COMPREHENSIVE Assessment of water management in agriculture

Research Report 5

Evolution of Irrigation in South and Southeast Asia

Randolph Barker and François Molle

International Water Management Institute

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Comprehensive Assessment of Water Management in Agriculture

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Summary

In what some may regard as an overly ambitious exercise, we have chosen in this report to present some salient aspects of the evolution of Asian irrigation. Our objective is to identify the major factors that have influenced irrigation development, to focus on the current issues, and to suggest what this implies for the future development of irrigation and for the steps needed to promote this development.

The focus is on South and Southeast Asia. Three time periods are identified: the Colonial Era (1850 to 1945), the Cold War Era (1946 to 1989), and the New Era of Globalization (1990 onward). The objectives of irrigation development set forth by colonial regimes, national governments, and multilateral development agencies in each of these time periods have been rather similar. The focus has been on the often conflicting goals of poverty alleviation and food security on the one hand and profitability and revenue collection on the other. More recently, with the achievement of food security at the national level, the agenda has broadened to include improved livelihoods, poverty alleviation, and environmental protection.

Irrigated agriculture, however, has changed dramatically and has in turn fostered change and economic development in rural communities. Irrigation has evolved in each of these periods through constant interaction among resources, technologies, institutions, and culture. Land and water, once abundant, have become scarce. Surface water and groundwater technologies have been developed to facilitate the expansion and intensification of irrigated agriculture.

But the success of these endeavors has brought new problems. The growth in population that fostered the intensification of irrigated agriculture and widespread use of agricultural chemicals has led to an increase in pollution and environmental degradation. Food grain prices have fallen to half of their levels in the 1960s and 1970s with the result that the benefits of irrigation development have gone largely to consumers. Farm households have looked to other sources of income, both farm and non-farm. Rural economies are undergoing social as well as economic transformation and the rural-urban frontier is becoming blurred.

As we enter an Era of Globalization, farmers and system operators have adjusted to the challenges posed by the growing demand for water by exploiting groundwater, recycling water 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 reduced both the quantity and quality of water.

Faced with budget constraints, governments have been reluctant to provide the resources needed to maintain the huge investment in surface irrigation systems. The numerous programs designed to encourage local farmer organizations to assume a greater financial and management role in operation and maintenance have met with limited success. Yet, with a growing demand for water, the demands on the state for water management, regulation, and planning at basin level is increasing. Thus, there is a trend on the one hand toward devolution and on the other toward centralization. The main challenge in the coming years is to make compatible these opposite and, at first glance, contradictory trends.

There has been a serious lag in the development of appropriate institutions to deal with the new environment of increased demand and competition for water. The challenge ahead lies in creating the institutions that can: (i) allocate water equitably among competing uses and users, (ii) integrate management of irrigation at farm, system, and basin level to reduce upstream-downstream

and head-tail conflicts, (iii) integrate the management of groundwater and surface water irrigation, and (iv) address the problems of the impact of irrigation development, including the use of wastewater, on environment and health.

A central point in institutional reform is to define entitlements or “rights,” in order to determine the allocation and access among users and uses at the basin, system, village, and farm level. This, however, comes with several prerequisites, notably a detailed knowledge of the hydrological cycle and of patterns of water use, which precludes overenthusiasm and fast-track changes. The growing importance of open-access groundwater resources adds greatly to the complexity of the problem. The task is monumental. It is likely to take years, probably even decades, to establish mechanisms for equitable and efficient water sharing, and a complementary set of institutions.

Evolution of Irrigation in South and Southeast Asia

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Introduction

Over 60 percent of the world's irrigated area is in Asia. Approximately two thirds is devoted to cereal grain production, rice and to a lesser extent wheat. The irrigated area has expanded rapidly over the past half century through the construction of canals and storage dams, and the exploitation of groundwater. Now the potential for further expansion has become limited, water has become scarce due to growing demand, and cereal grain prices have declined. Attention has turned to improving water management and control, to increase water productivity, facilitate diversification to higher-valued crops, and adapt to conditions of growing water scarcity.

This report presents a broad overview of irrigation development in South and Southeast Asia, emphasizing the current problems and challenges. The focus is on the interaction between socioeconomic and biophysical factors that have been the determinants of growth and development in selected time periods. We provide a framework for viewing the transition in Asian irrigation. First, we briefly mention the important antecedents of modern day irrigation—the communal irrigation systems and the large hydraulic works—and the lessons to be learned from this historical experience. Then we cover the development of modern Asian irrigation in three different time periods identified in terms of their geopolitical significance: the Colonial Era, the Cold War Era, and the New Era of Globalization. Our Colonial Era extends from 1850 until World War II, a period which saw considerable activity in irrigation development. The Cold War Era extends from the end of World War II to the fall of the Berlin Wall (1989) and encompasses the period of the *green revolution,* which saw the rapid expansion of both surface water and groundwater. In a region seen as threatened by communism and faced with rapid population growth, both national governments and multilateral lending agencies provided funds for irrigation in an effort to achieve food security. The New Era of Globalization begins at a time when water has become scarce due to growing demand, water pollution has been increasing, and yield gains in cereal production in most of Asia have slowed or leveled off. However, profits from cereal grain prices have declined and Asian farm households rely increasingly on income from non-farm sources. Finally, we discuss the challenges ahead—alternative ways to increase water productivity from the perspective of local users and national or global stakeholders, and the need to redefine the role of state and local stakeholders in the management of water resources.

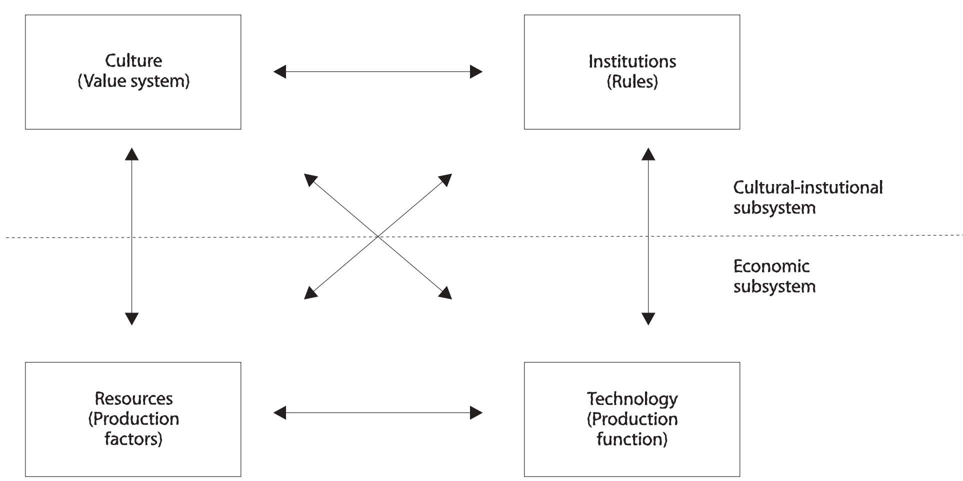
Trends in Irrigation and Periodization

A framework for economic development is presented in figure 1 (Hayami 2001). The development of irrigation fits very well within this framework, which shows a constant interplay between resources (land, labor and water), technologies (dams, tubewells and pumps), institutions and policies (water rights and management) and culture (values and value judgments) as irrigation evolves over time in a community, a basin, a country, or a region. It has been the tradition of neoclassical economics to emphasize the workings of the economic subsystem (figure 1). Combining the economic subsystem with the cultural-institutional subsystem, with greater attention to market failures and government failures, *fits our historical perspective and gives emphasis to the political-economic and geopolitical aspects of irrigation development.*

We examine the evolution of irrigation from a geopolitical perspective in three different time periods or eras: (i) the Colonial Era (1850-1945), (ii) the Cold War Era (1946-1989), and (iii) the New Era of Globalization (1990 onwards). In the first two periods, the desire to achieve food security, maintain political stability and reduce poverty, and the desire to achieve economic gains or profitability from project investment, which at times balanced the former, have been the driving forces for the development of irrigated agriculture in Asia. In fact, this mixture of goals seems to pre-date the Colonial Era. Pringle (1978) with reference to India notes that the state provision of irrigation and other public works was guided by a "mixture of moral and material incentives." More recently, in the Era of Globalization, with food security having been achieved at the national level in most Asian countries, attention has turned to improving livelihoods, poverty alleviation and the protection of the environment.

This mixture of goals has been pervasive not only among the countries of Asia but also among those who could be described as "stakeholders" in Asia. These include the British, the Dutch and the French in South and Southeast Asia, the Japanese in East Asia and, more recently, the Americans in all three regions of Asia. The

FIGURE 1.
Interrelated developments in the social system.



Source: Hayami 2001.

influence of the colonial powers is self-evident. They provided the financial support to develop new irrigation works or restore old systems. Particularly in the Indian subcontinent, famine or the threat of famine was a major factor in government investment decisions.

During the early Cold War years, rapidly expanding population threatened to outrun available food supplies and create political instability in Asia. Support for irrigation development, a major component of the green revolution technology, came both from developed countries and from a new set of stakeholders, the western controlled multilateral lending agencies. Certainly not all the decisions regarding irrigation development in this period could be attributed to Cold War politics (i.e., the containment of communism). In particular, the modernization and development agendas have been taken up by newly independent states as a means to establish their legitimacy and to fend off poverty. Yet, the importance of political objectives, beyond humanitarian ones, is well symbolized by the transfer of Robert McNamara from the US Defense Department, in charge of operations in Vietnam, to the presidency of the World Bank, which he held from 1968 to 1981 (see George and Sabelli 1993). These political and humanitarian objectives resulted in the freeing of massive capital outlays that were partly used for large-scale reservoirs and irrigation systems.

The end of the Cold War coincided with the achievement of food security at a national level (although millions of Asians still lacked an adequate diet). As noted above, there was a shift in focus toward *livelihoods*, *poverty alleviation* and *protection of the environment*. The growing scarcity and competition for water, particularly in the semiarid areas of Asia, poses a threat to food security. Water resource development and management is now high on the agenda of developing countries, and also of organizations from the North, such as the Organization for Economic Cooperation and Development (OECD). With the limited scope for more large-scale reservoir facilities, and the concurrent growth in demand from other sectors, there will be less water for agriculture in this Era of Globalization. Thus, pressure to save water and increase water productivity in agriculture is rising. In this new environment of water scarcity and low food grain prices, stakeholders at national and international level are seeking ways to create legal and institutional structures and promote policies for a more efficient and equitable allocation of water among users and uses. A major characteristic of the Era of Globalization is the diminution of the role of the state in planning, management, and investment and the increasing importance of the private sector, although in different degree according to each country. More decentralization of management, participation, and private investments in groundwater technologies are gradually changing the waterscape of Asia.

Table 1 defines the goals and the characteristics of irrigation development in each of the three eras described above. The first row of the table lists the primary goals of national and international agencies (or colonial powers) in irrigation development. The goals—food security, livelihoods, poverty alleviation and social stability—remained constant across time periods but each of them acquired particular salience in specific periods. The remaining rows reflect the major biophysical, technological, socioeconomic, and institutional features characterizing irrigation development in each time period. Looking across columns, it appears that each period is marked by differences in characteristics such as resource constraints, technological advance, and defining events such as famine or drought. For example, the opening of the Suez Canal, which revolutionized transportation and spurred markets (notably in rice), provided support for massive investments in infrastructure. As in figure 1, the view is that change in irrigated agriculture is the result of a dialectical interaction among economic and non-economic forces.

TABLE 1.
Evolution of publicly managed irrigation in South and Southeast Asia.

Issues	Colonial Era (1850 to 1940)	Cold War Era (1950 to 1990)	New Era of Globalization (1990 onward)
Primary goals of national and international agencies (or colonial powers)	Famine protection Revenue Exports	Food security Control of the spread of communism	Livelihoods Protection of environment Global markets Exports
Defining events	Famines Suez Canal (1869)	Droughts (1965; 1972/73) Population growth	Grain price decline Global warming
Resource availability	Land/labor plentiful	Land becoming scarce	Water and labor becoming scarce
Hydro-economic stages	Construction	Construction/utilization	Utilization/allocation
Professional orientation of development	Civil engineers	Agricultural Engineers	Multi-disciplinary
Dominant irrigation development	River diversion Flood control Canalling of deltas	Storage dams Gravity irrigation	Pumps and wells
System design	Protect/supplement	Supply driven	Demand driven
System management	Hydraulic	Agriculture-based	Farmer-oriented
Crops	Cereals/cotton	Cereals/cotton	Diversified
Cropping intensity	One crop	Two crops	Multiple cropping
Factors affecting livelihoods	Subsistence farming Colonial surplus extraction	Increasing mobility and economic diversification	High economic diversification
Value of water	Low	Increasing	High
Environmental degradation	Low	Increasing	High

In the sections that follow, we build upon this framework to describe the development of irrigation in Asia in each time period. It is important to emphasize that we are painting with a very broad brush. There have been marked differences in the pace of development of irrigated agriculture within Asia. Some events overlap between time periods and many areas do not fit the time frame. For example, there are similarities and important differences in the East Asian experience, where population pressures dictated an earlier development of irrigation. Many analysts have been critical of the inefficiencies of the government-managed irrigation systems in contemporary South and Southeast Asia, contrasting them with the higher efficiencies of the East Asian systems (Barker and Herdt 1985; Moore 1989). It is surprising that most of the Japanese analysts up to the early postwar period reached a strong negative evaluation of the Japanese systems (Kelly 1980). It was argued that rigid irrigation customs prevented rational operation and maintenance and efficient allocation of water. Shinizawa (1955) provided a strong rebuttal to this pessimistic view arguing that irrigation problems can be traced, not to a particular political and cultural background, but to a fundamental conflict between upstream and downstream users, which can be resolved by investments in physical improvements. In fact, the East Asian irrigation infrastructures (e.g., the multiplicity of farm ponds

TABLE 2.
Growth in irrigated area in Asian countries, 1961-1990.

Country	Irrigated area, 1998 ('000 ha)	Increase in total irrigated area, 1962-1998 ('000 ha)	Irrigated area in 1998 as a % of that in 1962	Average annual growth, 1962-98 (%)	Irrigated area as a % of harvested area, 1998
India	58,333	33,255	233	3.7	28
Pakistan	17,843	6,915	163	1.8	75
Bangladesh	3,841	3,369	814	19.8	28
Nepal	1,135	1,062	1,555	40.2	22
Sri Lanka	638	277	177	2.1	39
Bhutan	40	31	429	9.1	19
South Asia	*81,830*	*44,909*	*222*	*3.4*	*33*
Thailand	4,836	3,131	284	5.1	30
Indonesia	4,815	915	123	0.7	16
Vietnam	2,767	1,767	277	4.9	25
Myanmar	1,663	1,042	268	4.7	15
Philippines	1,550	850	221	3.4	11
Malaysia	357	126	155	1.5	9
Cambodia	270	206	422	8.9	12
Laos	167	154	1,285	34.8	19
South East Asia	*16,424*	*8,191*	*199*	*2.8*	*18*
China	52,714	21,736	170	1.9	28
Japan	2,680	-261	91	-0.2	82
North Korea	1,460	960	292	5.3	42
South Korea	1,160	0	100	0.0	54
Asia (all)	189,971	92,609	195	2.6	30

Data Source: Food and Agriculture Organization of the United Nations (FAO).
Notes: Calculations are based on 3-year averages centered on the year shown.
Total harvested area is the sum of areas of cereals, coarse grains, pulses, oil crops, fiber crops, fruits, tree nuts, roots and tubers, and vegetables.

or *melons on the vine* in South China, or the rotation irrigation systems in Taiwan) has a level of reticulation not found in South and Southeast Asia. This allows water to be delivered to farmers on demand (Moore 1989). However, institutions have been equally important. Lam (1996) illustrates how Taiwan's Irrigation Associations accommodated central authority but operated with local autonomy and accountability, leading to local financial support for the successful management of their irrigation systems.

Advances in irrigation in China, many occurring centuries ago, were not influenced by colonial programs. In Japan and her colonies, Korea and Taiwan, the development of irrigated agriculture, in conjunction with varietal improvement, use of chemical fertilizers and mechanization prior to World War II, helped to establish the direction of change in South and Southeast Asia after World War II (Ishikawa 1967).

Our analysis focuses on the evolution of irrigation in South Asia and Southeast Asia. In these two regions, the irrigated area has doubled over the last four decades of the 20th century (table 2). While historically surface irrigation has been dominant, more recently groundwater exploitation has been increasing rapidly. In many areas, the hydrological link between surface water and groundwater (surface systems being an important source of groundwater recharge) in the management of water resources is assuming greater significance (Chambers 1988; Dhawan and Sai 1990).

Before describing irrigation development in each of the three eras, we discuss briefly irrigation in Asia in the pre-colonial period. It is often suggested that we should follow the examples set by these societies of antiquity. As one considers the challenges of modern day irrigation, particularly the struggle to develop viable irrigation institutions and organizations, there are indeed lessons to be learned even from the very distant past.

We close this section by emphasizing that what we attempt here is not a detailed study of geo-politics governing irrigation development in each time period but rather a broad overview of what we regard as the major factors that have contributed to change. We recognize that there are major differences among countries and across regions that have influenced the path of irrigation development. But we also observe common threads influencing the direction of change, including the drive for food security, growing demand for water for nonagricultural uses, technological advances in surface irrigation systems and groundwater extraction, institutional changes in system management, and a number of other factors. Our objective in this paper is to identify the major factors that have influenced irrigation development, to focus on the current issues, and to suggest what this implies for future development of irrigation and for the steps needed to promote this development.

Antecedents

Community irrigation systems and large hydraulic works—why were they successful, why did they fail?

We recall here community irrigation systems and large hydraulic works managed by despotic states in what Wittfogel (1957) describes as *hydraulic societies*. These systems sustained growing populations over a considerable period of time, often centuries. They mirror two polarized modes of irrigation development, one endogenous and centered on community management, the other organized and implemented by powerful states.

Community Irrigation Systems

Community irrigation systems have been pervasive in Asia and even today serve a significant portion 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 or medium streams, especially in the Himalayas, northern Thailand, Laos, Vietnam, China, Japan, the Philippines and Indonesia, or on the construction of small tanks such as found in India and Sri Lanka. The need for community cooperation, and its successful realization, are most evident in areas of intense population pressure or limited water supplies, or both, where the organization of community labor and management is essential 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 Illocos 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, suggesting that the new context was not providing adequate incentives to collective action. He concludes that the behavior of Illocanos 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. Leach (1961) describes the *bethma* system in Sri Lanka that enables all farmers in a given tank command to share the limited water supply during the dry season irrespective of the location of their paddy fields. Geertz (1980) and Lansing (1991), writing about the Balinese *Subak,* describe 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[1] 1995; Goldsmith 1998). These systems are now exposed to new threats, as communities have become open to the world, agriculture has moved from subsistence to commercialization, villagers have diversified their economic activities, the cost of maintaining systems has risen, and competition for water is on the rise. Increased socioeconomic heterogeneity as well as the intervention of the state in the construction or maintenance of weirs has often weakened social cohesion and collective action.

In addition, deforestation, afforestation, or changes in land use in the upper part of catchments have often altered the hydrological regime and water quality, impacting on downstream users (Starkloff 1998; but for the controversy on this issue, see Forsyth 2002 and Walker 2003). Traditional rights to water and longstanding 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 upon 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,

[1]"People's Irrigation System (PIS) [in northern Thailand] can be viewed as an integrated system consisting of an intricate intertwining of local village technology with human commitment of cooperation, and a supportive philosophy which lends this system its coherence and cohesiveness."

but also the conflict between flexibility and adaptation to microphysical and sociocultural contexts and top-down, capital-intensive, and large-scale macro-strategies of development.

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). However, the threats to the sustainability of communal management (due in part to rising wage rates, off-farm migration, decline of agriculture and changes in the rural economy, technical changes such as low-cost pumps) raise questions on whether this form of management can adapt to changing circumstances and new challenges.

Hydraulic Societies

Wittfogel (1957), one of many scholars to show interest in hydraulic societies, states that he had "long been impressed with the developmental lessons to be learned from the study of agrarian societies based on large-scale and government-directed water works. These societies covered more territory, lasted for more years, and shaped more lives than any other stratified agrarian society." Wittfogel argued that the necessity to muster the labor force necessary for huge flood-control works and irrigation systems was conducive to totalitarian organization. Large waterworks were created for both irrigation and flood control. Irrigation made it possible to acquire food surpluses and release labor for other cultural (or warfare) activities. Among the non-hydraulic installations that grew with large-scale hydraulic installations were defense works, far-flung roads, tombs, temples, and pyramids. Improvements in farming and increase in food supply permitted population growth, the limits of the growth being determined by the limited water supply to a society equipped with pre-industrial techniques (Steward et al. 1955). In some areas, efforts to continue the intensification of irrigated agriculture led to environmental problems such as salinization, siltation and flooding, and disease epidemics such as malaria. Crop productivity stagnated or declined. As the productive limits of irrigation were approached, the hydraulic societies frequently moved into urban centers or conquered new territories in search of new resources for sustainability. But without the constant stream of technologies that characterize modern day agriculture, the limits to growth must eventually have been reached. With today's growing concerns relative to environmental sustainability, it is worth noting that many of the ancient systems collapsed because societies could not manage environmental problems such as salinity, drought, or malaria.

The epitome of the hydraulic society in Asia is China (Wittfogel 1957), although this is also an object of debate (Masubichi *circa* 1970), while northern Vietnam may provide another example. Wittfogel's powerful intuition is undoubtedly insightful when applied to classical states like those of ancient Egypt, Mesopotamia or the Indus valley, and his theory of the state has later been tested in all kinds of climatic (in particular tropical and subtropical) and historical contexts. Critics have been prompt to point out situations where impressive hydraulic works were not necessarily the result of a powerful, centralized, bureaucratic and despotic state (Bali: Lansing 1991; Sri Lanka: Leach 1961), while, on the other hand, there was no shortage of such states associated with modest hydraulic achievements (Wijeyewardene 1971). However, the intensity of the intellectual debate on Asian despotism in the postwar period has sent many researchers in a quest of hydraulic societies in Asia, which has not been always successful or convincing. Some scholars have tried to link irrigation and state formation in Java (see discussion in Christie 1995). Even the paradigmatic case of the Khmer empire and irrigation around Groslier's (1979) "hydraulic city" of Angkor, which has spurred much fascination for ancient hydraulic feats (e.g., Stargardt 1986 and Stargardt 1992 on Burma and southern Thailand), is now increasingly seen to owe much to imagination (Stott 1992; de Bernon 1997).

On balance, it seems that agro-hydraulic kingdoms have supported a high population density. The centralization of the economy was sometimes paralleled by the achievement of large-scale infrastructures (e.g., China, India, and northern Vietnam), but this was not always the case (e.g., Kingdom of Majapahit in Java, in the 14th century; Maurer 1990). A large part of Southeast Asia long remained underpopulated. However, particularly in the more populated areas (e.g., Illocos region in northern Philippines and Java and Bali in Indonesia), autonomous indigenous systems of communal irrigation were the rule.

In sum, these earlier hydraulic developments already outline a dichotomy between large-scale, state-centered irrigation schemes and local communal systems. In both cases, however, the relation between water control and society is at the heart of the social fabric. Regardless of the direction in which causality runs, harnessing water on a large scale has been associated with the formation of many of early powerful states, while water was also a structuring element of community formation where small streams could be diverted or dammed for use in agriculture.

The Colonial Era—1850-1945

Dominant irrigation strategies**:** *Protective irrigation in semiarid regions for famine prevention in years of drought*. *Flood control in the deltas and river diversion schemes in the monsoonal regions for assuring the main harvest and revenue collection.*

Most revenues of colonial powers in Asia were based on agriculture. This included plantations (rubber, tea, coffee, etc.) in rain-fed areas, while irrigation was developed in lowlands in order to provide rice as a staple food for the population as well as for export. Rulers had the twin and often conflicting objectives of producing food in order to control famine, unrest, or revolt and extracting as much surplus as possible.

This dilemma had different expressions in the semiarid regions and in the monsoonal areas. In the semiarid regions, crop production is almost totally dependent on irrigation. Systems were designed and crop production planned on the basis of irrigation water availability often with the objective of maximizing returns to scarce water rather than to land. In the monsoonal areas, however, the farmer 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 rather than additional water supply. In years of low rainfall, supplemental irrigation was needed to protect the main harvest, normally rice. In this section, we discuss irrigation development first in the semiarid regions and then in the monsoonal regions.

Semiarid Irrigation

The semiarid regions consist mainly of what are today northwest India and Pakistan. With the annexation of the Punjab in 1849, the British gained full control over the Indo-Gangetic Plain. They were quick to recognize the enormous potential of the area and initiated the construction of canals. The irrigated area grew rapidly to around 5 million hectares by the turn of the century (Bolding et al. 1995). Increasing the collection of land revenue was the primary objective. However, particularly after severe famines, famine prevention took precedence. This also had considerable influence on both the design and management of irrigation systems.

A dialectical tension existed between the concern for revenue generation or surplus extraction on the one hand, and the necessity to avoid famine and ensure social stability and order on the other. This tension is best illustrated by the debate on productive versus protective irrigation in British India (Stone 1984). Questions such as who was to finance infrastructures (local revenue, the Crown, or private interests), whether and how a water fee should be charged and how it would impact on different categories of people were fiercely debated. The British Government, the Government of India, local government, revenue officers, canal engineers, etc. had often sharply diverging opinions. Return to capital was a central concern. By 1921 "productive works" developed on 7 million hectares had yielded a net revenue of 9 percent against 1 percent for the 0.3 million hectares of "protective works" (Stone 1984), making irrigation a successful venture. Yet, those primarily concerned with social stability, in particular provincial governments, were able to maintain the level of taxation through water charges at a relatively low level.

The trade-off between economic return and food security was also quite apparent in Sri Lanka. Debates centered on whether and how much to invest in irrigation, on the estimation of direct and indirect costs and benefits, and also on the need to sustain the population or drive it out of sheer poverty. These debates were influenced by the particular inclination of each governor and on how he could negotiate his views with London (Keane 1905; Bastiampillai 1967).

The impact of design on management is discussed by Jurriens et al. (1996) and is briefly summarized here. The dominant practice is to design irrigation systems in such a manner that the water supply covers the full crop water requirement either completely by irrigation or in addition to rainfall. Most large-scale systems in the Indo-Gangetic Plain, however, are based on an essentially different objective. The concept of productive versus protective irrigation distinguishes between these two objectives. Protective irrigation systems are based on scarcity by design, spreading the water thinly over a large area, regardless of the degree of scarcity experienced. Jurriens et al. (1996) argue that most of the systems in the Indo-Gangetic Plain even today are *protective*: (i) they do not meet the water requirements of the full command area; (ii) they are supply-based, with continuous flow; (iii) there is a minimum of control structures; and (iv) they tend to maximize returns to scarce water rather than land. The *warabandi* system, practiced in India and Pakistan for more than 125 years, typifies this design-management approach (Bandaragoda 1998). In its original form, the *warabandi* is largely an administered system requiring a minimum of management. However, due to changes in the hydrology, including the development of groundwater, the original objectives can be achieved only through management decisions that reflect the response to changing conditions over time and space.

Monsoonal Irrigation

Irrigation in monsoonal regions of Asia presents different features. In Indonesia, the *sawah* (irrigated paddy fields) that were developed in the 17th and 18th centuries to support the growing population were expanded in the late 19th century by the Dutch to accommodate sugarcane. Huge hydraulic efforts to expand rice cultivation occurred later from 1900 to 1940, the paddy area growing from 1.26 million hectares to 3.4 million hectares (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 ha in 1930 (Henri 1930; Brocheux 1995; Molle and Dao The Tuan 2001). Similarly, in Burma, the reclamation of the Irrawaddy delta gave rise to a spectacular increase in rice area and exports (Adas 1974). In Siam (Thailand) also, despite the absence of formal colonization, the Chao Phraya delta was 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).

The deltas allowed the production of large quantities of rice for local consumption and for export (Owen 1976). The rice market benefited from the opening of the Suez Canal in 1869, which considerably eased transactions between Europe and its Asian colonies. As noted above, much of the expansion took place in deltas, with little or no technical change and without any major hydro-technological works. Canalling also served the crucial purpose of communication and provided places for homesteads. Flood regulation allowed better control of flood-based agriculture. River diversions of both small (Philippines and Java) and large scale (India) accounted for more classical gravity irrigation. In many instances, the intervention of engineers in construction and management of irrigation systems conflicted with local logic they did not understand (see, for example, Farmer 1957 for small tanks in Sri Lanka, and Kamal 2001 for flood management in Bangladesh).

The Colonial Era marks the expansion of the peasant population in Asia, particularly in deltas and other lowland areas. This expansion was underlain by investments as well as taxation of waxing states and was boosted by population growth and a context of gradual integration into the market economy (Elson 1997). The expansion of the peasant population, which started in the mid 19th century, was faltering around 1910 and came to an end in the 1929 global financial crisis.

The Cold War Era—1946-1989

Dominant irrigation strategy: *The expansion of government-managed irrigation systems and public and private groundwater facilities to achieve food security, poverty reduction, and related social objectives (the construction period).*

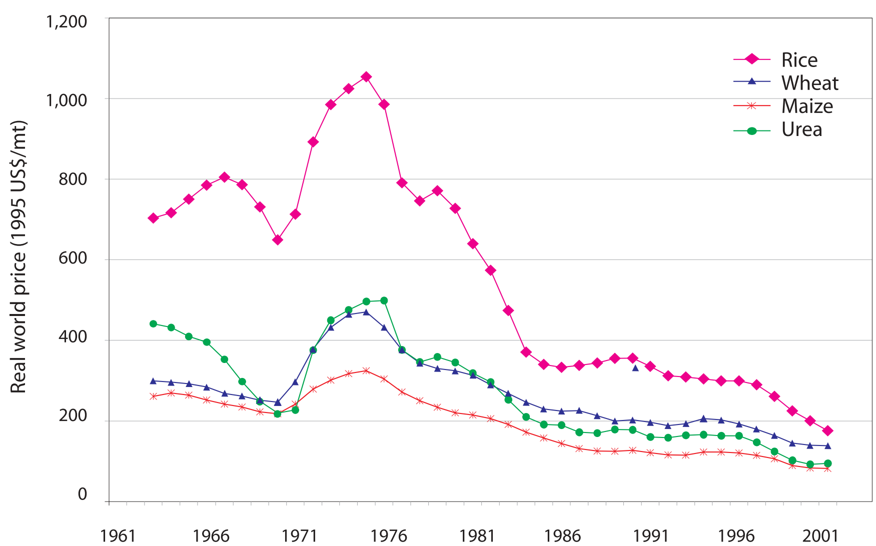
The Cold War Era corresponds to the postindependence period for many Asian countries. Newly independent states were faced with the necessity to provide jobs and food to a growing population. At the same time, the faith in science and technology to bring development, material progress and happiness for the millions, conceived on the model of the development of former colonial states, tended to enhance the legitimacy of the new states. Concurrently, concern grew in the West regarding the population explosion and the 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—increase cereal grain production in Asia. Attention has often focused on success in the development and extension of high-yielding, fertilizer-responsive varieties, the so-called green revolution. However, huge investments by multilateral lending agencies, 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.

The period 1945-1960 might be regarded as a transition period during which many Asian developing countries gained independence. Subsequently, two climatic events that led to shortfalls in annual rains throughout much of the world—the so-called *El Ninos*—served to catalyze the commitment to the food security goal and 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 (figure 2) and forcing Thailand, the world's largest rice exporter, to ban exports for several months in 1973. From the 1960s onward the developed countries and multilateral development agencies led by the World Bank and the Asian Development Bank played a major role in irrigation development.

Expansion of Irrigation

These climatic events, reflecting a threat to food security in Asia, sent a shock wave through the developing countries of Asia and the non-communist Western world. The investment in

FIGURE 2.
Real world prices (1995 US$ per metric ton) for rice, wheat, maize and urea.



Data sources: IWMI 2002. Data updated for 2001-2003 from http://www.worldbank.org/prospects and http://www.bls.gov/cpi/. Real World prices were obtained using US-CPI All Urban Consumers: US, all items. Figures are based on 5-year moving averages.

irrigation rose rapidly and high food grain prices in the 1960s and 1970s seemed to guarantee a high rate of return to this investment. The growth in irrigated area is shown for Asia by country in table 2. More than 60 percent of the world's irrigated area is in Asia. From the early 1960s to the end of the century, the irrigated area doubled.

Table 3 shows the growth in irrigated area by selected country groupings. By the mid-1970s the construction phase had reached a peak (figure 3). After 1985, there was a continued strong growth in irrigated area, particularly in some of the major river-delta countries, Bangladesh, Myanmar, and Vietnam. But there was a significant decline in the rate of growth in Indonesiaa, Malaysia, the Philippines, Thailand and China, and an absolute decline in irrigated area in East Asia.

The expansion in irrigation was facilitated by technological advances. These advances can be divided between (i) those relating to the development of surface water or canal irrigation systems largely through public investment and (ii) those relating to the exploitation of groundwater, initially through public investment, and subsequently largely through private investment.

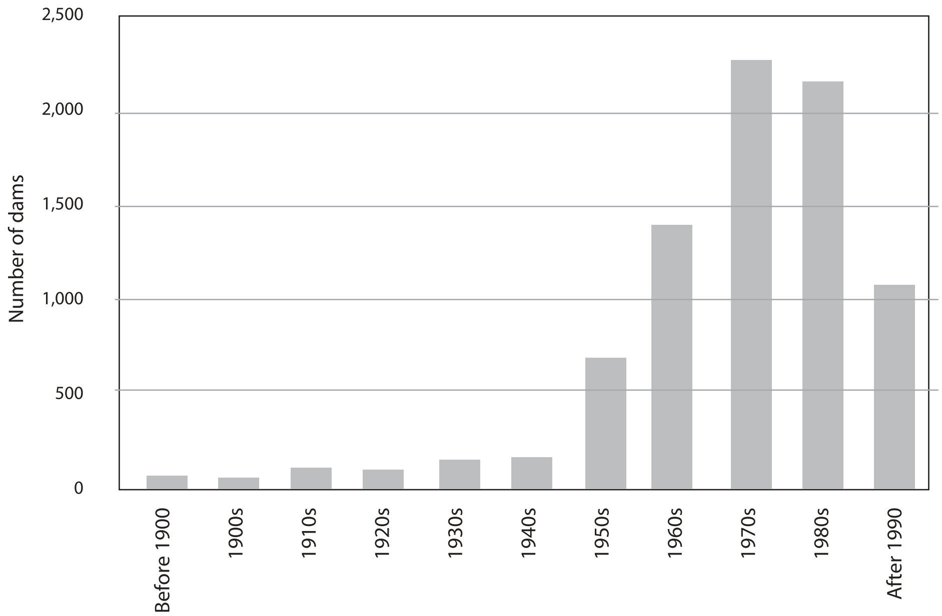
Despite the antiquity of earth dam technology, advances in the technology of large dam and reservoir construction in the western United States before World War II became the foundation for surface irrigation system development in Asia in the post-World War II period (McCully 1996). During the so-called *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 head works, pumps, canals, cross regulators, drainage roads and land leveling than in which the Bank has financed dams. In short, dams make up only a portion, albeit a very significant one, of the cost of irrigation development.

TABLE 3.
Annual growth in irrigated area in Asia and its subregion countries, 1961-1999.

Country or region	Average annual growth (%) in irrigated area		Share of total net irrigated area in Asia (total = 1.0)
	1962-85	1985-98	1998
Asia	2.3	2.0	1.00
SEA I	2.2	1.3	0.07
SEA II	3.7	4.2	0.03
Other South Asia	2.7	1.7	0.15
China	1.9	1.4	0.34
India	2.9	3.0	0.37
East Asia	0.9	-0.3	0.03

Notes: Calculations are based on 3-year averages centered on the years shown.
SEA I = Indonesia, Malaysia, the Philippines and Thailand
SEA II = Cambodia, Laos, Myanmar and Vietnam
Other South Asia = Bangladesh, Nepal, Pakistan and Sri Lanka

FIGURE 3.
Historical evolution of dam construction in Asia.



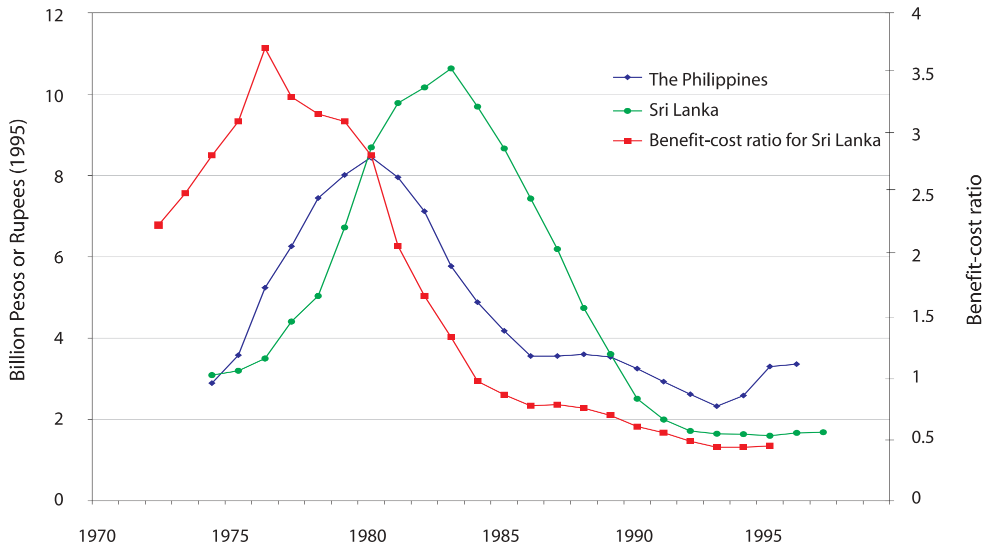
Source: International Commission on Large Dams (ICOLD).

Of the more than 40,000 large dams,[2] all but 5,000 have been built since 1950 (McCully 1996). Figure 3 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. During this period, in many countries, 50 percent or more of the agricultural budget was devoted to irrigation, with only a small fraction of that total for operation and maintenance. During the 1970s and the 1980s, more than half of the World Bank spending for agriculture was for irrigation (World Bank 1991). In the late 1970s and early 1980s, lending for irrigation by the World Bank and the Asian Development Bank reached a peak of over one billion US dollars per year in constant 1980 dollars, but fell to less than half that level by the late 1980s (Rosegrant and Svendsen 1993).

Three factors contributed to the decline in large dam construction. First was the sharp drop in cereal grain prices in the mid-1980s to fifty percent of their previous levels (figure 2). This decline was due to the successful spread of green revolution technology, the expansion of irrigation, and the increase in subsidies for grain production in developed countries. Second was the rise in construction costs that accompanied the decline in grain prices, 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 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. Figure 4 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 completion of dams and new irrigated area lagged approximately a decade behind the mid-

[2]The International Commission on Large Dams defines a "large dam" as one measuring 15 meters or more from foundation to crest.

FIGURE 4.
Trends in and real value of irrigation investments for the Philippines and Sri Lanka and the benefit-cost ratio of irrigation investments for Sri Lanka, 1972-1999.



1970s 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 Dams was created in 1997 to review and report on the positive and negative impacts of large dam construction and establish a framework for decision-making (WCD 2000). By the time of this report the construction phase had tapered off. However, there has been continued public reaction against large projects such as the Narmada in India and the Three Gorges in China. At the same time, there has been far less public concern over equally important but less visible environmental problems associated with groundwater exploitation. The cost of groundwater exploitation has been increasing in areas of deep aquifers and falling water tables. However, the cost has been declining in areas of shallow aquifers. Moreover, water quality issues have been frequently more important than those of water quantity.

As noted earlier, 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 so provide water for irrigation through wells (see also Dhawan and Sai 1990). Dhawan (1993), for example, estimates that half of the crop output originating from tubewell irrigated lands in the Punjab is from groundwater which is mostly of canal origin.

Principally for the reasons cited above, in the semiarid regions of Asia and more recently in monsoonal areas, the expansion of area irrigated by groundwater has tended to follow the very extensive development of canal irrigation. For example, the largest short-term expansion of irrigation in India began in the mid-1970s. From the 1970s to the 1990s the area irrigated by wells increased by 6.2 percent per annum and the area irrigated by canal by 1.5 percent per annum. As a result the area irrigated by groundwater is now approximately 60 percent of the total irrigated area. During this period, the World Bank and the Asian Development Bank provided loans to farmers to construct wells and purchase pumps. In the semiarid regions, overexploitation of groundwater has resulted in falling water tables. In the monsoonal areas, however, particularly in some of the major river deltas, there has been a recent groundswell in wells and pumps, an issue that we will discuss in more detail in the section on globalization.

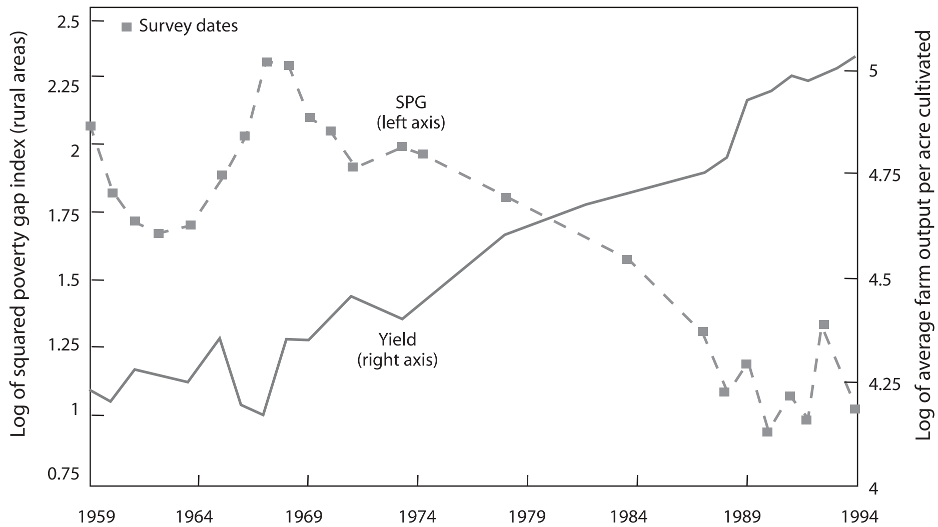
Institutional and Design Constraints

Despite the rapid expansion of food production, there was a general consensus that large public systems in South and Southeast Asia had not lived up to expectations. Two of the more important issues concerned *institutions* and *design* (Barker et al. 1984; Jones 1995; Horst 1998). Public irrigation systems had grown faster than the institutions needed to regulate them. Moreover governments had tried to build irrigation from top down. The norms of cooperative behavior, community organization, and sense of community ownership that accompanied the successful long-enduring communal irrigation systems described earlier had no chance to evolve. On the contrary, bureaucracies with little accountability to farmers and no incentive to improve management were empowered with the mode and timing of water distribution. These were also often responsible for construction works and maintenance. Their power was derived from the significant capital outlays allocated to these tasks. Management was poorly financed and operations were frequently plagued with the ubiquitous head-end and tail-end problems. Degradation of schemes more often than not entailed cycles of rehabilitation.

Outsiders from developed countries brought experience and promoted designs often inappropriate for the developing-country situation; irrigation projects are strewn with destroyed constant-head-orifice gates, and Romijn weirs and the like have never been used as intended. The necessity to arrive at attractive cost-benefit ratios often led to optimistic design assumptions that produced insufficient flows and led users to destroy facilities (Renwick and Molle, Forthcoming). Other design issues were manifested in the debate between the advocates of *crop-based* or *demand-driven* design, and *water-based* or *supply-driven* design (Jones 1995). In the former the amount of irrigation water delivered is tailored to crops farmers choose to grow while in the latter farmers have to tailor their cropping to the timing of irrigation water deliveries. The *demand-driven* advocates argue that the evolution of the world economy points toward the need for this type of solution. The decline in the rice price has placed pressure on systems to provide water when needed to grow crops other than rice. If farmers in adjacent plots are to grow rice and chilies in the same season, neither the traditional, low-reticulation, field-to-field paddy systems nor the water-spreading warabandi type systems will do. On the other hand, *supply-driven* advocates point to the poor performance in practice of crop-based, demand-driven systems, with the exception of the highly reticulated systems found in China and East Asia.

Meanwhile more and more farmers have found ways to obtain water when needed, installing tubewells or pumping and recycling from canals and drains. This conjunctive private sector investment (though largely ignored by those who finance and administer public sector systems) has greatly enhanced the productivity of public sector investment in irrigation and compensated for the lack of flexibility of large-scale schemes. It follows that in many instances, managing water for conjunctive use is potentially less costly and more productive than investing in *demand driven* surface irrigation systems and in the institutional structures required to make these a success.

FIGURE 5.
Squared poverty gap index (SPG) and average farm yield in rural India, 1959-1994.



Source: Datt and Ravallion 1998.
Note: 1 acre = 0.405 hectare.

Poverty Alleviation

The role of irrigation in *poverty alleviation* is a theme that pervades the history of irrigation development. For example, during the Mogul period in India, the Canal Act of Akbar (1568) detailed the Emperor’s desire to “supply the wants of the poor” and to “establish the permanent marks of greatness” of his rule (Baker 1849). This is not dissimilar to the implicit goals of many multilateral lending agencies or governments today.

The association between poverty reduction and irrigation investment is best illustrated in a study by Datt and Ravallion (1998). The study links the reduction in rural poverty and growth in farm productivity in India. Figure 5 compares the downward trend in the squared poverty gap index (SPG) with the upward trend in yield. The SPG is the mean of the square of the distance of individual observations below the poverty line. In contrast to the more frequently used *percent of population below the poverty line*, SPG reflects the *severity of poverty.* Significant poverty reduction in many parts of India is attributed to the availability of irrigation, which not only increased agricultural production but also made possible the adoption of modern farm technology—seeds, fertilizers and pesticides—that further reduced poverty (Lipton and Litchfield 2003). The study by Lipton and Litchfield (2003) on the impact of irrigation on poverty and a recent literature review by Hasnip et al. (2001) on the contribution of irrigation to sustaining rural livelihoods reach very much the same conclusion. The positive impact of irrigation on poverty reduction and enhancing rural livelihoods is felt through increased employment, lower food prices, and more stable outputs. There are also multiplier effects and indirect benefits (Meinzen-Dick 1997; Bakker et al. 1999) that increase nonagricultural output leading to poverty reduction in both rural and urban areas. However, the distribution of water rights and water yielding assets determines who benefits most from irrigation investments. These investments are likely to be less effective in reducing poverty when land and water rights are highly skewed, and when low-cost technologies or associated credit needs, or both, are not available beyond the initial construction phase. Furthermore, not everyone was able to benefit from irrigation development and the new technologies and the benefits did not occur at the same time. For example, the benefits were experienced in the semiarid regions of India well before monsoonal eastern India, and for many rain-fed-irrigation farmers benefits could only be achieved by migrating to meet increased labor demands in the irrigated areas.

The New Era of Globalization—1990 Onward

Dominant strategy: *The control and management of water for agricultural and nonagricultural uses.*

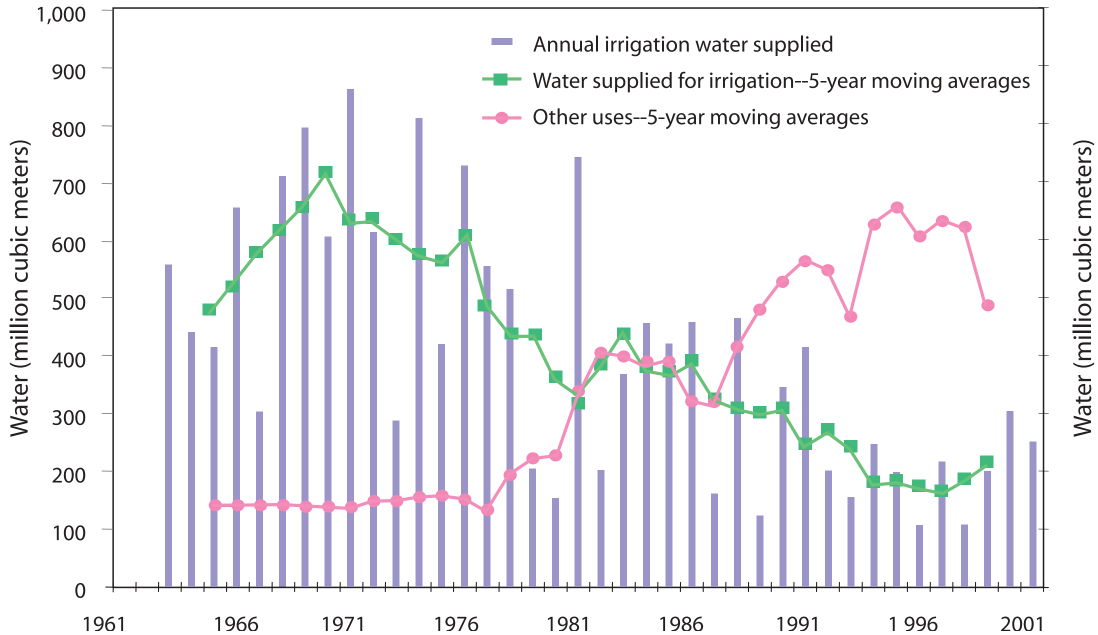
The concept of globalization emphasizes the growing links between world economies and their interdependency. In the developing countries, this is reflected in the shift from a peasant (self-sufficient) to a market economy. The widespread use of information technologies such as cell phones and the increased mobility of labor are symbols of this global transformation.

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 seemingly come to an end. That is to say, developing more of the world's potentially utilizable water resources is costly. (However, it must be recognized that advances in technologies such as desalinization may provide an important source of water in the future.) At the same time, there had been a rapid growth in demand for water for nonagricultural uses—industries, municipalities, hydropower and protection of the environment. 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 these nonagricultural uses. The role of the state is challenged by the development of private tubewells, by moves towards decentralization and more participatory patterns of governance. Next we discuss some of the key factors shaping the development of irrigated agriculture today.

Water Scarcity*—we used to believe that there would always be enough water.*

Irrigation consumes an estimated 70 percent of the total developed water supplies, but well over 70 percent of the consumption is 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.

FIGURE 6.
Annual water allocations for irrigation and other uses, 1965-1999: Zanghe Irrigation Reservoir, Hubei province, China.



An excellent example of the growing demand for water for nonagricultural purposes is illustrated by the Zanghe Reservoir (figure 6). The reservoir is located in the Yangtze River Basin near Jingmen City, 200 km west of Wuhan in the Hubei province of China. Over a period of 30 years the reservoir water allocated to agriculture has declined steadily from 80 percent to less than 20 percent. Meanwhile, water saving practices have been implemented at both system and farm level such that there has been only a modest decline in agricultural production in the 100,000-ha Zanghe Irrigation District. There are many situations such as this, particularly near urban centers where the demand for water for nonagricultural purposes has grown steadily.

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 in a given country, *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. When return flows are taken into account, a much higher estimate of irrigation efficiency is obtained. This 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, where water scarcity has become a reality, it is often overlooked that farmers, irrigation administrators and others are already making adjustments (see *Farmer and operator responses*, page 28).

***Advances in Pumping Technology and the Groundwater Revolution**—from exploitation to overexploitation*

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 and domestic and industrial use. While the construction of wells and purchase of pumps is often subsidized, the operation and management is typically in the hands of individual farmers or groups of farmers sharing the same well. As we have noted earlier, in the semiarid regions of South Asia, groundwater irrigation has grown steadily since the 1960s to the point where groundwater exceeds surface systems as a source of irrigation (see figure 7 for India). More recently, in just the past 10 to 15 years, pumps and wells have become important for irrigation in monsoonal Asia (see figure 8 for Sri Lanka and Vietnam; see Molle et al. 2003 for more details). The impact of improved water control and growth in irrigated area on crop production seems to have been most pronounced in the deltas, particularly the Ganges-Brahmaputra and the Mekong.

In discussing pumps and wells, it is useful to distinguish four very different situations:

1. The use of tubewells to tap deep aquifers for agriculture as commonly found in India and Pakistan, and also for the water supply to main cities. Foster et al. (1998) estimate that over one billion people in Asian cities rely on groundwater.

2. The use of low-lift pumps to tap shallow, alluvial aquifers, which are usually replenished every year.

3. Pumping river water in major river deltas such as the Ganges-Brahmaputra, Irrawaddy, Chao Phraya, and Mekong.

4. Other situations where pumps are used to abstract water from rivers and drains.

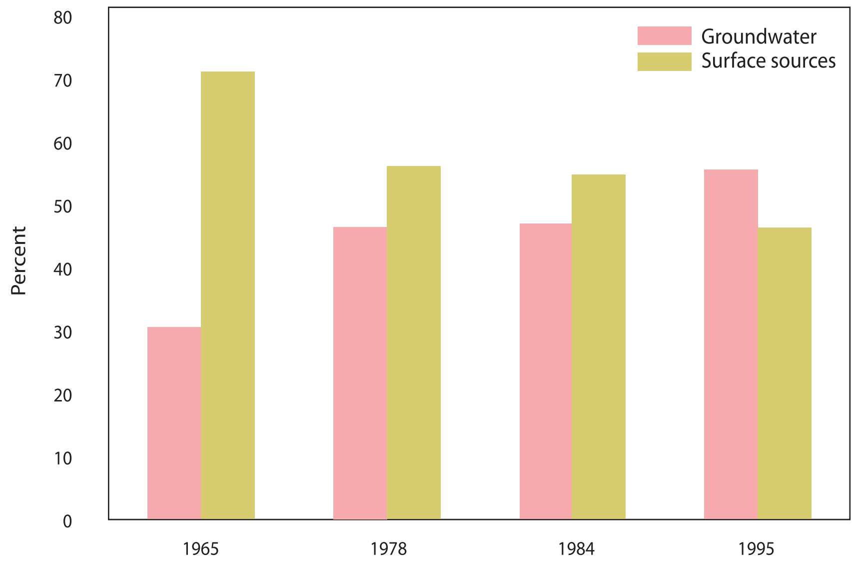
Each environment presents a very different management problem (Molle et al. 2003).

The groundswell of tubewells in semiarid areas has had a critical impact on poverty alleviation, and has also modified both the patterns of water use and the hydrological cycle. Massive groundwater withdrawals have altered the hydrology of the river basins (e.g., drying up of springs), jeopardized intergenerational equity (mining of main aquifers) and provoked environmental damage (see below). While groundwater has contributed much to the growth in agricultural productivity, the overexploitation of groundwater in the semiarid regions is affecting both the quantity and quality of water available for agriculture, domestic use, and other purposes (Shah et al. 2000).

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

The situation in monsoonal areas with shallow aquifers is different. In these areas, aquifers are replenished annually when abundant rainfall occurs. However, there is similarity with the former case in that pumps are being used to access groundwater, as well as canal and drain water, for providing greater flexibility in the reliability and delivery of surface water. Kikuchi et al. (2003) comment as follows:

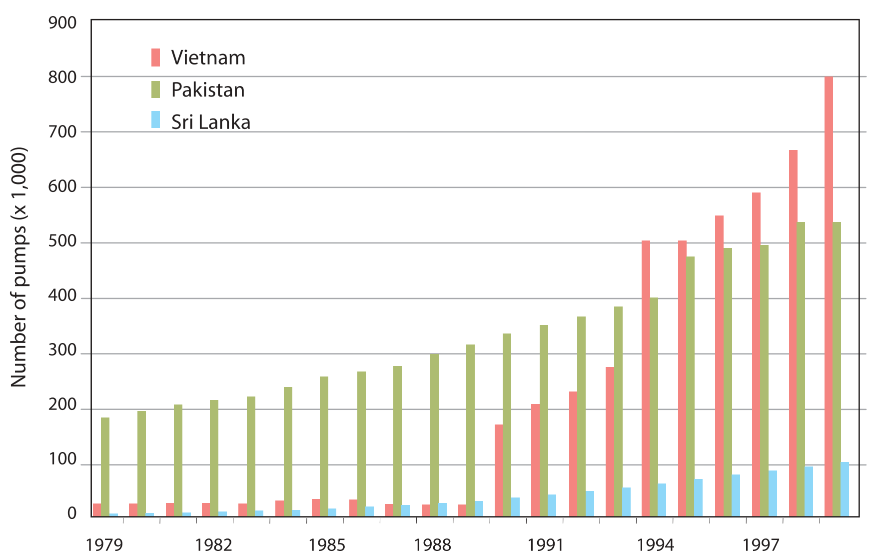
FIGURE 7.
Sources of irrigation, India.



Note: The years 1965, 1978, 1984 and 1995 represent the respective decades.

Source: IWMI 2002.

FIGURE 8.
Number of pumps in selected Asian countries, 1979-1999.



> In the history of irrigation and irrigated agriculture in the monsoonal tropics of Asia, the last few decades of the twentieth century would be remembered as the period of well and pump diffusion. It was a trend that enabled individual peasant farmers to irrigate their crops at their discretion, as opposed to the practice in gravity irrigation systems where decision making as to water allocation and distribution rests on groups of farmers or on government agencies.

In the deltas, pumps are ubiquitous and serve (whenever the tidal effect is not sufficient for this purpose) to raise water from the waterways onto the fields, and also to drain plots in time of high water level in the waterways. In the Chao Phraya delta, this is done with axial low-lift pumps. In the Mekong delta, "shrimp tail" pumps that use motors and propellers from small boats are common, while in the Red River delta, larger-scale collective pumps are used. Pump sets are also being used to abstract water directly from nearby rivers or ponds, independently of functioning irrigation schemes.

This groundswell of pumps in the Era of Globalization owes a lot to: (i) the devisability of groundwater technology—smaller and efficient pumps at affordable prices, at times coupled with micro-irrigation technologies, (ii) trade liberalization that enabled the import of pumps, and (iii) subsidies on energy—fuel and electricity. Such subsidies have been motivated by the possibility for states to use the pump boom—due largely to private investment—to spread the benefits of irrigation to larger areas and thus to alleviate poverty.

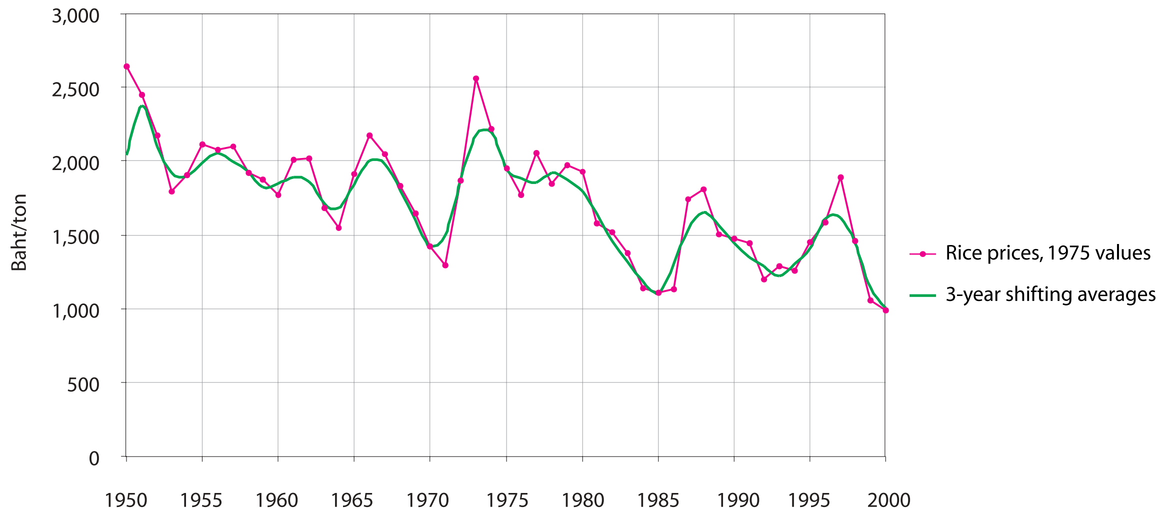
As the limits of groundwater expansion are reached, farmers are beginning to invest in micro-irrigation technologies to conserve water. The cost of these technologies has been declining. For example, the cost of trickle irrigation equipment is US$0.03 per cubic meter or US$300 per hectare, easily affordable for those growing high-valued crops, and the equipment can be manufactured locally with an investment of US$3,000 to US$4,000 (personal communication with Jack Keller, June 2004). Trickle irrigation can save 60 to 80 percent on water use and adds to the flexibility in timing of irrigation deliveries allowing crops to be planted ahead of the monsoon.

Collapse of Food Grain Prices*—no one makes much money growing rice anymore*

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 (figure 2). There are three reasons for this: (i) the extraordinary growth in production due to expansion of irrigated areas and adoption of green revolution technologies, (ii) the decline in demand for cereal grains as incomes rose and diets evolved, and (iii) the continuing and increasing level of subsidies provided by developed economies.

The decline has continued, with rice prices reaching historical lows in 2001. Equilibrium in the global rice market has little to do with either the marginal cost of supplying rice to consumers or willingness to pay for increased supply. At the margin, it reflects the willingness (and capacity) of exporting governments to subsidize rice exports, of importing countries to restrict rice imports and protect domestic producers, and the degree of price and income volatility that governments in the major consuming nations are willing to tolerate (Tabor et al. 2002). The volatility of the rice market is also due to the very low proportion of world production that is marketed (around 10%). Years of surplus or of shortfall in production therefore have a critical impact on the demand-supply situation on the world market. Figure 9 gives an example of the

FIGURE 9.
Historical evolution of farm-gate prices for rice, central Thailand.



long-term trend in farm-gate prices in central Thailand, and shows both fluctuations and the long-term decline.

Low cereal grain prices are often cited as an asset in reducing poverty and maintaining low and competitive wage rates. The urban bias that results from the taxation (both direct and indirect) of agriculture to the benefit of consumers and other economic sectors (Schiff and Valdes 1992) and the low prices received for farm products question the rationale of having farmers pay for the construction of a facility. However, farmers should be willing to pay for reliable services associated with operation and maintenance.

Importing developing countries are faced with the decision either to maintain an open market in keeping with World Trade Organization (WTO) rules or to restrict imports in order to protect local farmers, bolster rural employment, and stave off social unrest. Presumed benefits from free trade must be balanced against the vulnerability to changes in the world markets and devaluation of national currency that may critically raise domestic prices of food (Dawe 2001). The green revolution did much to lower food grain prices and to reduce poverty. However, given the setback of the Asian financial crisis and the inability of the non-farm sector to fully absorb surplus agricultural labor, a further lowering of food grain prices, with its adverse effect on farm incomes, is not likely to result in further poverty reduction.

The downward drift of cereal grain prices is bringing greater pressure for diversification. As previously noted, many canal systems were designed and managed as supply driven systems, which suited the major objective of producing cereal grains. There is a growing incentive to invest in pumps to improve flexibility and reliability in water deliveries and 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, and capital and labor constraints to the risk in marketing, including 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, these policies 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 (see Siriluck and Kammeier 2003 for Thailand). It is also dependent upon market demand, on changes in consumption patterns, and on information flows that can put producers in more direct contact with export markets.

Growing Environmental Concerns*—water quality is as important as water quantity*

The gradual commitment of water (*or* closure) in river basins results in less water available for dilution and flushing of pollutants. This, together with the development of industries and cities, has had a dramatic impact on water quality. 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 it impossible to implement the law. Agriculture also is 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 up of wells and rivers, particularly in semiarid areas, and also land subsidence and the sinking of major cities such as Jakarta and Bangkok. One third of Bangkok, for example, is already below sea level and costs of flood protection and damage are increasing.

Other environmental impacts of land and water development include waterlogging, salinization (e.g., Pakistan), arsenic poisoning (e.g., Bangladesh), the release of acid (e.g., Mekong), the destruction of mangroves and coastal areas after contamination by shrimp farms (e.g., Vietnam and 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. It remains to be seen whether public mobilization will be able to significantly confront environmental degradation typically associated with large-scale development projects. The on-going or planned interbasin transfers in China, Thailand and India, or dams in the Mekong basin, suggest that this opposition might not deter such investments. In addition, the focus is on the highly visible large dams, while, as noted earlier, many of the most serious environmental problems lie elsewhere.

Scheme Modernization*—technology, after all, matters*

The mixed success of technology and infrastructure-oriented development of the postwar modernist period resulted in a concern for management issues. In the 1970s and the 1980s, participatory management and management transfer were high on the agenda. In the last decade, however, technical concerns have made a comeback under the umbrella of scheme “modernization.” In some cases, using the term “modernization” is just a common way to continue to obtain funding for rehabilitation, operation and maintenance, or further capital-intensive interventions. But it is also the recognition that many of the disappointing results of turnover, participatory management, or irrigation agency reforms and water pricing policies eventually stem from difficulties with both infrastructure and management required to establish steady and predictable flows in distribution systems (Facon 2002). Modernization of infrastructure thus corresponds to the need to increase productivity by lowering risk and uncertainty, but also, more generally, to the necessity to increase control over flows. This is a prerequisite to improved allocation and to the definition of entitlements, service agreements, or water rights.

Irrigation and Agrarian Change*— rural households are depending increasingly on non-farm income*

The future of irrigation in Asia is tightly linked with agrarian change, itself a reflection of wider transformations of national and world economies and, therefore, cannot be considered in isolation. The pressure on land or water resources, the land-labor ratio, and the per capita farm income are strongly linked to demographic evolutions. Most significant in the last three decades has been the demographic transition in Asia (table 4). For most countries population growth rates have dropped from 2.5 percent or more to less than 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). The growing opportunity cost of labor has critically impacted on irrigation systems, inducing laborsaving innovations (such as direct seeding of rice in lieu of transplanting), but also lessening the time and attention devoted to irrigation operation and maintenance, and to collective activities.

In addition to inter-sectoral mobility and growth in urban areas, rural-household economies have become more composite. Various activities within the family as well as at the individual level have emerged as a common phenomenon. 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 from nonagricultural occupations (Rigg 2001; Estudillo and Otsuka 1989). 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.

TABLE 4.
Annual population growth (%) in Asia, 1965-70 and 1990-95.

Region/Country	1965-70	1990-95
East Asia	2.5	1.2
Southeast Asia	2.5	1.7
South Asia (excluding China)	2.4	1.9
China	2.6	1.1
India	2.3	1.8

Source: FAOSTAT database

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 re-thinking of the rural economy and rural life, a re-appraisal 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."

A Changing Role for the State*—balancing the role of state with increasingly empowered local entities*

The preceding section emphasizes that the evolution of irrigation, as well as of agriculture, cannot be considered independently of changes occurring in the wider economy. The planning and management of water resources, and of irrigation in particular, has also been, and is being, shaped by the on-going political processes of democratization, which constantly redefine the relationships between the state and the citizenry and have a bearing on the conditions of access to resources (see *Redefining Institutions and the Role of State and Local Actors*, page 34).

The age of globalization thus brings with it a pressure to blend the traditional top-down decision-making by the state with the growing empowerment of other sections of the civil society. This can be witnessed, for example, in the development of Asian nongovernmental organizations (NGOs), which are not merely the replication of western NGOs (Lohman 1995) and have successfully opposed some large-scale development. As mentioned above, the centrality of the state in water resource allocation has also been challenged by private—in general, individual—investments in pumping devices.

Another area where the idea of co-management has been gaining ground is that of river basin management. Closely linked to this, both academics and managers endorse a still vague consensual concept of *integrated water management*. However, like the limited results of earlier turnover and participatory management experiences, co-management is a political process in the making rather than a solution that can be either adopted or rejected.

The Challenge Ahead

Redefining the role of the state and local entities in water resource management

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 New 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 conjunctive management of surface water and groundwater irrigation.

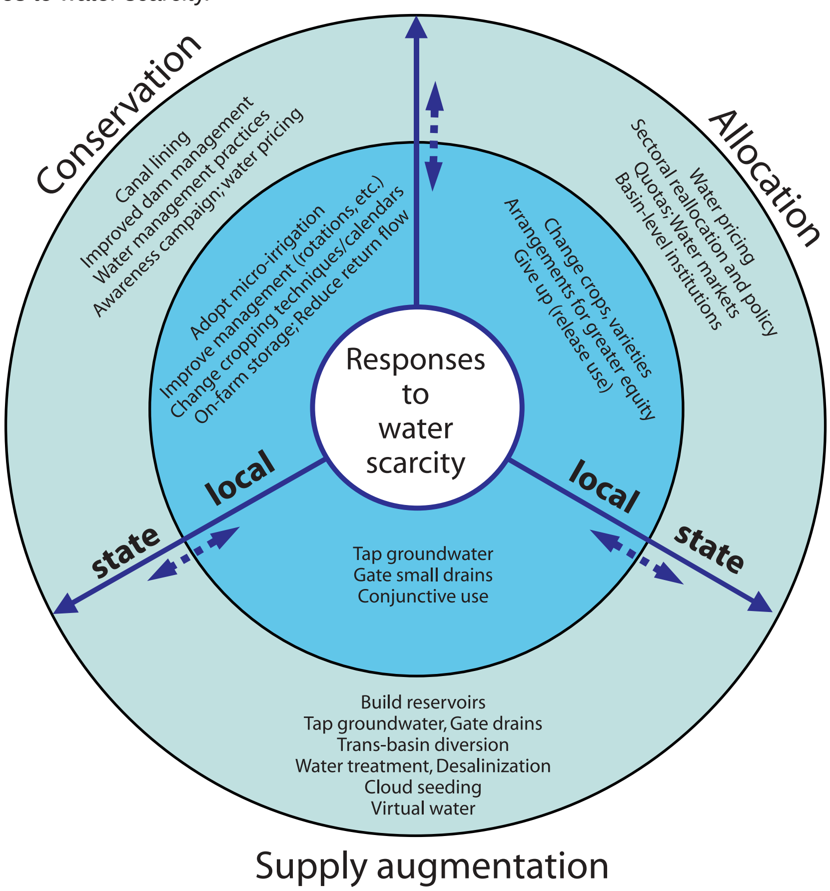
Many of the old communal systems face a challenge to their sustainability because, as noted above, interest in agriculture has declined in the village, the labor force required to maintain these systems is vanishing, and in some instances technologies such as pumps and tubewells offer a better avenue 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 that 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 overexploitation of a common property resource.

Increasing water scarcity 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. This conflict exists 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.

Paths to Improving Water Management and Increasing 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. Figure 10 (Molle 2003) synthesizes some of the main strategies for dealing with water scarcity and distinguishes between those that are implemented locally and those that are implemented primarily by government agencies or donor-assisted projects.

FIGURE 10.
Types of responses to water scarcity.



Source: Molle 2003.

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 are often interlinked (e.g., a farmer's decision to adopt micro-irrigation may be influenced by economic incentives). Most government irrigation agencies are involved in the operation of canal systems but they 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 and operator responses

Farmers are often accused of wasting water. But the farmer response to water scarcity and declining cereal grain prices has been fairly dramatic. As noted earlier, the tapping of groundwater and the use of pumps for recycling have been growing rapidly. Where opportunities permit, farmers are relying on more flexible and reliable groundwater supplies, coupled at times with micro-irrigation, to shift from cereal grains 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 (see Molle 2004a for a case study in Thailand).

However, the farmer response has not always led to positive results. Particularly in the semiarid areas, unregulated exploitation of groundwater has led either to falling water tables or 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 (Kurian 2002).

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. However, this practice is sometimes constrained by priorities for power generation, especially in countries such as Sri Lanka and Vietnam where hydroelectricity still accounts for about 70 percent of the installed capacity. Curtailing releases during rainfall is also an issue for dam management, but it generally requires a degree of automation and efficient management of information systems.

Government, multilateral lending agency, and academician responses

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 has been on conservation while the mechanism and associated water rights to support appropriate allocation are emerging as an important issue.

Government and multilateral lending agency interest in interventions to improve irrigation system *performance* continues. Figure 10 shows activities undertaken by agencies to save or conserve water. These include canal lining, water pricing and water markets, cost recovery, setting up water user associations, development of water saving technologies and management practices, and institutional reform and water policies. However, the potential effects of these interventions on *water productivity* are seldom mentioned and even less frequently measured.

Canal lining is extremely popular with both lending agencies and recipient governments. They provide the lenders with an opportunity to meet monetary disbursement targets and irrigation agencies with the opportunity for rent-seeking or “skimming” profits (Repetto 1986). A few years ago, the International Water Management Institute (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 US$500 million and none of the associated documents (appraisal reports and evaluations) included any assessment of benefits and costs. 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 overall. It is safe to assume that neither the donor agency nor the recipient bureaucracy were interested in knowing.

Water pricing and water markets have been an important focus for economists. In a market economy, prices should perform the task of signaling scarcity and 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; Smith et al. 1997; Morris 1996; Molle 2001). The World Bank recently undertook a comprehensive study called “Guidelines for Pricing Irrigation Water Based on Efficiency, Implementation, and Equity Concerns.” As a part of this study, Johansson (2000) conducted an exhaustive literature survey on the pricing of irrigation water, and most of the convincing evidence of price response relates to urban water supply and very little to large-scale gravity irrigation. The same can be observed in other literature collating international experience (e.g., Dinar and Subramanian 1997; Dinar 2000). More concise treatment of the issues can be found in Tsur and Dinar 1997 and in Perry 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. This is particularly difficult to measure. Water pricing methods might also have an effect on cropping patterns (Tsur and Dinar 1997) but this is seldom 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 agricultural situations where supply remains much under demand. In such cases, the value of water is already manifested by its very lack and users have readily adjusted 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 manifest and elicits adjustments in water use more efficiently than pricing.

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.[3] 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, (i) by the difficulty of controlling flows volumetrically and temporally, (ii) by the lack of infrastructure to move water from one point to the other, (iii) by the lack of definition of water rights, and (iv) by the greater probability of having a higher heterogeneity of users and, therefore, possible adverse impacts on poorer segments of the society. It is recognised 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). Also, from another point of view, "the social and environmental risks of getting it wrong are considerable" (Morris 1996). Water markets in most of Asia remain a long-term objective that comes with mature economies and institutions.

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 non-farm 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 is some doubt as to who should pay for infrastructure investments. The general situation, including that in developed countries, is that very little, if any, of the sunk costs of major public interventions are 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. It has, therefore, come back to the top of the agenda in the last two decades, in line with structural adjustment and other financial austerity measures. However, it is often unclear (i) whether such costs are really as considerable as it is claimed,[4] (ii) why users should pay for a service which is, more often than not, unsatisfactory and unreliable, and the costs of which are inflated by the overstaffing of agencies, and (iii) how this particular subsidy of free O&M or low O&M fee features in the wider arithmetic of taxes and subsidies that occur all along the production chain, from input provision to consumption. In other words, if the overall taxation results in a net extraction of surplus, the rationale for raising water fees might appear less convincing.

Second, O&M cost recovery is deemed critical to ensure the sustainability of schemes, and avoid the frustrating cycle of project rehabilitation, which development banks often get caught up in. However, water fee collection is

[3]This is common, for example, in schemes managed under the warabandi system. In most arid areas too, water rights tend to be well defined at the individual level and small-scale transactions (borrowing, renting or purchasing) are very common. Such transactions are also commonplace in arid countries with small-scale, privately owned water rights (e.g., irrigation based on springs or karez [*qanats*]).

[4]In Thailand, they are at 0.3% of the national income (Molle 2002). In Sri Lanka, they correspond to only 5% of the investments made. Concern for economic and financial efficiency may therefore miss the point by focusing on O&M rather than on how investments are decided and made (Renwick and Molle, Forthcoming).

very seldom associated with 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). This is well illustrated in Vietnam (Fontenelle and Molle 2002) where farmers are taxed for water and a number of other services. Most farmers do not know how much they paid for irrigation or flood control and how the money was used. The water fee collection in Vietnam, which if used for the purpose intended would cover about 50 percent of O&M costs, is high by Asian standards (Barker et al. 2003). In short, to provide the necessary incentive for cost recovery would require a realignment of institutional arrangements so that suppliers are accountable to users (World Bank 2003).

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 or wells, or both, 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 also for other agricultural services as well. These options are tantamount to a redistribution of power and responsibility away from the administration. As a result irrigation administrations typically pay lip service to the reforms without making a strong commitment.

Indeed, the World Bank, by far the most constant and insistent advocate of cost recovery for decades, observes that there has been 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).

Water user associations are seen by many social scientists as an essential element for improved irrigation system performance. In the area of institutional reform, the devolution of management and financial responsibility from irrigation system 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, historically a great deal of Asian irrigation was developed through communal or locally managed systems that evidenced a high degree of what we call today participatory irrigation management (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, the United States Agency for International Development (USAID), and the World Bank. The objective was to transfer full responsibility for the maintenance of tertiary canals, fee collection, and management responsibility to water user groups gradually and stepwise over a period of time. The transformation appeared to be on stream in the mid-1980s but collapsed apparently due to a change in leadership of 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 expenditure 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).

One should not be surprised that the hegemonic approach of the development banks would meet with limited success. The preconditions for the establishment of successful farmer-managed water user associations, including government commitment, exist in some areas but not in others. Even the more narrowly focused and carefully studied planned efforts in development of water user associations have not proved replicable or sustainable. The well-documented Gal Oya project in Sri Lanka combined physical rehabilitation with a highly successful establishment of farmer organizations, using irrigation organizers working directly with farmers (Uphoff 1992). The results of ex-post research have shown that physical and institutional changes contributed jointly to the significant increase in water productivity (Murray-Rust et al. 1999). However, in subsequent irrigation projects, the positive lessons from Gal Oya have never been repeated in Sri Lanka (Kikuchi et al. 2002).

Development of water saving technologies and management practices offer another potential for increasing water productivity. A distinction can be made between those measures that increase water productivity by increasing crop yield for a given evapotranspiration or diversion, as opposed to those that reduce the water diversion requirements. In the former case (e.g., increase in crop yields through varietal improvement) savings at the plant and field level are realized at the system and basin level. In the latter case (e.g., system of rice intensification or SRI) increase in water productivity at system and basin level is not assured. 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. This is referred to as "scaling-up" from farm to 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. However, the increase in grain productivity is in some ways deceptive. In almost all crops the greater grain yield is not due to an increase in biomass but almost entirely to an improved ratio of grain to biomass (harvest index or grain to straw ratio). Although the potential ceiling value for the harvest index is rapidly approaching in many crops, the only way to maintain increases in yield will be to increase biomass (Richards et al. 1993). There appears to be significant potential for increasing yields by selecting cultivars for increased water productivity and a significant amount of research is now being focused in this area.

There is also rapidly expanding interest in management practices and technologies that can save water and increase water productivity—zero tillage, dry seeding, raised beds, alternate wetting and drying, aerobic rice, system of rice intensification (SRI) and micro-irrigation such as drip or sprinkler. Field trials are being conducted in countries throughout Asia through collaborative research between national and international centers. For example, IWMI is collaborating with the International Rice Research Institute (IRRI), the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia, and Wuhan University in China to determine the impact of some of these technologies on water savings and gains in water productivity at farm, system, and basin level (Barker et al. 2001). However, the potential impact of this research and related technologies and practices on gains in water productivity is as yet unknown.

Institutional and policy reforms have, in the last decade, come up to the top of the agenda. For example, there is a concerted effort in several countries to establish river basin authorities. While it is recognized that typical approaches based on engineering, agronomic, or economic solutions have limited impact, the need is gradually felt to address "deeper layers" of the society and its institutions. There, however, external interventions are often based on visions of idealized social and political settings. Proposed reforms often owe more to the naivety of social engineering-based approaches than to a deep understanding of mechanisms of institutional change, informed by an analysis of local political economies. As Thomas and Grindle (1990) have observed, "reforms have been attempted when the administrative or political resources to implement them did not exist. The result has generally been misallocated resources, wasted political capital, and frustration."

In summary*,* what the above discussion reveals is that most of the public investments in irrigation and related research activities are focused on improving the performance of canal irrigation systems. There are situations where canal lining, volumetric pricing of water, or development of irrigation associations are appropriate. But in most developing countries these situations are limited. To a large degree the focus has been on physical improvement of canal systems while ignoring the impact of farmer response to water scarcity. Meanwhile, the focus is gradually shifting from the irrigation system to the river basin and from irrigation per se to, often loosely defined, *integrated water resources 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 (2004) states that the solution to successful water management "is not a mystery awaiting discovery." Successful water management, the sustainable and productive use of water for the use of 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 and geohydrology).
- Policies governing water resource development and assigning of priorities among users for the developed water resources (politics).
- Translation of the policies into allocation rules and procedures such that water services to each user or sector are clear for any hydrological circumstance (laws).
- Defined roles and responsibilities for the provision of all aspects of a specified water service (institutions).
- 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, overexploitation of resources, pollution, and deterioration of infrastructure.

Perry's criteria provide a useful framework, but reading it as a checklist provides no hint as to the path to improved management of water resources. 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 also 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 above remains unchanged but the problems have become more complex. For example, in *hydrology,* there is an urgent need in many areas to consider the conjunctive management of surface water 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 relationships 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 is a centralizing or centripetal trend, 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 or regulate allocation and water rights or 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 line agencies and bureaucracies will attempt to use the situation to further their role and power without being forced to implement needed reforms. For example, river basin authorities may 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 devolution, 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 process, borrowed from an anti-state stance, favors privatization and sees users as independent entrepreneurs who must have control over their input and pay for resources at their real value, as reflected by their market prices. This ideological stance is often put forward to obscure the more mundane state of affairs 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 recognition 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 positions 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, integrated river basin management, etc., 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. One should avoid pushing forward particular ideological agendas and foster blueprints focused on a particular societal arrangement. 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 focus point in institutional reform must be the definition and security of water entitlements, or “rights.” Water allocation and access among users and uses at system as well as 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 smallholders 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 multi-faceted implications (see Molle 2004b). As outlined above by Perry (2004), this has many far-reaching prerequisites. Up to now, such overall reforms have not been successful, as line agencies have generally retained their power and not effectively embraced the principle of decentralization. Water laws have remained enabling legislation with little impact (see Malano et al. 2000, for Vietnam), water fees are still conceived or perceived as flat taxes, and water allocation is still centrally defined and influenced by political intervention. A conventional bureaucratic and top-down definition of water rights is doomed to face many difficulties and conflicts because of the complexity of preexisting uses and rights (legal pluralism) and the poor knowledge or quantification of hydrological phenomena. In contrast, it might be easier and wiser to build consensual allocation patterns by negotiation, under the umbrella of a river basin organization giving a say to all stakeholders (Molle 2004b). The growing importance of open-access groundwater resources adds greatly to the complexity of the problem. 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 the tradeoff between efficiency and equity is addressed in a transparent and negotiated way.

Conclusions

In this report we have traced the evolution of irrigation focusing on South and Southeast Asia and identifying three separate time periods, the Colonial Era from 1850 to 1945, the Cold War Era from 1946 to 1989, and the New Era of Globalization from 1990 onward. We have said very little about the East Asian experience or the experience of Central and West Asia (the Middle East) in part because it does not fit well into our geopolitical and temporal framework. It is worth noting, however, that in East Asia (including China) 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 in transferable.

The development of irrigation, whether by colonial administrations or, more recently, by national governments and multilateral lending agencies, has been pursued with a fairly common set of goals, with the emphasis varying between social objectives (poverty alleviation and food security) and economic objectives (increased tax revenues and growth in value of agricultural output). More recently, with the achievement of food security at the national level, the agenda has broadened to include improved livelihoods, poverty reduction, and protection of the environment. 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, or supply-driven or demand-driven irrigation; and 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 water and groundwater technologies were developed to facilitate the expansion of irrigated area and increase 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 non-farm sources. The rural economies are undergoing a social as well as an economic transformation.

As we enter an Era of Globalization, farmers and system operators have adjusted to the challenges posed by growing water scarcity by exploiting groundwater, 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 demand and competition for water, 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 establishment 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: (i) allocate water equitably among competing uses and users, including environmental services, (ii) integrate management of irrigation at farm, system, and basin level to reduce upstream-downstream and head-tail conflicts, (iii) integrate the management of groundwater and surface water irrigation, and (iv) address the problems of irrigation development, including the impacts of the use of wastewater 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 is negotiated. The task is monumental. It is likely to take years, perhaps even decades, to establish enforceable water rights and a complementary set of institutions.

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