IRRIGATION MANAGEMENT IN RICE-BASED CROPPING SYSTEMS: ISSUES AND CHALLENGES IN SOUTHEAST ASIA

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ABSTRACT

This Bulletin identifies four distinct phases of irrigation development in Southeast Asia – community irrigation, river diversion schemes, large storage dams, and wells and pumps. The traditional lack of cohesion between public and private sector in irrigation development was noted. Contemporary issues such as water scarcity, collapse of rice prices, agrarian change, and growing environmental concerns were found to influence the way people value and manage their water resources. It was concluded that there is a need to redefine the role of state, local, and private actors in the management of water resources, not only for rice-based crop production but also for competing industry, domestic, and environmental demands.

INTRODUCTION

Four decades ago, before the green revolution, the same methods of growing rice and managing water had been practiced for hundreds of years. Now we have entered a period of rapid change which has major implications for water management in rice-based cropping systems which account for most of irrigation usage in Southeast Asia. Technological advances accompanied by changes in the physical environment and rural economy have created a need for new policies and institutions for irrigation management. Identifying and adopting appropriate policy and institutional reforms is the challenge that the irrigation sector in Southeast Asia faces.

This Bulletin is divided into three sections. First, we take a retrospective look at irrigation management in monsoon Southeast Asia. Next, we identify the contemporary issues facing irrigation management in rice-based cropping systems. Finally, we discuss the challenges ahead – the paths to improving water management and the need to redefine the role of state and local actors in the management of water resources.

IRRIGATION MANAGEMENT IN SOUTHEAST ASIA

Historically irrigation has developed in Southeast Asia in four distinct but overlapping phases: community irrigation; river diversion dams; large storage dams; and the groundswell in pumps.

Community systems

Community irrigation systems have been pervasive in Asia and even today serve a third or more of the total irrigated area. Many of these community systems have existed for centuries. While most are small, it is not unusual to find some serving 1,000 hectares or more. They have generally developed in mountainous or hilly areas based on the diversion of small/medium streams, most

Keywords: irrigation management, cropping systems, community irrigation, river diversion dams, groundswell of pumps, groundwater, water productivity, water-saving technologies

especially in the Himalayan, the Philippines, Northern Thailand and Laos, in China and Japan. The success of a community irrigation system depends most importantly on the felt need of the community of water users. The need for community cooperation is most evident in areas of intense population pressure and/or limited water supplies in order to gain access to and share water, and to minimize conflicts (Tang 1992, Ostrom 1992).

Lewis (1971) describes the zanjera irrigation societies of the densely populated Ilocos region of the Philippines. He compares the behavior of farmers in the zanjera with those who migrated to the less densely populated province of Isabela and finds in the latter case no evidence of functioning irrigation associations. He concludes that the behavior of Ilocanos is reflected in the differences in the respective natural and social environments. Siy (1982) studying the zanjeras and Yoder *et al.* (1987) studying the performance of irrigation organizations in the foothills of Nepal concluded that the need to periodically mobilize labor to gain access to water through the construction and maintenance of canals and dams was among the most important factors accounting for sustainable farmer managed irrigation systems. Geertz (1980) on the Balinese Subak also illustrates the sophistication of communal irrigation.

Traditional communal irrigation schemes are often praised for their endogenous mix of local wisdom and social cohesion, and sometimes romanticized (Tan-Kim-Yong 1995, Goldsmith 1998). For example, the "peoples irrigation system" in northern Thailand can be viewed as an integrated system consisting of an intricate intertwining of local village technology with human commitment of cooperation. These cohesive systems are now exposed to new threats, as communities become open to the world, agriculture has moved from subsistence to commercialization, villagers have diversified their economic activities, and competition for water is on the rise. Increased socioeconomic heterogeneity as well as the intervention of the state in construction/maintenance of weirs have often weakened social cohesion and collective action.

In addition, deforestation and changes in land use in the upper part of the catchment have often altered hydrological regime and water quality, impacting on downstream users. Traditional rights to water and long-standing rules for water sharing have been affected by the irruption of outsiders pumping or diverting water directly from the same sources, or by the state that has frequently superimposed large water storage and distribution infrastructures over the existing systems. National laws are often limited to increasingly inadequate definitions of riparian rights and "reasonable use". The confusion of legal repertoires reflects not only the conflict between local history and more recent state intervention, but also that between, on one hand, flexibility and adaptation to micro physical and sociocultural contexts and, on the other hand, top-down, capital-intensive, and large-scale macro-strategies of development.

Despite all these threats, the system of communal management and what comes under the more general term of common-pool resource management, still offers a convincing and appealing option for water management, as opposed to more commonplace emphases on state- or market-driven modes of regulation (Ostrom 1994).

River diversion schemes

In the monsoon areas of Asia, the farmer traditionally planned his crop production primarily on the basis of expected rainfall. In years of good rainfall, farmers needed no irrigation. Flooding was often prevalent with the need to provide adequate drainage. In years of low rainfall, supplemental irrigation was needed to protect the main harvest, normally rice. The advent of the colonial powers with the desire to promote exports provided an impetus for the expansion of irrigation. Expansion of canal systems occurred most rapidly in the major rice deltas which became the major source of rice exports.

In Indonesia, the sawah (irrigated paddy fields) that had developed in the 17^{th} and 18^{th} century to support the growing population were expanded in the late 19^{th} by the Dutch to accommodate sugarcane. Huge hydraulic efforts to expand rice cultivation later occurred from 1900 to 1940, the paddy area growing from 1.26 million ha to 3.4 million ha (Maurer, 1990). In Vietnam, the French rulers improved flood control in the Red River delta but the bulk of agricultural expansion was achieved in the Mekong delta, a still largely virgin area in the mid-19th century. The use of new mechanical dredgers allowed the expansion of canals and paddy fields, from 350,000 ha in 1868 to 2,443,000 in 1930 (Henri 1930, Brocheux 1995, Molle and Dao The Tuan 2000). Similarly, in Burma, the reclamation of the Irrawaddy delta gave rise to a spectacular increase in rice area and exports (Adas 1974). In Siam too, despite the absence of formal colonization, the Chao Phraya delta was equally reclaimed between 1850 and the mid 20th century, thanks to the abolition of bondage and the expansion of the rice trade and economy (Ingram 1971).

From these examples, it can be seen that most of the expansion took place in deltas, with little or no technical change, and without any major hydro-technological works (Owen, 1976). Canaling also served the crucial purpose of communication (and provided places for homesteads), flood regulation allowed to better control flood-based agriculture, while river diversions of both small (Philippines, Java) and large scale (India) accounted for more classical gravity irrigation.

Large storage dams

As we entered the cold war era following World War II, concern grew in the West regarding the population explosion and deteriorating food situation in Asia and its implications for political stability and the spread of communism. Among the governments of Asia and the West and the west-dominated international development agencies the priority was clear – to increase cereal grain production in Asia. A consensus gradually emerged as to how to get the job done as the pieces of the green revolution technology began to fall into place. Attention has often focused on the success in the development and extension of high-yielding, fertilizer-responsive varieties. However, the huge investments by the development banks, donor agencies, and national governments to develop and expand irrigation systems can easily be regarded as the *sine qua non* of food security in Asia today.

Two climatic events that led to shortfalls in annual rains throughout much of the world – so-called El Niños – served to catalyze the commitment to the food security goal and the investment in irrigation. The first of these occurred in the mid-1960s in the Indian subcontinent, where a shortfall in grain production threatened famine. The second occurred in 1972, resulting in a shortfall in crop production, leading to a sharp rise in world rice prices (Fig. 1) and forcing Thailand, the world's largest rice exporter, to ban exports for several months in 1973.

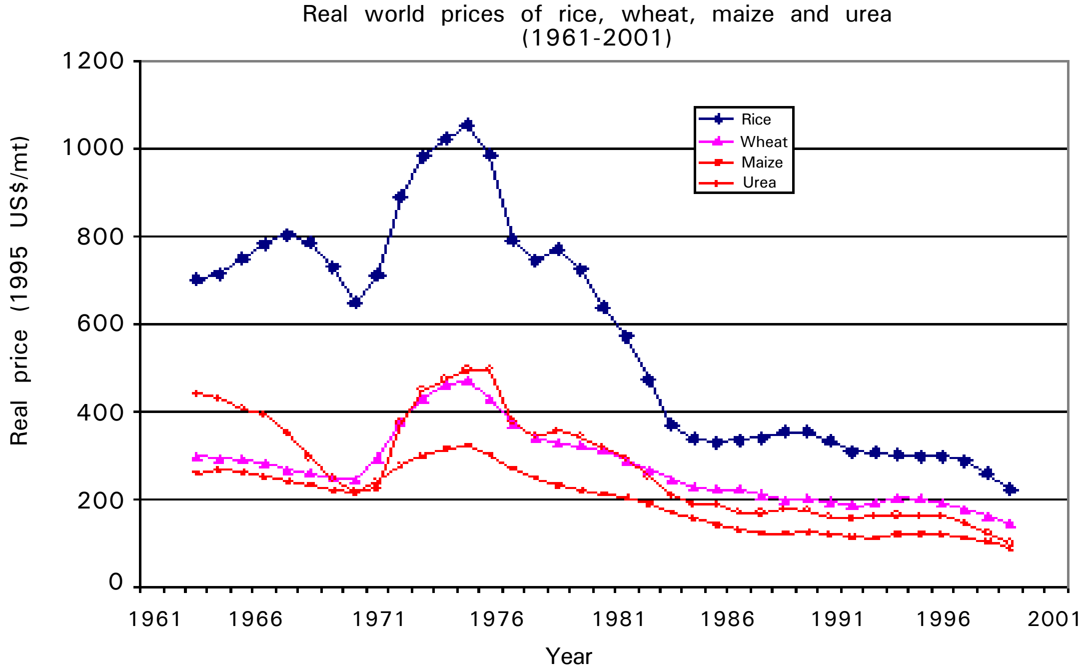


Fig. 1. Historical trends in prices of cereal grains and urea.

The growth in irrigated area in Asian countries is shown in Table 1. More than 60 percent of the world's irrigated area is in Asia, two thirds of it in India and China. From the early 1960s to the end of the century the irrigated area doubled.

Table 2 shows the rate of growth by selected country groupings. After 1985 there was an increase in the rate of growth in irrigated area in Cambodia, Laos, Myanmar, and Vietnam (SEA II in Table 2), a significant decline in the rate of growth in Indonesia, Malaysia, Philippines, and Thailand, and in China (SEA I in Table 2), and an absolute decline in irrigated area in East Asia. The increase in mainland Southeast Asia reflects the fact that for both political and technical reasons development of irrigation in the Mekong and Irrawaddy River Basins had been delayed.

Expansion in irrigation was facilitated by technological advances. Technological advances can be divided between: 1) those relating to the development of surface water or canal irrigation systems largely through public investment; and 2) those relating to the exploitation of groundwater, initially through public investments, and more recently in monsoon Asia largely through private investment.

Advances in the technology of large dam and reservoir construction in the western United States before World War II became the foundation for surface irrigation system development in Asia in the post-World War II period. During the so-called construction period the expansion of irrigation occurred largely through the construction of dams, reservoirs, and canal distribution networks. Dam construction is the most visible sign of surface development and lending agencies such as the World Bank are often associated with large dam construction (Jones 1995). But there have been many more projects in which the Bank has financed headworks, pumps, canals and cross regulators, drainage roads and land leveling than in which the Bank has financed dams. In short, dams make up only a portion,

Table 1. Growth in irrigated area in Asian countries 1961-99

Country	Irrigated area 1998	Increase in total irrigated area 1962-1998	Irrigated area in 1998 as a % of irrigated area 1962	Average annual growth 1962-98	Irrigated area as % of harvested area 1998
	"000" ha	"000" ha		%	
India	58333	33255	233	3.7	28
China	52714	21736	170	1.9	28
Pakistan	17843	6915	163	1.8	75
Thailand	4836	3131	284	5.1	30
Bangladesh	3841	3369	814	19.8	28
Myanmar	1663	1042	268	4.7	15
Vietnam	2767	1767	277	4.9	25
Nepal	1135	1062	1548	40.2	22
Philippines	1550	850	221	3.4	11
North Korea	1460	960	292	5.3	42
Indonesia	4815	915	123	0.7	16
Cambodia	270	206	422	8.9	12
Laos	167	154	1351	34.8	19
South Korea	1160	0	100	0.0	54
Sri Lanka	638	277	177	2.1	39
Malyasia	357	126	155	1.5	9
Bhutan	40	31	429	9.1	19
Japan	2680	-261	91	-0.2	82
Asia	189971	92609	195	2.6	30

Data sources: FAO

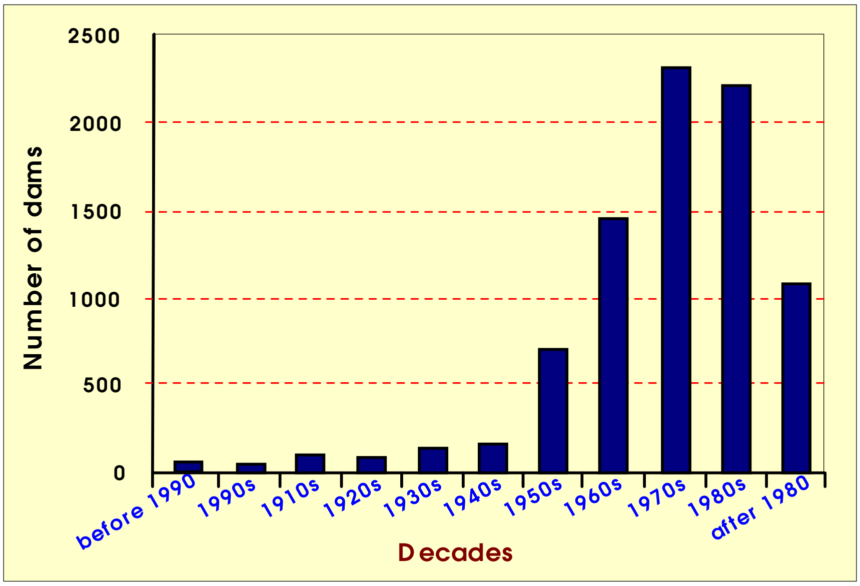
Calculations are based on 3-year averages centering on the year shown.

Total harvested area is the sum of cereals, coarse grains, pulses, oil crops, fiber crops, fruits, tree nuts, roots and tubers and vegetables.

Table 2. Growth in irrigated area in Asia and its sub-region countries, 1961-1999

Country	1962-85	1985-98	Share of total net irrigated area in Asia 1998
Asia	2.3	2.0	1.00
SEA I	2.2	1.3	0.07
SEA II	3.7	4.2	0.03
China	1.9	1.4	0.34
India	2.9	3.0	0.37
East Asia	0.9	-0.3	0.03

SEA I includes Indonesia, Malaysia, Philippines, Thailand
SEA II includes Cambodia, Laos, Myanmar, and Vietnam



Source: ICOLD, 1998.
Source: World Commission on Dams 2000.

Fig. 2. Historical evolution of dam construction in Asia.

albeit a very significant one, of the cost of irrigation development. Of the more than 40,000 large dams all but 5,000 have been built since 1950 (McCully 1996). (The international commission on dams defines large dams as one measuring 15 meters or more from foundation to crest). Fig. 2 shows the dramatic increase in large dam construction in Asia in the latter part of the 20th century, the peak being reached in the late 1970s and early 1980s. During this period in most countries 50 percent or more of the agricultural budgets were devoted to irrigation, with only a small fraction of that total for operation and maintenance.

There were three factors that led to the decline in large dam construction. First, cereal grain prices declined sharply in the mid-1980 to 50 percent of their previous levels (Fig. 1). This decline was due to the successful spread of the green revolution technology, the expansion of irrigation, and the increase in subsidies for grain production in the developed countries. Second, the decline in grain prices was accompanied by a rise in construction costs, particularly because new sites less suited for irrigation became more costly to develop. In many Asian countries the cost per hectare of new irrigated area has more than

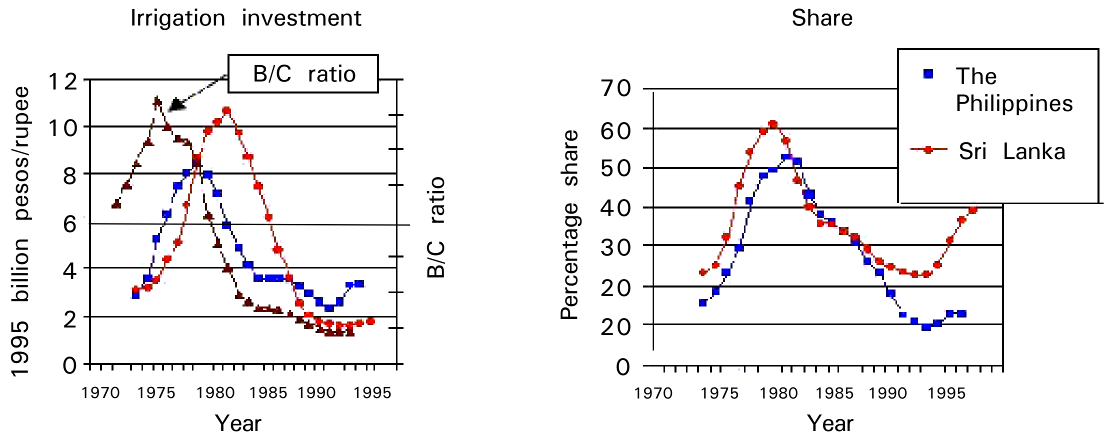


Fig. 3. Trends in and real value of irrigation investments and the share of irrigation expenditure in government expenditure in agriculture in the Philippines and Sri Lanka (1972-1999).

doubled since the 1970s (Svendsen and Rosegrant 1994). The effect of falling grain prices and rising construction costs was to reduce the benefit-cost ratios. Fig. 3 for Sri Lanka and the Philippines presents a fairly typical picture for much of Asia with the exception of the areas of mainland Southeast Asia noted above. The peak in large dam construction in the mid-1980s lagged approximately a decade behind the peak in the benefit-cost ratio reflecting the long gestation period in irrigation development.

The third factor accounting for the decline in investments was the growing opposition of the environmentalists. Reflecting these environmental concerns the World Commission on Large Dams was created in 1997 to review and report out on the positive and negative impacts of large dam construction and establish a framework for decision-making (World Commission of Dams 2000). By the time of this report, however, the construction phase had largely come to an end and attention was gradually turning to the equally important but less visible environmental problems associated with groundwater.

Groundswell of pumps

There is a tendency to associate irrigated agriculture in the developing world with canals, dams, tanks, and reservoirs. By contrast, largely hidden from attention, a worldwide explosion has occurred in the use of wells and pumps for irrigation, domestic, and industrial use. While the construction of wells and purchase of pumps is often subsidized, the operation and management is in the hands of individual farmers or groups of farmers sharing the same well.

In many areas, there is a hydrological link between the development of canal irrigation and the development of groundwater. Chambers (1988) notes that a major and perhaps the main beneficial effect of canal irrigation is to distribute water through the command area, allowing it to seep and to provide water for irrigation through wells (see also Dhawan and Sai 1990).

Principally for the reasons cited above, in the semiarid regions of Asia and more recently in the monsoon areas, the expansion of area irrigated by groundwater as well as pumping from canals and drains has tended to follow the very extensive development of canal irrigation.

In discussing pumps and wells it is useful to distinguish three very different environments: 1) the semiarid regions such as the Punjab; 2) the major river deltas such as the Ganges-Brahmaputra, Irrawaddy, Chao Phraya, and Mekong; and 3) the rest of monsoon Asia. Rice is the dominant crop in the wet season in latter two regions. Each environment presents a very different management problem. In most of Southeast Asia, farmers use low-lift pumps to tap shallow aquifers usually replenished every year during the monsoon rains and also use pumps both for surface irrigation and for drainage of excess water.

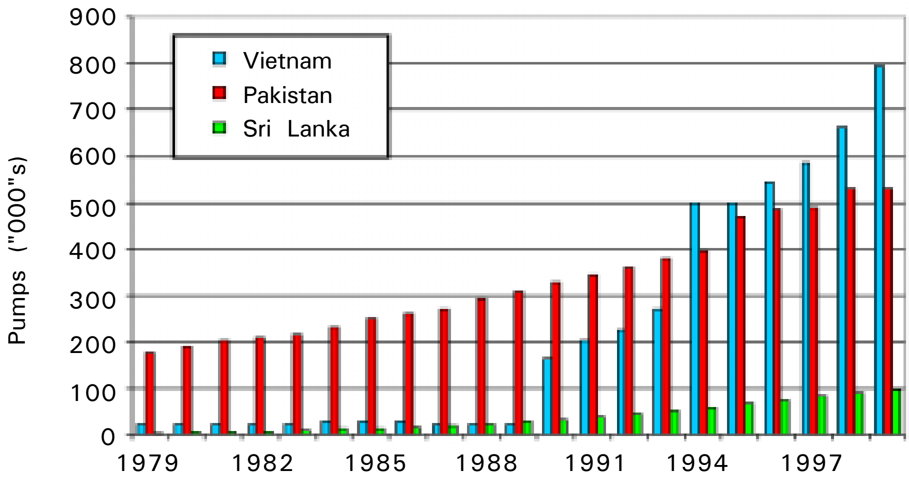


Fig. 4. Number of pumps in selected Asian countries, 1979-1999.

In the semiarid regions of South Asia, groundwater irrigation has grown steadily since the 1960s to the point where wells exceed surface systems as a source of irrigation in both India and Pakistan. More recently, in just the past 10-15 years, pumps and wells have become important for irrigation in monsoon Asia (Fig. 4 for Pakistan, Sri Lanka and Vietnam). Pumps are being used not only for groundwater extraction but also for providing greater flexibility in the reliability and delivery of surface water. Kikuchi *et al.* (2003) commented as follows:

"In the history of irrigation and irrigated agriculture in monsoon Asia in the tropics, the last few decades of the 20th century will be remembered as the decades of well and pump diffusion that enabled individual peasant farmers to irrigate their crops at their discretion, as opposed to those in gravity irrigation systems in which decision making as to water allocation and distribution rests at best on groups of farmers or at worst on bureaucratic government agency totally unaccountable to farmer beneficiaries."

A major reason for the recent groundswell of pumps for both groundwater extraction and surface irrigation has been the declining cost of pumps. Small (5 HP or less) low-lift pumps imported from China can now be purchased for US$ 200 or less making them readily accessible to small private farmers.

In the areas where surface and groundwater systems are hydrologically strongly linked, conjunctive use has not led to conjunctive management. The growing ascendancy of private investment in groundwater, stimulated in part by the poor services provided by government-managed systems, has undermined collective management by fostering individualistic strategies. Farmers who have acquired pumps may be less willing to participate in irrigation associations or the widely promoted participatory irrigation schemes. But failure to maintain the surface irrigation systems can in turn affect the groundwater recharge and increase the cost of pumping as groundwater tables fall.

CONTEMPORARY ISSUES

As we enter the era of globalization, the period of rapid expansion of irrigated area through either construction of surface irrigation systems or exploitation of groundwater has come to an end. Attention has turned to the improvement in the management and performance of existing irrigation systems both to reduce the financial burden and to allow an increasing share of water to be diverted to nonagricultural uses. Below we discuss some of the key factors shaping the development of irrigated agriculture today.

Water scarcity

Irrigation consumes an estimated 70 percent of the total developed water supplies, but well over 70 percent in the developing countries. A projected 2.7 billion people, including one third of the populations of India and China, will live in regions that will experience severe water scarcity within the first quarter of this century (Seckler *et al.* 1998). Water shortages could lead to conflicts in the Middle East and North Africa but are likely to impact most severely on the poorest segments of the population in South Asia and Sub-Saharan Africa, where incidents of poverty are already high.

However, the shortage of water will be pervasive, extending well beyond the semiarid regions and affecting even populations in well-watered areas such as Southeast Asia. Scarcity occurs throughout the monsoon area in the dry season often punctuated by droughts. Competition for water is also growing around the major urban and industrial centers, such as Bangkok, Manila and Ho Chi Minh City.

The growing scarcity and competition for water is dramatically changing the way we value and utilize water and the way we mobilize and manage water resources. With growing municipal and industrial demand for water and needed water requirements to protect the environment, there will be less water for agriculture in the future. We must produce more food and agricultural products with less water. Many people believe existing irrigation systems are so inefficient that most – if indeed not all – of the water needs of all sectors could be met by improved management of irrigation and transferring the water to the nonagricultural sectors. It is not uncommon to read that irrigation efficiency – the amount of water used by the crop divided by the amount of water diverted – is approximately 40 percent. But recently it has been pointed out that this measure of irrigation efficiency is extremely misleading. Taking into account return flows results in a much higher estimate of irrigation efficiency and leads to the conclusion that the scope for improving irrigation efficiency is much less than normally assumed (Frederiksen 1992, Keller and Keller 1995, Keller *et al.* 1996, Seckler 1996). The merits of this debate notwithstanding, it is often overlooked that farmers, irrigation administrators, and others are already making adjustments where water scarcity has become a reality.

Collapse of food grain prices

At least two thirds of the irrigation in Asia has been devoted to the production of rice and wheat. In the 1980s cereal grain prices declined to 50 percent of their levels in the previous three decades (Fig. 2). There are three reasons for this: 1) the extraordinary growth in production due to expansion of irrigated areas and adoption of green revolution technologies; 2) the decline in demand for cereal grains as incomes have risen and diets evolved; and 3) the continuing and increasing level of subsidies by the developed economies.

The downward drift of rice prices (reaching a historical low in 2001) is bringing greater pressure to bear for diversification. Many canal systems were designed and managed as supply driven systems, which was suitable when the major objective was producing cereal grains. There is a growing incentive to invest in pumps to improve flexibility and reliability in water deliveries or thus to obtain water on demand. Diversification is a crucial aspect of agricultural change but it is constrained by a host of factors, ranging from soil and water suitability, skill acquisition, capital and labor constraints, risk in marketing, and, foremost, by the development of adequate markets. In all Asian countries, frequently for more than 50 years, policies have been designed to foster agricultural diversification, often seen as a panacea to low staple food prices. However, they have been met with mixed success and it is doubtful that diversification can be boosted much beyond the level observed. This is because diversification is constrained by high levels of risk and lack of capital or skill (Siriluck and Kammeier 2003). It is also dependent upon market demand, on the change in consumption patterns, and on information technology that can put producers in more direct contact with export markets.

Irrigation and agrarian change

The future of irrigation in Asia is tightly linked with agrarian change, itself a reflection of wider transformations of national and world economies, and cannot be considered in isolation. The pressure on land/water resources, the man/land ratio, and the per capita farm income are strongly linked to demographic evolutions. One of the most significant changes in the last three decades is the demographic transition. For most countries population growth rates have dropped from 2.5 percent or more to under 2 percent. The mobility of labor is high and migrations also tend to remove people from the countryside, irrespective of whether this is a pull or push process. In the 10 years preceding the 1997 economic crisis, the labor force engaged in agriculture in the central region of Thailand dwindled down from 3.5 to 2.5 million. This shift concerned the age class under 35 and all socioeconomic strata, since investment in the education of children also motivates movements to cities (Molle and Srijantr 2003).

In addition to inter-sectoral mobility, rural households' economies have also become more composite and pluri-activity within the family as well as at the individual level has emerged as a general and central phenomena. Farmers are responding to new opportunities (see Preston's (1989) study on central Java: "Too busy to farm") and in many rural areas of Asia the household income from agriculture is now lower than that coming from nonagricultural occupations (Rigg 2001, Estudillo and Otsuka 1989). A study over three decades of changing sources of farm household income in a village in Laguna, Philippines by Hayami *et al.* (1997) clearly illustrates the point (Fig. 5). In some extreme cases, the shift is even more profound and the demise of agriculture is observed, as in Malaysia where a third of the agricultural land is now left fallow.

As emphasized by Rigg (2001):

"The distinctions between rural and urban are becoming blurred as households increasingly occupy, or have representation in both the rural and urban worlds and, more to the point, earn a living in both agricultural and non-farming activities. ... This requires a rethinking of the rural economy and rural life, a reappraisal of policy initiatives and planning strategies, and a reformulation of theories of agricultural and rural development."

Farmers are engaged in and draw income from a wide portfolio of activities, or receive remittances from relatives: this prompted Koppel and Zurick (1988) to observe that this "rural employment shift" suggests "that an increasing proportion of rural labor relations are not connected directly with traditional agrarian processes, but rather with more complex socioeconomic relationships in which agrarian processes may be only one part."

Thus, the evolution of irrigation, as well as of agriculture, cannot be considered independently of changes occurring in the wider economy. The management of water resources, and of irrigation in particular, will also be shaped by ongoing political processes of democratization, which constantly redefines

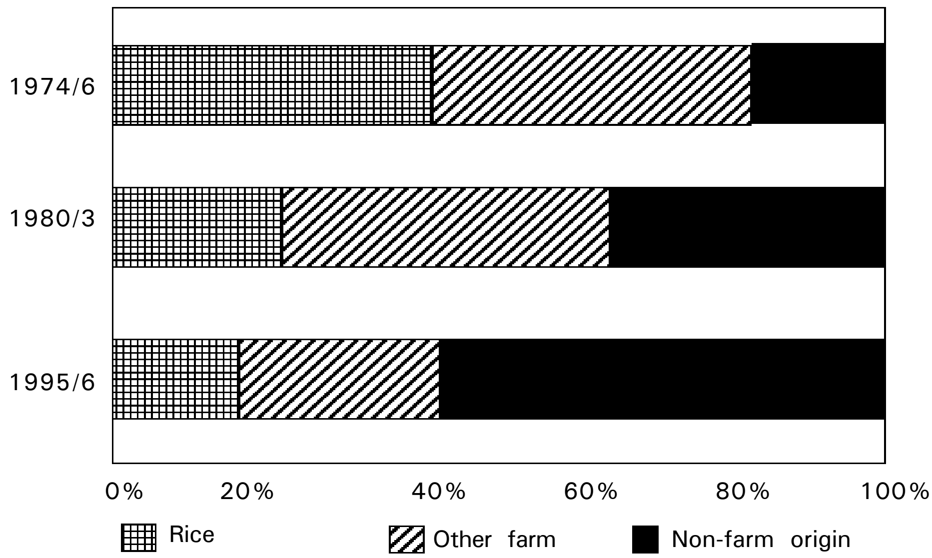


Fig. 5. Change in percent income from rice, other farming, and nonfarm activities in a Lanuna village, Philippines. (Adapted from Hayami and Kikuchi 2000).

the relationships between the state and the citizenry and has a bearing on the conditions of access to resources.

Growing environmental concerns

Despite the frequent enactment of pieces of legislation aimed at controlling pollution, most Asian countries are faced with problems of monitoring, technical capacity, and law enforcement that make the laws remain useless. Agriculture is also responsible for non-point-source pollution by nitrates and pesticides but this problem is still widely seen as secondary compared with other sources of pollution (waste disposal, mines, factories, pig farms, etc.).

The overdraft of deep aquifers is also causing disasters of critical magnitude. They include the intrusion of salt water into coastal aquifers, the drying of wells and rivers particularly in the semiarid areas, and land subsidence and the sinking of major cities such as Jakarta and Bangkok. One third of Bangkok, for example, is already under sea level and the costs of flood protection and damage are increasing.

Other environmental impacts of land and water development include water logging, salinization (Pakistan), arsenic poisoning (Bangladesh), the release of acid (Mekong), the destruction of mangroves and coastal areas after contamination of shrimp farms (e.g., Vietnam, Thailand), not to mention the spread of vector borne diseases and the externalities associated with dam construction. Environmentalism is still incipient in Asia. However, there is evidence that organized groups are already achieving some success in opposing large-scale projects with flawed impact assessment. But the focus is on the highly-visible large dams, while many of the most serious environmental problems lie elsewhere.

CHALLENGES AHEAD

In the previous section, we described some of the key forces influencing the direction of irrigation development in the decades ahead. It seems almost certain that there will be major changes in technologies, policies, and institutions as the era of globalization unfolds, but how, when, and where will these changes occur? The environmental setting for irrigation and irrigated agriculture is enormously diverse. There are areas (or seasons) experiencing acute water shortages, and other areas where drainage of excess water is the key problem. There are government-managed irrigation systems, communal systems, and areas with private pumps, and in some cases these areas overlap, offering the opportunity for example for conjunctive management of surface and groundwater irrigation.

Many of the old communal systems face a challenge to their sustainability because, as noted above, interest in agriculture has declined in the village, the labor force required to maintain these systems is vanishing, and in some instances technologies such as pumps and tube wells offer a better avenue for increasing crop productivity. The government-managed surface systems face a challenge to their sustainability due to budget constraints and to the continuing inability to develop institutional arrangements to integrate the authority, accountability, and responsibilities of government bureaucracies with those of local water users. Private producers face a challenge to their sustainability due to the inability to control the over-exploitation of a common property resource.

Increasing water scarcity and growing demand for nonagricultural uses elicits a growing interest in seeing that our water resources are properly managed. At the same time a conflict exists between stakeholders – national governments and multilateral lending agencies on the one hand and local water managers and users on the other – not so much in terms of goals, but rather in what each sees as the means to achieve these goals. In this section we discuss this conflict first in terms of stakeholder response to water shortage. This leads to what we regard as the main challenge ahead, redefining the role of the state and local actors in the management of water resources.

Improved water management and increased water productivity

Responses to water scarcity are extremely varied but can be classified under three different categories: (a) augmentation of supply, (b) conservation of water, and (c) reallocation of water. Fig. 6 (Molle 2003) synthesizes some

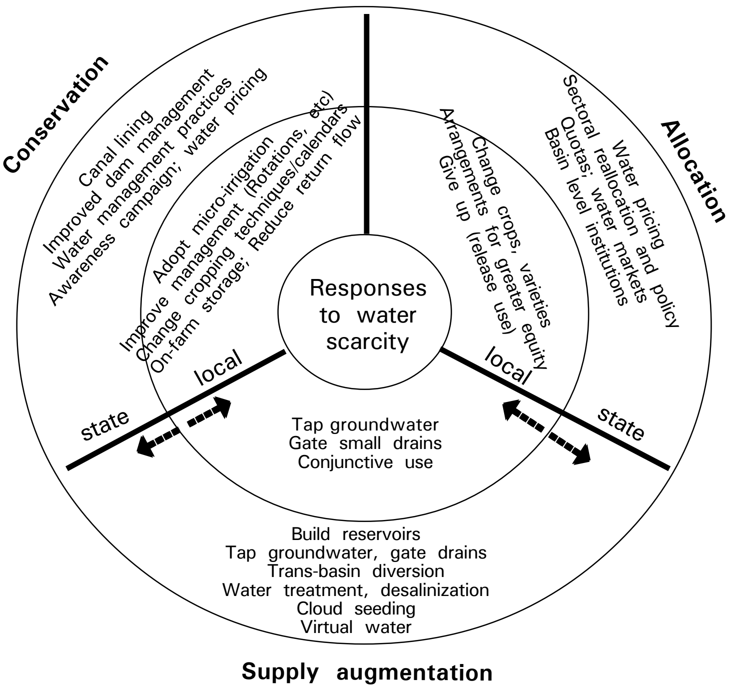


Fig. 6. Types of response to water scarcity
Source: Molle 2003

of the main strategies and distinguishes between those that are implemented by individuals (inner circle) and those that are collective, implemented primarily by government agencies or donor-assisted projects (outer circle). The focus today is on conservation and reallocation, the opportunities for supply augmentation having been nearly exhausted.

There is normally little if any coordination or communication between farmers and government agencies. That is to say, the decisions of both entities are often made quite independently, although they may also be interlinked (e.g. a farmer's decision to adopt micro-irrigation may be influenced by economic incentives). For example, most government irrigation agencies are involved in the operation of canal systems and do not have information on the number of privately operated wells and pumps even within their own command areas. However, the need to respond to water scarcity (whether drought or chronic shortage) tends to increase the interaction between parties and the potential benefits from collaboration.

Farmer/operators' response

Farmers are often accused of wasting water. But farmer response to water scarcity and to declining cereal grain prices has been fairly dramatic. As noted earlier, the tapping of groundwater and the use of pumps for recycling has been growing rapidly. Where opportunities permit, farmers are relying on more flexible and reliable groundwater supplies to shift from rice to higher valued crops. The development of on-farm storage is also becoming more prevalent in some areas. Thus, farmers are not passive: they are finding ways through both conservation and reallocation and through expanded supply to increase water productivity and income.

However, farmer response has not always led to positive results. Particularly in the semiarid areas, unregulated exploitation of groundwater has led in some areas to falling water tables and in others to rising water tables and increased salinity. Furthermore, the development of private farmer facilities may work against the development of collective action and undermine farmer irrigation associations.

Dam operators are also driven to improve their management when scarcity elicits growing scrutiny from the civil society on how releases are made. They tend to curtail releases that are not followed by some productive use downstream, although this latitude is sometimes constrained by priorities for power generation, especially in countries such as Sri Lanka where hydroelectricity still accounts for about 70 percent of the installed capacity. Responsiveness to rainfall is also an issue for dam management, but it generally requires a degree of automation and efficient management of information systems.

Response of governments, multilateral lending agencies, and academicians

As noted previously there has been a sharp decline in the construction of large dams and reservoirs particularly for the purpose of irrigation. In some areas such as China or Thailand trans-basin diversion is either underway or being planned. But the primary focus of governments and donor agencies today is on conservation while the mechanism for appropriate allocation is emerging as an important issue.

The interest of government and multilateral lending agency in interventions to improve irrigation systems performance continues, although the potential effect of these interventions on water productivity is seldom mentioned and even less frequently measured. The following are the list of activities undertaken by agencies to save or conserve water. These include: 1) development of water saving technologies and management practices; 2) canal lining; 3) water pricing and water markets; 4) cost recovery; and 5) participatory irrigation management (PIM) or irrigation management transfer (IMT).

Water saving technologies and management practices. Development of water saving technologies and management practices offer potential for increasing water productivity. A distinction can be made between those measures that increase water productivity by increasing crop yield for a given ET or diversion as opposed to those that reduce the water diversion requirements. In the former case (e.g. growing rice by alternative wetting and drying of paddy fields), savings at the plant and field level are realized at the system and basin level. Over the past three decades varietal improvement through plant breeding (aided by investments in irrigation and advances in fertilizer technology) has been the major source of increase in water productivity. In the latter case, whether increased water productivity at plant and field level translates into increased productivity at system and basin level needs to be determined by water balance studies (Molden *et al.* 2003, Barker *et al.* 2001). This is referred to as "scaling-up" from farm to system and basin level. Given the fact that rice is the largest consumer of irrigation water, today there is rapidly expanding interest in management practices and technologies that can save water and increase water productivity in rice-based irrigation systems. These include practices such as zero tillage, dry seeding, flush irrigation, raised beds, alternate wetting and drying, aerobic rice, and system of rice intensification (SRI). Field trials are being conducted in countries throughout Asia through collaborative research between national and international centers. However, the potential impact of this research on gains in water productivity is as yet unknown.

Canal lining. Canal lining is extremely popular with both lending agencies and recipient governments. They provide the lenders with an opportunity to meet disbursement targets and irrigation agencies with the opportunity for rent-seeking or "skimming" profits (Repetto 1986). A few years ago IWMI was asked to review a Project Completion Report of a number of World Bank investments in one of the world's major irrigating countries (Perry 1999). The loan was largely aimed at improving the "efficiency" of the irrigation system by lining, better control structures, improved management and so on. The investment costs totaled $500 million and none of the associated documents (appraisal reports and evaluations) included any form of water balance. The reduction in percolation and seepage loss may have been at the expense of farmers depending on groundwater. Thus, we do not know how much, if any, real water was saved by these investments, or whether water productivity was increased. It is safe to assume that neither the donor agency nor the recipient bureaucracy was interested in knowing.

Water pricing and water markets. Water pricing and water markets have been an important focus for economists. In a market economy, prices should perform the task of allocating resources among competing uses. But when it comes to water, particularly water for irrigation, there are problems with this approach (Sampath 1992, Perry *et al*. 1997, Perry 2001, Tsur and Dinar 1997, Smith *et al.* 1997, Morris 1996, Molle 2001). The authors emphasize the fact that water (particularly water used in irrigation) is a complicated natural, economic, and political resource. Moreover, while water supplied is a proper measure of service in domestic and industrial uses, much of the water supplied to a group of producers may be "lost" as runoff or seepage only to be consumed by others through recycling and this is particularly difficult to measure. Water pricing methods might also have an effect on cropping patterns (Tsur and Dinar 1997) but this is little observed in developing countries. In fact, particularly with today's low commodity prices, the politically acceptable level of charging for water is in general well below the point at which farmers would respond by saving water (Ray 2002; de Fraiture and Perry 2002; Molle 2002).

More importantly, common wisdom that water is wasted because it is not adequately priced is a widespread fallacy. This causal link may be valid for tap-water and for systems where users have no constraint on the amount of water they may use, but not for water-short situations, where supply remains much under demand. In such cases, the value of water is already manifested by its very lack and users have been pushed to adjust to the situation. If the objective is allocation in response to scarcity, rationing (i.e., assigning water to specific uses either within system or at basin level) represents an alternative mechanism for coping with water shortages where demand exceeds supply (Perry 2001). Rationing also makes scarcity manifests and elicits adjustments in water use more efficiently than pricing would do.

Water markets are an appealing option for an economically efficient allocation of water (Thobani 1997). They do occur spontaneously at the micro scale, where users may swap, borrow, and buy water allotments to better fit their needs. Likewise, groundwater markets in India, although they refer to the payment for a service (extracting water with mechanical means) rather than to the allocation of a scarce resource, provide flexible and price-sensitive water supply mechanisms. This flexibility, however, is much harder to obtain at a larger scale. There, the allocation of water through markets is constrained, among other things, by the difficulty to control flows volumetrically and temporally, by the lack of infrastructure to move water from one point to the other, by the lack of definition of water rights, and by the greater probability of having a higher heterogeneity of users and, therefore, possible adverse impacts on poorer segments of the society. It is recognized that water markets are prone to market failures and externalities (Smith *et al.* 1997, Perry *et al.* 1997, Meinzen-Dick and Rosegrant 1997) and demand a background of legal consistency, administrative accountability and law enforcement that are rarely found in developing countries (Sampath 1992), where, on the contrary, "the social and environmental risks of getting it wrong are considerable" (Morris 1996). Water markets in most of Asia have therefore little short-term potential to help managing water and, rather, remain a long-term objective that comes with mature economies and institutions.

Cost recovery. Cost recovery is often listed in the strategy papers of multilateral donors and in the covenants of irrigation projects often without a clear definition. It is clear that a major portion of the benefits of irrigation have not gone to farmer users but to the nonfarm sector (Bell *et al.* 1982, Hazell *et al.* 1991, Bhattarai *et al.* 2003). This includes in particular low income consumers who benefited from the decline in cereal grain prices and those who have benefited from expanded opportunities flowing from investments in irrigation (the so-called multiplier effects). Thus, there may be some doubt as to who should pay for infrastructure investments. The general situation, including in developed countries, is that very little, if any of the capital investment in irrigation infrastructure is paid back by users.

There is wider general agreement, however, that farmer-users should pay for irrigation services and cover operation and maintenance (O&M) costs, based on two principal considerations. First, O&M cost recovery is deemed critical for the supply of goods and services at a time when developing country governments face severe financial restrictions. Second, O&M cost recovery is needed to ensure the sustainability of schemes, and avoid the frustrating cycle of project rehabilitations which development banks often get caught up in. However, water fee collection is very seldom associated to a mechanism whereby the money raised is directly reallocated to the covering of O&M costs, ideally under the control of the users themselves. Therefore, incentives are lacking, no clear link is established between payment and performance, and defaulting is generally high. Even when the fees do not go to government coffers but are used to pay water supply agencies or communal facilities, the lack of transparency and accountability of the irrigation bureaucracies militates against this "virtuous" linkage (Small and Carruthers 1991).

One option is greater farmer participation in O&M of public irrigation schemes, which as noted in the following section, has had mixed success. An increasing number of farmers who own pumps and/or wells are even less interested in joining irrigation associations. Another option is to facilitate private sector provision of goods and services, not only for irrigation O&M but for other agricultural services as well. All these options are tantamount to a redistribution of power and responsibility away from the administration. As a result, irrigation administrations pay lip-service to the reforms without granting strong commitment.

Indeed, the World Bank, by far the most constant and insistent advocate of cost recovery for decades, observes that there is no evidence of better cost recovery or of covenant compliance (World Bank 2003). Part of the problem seems to lie in the policies of the multilateral lending agencies themselves. On the one hand, it is often claimed that countries know that when irrigation systems deteriorate, funds will almost certainly be available from the lenders for rehabilitation. On the other hand, the incentives to lend money, combined with the converging interest of local politicians, government administrations, and consultants to see new projects, are not conducive to establishing stricter mechanisms of project scrutiny and accountability (Renwick and Molle, forthcoming).

PIM/IMT. In the area of institutional reform, the devolution of management and financial responsibility from irrigation systems managers to local user groups has gained prominence. The popular terms for this are participatory irrigation management (PIM), and irrigation management transfer (IMT). These terms are defined as follows (Groenfeldt and Svendsen 2000):

- PIM usually refers to the level, mode, and intensity of user group participation that would increase farmer responsibility in the management process.
- IMT is a more specialized term that refers to the process of shifting basic irrigation management functions from a public agency or state government to a local or private sector entity.

As observed earlier, a great deal of Asian irrigation was developed through communal or locally managed systems that evidenced a high degree of what we might refer to today as PIM (Coward 1980). In many Asian countries irrigation has developed in a structurally dualistic mode, with the more recent state run systems being developed independently from the community managed systems. In the rush to construct large public systems, donors and national agencies have often ignored the presence in the command areas or neighboring regions of well functioning communal systems and the associated rich local experience in management.

The first major effort to introduce PIM in the management of public irrigation systems in Asia began in the Philippines in the late 1970s. Dissatisfied with the performance of the National Irrigation Administration (NIA), the enlightened leadership of NIA sought to transform the bureaucracy (Korten and Siy 1988). Taking note of the successful operation of community systems, they argued that PIM would result in better operation and maintenance and improved performance. The program lasted for a period of more than a decade, and was supported by the Ford Foundation, USAID, and the World Bank. The objective was to transfer full responsibility for maintenance of tertiary canals, fee collection, and management responsibility to water user groups gradually and step-wise over a period of time. The transformation appeared to be on stream in the mid-1980s but collapsed apparently due to change in leadership in NIA and the lack of political support.

Despite this failure, programs designed to transfer responsibility to user groups grew in the 1990s. This interest rests in large part on the desire of many governments to reduce expenditures in irrigation. IMT has become one of the cornerstones of World Bank water management policy (Groenfeldt and Svendsen 2000). Recent experience in IMT seems to suggest that there has been considerably more success in transferring management responsibilities in more advanced countries such as Turkey and Mexico than in the developing countries of Asia (Samad 2001). Where implementation has been successful, government expenditures and number of agency staff have declined, maintenance has in some cases improved, but there is little evidence yet that IMT has led to an increase in the productivity of irrigation water (Samad 2001, Murray-Rust and Svendsen 2002).

In summary, what the above discussion reveals is that most of the public investments in irrigation and related research activities focused on improving the performance of canal irrigation systems have had very limited success. There are situations where canal lining, volumetric pricing of water, or devolution of management to local users are appropriate. But in most developing countries these situations are limited. To a large degree, by focusing strictly on improving the performance of surface irrigation systems "the generals are fighting the last war" ignoring the impacts on irrigated agriculture of farmer response to water scarcity, private investments in pumps and tube wells, declining food grain prices, growth in environmental problems, and the transformation of the rural economy. Meanwhile, the focus is gradually shifting from the irrigation system to the river basin and from irrigation per se to an often loosely defined integrated water resource management. All of this suggests the need to redefine the role of the state and local actors.

Redefining institutions and the role of state and local actors

In one sense, the problems we face are old problems. Perry (2003) states that the solution to successful water management "is not a mystery awaiting discovery." Successful water management, and sustainable and productive use of water for mankind, has been practiced in many countries for centuries. The essential elements of successful management are:

- Clear and publicly available knowledge of resource availability in time, space, and statistical reliability (hydrology, geohydrology);
- Policies governing water resource development and assigning priorities among users for the developed water (politics);
- Translation of the policies into allocation rules and procedures such that water services to each user/sector are clear for any hydrological circumstances (laws);
- Defined roles and responsibilities for provision of all aspects of the specified water service (institutions); and
- Infrastructure to deliver the specific service to each user (hardware).

These essential elements are found wherever water management is effective and absent in whole or in part where water management is ineffective, as manifested by disputes over entitlements, chaotic supply schedules, over-exploitation of resources, pollution, and deterioration of infrastructure.

Perry's criteria provide a useful framework but reading it as a checklist provides no hint on the way to get there. Many of the problems of the present are unlike any we have faced in the past and will call for redefinition and revision within this framework. The growing scarcity of water has been accompanied by a decline in profitability of cereal grain production, national budget constraints, technological advances in irrigated agriculture, and major changes in the rural economy. Resources once plentiful – not only water, but land and labor – are becoming scarce. In short, the objective of sustained food security and environmental protection must be achieved in a very different biophysical and socioeconomic environment.

The very nature of each of the five categories defined by the above remains unchanged but the problems have become more complex. For example, in hydrology there is an urgent need in rice-based copping systems to consider the conjunctive management of surface and groundwater. This in turn has implications for development of appropriate policies, laws, and institutions. We must define water rights, set priorities, and enforce regulations at the sector as well as the local water user level. All of this affects the concerns and relationship among stakeholders in the management of water resources.

The main challenge of water management in the coming years is to make compatible, if not harmonious, two opposite and, at first sight, contradictory trends. The first trend is a centralizing or centripetal one, whereby the logic of integrated management at the river basin level calls for the development of regulatory bodies operating at that level. These organizations need the involvement of the state in order to define/regulate allocation and water rights/permits, as well as to enforce them and to offer mechanisms for litigation. This involvement may have different forms and intensity in different contexts. A major risk is that of line agencies and bureaucracies attempting to capture these changes to further their role and power without being forced to reconsider them. River Basin Organizations may therefore end up being considered as new supra-administrative structures and be dominated by bureaucratic thinking and top-down initiatives.

The second trend is a *decentralizing* or *centrifugal* one. It embodies the principle of subsidiarity, whereby management is done at the lowest relevant level in order to optimize the 'fit' between resources and their users. This decentralization trend is underlain by three main processes. The first one is the enduring populist call for community-based management and turnover of management to users, based on the claim that local knowledge must be tapped to ensure sustainable use of natural resources. The second one borrows from an anti-state stance, which favors privatization and see users as independent entrepreneurs who must have control over their input and/or pay them to their real value, as reflected by their market price. This ideological stance is often put forward to obscure the more mundane evidence that it is driven by state financial difficulties and the inability to cope with growing O&M costs. The third process is a more general trend towards democratization, with a growing importance of the civil society (for example, environmentalist NGOs) and decentralization of revenue generation and expenditure (Siamwalla and Roche 2001). Such a political process is, of course, not deprived of ambiguity and combines the emergence of genuine local democracy with the capture of these new parcels of power by particular vested interests.

It can be argued that many of the current concerns within the water sector such as sustainability, efficiency in management, cost-recovery or 'cost-sharing', water rights and integrated river basin management will continue being poorly addressed by top-down interventions mediated by the state and pushed by external development banks or agencies. Rather, the success in addressing these issues will reside in the adequate evolution of the respective roles of states, markets, and communities or the civil society. Following Ostrom (1990), it must be recognized that:

> "...any single, comprehensive set of formal laws intended to govern large expanse of territory and diverse ecological niches is bound to fail in many of the habitats where it is supposed to be applied. Such a match between institutions and physical, biological, and cultural environments can only be achieved when the people concerned are able to be fully involved in the process of institution building."

The focal point in institutional reform must be the definition and security of water entitlements, or 'rights'. Water allocation and access among users and uses at the system as well, as at the farm and village level, must be negotiated, made transparent, and enforced technically and legally. Reference is often made to the strictly defined and enforced system of water rights in developed countries such as the United States (Perry *et al.* 1997) but the Asian context of numerous small holders and the predominance of rice cultivation make it difficult to envisage the definition of individual rights. Even considering the more simple option of the definition of bulk entitlements (such as in Turkey or Mexico), the establishment of water rights has multifaceted implications (see Molle, forthcoming). As stressed by Perry (2003), this has many far-reaching prerequisites. In short, the task revolves around the redefinition of the role of state and local actors in the management of water resources, so that no right is impaired and that the trade-off between efficiency and equity is addressed in a transparent and negotiated way.

CONCLUSIONS

In this Bulletin, we have traced the evolution of irrigation focusing on South and Southeast Asia and identifying three separate geopolitical time periods: the colonial era from 1850 to 1940, the cold war era from 1950 to 1989, and the new era of globalization from 1990 onward. We have said very little about East Asian experience in part because it does not fit well into our geopolitical framework. It is worth noting, however, that there appears to have been a better balance in the development of institutional and physical infrastructure, with local autonomy and accountability resulting in generally better operation and maintenance than found in the South and Southeast Asian systems. While there are lessons to be learned from the East Asian experience, there are major questions as to whether the experience is transferable.

The development of irrigation, whether by colonial administrations or more recently national governments and lending agencies, has been pursued with a fairly common set of goals, with the emphasis varying between social objectives – poverty alleviation, food security, protection of the environment and economic objectives – increased tax revenues, growth in value of agricultural output. The theme of conflict also runs through the entire time period: conflict in the goals of equity and productivity; conflict among professionals as to whether to design for protective or productive, supply or demand drive irrigation, conflict between irrigation bureaucracies and local administrations in the management of systems. Throughout the entire period, however, farmers have had very little say in the design and management of public irrigation systems.

Against this background, the rapid development of irrigated agriculture has helped to foster extraordinary growth and changed the rural economies of Asia. The development of irrigated agriculture and of the economies as a whole reflects the dynamic interaction between resources, technology, institutions, and culture. Land and water, once abundant, have become scarce. During the cold war period, surface and groundwater technologies have been developed to facilitate the expansion of irrigated area and increase in crop yields. But the success of these endeavors has brought new problems. The intensification of irrigated agriculture has led to an increase in pollution and environmental degradation. Food grain prices have plummeted with the result that the benefits of irrigation have gone largely to consumers. Farm households have looked to other sources of income from both farm and nonfarm sources. The rural economies are undergoing a social as well as an economic transformation.

As we enter an era of globalization, farmers and systems operators have adjusted to the challenges posed by growing water scarcity, exploiting ground water, recycling from drains and canals, changing cropping patterns, and adjusting the timing of water releases. Tubewells and pumps have become commonplace giving producers greater flexibility in obtaining water when needed. But particularly in the semiarid regions, overexploitation of groundwater has affected both the quantity and quality of water.

However, irrigation bureaucracies and donors continue to focus on improving the performance of canal irrigation systems by lining canals, encouraging greater farmer participation, calling for water pricing, cost recovery, and irrigation management transfer. We argue that these efforts have not been very successful in the past and are likely to be even less so in the future given not only the growing importance of groundwater and the hydrological nature of closing basins, but also the social and economic changes occurring in the rural communities of Asia. Reforms have failed because they have remained partial, with optimistic assumptions about the willingness or capacity of local bureaucracies to carry out the necessary changes.

There has been a serious lag in the implementation of appropriate institutions to deal with the new environment of water scarcity. The challenge ahead lies in reforming existing institutions or in some cases creating new institutions that can: 1) allocate water equitably among competing uses and users, including environmental services; 2) integrate management of irrigation at farm, system, and basin level to reduce upstream-downstream and head-tail conflicts; 3) integrate the management of ground and surface water irrigation; and 4) address the problems of irrigation development, including use of waste water, on environment and health.

The allocation and access to water among users and uses at the basin, system, village, and farm level must be defined through a formalized process whereby economic and cultural values of water are made explicit and water sharing negotiated. The task is monumental. It is likely to take years, perhaps even decades, to establish enforceable water rights and the complementary set of institutions.

REFERENCES

Adas, M. 1974. The Burma delta: economic development and social change on an Asian rice frontier, 1852-1941. The University of Wisconsin Press.

Barker, R., R. Loeve, Y.H. Li and T.P. Tuong (eds.). 2001. Water-saving irrigation for rice: Proceedings of an International Workshop held in Wuhan, China, 23-25 March 2002. Colombo, Sri Lanka: International Water Management Institute.

Bell, C., P. Hazell and R. Slade. 1982. Project Evaluation in Regional Perspective. A study of an Irrigation Project in Northwest Malaysia. The World Bank and The John Hopkins University press. Baltimore and London.

Chambers, R. 1988. Managing canal irrigation. Practical analysis from South Asia. Oxford & IBH Publishing Co. Pvt. Ltd, New Delhi.

Coward, E.W., Jr. 1980. Irrigation development: Institutional and organizational issues. Irrigation and Agricultural Development in Asia. USA: Cornell University.

De Fraiture, C. and C. Perry. 2002. Why is irrigation water demand inelastic at low price ranges? Paper presented at the workshop "Irrigation water policies: macro and micro considerations," Agadir, Morocco, 15-17 June 2002.

Dhawan, B.D. and K.J. Sai. 1990. Economic Linkages among Irrigation Sources: A Study of the Beneficial Role of Canal Seepage. In Future Directions for Indian Irrigation. R. Meinzen-Dick, and M. Svendsen, IFPRI, Washington D.C. ch. 10: 124-133.

Estudillo, J.P. and K. Otsuka. 1989. Green revolution, human capital and off-farm employment: changing sources of income among farm households in Central Luzon, 1966-1994. Economic Development and Cultural Change 47(3).

Frederiksen, H. 1992. 'Drought planning and water efficiency.' World Bank Technical Paper # 185. World Bank, Washington DC.

Geertz, C. 1980. Organization of the Balinese Subak, in: Coward, E.W., Jr. (ed.): Irrigation and agricultural development in Asia. Perspectives from the Social Science. Ithaca/N.Y./USA: Cornell University Press, pp. 70-90.

Goldsmith, E. 1998. Learning to leave with nature: the lessons of traditional irrigation. The Ecologist 28(3).

Groenfeldt D. and M. Svendsen. (eds.). 2000. Case studies in participatory irrigation management. Washington, DC, USA: World Bank Institute. Xii, 157 p. (WBI learning resources series).

Hayami, Y. and N. Kikuchi. 2000. A rice village saga: three decades of green revolution in the Philippines. Los Banos (Philippines): International Rice Research Institute.

Hazell, P., C. Ramasamy and V. Rajagopalan. 1991. An Analysis of the Indirect Effects of Agricultural Growth on the Regional Economy. Green Revolution Reconsidered: The Impact of High Yielding Rice Varieties in South India. P. Hazell, and C. Ramasamy, John Hopkins University Press. Ch. 8, pp. 153-180.

Henri, Y. 1930. Economie agricole de l'Indochine, Hanoi, 1932.

Ingram, J.C. 1971. Economic change in Thailand 1850-1970. Kuala Lumpur, London, Singapore: Oxford University Press, 350 p.

Jones, W.I. 1995. The World Bank and irrigation. Washington, D.C., USA: Operations Evaluation Department, the World Bank.

Keller, A. and J. Keller. 1995. Effective efficiency: a water use concept of allocating fresh water resources. Water Resources and Irrigation Division Discussion Paper 22. Arlington, Virginia: Winrock International.

Keller, A., J. Keller and D. Seckler. 1996. Integrated water resources systems: theory and policy implications. Research Report 3. Colombo, Sri Lanka: International Irrigation Management Institute.

Kikuchi, M., P. Weligamage, R. Barker, M. Samad, H. Kono and H.M. Somaratne. 2003. Agro-Well and Pump in Irrigation

Schemes in the Dry Zone of Sri Lanka: Past Trends, Present Status and Future Prospects. Research Report 66. Colombo, Sri Lanka: International Water Management Institute.

Koppel, B. and Zurick, D. 1988. "Rural transformation and the future of agricultural development policy in Asia". Agricultural Administration and Extension, Vol. 28, pp. 283-301.

Korten, F.W. and R.Y. Siy, Jr. 1988. Transforming a bureaucracy - The experience of the Philippine National Irrigation Administration. USA: West Hartford, Conn.

Lewis, H.T. 1971. Ilocano farmers: a comparative study of two Philippine barrios, Honolulu: University of Hawaii Press.

Maurer, J.L. 1990. Irrigation, riziculture et gestion de l'eau en Indonésie: la modernisation des traditions agro-hydrauliques à Java et Bali. Revue de Géographie de Lyon, 65(1), pp. 27-37.

McCully, P. 1996. Silence drivers: the ecology and politics of large dams. London: Zed Books.

Meinzen-Dick, R. and M.W. Rosegrant. 1997. Water as an economic good: incentives, institutions and infrastructure, in Water: Economic, Management and Demand, Melvyn Kay, Tom Franks and Laurence Smith (eds.).

Molden, D., H. Murray Rust, R. Sakthivadivel and I. Makin. 2003. A water productivity framework for understanding and action. In J.W. Kijne, R. Barker and D. Molden (eds). Water productivity in agriculture: limits and opportunities for improvement. Wallingford, UK: CABI Publishing.

Molle, F. and T. Srijantr. 2003. Between concentration and fragmentation: the resilience of the land system in the Chao Phraya Delta. In Thailand's Rice Bowl: Perspectives on Social and Agricultural Change in the Chao Phraya Delta, edited by François Molle and Thippawal Srijantr, Bangkok: White Lotus.

Molle, F. 2001. Water pricing in Thailand: Theory and practice. Research Report No.7, DORAS Project. Bangkok: Kasetsart University. 78 p. http://std.cpc.ku.ac.th/delta/conf/Acrobat/Papers_Eng/pricing.pdf

Molle, F. 2003. Development trajectories of river basins: a preliminary conceptual framework. IWMI Research Paper. Draft.

Morris, J. 1996. Water Policy: economic theory and political reality, in Howsam, P. and R. C. Carter (eds.): Water policy: allocation and management in practice, pp. 228-234

Murray-Rust, H. and M. Svendsen. 2002. Performance of locally managed irrigation in Turkey: Gediz case study. Irrigation and Drainage Systems 15: 373-388.

Ostrom, E. 1992. Crafting institutions for self-governing irrigation systems. Institute for Contemporary Studies, San Francisco.

Ostrom, E. 1994. Neither market nor state: Governance of common-pool resources in the twenty-first century. IFPRI lecture series. Washington D.C.: International Food Policy Research Institute.

Owen, N. 1976. The rice industry of mainland Southeast Asia, 1850-1914. Siam Society, Bangkok.

Perry, C.J. 1999. The IWMI water resources paradigm: Definitions and implications. Agricultural Water Management. 40,1: 45-50.

Perry, C.J., M. Rock and D. Seckler. 1997. Water as an economic good: a solution, or a problem? Research Report 14, IWMI, Colombo, 17 p.

Perry, C. 2001. Water at any price? Issues and options in charging for irrigation water. Irrigation and Drainage 50:1-7. UK: John Wiley & Sons Ltd.

Preston, D.A. 1989. 'Too busy to farm: under-utilisation of farm land in central Java, Journal of Development Studies 26,1: 43-57.

Ray, I. 2002. Farm-level incentives for irrigation efficiency: some lessons from an Indian canal. Draft.

Repetto, R. 1986. Skimming the water: rent seeking and the performance of public irrigation systems. Research Report 4, World Resource Institute, Washington DC, p. 47.

Rigg, J. 2001. More than the soil: rural change in Southeast Asia. Prentice Hall.

Samad, M. 2001. Impact of irrigation management transfer on the performance of irrigation systems: A review of selected Asian experiences. Paper presented at the ACIAR Water Policy Workshop, 8-9 June 2001, Bangkok, Thailand.

Sampath, R.K. 1992. Issues in irrigation pricing in developing countries. World

Development, Vol. 20, No. 7, pp. 967-977.

Seckler, D., U. Amarasinghe, D. Molden, R. de Silva and R. Barker. 1998. World water demand and supply, 1990-2025: Scenarios and issues. Research Report 19. Colombo, Sri Lanka: International Water Management Institute.

Seckler, D. 1996. The new era of water resources management: from "dry" to "wet" water savings. Research Report 1. Colombo, Sri Lanka: International Irrigation Management Institute (IIMI).

Siamwalla, A. and F. Roche. 2001. Irrigation management under resource scarcity. In The Evolving Roles of the State, Private, and Local Actors in Rural Asia. Study of Rural Asia, edited by Ammar Siamwalla, Hong Kong: Oxford University Press. pp. 183-212.

Siriluck, S. and H. Detlef Kammeier. 2003. Government policy and farmers' decision making: the agricultural diversification programme for the Chao Phraya River Basin (1993-95) revisited. In Thailand's Rice Bowl: Perspectives on Social and Agricultural Change in the Chao Phraya Delta, edited by François Molle and Thippawal Srijantr, Bangkok: White Lotus.

Siy, R.Y. 1982. Community resource management: Lessons from the Zanjera. Quezon City, Philippines: University of the Philippines Press.

Small, L.E. and I. Carruthers. 1991. Farmer-financed irrigation: the economic of reform. Cambridge University Press, 233 p.

Smith, L.E.D., T. Franks and M. Kay. 1997. Water – An economic good? : Theory and practice. ICID Journal, Vol. 46 No. 2, 1-13 p.

Tan-Kim-Yong, U. 1995. Muang-fai communities are for people: Institutional strength and potential. Bangkok: Chulalongkorn University Social Research Institute, 109 p.

Tang, S.Y. 1992. Institutions and Collective Action: Self-Governance in Irrigation. San Francisco: Institute for Contemporary Studies Press.

The World Commission on Dams. 2000. Dams and development: a new framework for decision-making. Earthscan, London.

Thobani, M. 1997. Formal water markets: why, when and how to introduce tradable water rights, World Bank Research Observer 12(2): pp. 161-179.

Tsur, Y. and A. Dinar. 1997. The relative efficiency and implementation costs of alternative methods of pricing irrigation water. The World Bank Economic Review, Vol. 11, No. 2: 243-62.

World Bank. 2003. Water sector strategy. Washington D.C.: the World Bank

Yoder, R., E.D. Martin, R. Barker and T.S. Steeinhuis. 1987. Variations in irrigation management intensity: Farmer-managed hill irrigation systems in Nepal. Paper prepared at Cornell University for the Water Management Synthesis II Project. WMS Report 67.

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Irrigation management in rice-based cropping systems : issues and challenges in southeast Asia

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