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Perspectives on Asian Irrigation*

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Introduction

Asia covers over 60 percent of the world's irrigated area. Approximately two-thirds of it 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, and cereal grain prices have declined. Attention has shifted to improvement of management and control in order to increase water productivity and facilitate diversification to higher valued crops.

This chapter presents a broad overview of irrigation development in Asia, emphasizing current problems and challenges. The focus is on the interaction between socioeconomic and bio-physical factors that have been the determinants of growth and development in selected time periods. First, we provide a framework for viewing the transition in Asian irrigation. 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. Second, we cover the development of modern Asian irrigation in three different time periods identified in terms of their geo-political significance—the Colonial Era, the Cold War Era, the New Era of Globalization. Our Colonial Era extends from 1850 until World War II, a period which saw considerable activity in irrigation development.

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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 and groundwater. The Globalization Era begins in a period when water has become scarce, water pollution has increased, yield gains in cereal production in most of Asia have slowed down or stagnated, 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, and the need for new institutions to support *integrated water resource management* (IWRM).

A Framework for the Evolution of Asian Irrigation

The development of irrigation involves a constant interplay between resources (land, labor, water), technologies (dams, tubewells, pumps), institutions and policies (water rights, management), and culture (values and value judgments) as irrigation evolves over time in a community, a basin, a country, or a region. To capture this dialectic interaction over time, we have defined the evolution of Asian irrigation over three geo-political time periods—the Colonial Era, the Cold War Era, and the new era of Globalization. We believe that in all three periods, geo-political forces have been dominant in establishing the direction of change in the development of irrigation and irrigated agriculture.

The columns in Table 2.1 are divided into the three time periods. In each column we identify the major determinants of change, including geo-political objectives, resource constraints, technological advances, and defining events such as famines and droughts and the opening of the Suez Canal. We also list the changes taking place in irrigation construction and utilization, and parallel changes in irrigated agriculture. In the sections that follow, we build upon this framework to describe the development of irrigation 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 irrigation and irrigated agriculture within Asia. Many events overlap between time periods and many areas do not fit in the time frame. For example, population pressure dictated earlier development of irrigation in East Asia. There are both similarities and important differences in the East Asian experience. The earlier development of irrigated

agriculture in East Asia in conjunction with varietal improvement, use of chemical fertilizers and mechanization helped establish the direction of change in South and Southeast Asia after World War II.

Table 2.1
Evolution of Publicly Managed Irrigation in South and Southeast Asia

Geo-politics	*Colonial Era 1850 to 1940*	*Cold War Era 1950 to 1989*	*Globalization 1990 Onward*
Primary goal of national and international agencies	Famine protection/ revenue/exports	Food security	Livelihood/protection of environment/ exports
Defining events	Famines, Suez Canal	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/ utilization	Construction/ utilization	Utilization/allocation
Professional orientation	Civil engineers	Agricultural engineers	Multi-disciplinary
Dominant irrigation development	River diversion, flood control, canalization of deltas	Storage dams, gravity irrigation	Pumps and wells
System design	Protect/supplement	Supply-driven	Demand-driven
System management	Hydraulic	Agricultural-based	Farmer-oriented
Crops	Cereals/cotton	Cereals/cotton	Diversified
Cropping intensity	One crop	Two crops	Multiple cropping
Livelihoods	Subsistence/colonial surplus extraction	Increasing mobility and economic diversification	High economic diversification
Value of water	Low	Increasing	High
Environmental degradation	Low	Increasing	High

It is also important to recognize that irrigated agriculture in Asia has a history that extends for centuries prior to the colonial period, with notable achievements and important lessons for present-day administrators and practitioners. For example, community irrigation systems have long been pervasive in Asia and, even today, serve a third or more of the total irrigated area. Many of these community systems have

existed for centuries. The success of these community systems depends most importantly on the felt need of the community water users. This felt need for community cooperation is most evident in areas of intense population pressure and/or limited water supplies, in order to gain access to and share water and minimize conflicts. Likewise, there is the experience of the development of large irrigation systems in what Wittfogel (1957) has referred to as "hydraulic societies." How these societies managed to succeed for so long, and why they failed, is still a matter of debate among scholars.

The Colonial Era

The dominant irrigation strategies include river diversion schemes for assuring the main harvest, and protective irrigation in semi-arid regions for famine prevention in years of drought and for revenue collection.

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

Irrigation in the semi-arid and the monsoon areas had distinct characteristics. In semi-arid regions, crop production is dependent on irrigation. Hence, systems were designed and crop production planned on the basis of the availability of irrigation water, often with the objective of maximizing returns to scarce water rather than to land. In the monsoon areas, however, the farmer planned his crop production primarily on the basis of expected rainfall. In case of years of good rainfall, farmers did not require irrigation. Flooding was often prevalent with the need to provide adequate drainage. In years of low rainfall, supplemental irrigation was needed to protect the main harvest, normally that of rice.

Semi-arid Irrigation

The semi-arid regions consist mainly of what is today Northwest India and Pakistan. With the annexation of 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 five million hectares by the turn of the century (Bolding et al., 1995). Increasing the collection of land revenue was perhaps the primary objective. However, particularly after severe famines, the prevention of famines took precedence. This had considerable influence on both the design and management of irrigation systems; this impact has been discussed by Jurriens et al. (1996).

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* vs. *protective* irrigation distinguishes between these two objectives. Protective irrigation systems are based on scarcity by design, and have a thin spread of water over a large area in periods of severe drought. Jurriens et al. argue that most of the systems in the Indo-Gangetic Plain even today are protective: they do not meet the water requirements of the full command area; they are supply based with continuous flow; there is a minimum of control structures; 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.

There was considerable debate over the suitability of *production* vs. *protection* designs. Consider the case of the Nira Canal near Mumbai in India reported by Bolding and Mollinga (1995). Operating as a *protectionist* scheme at the beginning of the twentieth-century, the system faced severe problems with inequitable distribution of waters, water logging, and salinity. To combat the problem of protective irrigation, a plan was launched by the Indian Irrigation Commission in 1903 consisting of three steps:

- Concentrate the irrigated areas in blocks, fix the demand for irrigation water, and promote higher valued crops.
- Control the distribution of water, avoiding corrupt practices and cultivator interference.
- Sell water by volume to cultivators to avoid waste of water and optimize its economic use according to market principles.

Although it is clear from various reports that the objectives were by and large not achieved, largely due to management and not technical

failures, the "success" of the block system is subject to debate even today. As we shall see later, this debate has its modern counterpart in the debate over *supply* vs. *demand* driven systems during the Cold War period, and extending to the present.

In the *warabandi* system, British irrigation authorities attempted standard programs for water release, subject to as little influence from events and personalities as possible. But there was often a conflict between the engineers and local authorities concerned with agricultural production. This is illustrated in the case of Kirindi Oya, in Sri Lanka (Ostrom, 1990, pp. 159–61). From 1920 to 1958, the system was managed under a dual executive structure by the Irrigation Department which wanted a regular schedule and a set time for the maintenance of canals, and the Revenue Department which wanted to save crops in periods of drought. The farmers, mostly tenants, had no voice in decisions.

Monsoon Irrigation

In Indonesia, the *sawah* (irrigated paddy fields), that had developed in late seventeenth and early eighteenth centuries to support the growing population, was expanded in the late nineteenth century by the Dutch to accommodate sugarcane. Huge hydraulic efforts to expand rice cultivation later occurred between 1900 to 1940, with the paddy area growing from 1.26 million ha to 3.4 million ha (Maurer, 1990). In Vietnam, the French rulers improved flood control in the Red River delta but the bulk of agricultural expansion was achieved in the Mekong delta, a still largely virgin area in the mid-nineteenth century. The use of new mechanical dredgers allowed the expansion of canals and paddy fields, from 350,000 ha in 1868 to 2,443,000 in 1930 (Brocheux, 1995; Dao The Tuan and Molle, 2001; Henri, 1930). Similarly, in Burma, the reclamation of the Irrawaddy delta gave rise to a spectacular increase in rice area and exports (Adas, 1974). In Siam too, despite the absence of formal colonization, the Chao Phraya delta was equally reclaimed between 1850 and the mid-twentieth century, thanks to the abolition of bondage and the expansion of the rice trade and economy.

From these examples, it can be seen that most of the expansion took place in deltas, with little or no technical change, and without any major hydro-technological works (Owen, 1976). Canalization also served the crucial purpose of communication (and provided sites for homesteads). Flood regulation allowed better control of flood-based agriculture, while

river diversions of both small (Philippines, Java) and large-scale (India) accounted for more classical gravity irrigation. In many instances, the intervention of colonial engineers in traditional irrigation conflicted with management logics they did not understand (see for example, Farmer [1976] for the small tanks in Sri Lanka; Kamal [2001] for the flood management in Bangladesh).

The colonial era also marks the expansion of peasantry in Asia, together with its gradual integration into the market economy. There has been wide debate on whether this period signaled the end of the "moral economy" of communities engaged mainly in subsistence production, or whether, contrarily, it only developed or revitalized old forms of traditional commerce, although exposing farmers to greater risk by provoking higher socioeconomic differentiation (Scott, 1976). Several studies have stressed that the second point may be more valid, especially in areas with good communication, such as the deltas (see Bowie [1992] for northern Thailand; Huang [1990] for China; White [1991] for Indonesia, etc.).

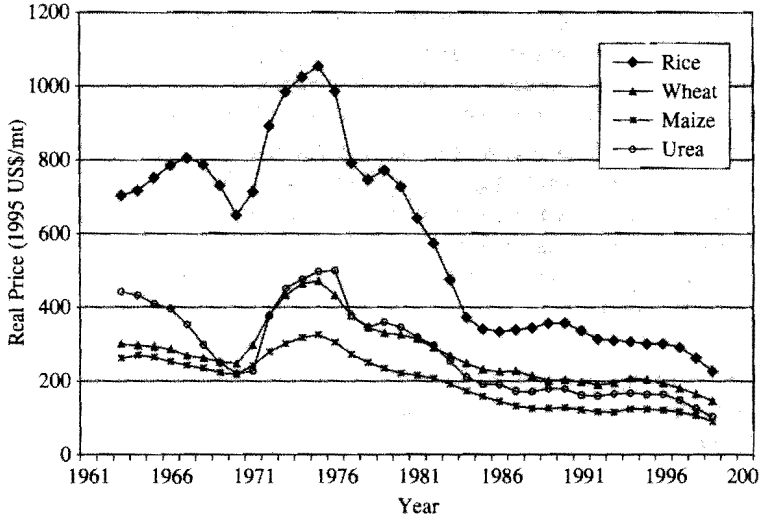
The Cold War Era

The dominant irrigation strategies include the construction of large storage dams and expansion of public irrigation systems to achieve food security, poverty reduction, and related social objectives.

With the beginning of the Cold War Era, concern grew in the West regarding the population explosion and deteriorating food situation in Asia, and its implications for political stability. Among the governments of Asia and the West and the West-dominated international development agencies, the priority was clear—to increase cereal grain production in Asia. A consensus gradually emerged as to how to get the job done as the pieces of the green revolution technology began to fall into place. Attention has focused on the success in the development and extension of high-yielding, fertilizer-responsive crop varieties. However, the huge investments by the development banks, donor agencies, and national governments to develop and expand the irrigation systems can easily be regarded as the *sine qua non* of food security in Asia today. Two climatic events were linked to shortfalls in annual rains throughout much of the world—so-called *El Ninos*—that served to catalyze the commitment to the goal of food security 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, and leading to a sharp rise in world rice prices (see Figure 2.1), forcing Thailand, the world's largest rice exporter, to ban exports for several months in 1973.

Figure 2.1
Real World Prices of Rice, Wheat, Maize and Urea (1961–2001)



Expansion of Irrigation

From the early 1960s to the end of the century, the total irrigated area doubled. India and China together account for two-thirds of the world's irrigated area (see Table 2.2).

Table 2.2 shows the growth in irrigated area by selected country groupings. After 1985 there was: (*i*) an increase in the rate of growth in irrigated area in Cambodia, Laos, Myanmar, and Vietnam; (*ii*) a significant decline in the rate of growth in Indonesia, Malaysia, Philippines, Thailand, and in China; and (*iii*) an absolute decline in irrigated area in East Asia. The increase in mainland Southeast Asia reflects the fact that for both political and technical reasons development of irrigation in the Mekong and Irrawaddy River Basins had been delayed.

Table 2.2
Growth in Irrigated Area in Asia and its Sub-region Countries (1961–1999)

Country	*1962–65*	*1985–98*	*Share of Total Net Irrigated Area in Asia*
Asia	2.3	2.0	1.00
SEA I	2.2	1.3	0.07
SEA II	3.7	4.2	0.03
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

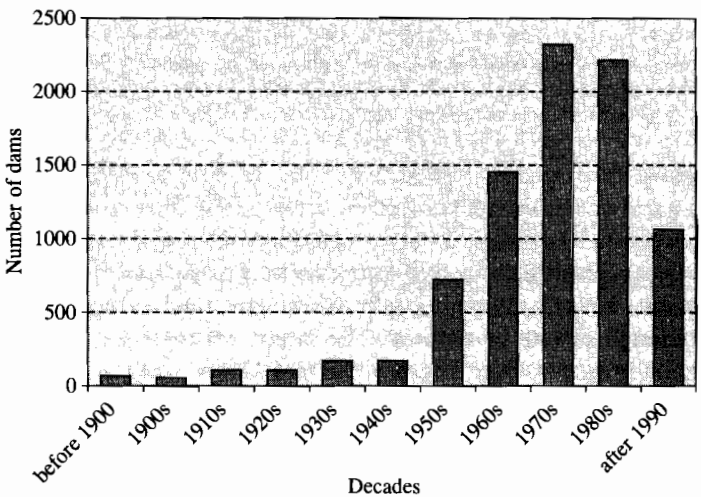
Source for Basic Data: FAO Stat 1997.
Notes: Southeast Asia (I) includes Indonesia, Malaysia, Philippines and Thailand.
Southeast Asia (II) includes Cambodia, Laos, Myanmar and Vietnam.
South Asia includes Bangladesh, Nepal, Pakistan and Sri Lanka (excludes India).
East Asia includes Japan, North Korea and South Korea (excludes China).
Asia includes all, and only those, countries covered in the listed sub-regions.

Expansion in irrigation was facilitated by technological advances. Technological advances can be divided between: (*a*) those relating to the development of surface water or canal irrigation systems largely through public investment, and (*b*) those relating to the exploitation of groundwater, initially through public investments and subsequently, largely through private investment. The largest short-term expansion of irrigation in India, which began in the mid-1970s, was provided by World Bank loans to the Agricultural Development Bank and used by farmers to construct wells and purchase pumps. There is a natural 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 thus provide water for irrigation through wells. Dhawan (1993), for example, estimates that half of the crop output originating from tubewell irrigated lands in Punjab is from groundwater, that is, mostly of canal origin.

Technological advances in large dam and reservoir construction in the western United States prior to World War II became the foundation for later surface irrigation system development in Asia. During the so-called "construction period," irrigation expansion occurred largely through the construction of dams, reservoirs, and a distribution network

of canals. Of the more than 40,000 large dams (the International Commission On Large Dams defines a "large dam" as one measuring 15 meters or more from foundation to crest), all but 5,000 have been built since 1950 (McCully, 1996). Figure 2.2 shows the dramatic increase in large dam construction in Asia in the latter part of the twentieth century, which peaked in the late 1970s and early 1980s. During this period, most countries devoted 50 percent or more of their agricultural budgets to irrigation, with only a small fraction of the total for operations and maintenance.

Figure 2.2
Historical Evolution of Dam Construction in Asia

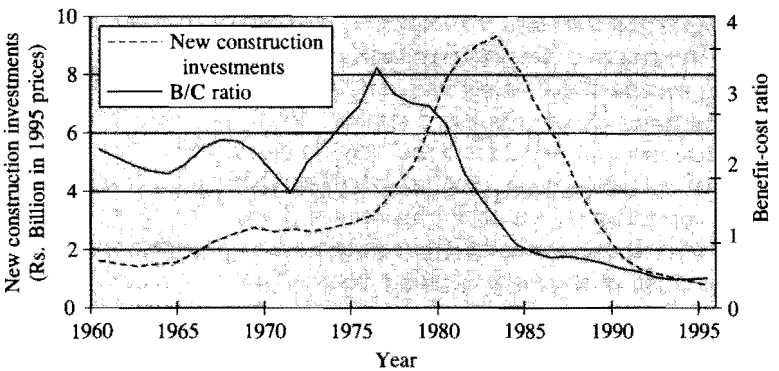


Source: WCD, 2000.

There were three factors that led to the decline in large dam construction. Cereal grain prices declined sharply in the mid-1980s to 50 percent of their previous levels (Figure 2.1), and this was accompanied by a rise in construction costs, particularly as new irrigation sites became costly to develop. The effect of these two factors was to reduce the benefit-cost ratios. Figure 2.3 for Sri Lanka, presents a fairly typical picture for much of Asia. The peak in large dam construction in the mid-1980s lagged approximately a decade behind the peak in the benefit-cost ratio, reflecting a long gestation period in irrigation development. The third factor accounting for the decline in investments was the growing opposition of the environmentalists. Reflecting their environmental

concerns, and yet after a further time lag of more than a decade, the World Commission on Dams was created to review and report on the positive and negative impacts of large dam construction and establish a framework for decision making (World Commission on Dams, 2000).

Figure 2.3
Changes in Benefit-Cost Ratio of New Irrigation Construction Investments in Sri Lanka*



Note: *Evaluated at current world prices and total new irrigation construction investments in 1995 constant prices—five-year moving averages, 1960–1995.

A consequence of the dramatic expansion of irrigated area is that it has occurred on more and more marginal land, where the development costs are also higher. In many Asian countries, the cost per ha of new irrigated area has more than doubled since the 1970s (Svendsen and Rosegrant, 1994). Meanwhile, the cost of groundwater exploitation has been declining. As all water becomes fully committed, further investment or "overinvestment" often simply shifts the benefit of irrigation from one point in the basin to another, without any increased productivity—simply robbing Peter to pay Paul. The decline in opportunities for productive investments, together with the low price of food products, accounts for most of the decline in investments and external funding for irrigation in the 1980s and 1990s.

Supply vs. Demand Driven Systems

The debate (referred to earlier in the Colonial Era) over the design of productive vs. protective has its modern counterpart in the debate between the advocates of *crop-based* or *demand driven* design and

water-based or *supply driven* design (Jones, 1995). In case of the former, the amount of irrigation water delivered is tailored to crops the farmers choose to grow, while in the latter farmers have to tailor their cropping to the delivery timing of irrigation waters. The advocates of demand driven systems 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 to grow crops other than rice. If farmers in adjacent plots are to grow rice and chillies 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, advocates of supply driven systems point to the poor performance of crop-based demand driven systems. Meanwhile, more and more farmers have found ways to obtain water when needed, by 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. It follows that in many instances, managing water for conjunctive use may be less costly and more productive than purely investing in demand driven surface irrigation systems.

Poverty Alleviation

The role of irrigation in poverty alleviation is a theme that pervades the history of irrigation development. For example, during the Mughal 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 Ravillion (1998). The study links the reduction in rural poverty with growth in farm productivity in India. 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, forthcoming).

The study by Lipton and Litchfield (forthcoming) 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 that increase non-agricultural output, leading to poverty reduction in both rural and urban areas. However, the distribution of water rights and water-yielding assets determines who benefits 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 and/or associated credit needs are not available beyond the initial construction phase.

The New Era of Globalization

The dominant strategy involves the control and management of water at farm, system, and at basin level, for food security, poverty reduction, and environmental protection.

As we enter the era of globalization, we need to realize:

- Growing water scarcity and increasing competition for water among users and its usage will mean less water for irrigation in the future.
- Irrigation is becoming increasingly private through investments by farmers in pumps and tubewells and other micro irrigation technologies, leading to overexploitation of groundwater in many regions.
- The expansion of irrigation and improved cereal grain technologies coupled with government subsidies (free trade doesn't apply to agriculture) has driven down the price of cereal grains to less than half their level during most of the Cold War Era.
- Protection of the environment is a major concern and global warming is becoming a reality.

These forces are bringing about a rapid change in irrigated agriculture, calling for new ways of managing our water resources and creating new institutions. In the sections that follow, we will briefly discuss each of the four areas outlined above. Then we will examine the various practices that are being undertaken by governments and by farmers to cope with growing water scarcity and declining farm prices. Finally, we will

consider the institutional changes required to achieve more effective allocation and utilization of water resources in agriculture.

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

However, the shortage of water will be pervasive, extending well beyond the semi-arid regions and affecting populations in even well-watered areas. Increasing demand for water is draining some of the world's major rivers, leaving them dry throughout most of the year.

The rising 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 transfer of water to the non-agricultural sectors. Others argue that the potential savings from new or improved management practices is not as great as frequently assumed. The merits of this debate notwithstanding, farmers, irrigation administrators, and others are already making adjustments where water scarcity has become a reality.

Advances in Pumping Technology and the Groundwater Revolution—From Exploitation to Overexploitation

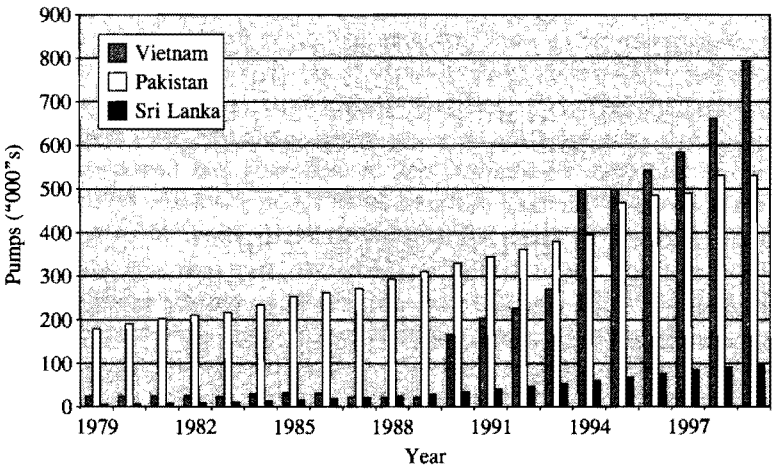
There is a tendency to associate irrigated agriculture in the developing world with canals, dams, tanks or reservoirs. In contrast, largely hidden

from view and attention, a worldwide explosion has occurred in the use of wells and pumps for irrigation—domestic as well as industrial. Pumps are being used not only for groundwater extraction but also for providing greater flexibility and reliability in delivery of surface water.

In discussing the development of groundwater, it is useful to distinguish three very different environments—(*i*) the semi-arid regions, such as Punjab and the North China Plain; (*ii*) the major river deltas, such as the Ganges-Brahmaputra, Irrawaddy, Chao Phraya, and Mekong; and (*iii*) the rest of monsoon Asia, where rice is the dominant crop in the wet season. Each environment presents very different management problems. In addition, one must distinguish between shallow alluvial aquifers, which are tapped by farmers with suction pumps and usually replenished every year, and deep aquifers where recharge is low and groundwater is being mined.

The groundwater revolution began in the 1960s in the semi-arid regions of Asia, Pakistan, Northwest India, and the North China Plain. India and China together account for over two-thirds of Asia's net irrigated area. The growth in canal irrigation slowed appreciably after 1985 but irrigated area served by wells has continued to grow quite rapidly. Figure 2.4 illustrates the steady growth in pumps for irrigation in semi-arid Pakistan (India would be similar) and the more recent growth in the use of pumps in monsoon countries such as Vietnam and Sri Lanka.

Figure 2.4
Number of Pumps in Selected Asian Countries (1979–1999)



This groundswell of pumps and wells has had a critical impact on poverty alleviation; it also modified both the patterns of water usage and the hydrological cycle. Conjunctive use was developed in large-scale surface irrigation schemes, whereby contributing to a more even overall access to water but making management more complex, and undermining collective action by fostering more individualistic strategies. Massive groundwater withdrawals have altered the hydrology of river basins (for instance, drying up of springs), jeopardized inter-generational equity (mining of main aquifers), and provoked environmental damages.

Collapse of Food Grain Prices—Nobody Makes Money Growing Rice Anymore

At least two-thirds of 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 2.1). 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 (*iii*) the continuing and increasing level of subsidies by the developed economies.

The downward drift of cereal grain prices is bringing greater pressure to bear for diversification. As previously noted, many canal systems were designed and managed as supply driven systems, which was suitable when the major objective was producing cereal grains. There is a growing incentive to invest in pumps to improve flexibility and reliability in water deliveries, or in short, obtain water on demand. Diversification is a crucial aspect of agricultural change, but it is constrained by a host of factors, ranging from soil and water suitability, skill acquisition, capital and labor constraints, risk in marketing and foremost, by the development of adequate markets. In all Asian countries, policies have been designed to foster agricultural diversification, often seen as a panacea to low staple food prices. However, they have met with mixed success and it is doubtful that diversification can be boosted much beyond the level observed, which is mainly determined by the change in consumption patterns, and by information technology that can put producers in more direct contact with export markets.

Growing Environmental Concerns

The closure of river basins, which means that less water is available for dilution and flushing of pollutants, together with the development of industries and cities, have had 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 the enacted laws to be dead letters. Agriculture is also responsible for non-point source pollution by nitrates (from nitrogen fertilizer) 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 not only the intrusion of salt water into coastal aquifers, the drying of wells and rivers, particularly in the semi-arid areas, but also land subsidence and the sinking of major cities such as Jakarta or Bangkok. One-third of Bangkok, for example, is already under sea level and the costs of flood protection and damage control are Skyrocketing.

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

The Challenges Ahead

In this section we discuss: (1) the need to increase water productivity or augment existing supplies, and (2) the need to create new institutions or reform existing institutions to facilitate integrated water resource management.

Before discussing these two areas, there is a need to clarify the confusion surrounding irrigation system performance. There is conventional wisdom held by many policymakers, academics, and others that Asian irrigation systems are poorly managed and perform very poorly. It is not uncommon to read that *irrigation efficiency*—the amount of water used by the crop divided by the amount of water diverted—is approximately 40%. But recently it has been pointed out that this measure of irrigation efficiency is extremely misleading. While taking into account return flows, there results a much higher estimate of irrigation efficiency, and leads to the conclusion that the scope for improving irrigation efficiency is much less than normally assumed (Keller and Keller, 1995; Keller et al., 1996; Seckler, 1996).

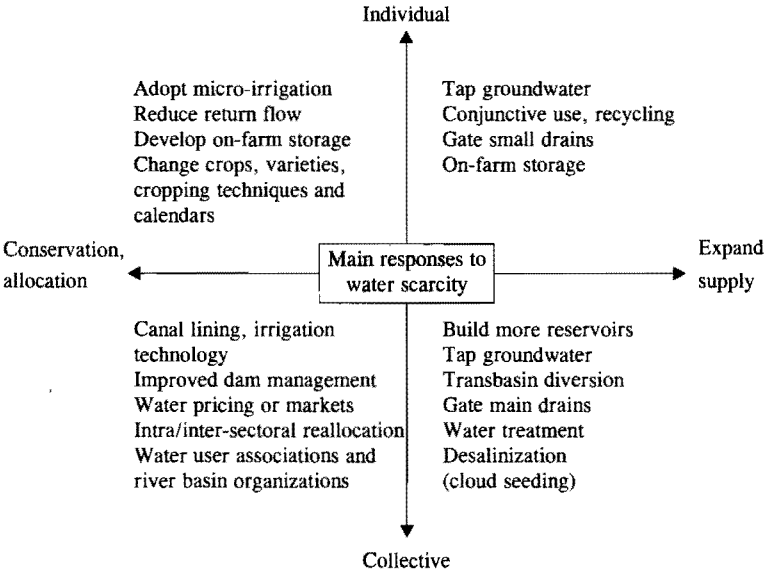
Paths to Increase Water Productivity—Stakeholder Responses

As water becomes scarce and its value rises, government agencies, communities, and farmers respond in different ways, either to conserve or reallocate water or to expand supplies. In this section, we borrow from a framework developed by Molle (2002a) to show the various individual and collective options of responding to water scarcity. We then indicate which options appear to be the more popular among farmers and among government agencies and policymakers. Also, based on existing evidence, we point out measures that appear to be achieving economic gains in water productivity.

Responses to water scarcity are extremely varied and come under three different categories: (*a*) augmentation of supply, (*b*) conservation of water, and (*c*) reallocation of water. Figure 2.5 synthesizes some of the main strategies and distinguishes between those that are implemented by individuals and those that are collective, implemented primarily by government agencies or donor-assisted projects.

There is normally little, if any, coordination or communication between farmers and government agencies. That is to say, the decisions of both groups are made quite independently. For example, most government irrigation agencies are involved in the operation of canal systems and do not have information on the number of privately operated wells and pumps, even within their own command areas. However, the response to water scarcity (whether drought or chronic shortage) tends to increase the interaction between parties and the potential benefits from collaboration.

Figure 2.5
Types of Responses to Water Scarcity



Source: Molle (2002).

Farmer/Operators' Response

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

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

Dam operators are also driven to improve their management when scarcity elicits growing scrutiny on how water releases are made. They tend to curtail releases that are not followed by some productive use downstream, although this latitude is sometimes constrained by priorities of power generation, especially in countries such as Sri Lanka where hydroelectricity still accounts for more than half of the installed capacity. The response to 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 Response

Government and multilateral lending agency interests in interventions to improve performance of irrigation systems continue, although the potential effect of these interventions on water productivity is seldom mentioned, and even less frequently measured. Figure 2.5 shows activities undertaken by agencies to save or conserve water. These include: (*a*) canal lining, (*b*) water pricing and water markets, (*c*) cost recovery, (*d*) water user associations, and (*e*) development of water-saving technologies and management practices.

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

particularly water for irrigation, there are problems with this approach (Molle, 2001; Morris, 1996; Perry et al., 1997; Smith et al., 1997; Sampath, 1992). The World Bank has recently undertaken a comprehensive study, "Guidelines for Pricing Irrigation Water based on Efficiency, Implementation, and Equity Concerns." As a part of that study, Johansson (2000) has conducted an exhaustive literature survey on pricing irrigation water. More concise treatment of the issue can be found in Tsur and Dinar (1997) and in Perry (2001). The authors emphasize the fact that water (particularly that used in irrigation) is a complicated natural resource, a complicated economic resource, and a complicated political resource. Moreover, while water *supplied* is a proper measure of service in domestic and industrial uses, much of the water supplied to a group of producers may be "lost" as runoff or seepage only to be consumed by others through recycling, and this is particularly difficult to measure. Water pricing methods are more likely to have an effect on cropping pattern (even though this is little observed in developing countries) than on water demand for a given crop (Tsur and Dinar, 1997). In fact, particularly with today's low commodity prices, the politically acceptable level of water charges is well below the point at which farmers would respond by saving water (de Fraiture and Perry, 2002; Molle, 2002b; Ray, 2002). If the objective is allocation, 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).

Cost recovery is often listed in the covenants of irrigation projects funded by the multilateral donor agencies and normally implies full or partial cost recovery of capital expenditures, plus operation and maintenance costs. Yet, Asian farmers typically do not pay enough to cover even the annual operation and maintenance costs, and governments increasingly find themselves unable to meet the costs for water-related services. The result has been a steady deterioration of irrigation systems and frequent requests by governments for rehabilitation loans that multilateral lending agencies seem all too willing to provide.

The typical project feasibility study or project appraisal report shows that all benefits go to farmers under the assumption that commodity prices remain constant. This is correct for a single project. However, over the past several decades, the multitude of irrigation projects completed throughout Asia have led to a sharp decline in cereal grain prices, with low income net consumers (and not producers) being the major beneficiaries. Furthermore, investment in irrigation has a spillover or

multiplier effect, with non-farm benefits in terms of employment generation and higher incomes being even greater than direct benefits to producers (Mellor, 2001). Thus, the benefits of capital investments in public irrigation systems have gone largely to the non-farm sector and cost recovery for major capital investments should fall mainly on revenue sources other than farmers. Farmers should be required to pay operation and maintenance fees, but it is still too often the case that irrigation agencies need these fees to sustain their activities without farmers having any sort of control on them, or on the management of water resources. Collecting fees is likely to be worthwhile only if it is a binding element of a real turnover of O&M responsibilities, in which users have control over water and over the fees collected, and pay for the local operation of the irrigation system and part of the maintenance (Small and Carruthers, 1991).

The situation for groundwater is very different. Here farmers have been willing to pay for the development of tubewells and purchase of pumps to provide reliable water supplies. However, particularly in India, the subsidization of electricity for pumping (in some states electricity is free) is encouraging the overexploitation of groundwater. A more rational pricing policy coupled with the regulation of water withdrawals is urgently needed (Shah et al., 2002).

Water user associations are seen by many social scientists as an essential element for improved performance of irrigation systems. 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, 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 of well-functioning communal systems in the command areas or neighboring regions, 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), its enlightened leadership sought to transform the bureaucracy (Korten and Siy, 1988). Taking note of the successful operation of community systems, they argued that PIM would result in better operation and maintenance, and improved performance. The program lasted for a period of more than a decade, and was supported by the Ford Foundation, USAID, and the World Bank. The objective was to transfer full responsibility for maintenance of tertiary canals, fee collection, and management responsibility to water user groups gradually, and step-wise, over a period of time. The transformation appeared to be onstream in the mid-1980s but came to nought due to change in leadership in NIA and lack of political support.

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

One should not be surprised that the hegemonic approach of the development banks met with limited success. The preconditions for 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 and/or sustainable. The well documented Gal Oya project in Sri Lanka

combined physical rehabilitation in combination with a highly successful establishment of farmer organizations, using irrigation organizers working directly with farmers (Uphoff, 1992). The results of research conducted following the rehabilitation has 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 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 scope for increasing water productivity. A distinction can be made between those measures that increase water productivity by increasing crop yield for a given evapotranspiration (ET) or diversion as opposed to reducing 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—SRI), water balance studies would determine whether increased water productivity at plant and field level translates into increased productivity at system and basin level. This is referred to as "scaling-up" from farm to system and basin level.

There is also rapid expansion of interest in management practices and technologies that can save water and increase water productivity—zero tillage, raised beds, alternate wetting and drying, aerobic rice,[1] and system of rice intensification (SRI). Field trials are being conducted in countries throughout Asia through collaborative research between national and international centers. For example, IWMI is collaborating with International Rice Research Institute (IRRI), International Maize and Wheat Improvement Center (CIMMYT), and national research centers in China and India 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 on gains in water productivity is as yet unknown.

In summary, what the above discussion reveals is that most of the public investments in irrigation and related research activities are still focused on improving the performance of canal irrigation systems. There are situations where canal lining, volumetric pricing of water, or development and/or irrigation associations are appropriate. But in most developing countries these situations are limited. To a large degree, "the generals are fighting the last war," ignoring the impacts of water

scarcity, private investments in pumps and tubewells, and declining food grain prices on irrigated agriculture and related growth of environmental problems. However, the focus is gradually shifting from the irrigation system to the river basin, and from irrigation *per se* to integrated water resource management (IWRM). This change in focus and perspective will enable us better to address the emerging problems discussed above.

Integrated Water Resource Management—The Need for New Institutions and Water Rights

We adopt the concept of IWRM cited below from Jonch-Clausen and Fugl (2001, p. 501). This definition emphasizes in particular what is being integrated:

> In the "natural system" integration typically involves land and water; surface water and ground water; water quantity and quality; and upstream-downstream water related interests including the upstream fresh-water catchments and the down-stream coastal zone. However, equally important, but less traditional, is the integration of the "human system" involving a holistic institutional approach; mainstreaming water in the national economy; cross-sectoral integration in national policy development; linkages to national security and trade regimes; and involvement of stakeholders across different management levels.

This is a broad agenda, in which integration of both the "natural" and the "human" system rests heavily on the development of institutions. In this section, we emphasize a few key points in the integration that relate specifically to our discussion of irrigation.

First, as water supplies become limited, countries need to allocate among competing uses and users. These basin-level allocations will favor water for municipal and industrial use over water for agriculture and environment.

Second, there is a need to integrate management of irrigation water at farm, system, and basin level. Are the practices at farm level consistent with basin-level water use efficiency? This question becomes critical as water becomes fully committed in a basin. That is to say, when all water resources are fully committed and no water of unusable quality is flowing to the sea.

Third, there is the clear need to integrate the management of ground and surface water irrigation. This is particularly urgent in the semi-arid regions where problems exist with both *rising water tables* leading to salinity and waterlogging and *falling water tables* leading to over-exploitation of the aquifer. In general, it is desirable to maintain the water table between the upper extreme, above which crop yields are affected, and the lower extreme, where pumping becomes excessively expensive or where there is a threat of lateral inflows from saline aquifers (Perry and Hassan, 2000). We need information on the effect of different water management practices on both water balance and salt balance, and in turn, their effect on crop yields.

Finally, the impact of irrigation, including the use of waste water on environment and health, needs to be assessed. The dislocation and environmental damage caused by large dam construction currently receives the headlines. Less publicized examples include the deterioration in the quality of drinking water caused by overexploitation of groundwater and nitrate pollution, the damage to wildlife sanctuaries and fishing grounds caused by uncontrolled drainage water, and the increasing incidents of malaria associated with irrigation development.

The discussion so far serves to emphasize the complexity of the institutions needed for IWRM. The present institutions were created in an era when water was plentiful. They deal with water resources in a fragmented manner. The state irrigation departments are not well informed on groundwater use even within their own command areas. The irrigation departments typically do not coordinate their activities with other agencies to manage effects of irrigation development and management, including damage to the environment and threats to human health. The Asian Development Bank is actively supporting initiatives by some governments to develop water resource boards and related organizations that will coordinate the planning for water use and management of water resources at national and at river basin levels.

The starting point in institutional reform must be the definition and security of water entitlements, or "rights". Water rights are needed to determine the allocation and access among users and uses at the system, farm, and village level. There is often reference to the strictly defined and enforced system of water rights in developed countries such as the United States (Perry et al., 1997), but the Asian context of numerous small holders and the predominance of rice cultivation make it difficult to envisage a definition of individual rights. Rather, it seems more

appropriate to pave the way for a definition of bulk entitlements that would specify how much water goes to groups of users (such as in Turkey or Mexico). The crux of the matter is to establish a basin-level mode of water management where seasonal water entitlements are defined in a multi-leveled process, down to the bulk allocation to groups of users under a main or secondary canal, with the involvement of users' representatives. While such an arrangement may seem a matter of goodwill, it has in reality far-reaching and multi-faceted implications that include (see Molle, 2002; this volume): (*a*) the need to register users and control free-riders; (*b*) the technical capacity to deliver the agreed-upon discharges at different points in the network; (*c*) the establishment of a process of collective decision making where groups of users are federated in higher hierarchical levels, with corresponding representatives; (*d*) the definition of a "partnership" between users and irrigation officials, where a service fee contributes to payment of field staffs; (*e*) a legal framework to support this new institutional setting; and (*f*) a strong commitment from the administration, and from politicians. Up to now, such overall reforms have not been successful, as line agencies have generally retained their power and not effectively embraced the rhetoric of decentralization. Water laws have remained, enabling legislations 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 ridden with political intervention.

Irrigation and Agrarian Change

The future of irrigation in Asia is tightly linked with agrarian change—itself a reflection of wider transformations of national and world economies—and cannot be considered in isolation. The pressure on land/water resources, the man/land ratio and the per capita farm income are strongly linked to demographic evolutions. One of the most significant changes in the last three decades is the demographic transition observed in many countries. Thailand's fertility rate, for example, has shifted from 5.6 in 1970 to 1.7 in 2000! The mobility of labor is high with migrations tending to remove people from the countryside, irrespective of whether it is a pull or push process. In the ten years preceding the 1997 economic crisis, the labor force engaged in agriculture in the central region of Thailand dwindled from 3.5 to 2.5 million. This shift

concerned the age group under 35 and all socioeconomic strata, since investment in the education of children also often motivates movement to cities.

In addition to inter-sectoral mobility, rural household economies have also become more composite, and pluri-activity within the family and at an individual level has emerged as a general phenomena. Farmers are responding to new opportunities (see Preston's [1989] study on central Java "Too busy to farm"), and in many rural areas of Asia the household income from agriculture is now lower than that coming from non-agricultural occupations (Rigg, 1996; Estudillo and Otsuka, 1989).

As emphasized by Rigg (1996, p. 20),

> [T]he 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 labour 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 "

This emphasizes that the evolution of irrigation, as well as of agriculture, cannot be considered independently of changes occurring in the wider economy. The management of water resources, and of irrigation in particular, will also be shaped by ongoing political processes of democratization, which constantly redefine the relationships between the state and the citizenry and have a bearing on the conditions of access to resources.

Conclusions

In this chapter we have traced the evolution of irrigation in South and Southeast Asia by identifying three separate geo-political time periods:

the Colonial Era from 1850 to 1940, the Cold War Era from 1950 to 1989, and the new Era of Globalization from 1990 onward. The development of irrigation, whether by colonial administrations, or more recently national governments and lending agencies, has been pursued with a fairly common set of goals, with the emphasis varying between *social* objectives—poverty alleviation, food security, protection of the environment, and *economic* objectives—increased tax revenues, growth in value of agricultural output. The theme of conflict also runs through the entire time period: conflict in the goals of equity and productivity; conflict among professionals as to whether to design for protective or productive, supply or demand-driven irrigation; conflict between irrigation bureaucracies and local administrations in the management of systems. Throughout the entire period, however, farmers have had very little say in the design and management of public irrigation systems.

Against this background, the rapid development of irrigated agriculture has helped to foster extraordinary growth and change the face of rural economies of Asia. The development of irrigated agriculture and of the economies as a whole reflect the dynamic interaction between resources, technology, institutions, and culture. Land and water, once abundant, have become scarce. During the Cold War period, surface and groundwater technologies had been developed to facilitate the expansion of irrigated area and increase in crop yields. But the success of these endeavors has brought in 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 toward 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 the new era of globalization, farmers and systems operators have adjusted to the challenges posed by growing water scarcity, exploiting of 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 in semi-arid 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 (IMT). We argue that these efforts have not been very successful in the past and are likely to be even less so in the future, given not only the growing importance of groundwater but also the social and economic changes occurring in the rural communities of Asia. Reforms have failed because they have remained partial, with optimistic assumptions about the willingness or capacity of local bureaucracies to carry out the necessary changes.

There has been a serious lag in the implementation of appropriate institutions to deal with the new environment of water scarcity. The challenge ahead lies in reforming existing institutions, or in some cases, creating new institutions that can: (*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 ground and surface water irrigation; and (*iv*) address the problems of irrigation development, including use of waste water, in environment and health.

This agenda represents an important component of integrated water resource management (IWRM). The allocation and access to water among competing users and uses at the basin, system, village, and farm level must be defined through a negotiated and formalized process that leads to the definition of entitlements. The growing importance of common-pool groundwater resources adds greatly to the complexity of that problem. The task is monumental. It is likely to take years, perhaps even decades, to establish enforceable water rights and a complementary set of institutions associated with IWRM.

NOTE

1. Rice grown under non-puddled soils.

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