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Irrigation Landscapes and Waterscapes in the Rice Land of Tropical Asia

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Introduction

Rice culture in tropical Asia is practiced in quite diverse environments, especially with respect to hydrology. The diversity of modes of irrigation, which are adjusted and adapted to their respective hydrological settings, is accordingly very large.

The physiological resiliency and adaptability of the rice plant to its climatic and hydrological environment are higher than those of any other field crop. The physiological diversity of the rice plant itself is extremely large: from upland rice on mountain slopes to floating rice in deltas; from rice grown in the tropics to rice in semi-cold zones like Hokkaido; from rice adapted to the perhumid western coast of the Indian subcontinent, where annual rainfall amounts to several thousands millimeters, to rice grown in the desert of Pakistan.

The diversity of rice varieties is also tremendous: from very short-maturing varieties that ripen in only three months to those requiring almost nine months to mature; aus, aman and boro rices in the Bengal delta, which grow in the pre-monsoon, monsoon and dry seasons respectively; from varieties highly sensitive to photo-period to those totally insensitive.

In the light of these adaptive capabilities of Asian rice, and of the nature of the rice-farming system developed by Asian peasants over many generations, the Asian rice cultural system has been defined as "environment-adaptive,[1]" the result of "agronomic adaptation." In contrast, the system which has been developed through modifying the environment, especially hydrological conditions, to suit to rice, and which is typically observed in Japanese rice culture, was termed "environment-formative," the result of "engineering adaptation." The paradigm of "environment-adaptation" is very useful in investigating Asian rice culture from the view point of its cultural history, but overemphasis of this idea may distract us from the essential fact that irrigated cropping systems are found mainly in Asia, and Asian rice culture is basically an irrigated cultural system. This article examines the hydrology of rice land and engineering re-

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1) The terminology "environment-adaptive," "agronomic adaptation," "environment-formative," and "engineering adaptation," has been discussed among scholars at the Center for Southeast Asian Studies of Kyoto University for many years and appeared in many papers. The most recent and refined discussion is given in: Tanaka, Koji, 1991, "A Note on Typology and Evolution of Asian Rice Culture: Toward a Comparative Study of the Historical Development of Rice Culture in Tropical and Temperate Asia," *Tonan Ajia Kenkyu* [Southeast Asian Studies] 28(4).

sponses to given hydrological environments in the rice-based agriculture of tropical Asia; and it presents the idea of the "world's largest Asian irrigated agriculture system.[2)]"

The five largest countries in terms of irrigated acreage are China, India, the United States of America, the Soviet Union and Pakistan. In Fig. 1, various countries are positioned on a diagram of irrigation ratio (percentage of irrigated land in total arable land) plotted against arable land ratio (percentage of arable land to gross country area) and can be seen to fall into four clusters: the arid world, Asia, the Mediterranean world, and Western Europe.

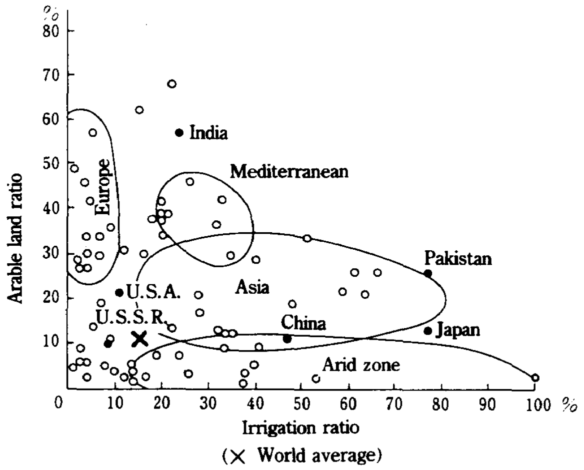

Fig. 1 World Irrigation Status

The U.S.A. and the Soviet Union, being located near the origin of the diagram, in a sense loose the status of countries predominated by irrigated agriculture. With respect to irrigation ratio, East Asia, including China and Japan, ranks highest, followed by Southeast Asia, South Asia and the Mediterranean countries. The countries in the Middle and Near East have very high irrigation ratios, but the irrigated lands occupy only very small fractions of the gross country areas. In Western Europe, almost a half of the national areas are given over arable land, but all of it is rainfed. It can be said, therefore, that the "countries with irrigated agriculture" are mainly in Asia [Kaida 1988].

I Irrigation Landscapes

Eight major modes of irrigation were identified in rice land in tropical Asia (Table 1). They are presented here in relation to the corresponding agroecological regions, which are defined mainly by topographical characteristics. The agroecological regions used in this article include intermontane basins, plains and plateaus, fan-terrace complexes, upper and lower deltas (or old and new deltas) in Continental South and Southeast Asia, and volcanic footslopes and coastal plains in Insular Southeast Asia. I will not elaborate on these here because they have been fully discussed elsewhere, mainly by staff of the Center for Southeast Asian Studies of Kyoto University.[3)]

2) This article is based mainly on a recent paper of mine: Kaida, Yoshihiro, 1990, "Inasaku to Suiri [Rice Culture and Irrigation]," in *Tonanajia no Shizen* [Nature in Southeast Asia], edited by Yoshikazu, Takaya, Tokyo: Kobundo. I have earlier presented similar ideas in (a) Kaida, Yoshihiro, 1987, "Suimon to Suiri no Seitai [The Ecology of Hydrology and Irrigation]," in *Ine no Ajia Shi: Ajia Inasaku Bunka no Seitai Kiban* [Asian History of Rice: Ecological Setting of the Asian Rice Culture], Vol. 1, edited by Watabe and Fukui, Tokyo: Shogakukan, and (b) Kaida, Yoshihiro, 1985, "Hydrology of Rice Land," in *Soil Physics and Rice*, International Rice Research Institute.

3) Several ideas on the division of agroecological regions in tropical Asia have been presented since late 1960s by agriculturists at the Center for Southeast Asian Studies of Kyoto University. One of the earliest is: Takaya, Yoshikazu, 1978, ↗

Table 1 The Modes of Rice Land Irrigation in Tropical Asia (Present)

Mode of Irrigation	Physiographic Setting
Rainfed	Plain
Tank irrigation	Plain and Plateau
Controlled stream diversion irrigation	Intermontane basin, Volcanic footslope, and Fan
Tube-well irrigation	Plain (Gangetic plain)
Lifting irrigation from controlled creeks	Lower Delta
Semi-controlled gravitational canal irrigation	Major part of Upper Delta, Plain
Water conservation	Floodplain in delta
Tidal irrigation	Coastal plain

Note: Listed in order of area covered by each mode of irrigation.

1. *Rainfed Rice Land: The Rice Landscape in the Plains*

Almost 70 percent of all the rice land in tropical Asia is so-called "rainfed" rice land. Rainfed bunded rice fields constitute the typical "rice landscape" of the plains and planteaus and can be found in vast expanses of the Khorat plateau in Northeast Thailand, the Cambodian plain, and the Upper Burma plain.

In the Khorat plateau, for example, rice fields were originally opened around natural depressions and were irrigated. These were gradually expanded towards higher elevations in concentric circles, and the resultant bunded rice fields are generally rainfed, since the generally flat terrain has sparse stream systems and watershed that are too small to provide water for irrigation. Generally, the rainfed rice land sustains very poor and unstable production in this region, where annual rainfall ranges from a low of about 800 mm to a high of about 1,400 mm. Our field study in Northeast Thailand found that the annual rice production, as a percentage of the exceptionally good harvest of 1983, was only 6 in 1978, 11 in 1979, 7 in 1980, 54 in 1981, and 19 in 1982. It also found that a dependable harvest was mostly obtained in the low-lying and somewhat naturally watered field plots, and that the high land experienced a total crop loss once every three years, and in an average year yielded 20 percent of the potential yield [Kaida *et al.* 1985]. Here, instability is a reality accepted by the peasants, who have adapted their farming systems to this cyclic uncertainty by means of larger landholdings, crop diversification, subsidiary livestock production, by taking various off-farm job opportunities, etc.

Typical rainfed rice land is also found in the fans and fan-terrace complexes on the periphery of the river plains, typically in the Chao Phraya river basin. The total of about 1.4 million ha of the rainfed rice land on these particular topographic units accounts for nearly

↘ "Suiden no Keikangakuteki Bunrui Sian [Rice Growing Region as a Landscape]," *Noko no Gijutsu* [Farming and Technology], No. 1. More recent and comprehensive discussions are given in: (a) Takaya, Yoshikazu, 1985, *Tonanajia no Shizen to Tochiriyo* [Nature and Landuse in Southeast Asia], Tokyo: Keiso Shobo, and (b) Furukawa, Hisao, 1987, "Nettai Tosho no Inasaku Bunka [Rice Culture in the Insular Southeast Asia]," in *Ine no Ajia Shi* [Asian History of Rice], Vol. 2, edited by Watabe and Takaya, Tokyo: Shogakukan.

40 percent of all the rice land in this river basin. The poorer water availability here than in the smaller fans in the intermontane basins and volcanic footslopes is due to the much smaller watershed to rice land area ratio: about five in the former and about twenty in the latter. The relative lack of water sources confines irrigated rice land to the apexes of the fans and terraces, leaving major rice land in the lower slopes totally rainfed.

2. *Tank Irrigation: The Irrigation Landscape in Plateaus*

Tank irrigation is found in a zone extending from the dry zone of Sri Lanka, through South India, parts of the Deccan plateau, the western rim of the Bay of Bengal, Upper Burma, the Khorat plateau in Northeast Thailand into the Cambodian plain, being practiced in more-or-less rain-deficient plains and plateaus. Tanks are of three different types. One type is found in Sri Lanka and South India in wide, shallow valleys that have been impounded in many sections to make a series of almost continuous ponds. Many of these tanks date back to the second to seventh centuries, when they were built by local lords, and have been maintained for centuries by communes formulated for tank irrigation. Tank irrigation might have been associated with complex farming including rice, upland field crops and livestock, because the water surfaces are too large compared with the area of irrigable rice land, for example, one unit of water surface to only 1–2 units of irrigable land, and because the dried-up tank floors would have provided good meadows to graze herds of livestock in the long dry season. The present tanks in Northeast Thailand are of this type, being built primarily to provide irrigation water and tank floors for cattle rearing.

The second type is the square ponds almost always located in or attached to old temple compounds, which are found mainly in the northern Cambodian plain, formerly the seat of the Angkor Empire, and in medieval Northeast Thailand. They are exact copies of the holy ponds attached to South India's Hindu temples that have been transplanted into a different environment. Their prime use must thus have been to store holy water for religious ceremonies, though some water might have been taken for domestic water supply and irrigation of horticultural crops.

The third type, typically seen in the Bengal delta, where they are called ***pukur,*** are generally small, dug-out square ponds located in the village homesteads for the purposes of supplying domestic water, watering horticultural crops, and growing fish. The ubiquity of ponds of this type indicates that they were also dug to provide earth to pile up for creating homesteads in the flood-prone Bengal delta. Besides the ***pukur,*** there are a number of larger square ponds built in rice fields, mainly by the old *jamindars,* who were local landlords under the British rule. These are rarely used for any purpose, including rice irrigation. It is sometimes said that the *jamindars* built them only to show their authority and affluence. If this notion is true, I see here the copy of advanced southern Indian style, but with almost no purpose.

Only few tank irrigation systems of small and medium scales are functioning properly, even though they are being operated and maintained by communal organizations. In modern times, no more tanks have ever been built under communal management, either [Oppen *et al.*

1987]. As will be discussed later, tank irrigation systems tend to function poorly without strong leadership and well-organized land and water use programs. It is interesting to note that at time of drought farmers secure water individually through water-collecting dug-wells in the vicinity of the individual field plots.

3. Controlled Stream Diversion Irrigation: The Irrigation Landscape in Intermontane Basins and Volcanic Footslopes

In almost all the intermontane basins in Continental Southeast Asia and on the volcanic footslopes in Insular Southeast Asia, precisely controlled stream-diversion irrigation systems of very similar type have evolved. These systems typically consist of a diversion weir that checks up stream flow, an intricate water-channel network to convey the water through rugged terrain, and a commune to operate and maintain the system. The technical basis sustaining such irrigation systmes is the stable run-off from the large mountain basins in comparison to paddy land to be irrigated, and the relative ease of conveying and distributing water according to the slopes. The systems vary greatly in size, the smallest irrigating a few families' paddy land, the largest diverting a main stream and conveying water to a whole basin floor of, say, 30,000 ha.

The smaller ones are all communal, but many of the larger systems originate in the state-controlled irrigation by the kingdoms that once flourished in the basins. Well-known large systems include those of the Chiang Mai basin in North Thailand and the Chaukse plain in Upper Burma, which respectively provided an economic base for kingdoms from the eleventh to thirteenth centuries.

Many of the small communal systems developed on the volcanic footslopes in Central Java were improved and consolidated by Dutch engineers in order to sustain the rotational cropping of rice and sugarcane under the culture system imposed by the colonial government. The ***subak*** irrigation system in Bali is reknowned for its intricate design, workmanship, landscaping and tightly-knit commune formed solely for the purpose of irrigation. It is interesting to note that these systems of irrigation by controlled stream diversion flourished only in the core cultural regions of medieval and modern Southeast Asia.

4. Tube-well Irrigation: The Irrigation Landscape Sustaining the Green Revolution

The Bengal delta of Bangladesh is the largest delta in the world. Its nature is of more that of a floodplain than a delta, and thus it is endowed with both surface water and groundwater resources. The intensification of landuse since the introduction of high-yielding modern rice varieties in the late 1960s has been made possible owing to the use of the locally available water, especially groundwater. Acreage actually irrigated by tube-wells, both shallow and deep, account for almost 50 percent of the total irrigated area; and double cropping of the modern rice and the dissemination of water pumps advanced more or less hand in hand from the 1970s.

According to one estimate, a large amount of shallow groundwater, equivalent to one third of the annual flow of the mighty Ganga, is lifted through dug-wells and tube-wells in the Gangetic plain of India [Rogers ***et al.*** 1989], where the irrigated areas are, at least in the government statistics, accounted for by large state-operated gravitational canal irrigation systems. Having observed a number of tube-wells in operation within state irrigation project areas, it is my view that the Indian canal irrigation system, a world-famous monument to engineering, which was constructed from the middle of the nineteenth century by the British colonial government and subsequently been extended by Indian state governments, and which conveys a huge volume of water over immense distances from the Himalayan foothills, may be simply providing the shallow groundwater of the Gangetic plain through leakage, mistimed delivery and perhaps over-irrigation. This water is then regulated under the ground and lifted by peasants to sustain their famous, intricate multiple cropping systems in rice fields. Indeed, the lifting of irrigation water by individuals from dug-wells, and shallow and deep tube-wells has been sustaining the expansion of the rice-based multiple cropping system, which is the new phase of the Green Revolution in South Asia.

5. *Delta Development*

A typical delta in Southeast Asia comprises an Upper Delta (or Old Delta) and a Lower Delta (or Young Delta). The Upper Delta has a pronounced microrelief of alternating levees and backswamps differing by 3–5 meters in elevation, and a gentle longitudinal gradient of ca. 1:5,000. This area receives all the waters of the basin and susceptible to an annual onrush of flooding. The typical age-old landuse is settlement on the wooded levees, and floating rice culture and fishing in the backswamp. Before the systematic reclamation that started only in the middle of the nineteenth century through canalization, the Lower Delta had defied human settlement because of its inaccessibility and inhospitability. The annual hydrological cycle alternated between two extremes: total submersion of all land surfaces under about one meters of water, and complete desiccation of the land surface in the late part of the 3–4 month long dry season.

Organized reclamation of the deltas in Southeast Asia started almost coincidentally in the middle of the nineteenth century in the three major deltas of the Mekong, the Chao Phraya and the Irrawaddy, when the demand for rice from colonized neighboring countries increased. These countries were then characterized by monoculture of certain commercial and industrial crops such as cotton in the Indian subcontinent, rubber in the Malay peninsula, sugarcane in Java, rubber and coffee in Sumatra, coconut and sugarcane in the Philippine islands.

The key technology for opening the deltas, especially the Young Delta of the Chao Phraya river was canalization. This had three functions: provision of access to the inland by boat, provision of homestead land on the dug-out earth along the canals, and supply of domestic water. With the meeting of these three basic human needs, rice land expanded rapidly because soil and water conditions were basically suitable for extensive rice cultivation. Rice exports from Thailand increased sharply from a nominal 120 thousand tons before 1870 to a high of 1.5 million tons in 1929 [Ingram 1971]. All development works and the rice trade were monopolized by royalty, nobility, big merchants, and high-ranking government officials. Rice farming was practiced by owner farmers as well as tenant peasants who moved to the delta to make a quick fortune. The farming system was rice monoculture under a quasi-estate farming system, although individual farmers and peasants were not necessarily employed as wage laborers.

The Chao Phraya delta saw a renewal of irrigation development after World War II, when Thailand received financial and technical assistance from the world community to boost its rice production in order to help cope with the worldwide food shortage. A large diversion weir was installed at the apex of the delta, from which five main canals conveyed water to hundreds of secondary and tertiary canals and to the blocks of rice land covering about 600,000 ha of the Upper Delta. The hydrological environment of the 600,000-ha Lower Delta was totally changed by empoldering the formerly canalized tracts and supplying water constantly throughout the year through numerous gated canals and creeks. Thanks to the large annual budget of the state Royal Irrigation Department for operating and maintaining the new Chao Phraya Irrigation System, farmers in the Upper Delta now enjoy stable gravitational canal irrigation and irrigation by means of "water conservation" in the floodplains of the delta; and those in the Lower Delta have adopted individual lifting irrigation of their flood-free farms, tapping the ubiquitous creeks that carry controlled, perennial water.

The engineering design of the post-war development of the Chao Phraya delta was not new. It simply followed a grand design that had been submitted to the government by a Dutch engineer back in 1902. The engineer, Van der Heide, came from Java, then a Dutch colony, to become the first director-general of the newly established Royal Irrigation Department and conducted a very intensive field survey for about a year, which culminated in his grand design for delta development. The grand design, however, was shelved, as it required a far larger budget than the government could afford. Instead, several individual smaller projects were undertaken, mainly in Lower Delta, under the leadership of an Englishman, Sir Thomas Ward, who succeeded Van der Heide as the second foreigner to become director-general.

To these European engineers, planning and design criteria of large-scale gravitational canal irrigation systems must have presented familiar engineering problems, because similar major irrigation projects had been undertaken elsewhere in the then colonized countries. For example, English engineers had completed the great Upper Ganga irrigation project in India during 1836–54, started the 1.5 million-ha Indus valley irrigation project in the Punjab from 1849, and developed other major Indian deltas such as the Krishna, the Godavari and the Cauvery deltas since the middle of the nineteenth century [Rao 1979]. The predecessor of these large-scale projects through which engineers had gained their engineering knowhow was the Nile delta development, which had started early in the nineteenth century. All of these major irrigation systems helped boost crop production, intensify cropping patterns, and promote commercial cropping. Commercial crops included cotton in the Nile; cotton or sugarcane added to the original traditional patterns of wheat combined with millet, pulses or rice in the Indian deltas; and rotational cropping of rice and sugarcane in rice land in Java.

(1) Lifting Irrigation from Controlled Creeks: The Irrigation Landscape in the Lower Deltas

With the provision of these irrigation systems, the peasants have devised a new form of landuse, especially in the "controlled creek" area of the Lower Delta. Along the controlled creeks and behind their homesteads, they have carried out a number of small earth works, digging deep furrows and piling the earth removed in ridges one meter high to make alternating furrow and ridges at the intervals of, say, 2–4 meters. On the ridges they plant banana, intercropping with slower-growing fruit trees such as mango, mangosteen, and coconut, etc. Some furrows may be planted with rice, but basically they are used to rear water fowl. Small ponds may be dug out near the house to keep fish, and larger ones may be dug further away in the paddy fields for more commercialized cage culture of fish. Although this "homestead" landuse occupies less than five percent of the Lower Delta in the Chao Phraya delta, leaving the rest, of course, for rice cultivatoin, it has drastically changed the rural scene along such canals from one of a monotonous, treeless and desolate line of shacks to one of a more woody, shady, green landscape comprising rice land, fruit groves and sheltered homesteads. I have named this landuse the "rice, fish, fruit and poultry complex" in the Lower Delta. This may be indicative of future landscape in Southeast Asian deltas.

(2) *Water Conservation: The Waterscape in the Upper Deltas*

Following the development of the trunk canal systems in the Upper Delta, a further large investment was made in improving on-farm irrigation through such means as a dikes and ditch project and preliminary land consolidation trials. Most of the sloped land suitable for gravitational canal irrigation is now equipped with the irrigation and drainage. However, the more the irrigation and drainage was improved here, the more flood-susceptible became the low-lying floodplain immediately downstream, which came to serve as water conservation areas, where floating rice is still predominant [Kaida 1973].

6. *Tidal Irrigation: The Landscape and Waterscape in Coastal Plains*

The coastal plains on the rim of the Sunda sea encompass the eastern coast of Sumatra, the Malay peninsula, the southern coast of Kalimantan, to as far east as Irian Jaya, and account for about ten million ha. Peat soils prevail and the dense tropical swampy forest is considered to be the last frontier land to be reclaimed into rice land. A vigorous drive to open this area has been undertaken by the Indonesian government, under the transmigration project to provide land for land-poor Javanese peasants.

Before the organized reclamation of the swamp forest, small local groups of Sumatrans, Banjar, Bugis, Javanese and others had settled in the swamp forest. They found suitable, less salty and less acid soils, dug shallow channels to convey fresh river water inland, cut trees, opened coconut groves by making floors of alternate furrows and ridges, and reclaimed rice fields on the river levees, where they make use of tidal irrigation. In well-designed tidal irrigation, fresh river water floating on the so-called salt water wedge is pushed up by the high tide and carried onto the rice fields, and at low tide it drains. The acidity may be diluted and made less harmful by this alternating irrigation and drainage, not only in the rice fields but also inland, where coconuts are extensively grown. Normally, these frontier rice lands and settlements are made quickly and also abandoned quickly. However, in some settled and more mature villages, the settlers have devised a form of landuse similar to the "rice, fish, fruit and poultry complex" in the Chao Phraya delta, by performing individual earth works to create fields with "high ridges and low furrows" and by using the fresh water available in the coastal swamps, i.e., two of the key technologies for creating environment-adaptive-cum-environment-formative farming systems.

II Changes in the Irrigation Landscape

The irrigation landscape of rice land in tropical Asia has evolved gradually over the centuries, and exceptionally rapidly since World War II, by means of environment-adaptive technologies as well as engineering installations. In the future, I see two major directions in which the irrigation landscapes will change. One is the individualization of water management in association with diversified and multiple landuse in individual farm management; and the other, though much the lesser, is the assimilation of engineering works into the surrounding natural landscape or, in short, "landscaped irrigation."

1. Individualizing Irrigation

Agricultural technology is basically the individual farmers' technology. Irrigation technology alone has been regarded as communal, collective, and often governmental by many engineers, and naturally the ethics of communalism and collectivism was encouraged for proper operation of gravitational canal irrigation systems. Always the concern among irrigation specialists was how to develop communal organizations to operate and maintain the irrigation systems more efficiently.

The modernization of irrigation facilities has largely been motivated by the introduction of modern high-yielding rice varieties since the late 1960s, and the improved irrigation has in turn given greater freedom in selecting varieties and combining crops grown in rice land almost throughout the year. The modern rice varieties were particularly suitable for adoption as major component crops in multiple cropping systems, in part because of their higher yielding potential than their local traditional counterparts. In addition, their photo-period insensitivity and short maturity allowed them to be easily incorporated in the original cropping patterns.

In the case of a small tank irrigation system in the dry zone of Sri Lanka, the efficiency of irrigation delivery in the dry season was found sometimes to be as low as 40 percent, with the rest of the water running to waste down the field channel. Despite the many engineering and organizational deficiencies that remained to be overcome, it was found that the major cause of the loss was the complicated, multiple cropping patterns adopted by individual farmers. Given a block of rice land of which a certain percentages is planted to non-rice crops, the right amount of irrigation water calculated for the crop water requirement cannot be delivered properly, because the physical dimensions of the canal and field channel networks are designed for the full irrigation of rice land, which requires much more water than mixed cropping. A remodeling of the whole irrigation system may be required to meet the various water requirements of individual field plots and blocks in terms of amount and timing.

Several measures can be applied to cope with maldistribution of water. The first is the improvement of "hardware," e.g., by linking several tank irrigation systems in series or in parallel in order to minimize the overall loss of water, in a way adopted in many of the traditional tank systems in the dry zone of Sri Lanka. The second is the refinement of "hardware and software," e.g., by operating a very intricate tertiary irrigation network through an operational organization which allows the famous "rotational irrigation" practiced in parts of Taiwan. The third measure, mentioned earlier, is to use shallow wells dug in individual field plots to collect groundwater seepage from the tank in order to supplement uncertain surface delivery. This regulation by individual use of dug-wells may also be applicable in large gravitational irrigation systems where water delivery tends to be uncertain and unreliable. Instead of the wells, a group of small regulating ponds could be used to temporarily store rainfall and excess water delivered through irrigation canals, thereby greatly improving irrigation efficiency. These measures are all directed toward the individualization of irrigation.

The control of flooding in the floodplains in the delta, though feasible purely from the standpoint of engineering, may not be a wise alternative. Costs would be high, and it might threaten a delicate water balance. The floodplain makes a better contribution by serving as a water conservation area, where floating rice and fish can be grown safely. This area provides a water retarding basin for the whole delta, which allows further development of irrigation and drainage in the upper and major part of the delta. This waterscape will have to be conserved as a base for commercial production of floating rice.

2. *Landscaping Irrigation*

Many of the traditional Japanese irrigation systems in fans had multiple uses: before being channeled into the rice land, the clean water diverted from a weir ran first through the settlements, providing water for such domestic uses as washing vegetables for marketing, rearing carp and other fish, washing household utensils, washing clothes, and fire-fighting. Water and the irrigation landscape were kept clean for these minor uses. Many of them, however, have been abandoned with the "modernization" of the past thirty years, resulting in polluted water and "poor" irrigation landscapes. Modern rationalism in planning of irrigation has bypassed the multiple water use, and considered single purpose of efficient irrigation. Only recently has the notion begun to be revived from the standpoint of creating and improving the waterfront landscape and enhancing the recreational utility of irrigation facilities.

We have many lessons to learn in this respect from the small irrigation systems in Southeast Asia. Irrigation networks in the volcanic footslopes in central Java and in Bali, for example, are all designed to serve multiple purposes. The water runs down through settlements and homestead gardens and is used for watering gardens, daily washing and bathing and other purposes, then runs into the rice land behind the homestead forests and gardens. I have been fascinated by this multiple use of irrigation water and people's ingenuity in making engineering structures and works a part of the "landscape," in fusing the natural and man-made landscapes into one. I view this irrigation water running through homestead woods and gardens into the rice land behind as a typical and desirable irrigation landscape in small fans and volcanic footslopes.

Table 2 Future Modes of Rice Land Irrigation in Tropical Asia

Mode of Irrigation and Landuse	Area
Rainfed	50%
Controllable irrigation	35%
Controlled stream diversion irrigation ("Irrigation water running through homestead woods and gardens into rice land behind")	
Gravitational canal irrigation ("Rice estate")	
Tube-well irrigation ("Multiple cropping on the basis of individual lifting irrigation")	
Tank plus dug-well irrigation	
Lifting irrigation from controlled creek ("Rice, fish, fruit and poultry complex")	
Water conservation ("Floating rice and fish culture")	15%

3. *Conclusion*

In tropical Asia, like in Japan, rice land irrigation does not exist solely for the economical production of rice alone, nor do peasants request that irrigation facilities be built for the single purpose of efficient production of rice. We engineers would better pay more attention to the functions of irrigation that enhance multiple water use and create and maintain better irrigation landscapes and waterscapes.

A desirable irrigation landscape for the Lower Delta will be, as stated earlier in some detail, one of rich land and waterscape supporting a "rice, fish, fruit and poultry complex."

Summing up the foregoing discussion, Table 2 presents a foreseeable future irrigation landscape. Fifty percent of all rice land will remain rainfed. Irrigation by means of water conservation will occupy about 15 percent of rice land, mainly in the floodplain in the deltas, where deep-water rice, floating rice and fish may be cultured safely. Thirty-five percent of the rice land will be equipped with controlled irrigation facilities. They comprise, in phrasing which expresses my hopes, (a) "irrigation water running through homestead woods and gardens into rice land behind" in small fans, intermontane basins and volcanic footslopes in Southeast Asia, (b) the "rice, fish, fruit and poultry complex" in the Lower Delta and some of the coastal plains in Malaysia, Sumatra and Kalimantan, where controlled water supply by canals and creeks is assured, and (c) "rice-based multiple cropping" on the basis of individual watering through tube-wells and dug-wells in both the tank irrigation areas and gravitational canal irrigation areas.

This is the world's largest irrigation landscape and waterscape where almost 50 percent of all rice land is equipped with some form of irrigation and water control.

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