	No prize [or] punishment
Below 60	D	Punishment upon consultation

Another important aspect of the incentive system is the interrelationship between collection of irrigation fees and financing the operations of an irrigation association. The operating budget of an irrigation association

depends directly on the collection of water fees from farmers. In order to preserve their jobs, the technical and administrative staffs of an irrigation association have a strong interest in ensuring the collection of fees. If collections are poor, revenue will not be adequate to cover operating costs and will eventually result in a reduction in the size of the association's staff [Wickham, Benemerito, Saclolo, Salazar, and Villamar, 1974; Ko and Levine, 1972].

The willingness of farmers to pay their fees depends heavily on how well the irrigation associations are operated, i.e., the amount and timeliness of water received. The better the system is managed, the more willing the farmers will be to pay their fees. This is also true for voluntary farmer participation in certain operations of the system, such as controlling the release of water into fields, performing maintenance work on the portion of the system located near their farms, etc. Thus, job security levels of remuneration for management personnel are tied directly to how well a system is managed.

IMPLICATIONS FOR OTHER COUNTRIES

We have tried to distill a set of economic and management principles which appear to explain the high level of efficiency of irrigation systems in Taiwan. However, we have not indicated the true complexity of irrigation systems and irrigated crop production found in Taiwan today with which the management of these systems must contend. One source of complexity grows out of the size of some of the systems. The Chainan Irrigation Association serves an area of approximately 150,000 hectares containing probably about the same number of farmers. Another source of complexity is the complicated cropping systems that farmers follow involving several crops, each with a different length of growing season and with different water requirements. It should be obvious that the structure of management and the information required to run efficiently large irrigation systems like the Chainan system must indeed be very complicated.

The management of irrigation systems in Taiwan is often used as a model that other countries, particularly in Asia, might follow. However, it is doubtful that other countries could, in a short period of time, achieve anything like the level of technical efficiency one finds today in Taiwan. In most other countries one or more of the four prerequisites for successful management discussed above is missing and could not easily be established. Creating strong and effectively implemented agricultural development policies that recognize the value of irrigation water will require (a) substantial reordering of development priorities and (b) strengthening of administrative services dealing with implementation of development plans and programs. These changes require a reorientation of national development policies and programs and will be fraught with all manner of political problems. The same can be said for providing legal and administrative bases for permitting centralized planning of

investments in irrigation development, but decentralized management of irrigation systems.

The creation of information and incentive systems within the management structure of irrigation systems will require considerable research, training of management staff, and education of the users of water with respect to the benefits to them of improved management. These steps also require considerable time and effort.

There are also environmental, cultural, and political considerations involved in trying to transfer the Taiwan model of irrigation to other countries. The technical design of irrigation systems, as well as the development of certain management principles in Taiwan, was influenced by local environmental conditions, particularly with respect to topography, climate, soils, and crop technology. One would expect to find considerable differences in these conditions among countries as well as within certain countries. Design and management principles will have to be adjusted to specific environmental conditions.

The political institutional framework for the management of irrigation systems in Taiwan grew out of a particular political history and cultural setting. During the 50-year period of Japanese colonial rule and the subsequent 30 years of independence, strong emphasis was placed on the investments in technology and infrastructure, including irrigation, required to accomplish rapid rates of growth in agricultural output. These achievements involved a combination of incentives to farmers and an ample measure of force. Furthermore the institutions that were developed to implement agricultural development programs, such as the irrigation association, seemed to be politically and culturally acceptable in the sense that they elicited responses from participants that were desired by the governments. It is doubtful that direct transfer of Taiwan's approach to the development and management of irrigation systems would yield beneficial results in other political and cultural settings. The Taiwan

experience would have to be molded and adapted to conditions prevailing in other countries.

The relevance of the Taiwan experience to other countries lies in recognizing the importance of the economic and management principles we have discussed and the key interrelations among at least some of them. Beyond this, other countries should try to learn more about how policies, institutions, and technology related to irrigation evolved in Taiwan.

As already pointed out by Levine and Wickham [1975], improvements in the design and management of irrigation systems will, under the best of circumstances, be a continuous process involving a series of numerous small but significant improvements. It might be highly worthwhile, therefore, to study in detail the evolution of irrigation management in Taiwan since about 1920, paying particular attention to each improvement that was introduced, the technical and economic forces that created the basis for each change, and the institutional response required to make each change effective. This kind of detailed sequential history of the evolution of current irrigation management in Taiwan might provide useful insights as to how to proceed in other countries. One could compare the current state of irrigation technology and management in a particular country to a "comparable" period in Taiwan's history. The focus would be on how the relevant principles of successful management in a particular period in Taiwan might be transferred and adapted to conditions prevailing in other countries.

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