Trends and Drivers of Asian Irrigation
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Table of Contents

Introduction .......................................................................................................................... 1
Trends in Asian irrigation ......................................................................................................... 1
  Asia has had a long tradition of irrigated agriculture ......................................................... 2
  Irrigated land has expanded rapidly since the 1960s ......................................................... 3
  Expansion in irrigation boosted rural growth and reduced poverty, though with certain environmental costs .................................................................................................................. 5
Area under groundwater irrigation has been booming since 1980s .................................... 6
Public vs. private investments in irrigation .......................................................................... 7
Drivers of change in Asian irrigation .................................................................................... 9
  Demography, urbanization and changes in dietary preferences ........................................ 10
  Diversification of agriculture and competing demands from other sectors .................... 12
  Food prices, national food and energy policies and international trade regimes ............. 13
Emerging challenges and opportunities for change ............................................................ 15
  Climate change and variability ......................................................................................... 15
  Renewed concern for food security in the context of economic crisis ............................. 16
Conclusion .......................................................................................................................... 17
References ............................................................................................................................ 20

List of Tables

Table 1 Asia has by far the largest area of irrigated land of any continent ............................. 3
Table 2 Evolution of public irrigation thinking since the 1960s ............................................ 10
Table 3 Relative importance of different drivers of change in Asian irrigation .................. 18
Table 4 Level of agricultural development and I&D sector strategy .................................... 19

List of Figures

Figure 1. Irrigation, water use and poverty in various countries of Asia ............................... 2
Figure 2 Changes in irrigated area in Asia, 1961-2003 Source: Food and Agricultural Organization (2006) .................................................................................................................... 3
Figure 3 Food production, net and gross irrigated area in India, 1951 to 2008 .................... 4
Figure 4 Area under irrigation and food production in China, 1949-2007 ........................ 4
Figure 5 Physical and economic water scarcity ................................................................... 5
Figure 6 Irrigated area in India by source, 1951-2007 ........................................................ 6
Figure 7 Atomistic irrigation has boomed across large parts of Asia ................................ 7
Figure 8 Public spending in surface irrigation in Sri Lanka ................................................ 8
Figure 9 Investment in irrigation and change in irrigated area and food price index ............ 9
Figure 10 Population growth rates have slowed down in Asia yet populations will continue grow in the near future ........................................................................................................ 10
Figure 11 Agricultural GDPs are declining across Asia ..................................................... 11
Figure 12 Per capita meat supply versus income in India (pink), China (green) and USA (black) over the period 1961-2003 ........................................................................................................ 12
Figure 13 Per capita milk supply versus income in India (pink), China (green) and USA (black) over the period 1961-2003 ........................................................................................................ 12
Figure 14 Area harvested (index number, 1990=100) of different crops in China, 1995-2003 .......................................................................................................................... 13
Figure 15 Food price index .................................................................................................. 14
Figure 16 Trends in biofuels production ............................................................................. 15
Figure 17 Changes in runoff based on IPCC Scenario A1, 2050 compared with 1961-1990 average ....................................................................................................................... 16
Figure 18 Many countries are acquiring rights to land abroad to secure food for their people .................................................. 17
Introduction

In the 1960s, it was feared that much of Asia was in imminent danger of falling into the Malthusian trap of high population growth and low agricultural productivities resulting in widespread food crisis and famines. The food crisis in India in the mid-1960s was a grim reminder of a catastrophe about to be unleashed elsewhere in Asia. However, belying such doomsday predictions of starvation and deaths, most Asian countries emerged as food self sufficient through the 1970s and the 1980s. Asian economies avoided the Malthusian tragedy by embarking upon a Boserupian path of agricultural intensification. The use of high yielding varieties of seeds, high doses of fertilizers and other complimentary inputs such as timely and adequate irrigation came to be known as the Green Revolution. In South Asia, cereal production rose by 137% from 1970 to 2007, using only 3% additional land (FAO, 2009a) and boosted per capita food supply from 2,105 to 2,361 calories per day (Rosegrant & Hazell, 2000).

Irrigation contributed in a number of ways. It enabled farmers to increase yields and cropping intensity, stabilise production by buffering against the vagaries of weather, and generated employment in rural areas. Irrigated areas accounted for only 34 per cent of the arable land yet produced 60 per cent of the total food grains in Asia (FAO, 2009b). Irrigated agriculture was also key to alleviating poverty. In India, poverty incidence reduced from 44.5% in 1983 to 27.5% in 2004-05 (Bardhan 2007). Rural poverty in intensively irrigated areas, such as the states of Punjab and Haryana in India, became much lower than in predominantly rain-fed states, such as Orissa and Madhya Pradesh. In East and South East Asia, gains were even more impressive where agricultural productivities more than tripled and rural poverty declined rapidly. In China, poverty incidence reduced from 33% to 3% between 1979 and 2001(Gulati et al. 2005). The recent World Development Report (2008) points out that agricultural growth is more effective in alleviating poverty than overall GDP growth outside agriculture and that high agricultural growth rate is often positively associated with irrigation development.

While massive gains have been made in terms of increased agricultural production, alleviation of poverty thereby averting the dangers of famine and starvation, there is hardly any room for complacency. The Green Revolution, while solving a number of pressing issues had brought about what may be called second generation problems such as loss of soil fertility due to mono cropping, high input use leading to pollution of soil and water bodies, pest resistance, loss of bio-diversity and stress on natural resources. Total factor productivity has been growing at a slower pace than before in most Asian countries. In the meanwhile, population in Asia continues to grow, albeit at a slower pace. Asian economies also continue to diversify and integrate better with the global economy, thereby opening it up both to the opportunities and threats inherent in globalization. Similarly, Asia is becoming increasingly urbanized, and people’s aspirations and diets are changing. Yet Asia remains the home to the largest number of absolute poor. Climate change poses particular challenge to poorer economies in Asia and would manifest itself through higher variability in temperature and rainfall, thereby directly affecting the agriculture sector.

Asia accounts for 70 percent of the world’s irrigated land. This report analyses the past and current trends in Asian irrigation and looks at the drivers of such trends. This is the 1st part of the 4 part Background Paper on Asian Irrigation commissioned by the Asian Development Bank.

Trends in Asian irrigation

The climates, economies, politics and stages of development of Asian countries differ greatly. Climates range from arid and semi-arid to monsoonal. Some economies are predominately agricultural while others have become industrialised. There are developing and developing nations, as well as those with economies in transition. Governing processes range from multi-party democracies to centralized authorities. Meanwhile, Asian nations exhibit vastly differing levels of poverty, child mortality and nutrition. This analysis divides the continent into four units: South Asia, Southeast Asia, East Asia and Central Asia. Figure 1 show how the area of irrigated lands, annual average water withdrawals and levels of poverty vary. In absolute numbers, South Asia (India, Pakistan, Bangladesh, Nepal, Bhutan, Sri Lanka, Maldives and

1 Food and Agriculture Organization, Rome, Italy
2 International Water Management Institute, Colombo, Sri Lanka
Afghanistan) is responsible for the largest amount of irrigated land and water withdrawals, followed by East Asia (China, Japan, Mongolia, North and South Korea), Southeast Asia (Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Thailand and Vietnam) and Central Asia (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan). In percentage terms, Central Asia is the most intensively irrigated part of Asia.

Figure 1. Irrigation, water use and poverty in various countries of Asia

(Source: FAO, 2009c)

Asia has had a long tradition of irrigated agriculture

The tradition of irrigated agriculture in Asia goes back to the millennia when the continent supported some of the largest irrigation schemes (for example the hydraulic civilization of Sri Lanka and tank irrigation schemes in India) lending support to Wittfogel’s (1957) famous and now somewhat discredited thesis of oriental despotism. Ibn Batutah, a 13th century traveler found irrigation from open dug wells (bawli) to be common in India. In modern times, the colonial powers embarked on creation of large scale water infrastructure, the pioneer being irrigation engineers like Sir Arthur Cotton who are, till this day revered by villages in Southern India. Irrigation and wealth generated thereof, were important sources of revenue for the colonial governments (Shah, 2008). Creation of irrigation potential remained a priority in independent post colonial Asian countries where irrigation was often seen as a pathway out of poverty and hunger. Historically, irrigation has played an important role in the continent and it continues to be so now. At present, Asia accounts for more than 70% of the world irrigated area (Table 1) and roughly 2/3rd of this area is devoted to staple crop of rice and to a lesser extent wheat (Molden, 2007).
Table 1 Asia has by far the largest area of irrigated land of any continent

| Area equipped for irrigation and the percentage of cultivated land it represents |
|---------------------------------|-----------------|-----------------|-----------------|--------|--------|--------|
| Year                            | Area irrigated (million hectares) | Area irrigated as % of cultivated land |
| World                           | 193.0 | 224.2 | 277.1 | 15.8 | 17.3 | 17.9 |
| Africa                          | 9.5  | 11.2  | 13.4  | 5.1  | 5.7  | 5.9  |
| Asia                            | 132.4 | 155.0 | 193.9 | 28.9 | 30.5 | 34.0 |
| Latin America                   | 12.7 | 15.5  | 17.3  | 9.4  | 10.9 | 11.1 |
| Caribbean                       | 1.1  | 1.3   | 1.3   | 16.4 | 17.9 | 18.2 |
| North America                   | 21.2 | 21.6  | 23.2  | 8.6  | 8.8  | 9.9 |
| Caribbean                       | 1.7  | 2.1   | 2.8   | 3.4  | 4.0  | 5.4 |
| Europe                          | 14.5 | 17.4  | 25.2  | 10.3 | 12.6 | 8.4 |


Irrigated land has expanded rapidly since the 1960s

Asia registered rapid increase in irrigated area for the last fifty years through the construction of dams and storage structures (from 1950s to 1970s) and then from increasing abstraction of groundwater resources. Between 1961 and 2003, the area of irrigated land in Asia more than doubled, with an average annual growth rate of 2.6 per cent. In 2003, South Asia accounted for the bulk of irrigated land (82.4mha) followed by East Asia (59.6mha), Southeast Asia (16.7mha) and Central Asia (10.1mha) (see Figure 2). India and China accounted for the bulk of irrigated area in Asia. In 2005-06, India’s net irrigated area was 60.2 million hectares and gross irrigated area was 82.6 million ha (Ministry of Agriculture, Government of India, 2007). In China, some 58.0 million ha was irrigated in 2007, up from mere 14.0 million ha in 1949 (Li, 2009). Expansion in irrigated area kept pace with growth in population and enabled most Asian countries, including India and China to expand their food production (see Fig. 3 and 4).

Figure 2 Changes in irrigated area in Asia, 1961-2003 Source: Food and Agricultural Organization (2006)

Figure 3  Food production, net and gross irrigated area in India, 1951 to 2008

Source: Ministry of Agriculture, Government of India, various years

Figure 4 Area under irrigation and food production in China, 1949-2007

Source: Li, 2009
Expansion in irrigation boosted rural growth and reduced poverty, though with certain environmental costs

Following the Green Revolution, most Asian economies emerged as food self-sufficient in the 1970s and 1980s. The large-scale irrigation projects developed during this period, which were frequently linked with land reform and settlement programmes, played a key role in increasing productivity, raising the volume of crops produced (through higher productivity and cropping intensity) and reducing poverty. In East and Southeast Asia, agricultural productivity more than tripled, and rural poverty decreased rapidly. The World Development Report 2008 states that agricultural growth is more effective at alleviating poverty than overall GDP growth outside farming, and that high agricultural growth rates are often positively associated with irrigation. A study conducted by IWMI in 2007 found the incidence of poverty in irrigated areas to be half as much as that in non-irrigated areas.

While large gains have been made in terms of increasing agricultural productivity and reducing poverty, these have come at a cost to the environment. Negative impacts of the Green Revolution include loss of soil fertility due to mono-cropping, pollution of water bodies and soils from fertilizers, and resistance of insects to pesticides. Improperly designed irrigation schemes caused salinization and water-logging in some places and declining groundwater levels in others. Irrigation introduced in upstream locations often affected downstream biodiversity, particularly natural fisheries.

While irrigation has been central to the agricultural economies of Asia and has contributed greatly to socio-economic development in the region, the sector is under serious threat. For one, more and more countries of Asia face the threat of physical water scarcity and those who do not, are crippled by economic scarcity of water\(^3\) (Fig. 5). Problems with irrigation projects started right from the late 1960s (UNESCO-WWAP, 2006) but they have exacerbated in recent times. Surface irrigation infrastructure has deteriorated due to lack of maintenance, inadequate cost recovery, and financial and managerial problems.

\*Figure 5  Physical and economic water scarcity

\*Source: Comprehensive Assessment of Water Management in Agriculture, 2007

\(^{3}\) Physical water scarcity occurs when water resources are overcommitted to various users, due to overdevelopment of hydraulic infrastructure, most often for irrigation\(^{3}\) (Molden et al. 2007), while economic scarcity is defined as limited access to water because of the high costs involved and may occur with or without physical water scarcity.
Area under groundwater irrigation has been booming since 1980s

During recent decades, surface irrigation is in decline in many parts of Asia. Public irrigation systems have tended to be underutilized and over-capitalized, and typically serve only a fraction of the designed command. With aging, irrigation commands have been sinking under the weight of their managerial, economic and environmental problems. Increasingly, farmers in South Asia, north China and to some extent in South East Asia are turning to groundwater or surface water based lift irrigation which gives them a greater control over use of water. While some of this use is of conjunctive nature (e.g. in Pakistan Punjab), in South Asia, especially in India and Bangladesh, use of groundwater outside the canal command area is far more pervasive than its use within the command area showing groundwater is often the only source of irrigation in such regions. For almost two decades now, area under groundwater irrigation has been growing relatively faster than area under surface water irrigation, but in recent years, there has been even an absolute decline in surface irrigated area in the country (Fig. 5), giving rise to concern about long term viability of surface irrigation schemes (Shah, 2008).

Shrinking of surface irrigation does not mean irrigation areas of Asia are declining overall. In fact, they are not (Figure 2, 3, 4 and 5). Old community and government-managed systems are rapidly giving way to a new atomistic mode of irrigation in which millions of small-holders are creating their own mini irrigation systems and scavenge water at will using a mechanical pump, a well and rubber/PVC pipes. The rise of this new water-scavenging irrigation economy is most visible in South Asia and North China plains; here pump irrigation has begun dominating not only dry-land areas but also irrigated areas where public and community irrigation ruled the roost until around 1960’s. In India, for example, even as governments keep investing in large, centrally managed surface irrigation projects, over 60% of irrigated areas today are under atomistic pump irrigation (Fig. 6). Farmers in India, Pakistan, Bangladesh and Nepal have created more irrigation under this atomistic mode in the past 30 years than governments and colonial powers created in 200 years before. During the 1950s and 60s, Mao’s China built massive irrigation systems to water North China plains; but today, the region irrigates mostly with small pumps and boreholes. In Sri Lanka, known for its centuries-old tank irrigation of rice paddies, farmers were unfamiliar with irrigation pumps until the 1980s but were using some 106,000 by 2000 to scavenge water from whatever source — wells, tanks, streams—to irrigate dry-season rice and vegetables.

Figure 6  Irrigated area in India by source, 1951-2007

The same trend is now also evident in rice economies of South East Asia, for long home to gravity flow irrigation communities. By 1999, Vietnamese farmers had pressed in to service more than 800,000 diesel pumps; and in Thailand, farmers increased their pumps from 500,000 in 1985 to more than 3 million in 1999. And the trend was just picking up; Molle (??) found that between 1995 and 1999 alone, Vietnamese
farmers purchased 300,000 irrigation pumps, and Thai farmers added a million. Between 1998 and 2002, Indonesian farmers increased their pumps from 1.17 million to 2.17 million. In the Philippines, Dawe (??) noted that “approximately 23 percent of rice farms now use pumps to access water, either from sub-soil reservoirs, drainage canals, or natural creeks and rivers.” In the Chao Phraya delta of Thailand, 80 percent of farmers were said to have at least one pump, and in Thailand’s Mae Klong project, the World Bank estimated that in the early 1990s, a million pumps were drawing water from canals, drains, ditches, and ponds to irrigate dry-season crops. Regarding the Makhmato-Uthong canal system in Chao Phraya, Facon (??) wrote, “Use of groundwater for irrigation has exploded during the last five years. It is reported that 28,000 tubewells are in use in the region ... All the farmers interviewed during the field visit reported having individual pumping equipment used to pump from any possible source of water.” Figure 7 shows the spread of so called atomistic irrigation in Asia.

Figure 7  Atomistic irrigation has boomed across large parts of Asia

Groundwater boom, while bestowing a large number of benefits, have created its own set of intractable problems in terms of over-exploitation and depletion of groundwater resources in some pockets of Asia (north western and peninsular India and Pakistan) thereby putting in jeopardy the livelihoods of millions of farmers who depend on it. At the same time, there are regions within Asia where groundwater has huge unutilized potential such as in eastern parts of Indo-Gangetic basin, Southeast Asia and Central Asia. In Central Asia, contrary to what has been happening in the rest of Asia, usage of groundwater has declined since the disintegration of Soviet Union and this in turn has created a number of problems such as water logging and soil salinization (Rakhimov, 2005). Here, water management problems have been further complicated by transboundary nature of water resources since the independence of the Central Asian Republics.

This drastic shift in irrigation from being a largely government controlled centralized system to private controlled atomistic one has important implication for the way irrigation would have to managed in the future – an implication that is hardly well appreciated by the governments and donor agencies steeped in the culture of large infrastructure based irrigation development.

Public vs. private investments in irrigation

Related to the changing composition in the irrigation sector is the pattern of investment. Investments in large scale public irrigation infrastructure, mostly in the form of surface water structures and canals
peaked around early 1970s to mid-1980s in response to steep increase in food prices in 1970-73. Early irrigation investment projects were justified on grounds of social welfare as much as they on grounds of financial cost benefit analysis and this had implications on the way water charges were determined and levied. Much of the irrigation investments came from the national governments with additional support from the international lending agencies such as the World Bank and Asian Development Bank. For instance, in India, during the 1st Five Year Plan (1951-56), a total of INR 4.4 million (at current prices) was invested for irrigation, of which 85% went to creation of major and medium sized irrigation infrastructure and the rest to creation of minor (mostly public tubewells and river lift irrigation) infrastructure. At that time, only 15% of India’s net irrigated area was irrigated by groundwater. Come 2002, and the at end of the Ninth Five Year Plan, India’s irrigation investment had gone upto Rs. 58 million, of which again 85% (INR 48.3 million) was for creation and maintenance of large and medium scale surface water based irrigation systems. However, by 2002, groundwater provided irrigation on 53% (27.5 m ha out of 51.2 m ha, see Fig. 5) and yet, government spending on minor irrigation remained stagnant in percentage terms. It is therefore evident that most of the groundwater irrigation infrastructure was created through private investment of millions of farmers scattered throughout the length and breadth of the country. It is indeed estimated that private investment in groundwater irrigation might as well have equaled public investment in major and medium irrigation projects (Shah et al. 2005).

Even poorer countries like the Lao PDR in South East Asia have made substantial investments in irrigation. According to UNEP (2001), the government in Laos has invested upto USD 47 million (~40 billion kips) and created 3306 irrigation schemes of which 64% are pump irrigation based schemes. As a result, the country was able to achieve self sufficiency in rice production by producing over 2 million tons of rice by 1999. In Sri Lanka too, national government has invested massively in creation and maintenance of irrigation infrastructure (fig. 8).

International lending agencies have for a long time been source of finance for irrigation infrastructure in Asia. For example, Asia has been the chief recipient of such World Bank lending, receiving 70 percent of the total. India alone accounts for 27 percent of all irrigation borrowing (Campbell, 1995). What is to be noted in figure 8 is that, though World Bank investments in irrigation slowed down after 1980s, area under irrigation kept rising, showing that much of the new investments were either by the national governments (as in Sri Lanka, Fig. 8) or by private individuals as was the case of groundwater irrigation in South Asia.

Figure 8 Public spending in surface irrigation in Sri Lanka

Source: Kikuchi et al. 1995
Drivers of change in Asian irrigation

Globalization, urbanization, climate change, competing demands for water, changing aspirations, renewed emphasis on environmental water needs and the need to keep feeding millions of people in Asia continue to offer great challenges to the irrigation and drainage sector in Asia. The Asian countries and regions differ greatly from one another in terms of climate (arid vs. semi arid vs. monsoonal climate), economy (agricultural vs. industrialized; developed vs. developing vs. economies in transition), politics and mode of decision making (multi party democracy vs. centralized system), development outcomes (poverty, child mortality, nutrition etc.).

There are numerous factors that have driven irrigation related developments in Asia. These range from demographics to changing diets to international food prices. Most often, drivers of change in the irrigation sector lie in the broader political economy and changes in developmental thinking. In agricultural water specifically, new paradigms call for considering agricultural water management within a basin context, the inclusion of rainfed agriculture in water discussions (blue and green water), more integration across sectors, appropriate roles for public and private sectors, the inclusion of fish and livestock in water and food debates. Good practice recommendations in agriculture also increasingly are more ecosystem sensitive, calling for recognition, for example, of the importance of watershed protection, environmental flows and sustainable management of aquatic ecosystems, springs and aquifers. The extent to which this paradigm has been put into practice may be questioned, but at a minimum it has impacted the availability of irrigation financing, most prominently from international lenders. Table 2 captures the evolution of public irrigation policies and drivers and is based on Barker and Molle, 2004.
Table 2  Evolution of public irrigation thinking since the 1960s

<table>
<thead>
<tr>
<th>Context</th>
<th>1960s to 1980s</th>
<th>1990s to present</th>
</tr>
</thead>
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<tr>
<td>Goals and drivers</td>
<td>Food security</td>
<td>Livelihoods, sustainability</td>
</tr>
<tr>
<td>Resources: land, water and labour</td>
<td>Abundant</td>
<td>Increased scarcity</td>
</tr>
<tr>
<td>Hydraulic development stages</td>
<td>Construction, utilization</td>
<td>Utilization, allocation and new investments</td>
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<td></td>
<td></td>
<td>in infrastructure development</td>
</tr>
<tr>
<td>Dominant expertise</td>
<td>Hydraulic engineering, agronomy</td>
<td>Multidisciplinary, sociology, economics</td>
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<td>Irrigation governance</td>
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<td>Mixed</td>
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<tr>
<td>Irrigation technology</td>
<td>Surface gravity flow</td>
<td>Groundwater, conjunctive, lift based</td>
</tr>
<tr>
<td>System management</td>
<td>Supply driven</td>
<td>Farmers demand oriented</td>
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<tr>
<td>Crops</td>
<td>Cereals and cotton</td>
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<td>Cropping intensity</td>
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</tr>
<tr>
<td>Value of water</td>
<td>Low</td>
<td>Increasing</td>
</tr>
<tr>
<td>Concern for environment</td>
<td>Low</td>
<td>Increasing</td>
</tr>
</tbody>
</table>

Source: Adapted from Barker and Molle, 2004

Demography, urbanization and changes in dietary preferences

Despite the expansion of agricultural and irrigated lands, per capita land availability in Asia (0.16 ha of person) is lower than world average (0.26 ha per person) (World Resources Institute 2001). Urbanization, industrialization and land degradation means that scope for expansion in agricultural area is limited. Even if the absolute area under cultivation remains unchanged, and population growth rates declined as it is now (Fig. 10), total population in Asia will continue to increase reducing the amount of arable land available per person. Similarly, water resources will become scarcer in the future (Fig. 5).

Figure 10  Population growth rates have slowed down in Asia yet populations will continue grow in the near future

Source: FAO

In all regions of Asia, the contribution of value added agriculture to GDP is showing a downward trend (Fig. 11). Declining contribution of agricultural GDP often makes it harder to justify new irrigation schemes. At the same time, increasing contribution of other sectors mean that farmers have newer exit options from agricultural livelihoods, option that they did not have 20 to 30 years ago. In relatively developed countries like Malaysia, exit from farming is leading to corporatization of agriculture and land consolidation, while
in some of the poorer countries like Bangladesh; land fragmentation is on the rise and exit options still limited.

Figure 11 Agricultural GDPs are declining across Asia

![Graph showing agricultural GDPs declining across Asia](image)

Source: FAO, 2007 (Y axis shows share of agricultural GDP to total GDP)

Asia is going through a demographic transition manifested through rapid urbanization and a phenomenon dubbed as “new rurality” by Rauch (2007). By 2025, 52 percent of the population in East Asia, 53 percent in Southeast Asia and 45 percent in South and Central Asia is projected to be urban. Asia’s rural population is also growing and is predicted to grow, although at a slower rate. ‘New rurality’ manifested through better integration with national and international markets offer both an opportunity and threat to farmers. For one, for the first time in several centuries, farmers in Asia have real opportunity of exiting agricultural sector for better paying jobs and those who are left behind can earn higher incomes through cultivation of ‘niche crops’. Rural livelihoods are becoming increasingly diversified, mobile and multilocal (Faurès and Santini 2008) and hence irrigation interventions need enough flexibility to cater to these changing realities.

A growing, wealthier and urbanized population requires more food per person and a rich and varied diet (Molden et al. 2007). In Asia, beside the rising per capita consumption, which is expected to level off by 2030, dietary changes are reflected by a move away from cereal crops to fruits, vegetables milk and animal protein (Fig. 12 and 13). In China over the last 20 years, meat consumption has more than doubled and it is projected to double again by 2030. Increasing consumption of fruits and vegetables means increasing production of the same and these have different irrigation requirements than cereal crops.
Diversification of agriculture and competing demands from other sectors

While Asian agriculture feel the pressure of both land and water scarcity, what compounds the problem is that productivity gains attained during the early years of Green Revolution are leveling off, creating concerns that unless land and water resources are managed better, producing enough food to feed the increasing number of people may emerge as a challenge. Increase in food demand and a diversification in diets by a rapidly growing urban population bring pressures for a change in domestic agricultural systems from traditional subsistence production to diversified production including livestock and biofuels. In China, for instance, both area and production of fruits and vegetables has been increasing steadily, often at the cost of staple crops like rice (Fig. 14).

In Asia, as in other parts of the world, agriculture still remains the main consumer of water, though demands from other sectors are on the rise, especially in China. In Central Asia the share of agriculture in water use has increased since the early 80’s. The increase is most probably due to a combination of factors, such as use of degraded infrastructure that results in high water losses and inefficient management. According to a large number of predictions, including IWMI’s Comprehensive Assessment and IPCC, in the 21st century water is going to be a scarce commodity in much of Asia. This implies that food security for a growing population must be achieved using less water for agriculture and this will entail better management of both rainfed and irrigated agriculture.
Poorly conceived irrigation infrastructure and management has caused adverse changes in the quality and quantity of water in inland and coastal aquatic and terrestrial ecosystems. Today, excessive withdrawal of water is greatly impacting many of the major river basins of Asia, including the Yellow River, the Aral Sea tributaries and the Ganges and Indus rivers suggesting that the minimum flows that are required for ecosystem health have been over-appropriated (Falkenmark 2007). Due to unsustainable groundwater use in the pump-intensive areas of India and China, water tables are falling at a rate of 1-3 m/year in some pockets.

**Food prices, national food and energy policies and international trade regimes**

Since mid 1970s cereal prices have been going down in real terms (see Fig. 8). The reasons for this were unprecedented increase in grain production as a result of the expansion of irrigated areas; the decline in demand of cereal grains as incomes rose and diets changed; and to a large extent, subsidies provided by developed economies. Since then, consumers, including millions of poor rural households, enjoyed relatively low staple food prices. That declining trend was reversed by a sudden and dramatic increase in world food prices in 2007-2008 causing wide spread panic. The increase is attributed factors such as the declining dollar, rising energy prices, an increase in biofuel production, increased demand for wheat, meat, milk, oil, food and vegetable produce and an underinvestment in research and technology and rural infrastructure, especially irrigation (IFPRI, 2008). However, this spike was short lived and prices of food grains fell below 2007 prices (Fig. 12). Nonetheless, it is widely believed that there will be an upward shift in the food prices in the long run (IFPRI, 2008; USDA 2009). In parts of Asia where input and output markets are not overtly controlled (China, India, SE Asia), farmers react quickly to price signals, while in state controlled farming as in most Central Asian Republics, farmers rarely benefit from price signals in the international markets. It is still too early to understand how the current food crisis will impact on future food production and prices, but the crisis has prompted renewed interest in the concept of national food self-sufficiency, and concern among decision makers about ways to secure food supply at national level. Hence, there is renewed interest among decision makers and donors in infrastructure investment in recent years.
Energy and food policies are closely interlinked. Energy prices affect agricultural production in two ways, one, by increasing the costs of inputs (e.g. fertilizer, pumping costs if using diesel pumps etc.) and also the cost of transportation of agricultural produce to the market. In conjunction with low food prices, high energy prices often squeeze farmers farm gate profits (Mukherji, 2007).

In recent times, high fossil fuel prices have started impacting agricultural production in a third and perhaps more important way than ever, through demand for bio fuels (Fig. 13). For instance, the USA, one of the largest producers of corn, has diverted substantial quantities of corn to bio-fuel production. In Asia, sugarcane is seen as a viable crop for producing bio-ethanol, but this might have livelihoods implications as sugarcane is a land intensive and labor extensive crop, not particularly suited to regions with surplus labor. Food polices, especially national food pricing and subsidy policies affect cropping decisions by distorting incentive structure. An apt example of such distortion is the water intensive rice-wheat cropping pattern in water scarce Pakistan and Indian Punjab.

Growing population pressure, volatility of food prices in the international markets, political exigencies and past bitter experiences of importing food from other countries makes food self sufficiency a desired goal in many countries of Asia and this has consequences for the irrigation sector. India, for example, in order to achieve its stated goal of food self sufficiency, ended up with huge surpluses in 2003-04 and once it offloaded its surplus in the world markets, prices slumped in response. Further down the line, when world prices shot up in 2007 or so, India’s reserve had considerably dwindled.
Multilateral trade agreements (WTO) have potentially profound influence on agricultural production in developing countries. Most Asian countries, including India and China have taken cautious steps towards liberalization of agricultural trade (UNESCAP 2008). However, in the future, chances are barriers to trade would have to eased, both by the developed as well as the developing countries and this would certainly drive changes in the agricultural sector.

Dismantling of the former Soviet Union in 1991 was an important driver of change in irrigation in Central Asia. In the landlocked Central Asian region endowed with arid and semi-arid climates, where much of the countries’ agricultural lands are located, the Soviet Union developed one of the largest irrigation systems in the world. Today, approximately 22 million people depend, directly or indirectly, on irrigated agriculture (Bucknall et al. 2003). Due to the neglect of infrastructure by the independent governments in the post Soviet era irrigation infrastructure has greatly deteriorated.

**Emerging challenges and opportunities for change**

Asian irrigation is in a transition and needs to respond to new sets of challenges such as globalization, climate change, changing aspirations and diets and changes in the larger political economy (Shivakoti et al. 2005). Globally there are sufficient land and water resources to produce food for a growing population over the next 50 years and this holds true for Asia as well provided rapid productivity gains can be made in the coming few decades. But it is probable that today’s food production and environmental trends, if continued, will lead to crises in many parts of the world, including Asia.

**Climate change and variability**

Potentially, the greatest environmental threat is climate change. Asia’s climate patterns are already changing; the frequency of extreme events associated with El Niño has increased in Southeast Asia, the monsoon has become more variable in South Asia and the number of droughts is rising across the continent. The IPCC’s 2008 report *Climate Change and Water* states that future changes in water quantity and quality are expected to affect food production, as well as how systems used for managing agricultural water operate. In Asia, it is predicted that climate change will exacerbate water scarcity in large areas that are already suffering from water stress and high population densities. However, some places are likely to lose out while others benefit. The increased evaporation from climate change may increase the amount of irrigation water crops in Southeast Asia require by as much as 15 percent (Doll, 2002). Meanwhile in Central Asia, land suitable for growing (Fisher et al. 2006) crops may expand. A recent report by the Bates
et al. (2008), states that changes in water quantity and quality due to climate change are expected to affect food production and that it will affect function and operations of existing water infrastructures, including those of drainage and irrigation systems as well as agricultural water management. Asia, where water distribution is highly uneven and large areas are already water stressed and population densities are high, climate change is expected to exacerbate the water scarcity situation in the continent. It is predicted that inter-seasonal, inter-annual and spatial variability in rainfall and runoff will increase, in many parts of Asia (Fig. 14). Most of Asia’s rivers originate in the Himalaya. Scientists forecast that melting of mountain glaciers from higher global temperatures will bring about major shifts in river flows. These changes will have serious repercussions on agriculture. One study forecasts that demand for water to irrigate crops in arid and semi-arid parts of Asia will rise by 10 per cent for every 1°C rise in temperature (Fischer et al. 2002). Another suggests rice paddy yields are likely to drop by 18 per cent by 2020 and 28 per cent by 2050 (Agrawal, 2008).

Figure 17 Changes in runoff based on IPCC Scenario A1, 2050 compared with 1961-1990 average

![Figure 17](image)


Renewed concern for food security in the context of economic crisis

A fairly recent development to meet food demands in land scarce countries has been to lease land in other countries, notably that in Africa. Developed and emerging governments and private entities (agribusiness, investment banks and private equity funds) bought rights to large track of arable lands (Redfern November 23, 2008; Branford November 22, 2008). The purchase of lands was set off by the recent food and financial crisis and represents the governments’ long-term strategies to resolve food insecurity that arises from limited land and water supplies. The most important Asian buyers are China, India, Japan, South Korea and Malaysia (Fig. 15). Although China today is self-sufficient in food, its population is growing, its agricultural lands are shrinking as a result of industrialization and urbanization and it is increasingly experiencing water scarcity. The Chinese government has been gradually investing in outsourcing food production (mainly to Africa). Its offshore crops are rice, soybean, maize, cassava and biofuels. India, responding to concerns such as declining soil fertility and long-term water supplies, is buying up lands in Burma, Indonesia and in various countries in South America (Grain 2008). Lands are being bought up in Central and

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Grain published a document that lists known land transactions. The list contains information about lands that were bought by Asian governments and companies outside Asia and about lands bought by Asian and other governments and companies in Asia. The report may be accessed at [http://www.grain.org/briefings_files/landgrab-2008-en-annex.pdf](http://www.grain.org/briefings_files/landgrab-2008-en-annex.pdf).
South East Asia mainly by the Gulf States. The countries that are the most targeted are Burma, Cambodia, Indonesia, Laos, the Philippines, Thailand, Vietnam and Kazakhstan (Grain 2008). The implications and impacts of these developments in terms of modes of farming (whether large farming enterprises will take the place of small landholders), rural development, research and development in agriculture, food security and land and water resources are not well understood.

Figure 18 Many countries are acquiring rights to land abroad to secure food for their people

Conclusion

While the drivers of change described in the preceding paragraphs impact the irrigation sector in Asia as a whole, some drivers are relatively more important than others in specific regions of Asia. Table 3 presents a qualitative assessment of importance of each driver in four different regions of Asia.
Table 3 Relative importance of different drivers of change in Asian irrigation

<table>
<thead>
<tr>
<th>Drivers of change</th>
<th>South Asia including India</th>
<th>SE Asia</th>
<th>China</th>
<th>Central Asia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographic pressure</td>
<td>+++</td>
<td>+++</td>
<td>++++</td>
<td>+</td>
</tr>
<tr>
<td>Diversification of agriculture</td>
<td>++</td>
<td>++++</td>
<td>++++</td>
<td>+</td>
</tr>
<tr>
<td>Declining share of agriculture</td>
<td>+++</td>
<td>+++</td>
<td>++++</td>
<td>++</td>
</tr>
<tr>
<td>Changing diets and aspirations</td>
<td>+++</td>
<td>++++</td>
<td>++++</td>
<td>++</td>
</tr>
<tr>
<td>Competing water demands</td>
<td>+++</td>
<td>+++</td>
<td>++++</td>
<td>++</td>
</tr>
<tr>
<td>Environmental water demand</td>
<td>+++</td>
<td>+++</td>
<td>++++</td>
<td>+++</td>
</tr>
<tr>
<td>National land &amp; agricultural policies</td>
<td>+++</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>Disintegration of USSR</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>++++</td>
</tr>
<tr>
<td>Climate change</td>
<td>+++</td>
<td>++++</td>
<td>+++</td>
<td>+++</td>
</tr>
</tbody>
</table>

Source: Authors

Asia has one of the most extensive irrigation infrastructures in the world and much of it was constructed in 1960s and 1970s when increasing production of cereal crops to avert imminent famines was the main concern. Since then, Asian economies have changed in myriad different ways. Within Asia, countries are at varying levels of development. It is therefore, evident that irrigation infrastructure created in the 1960s and the 1970s needs to be adapted to meet the future challenges – the most important of which is catering to farmers demand for timely and reliable water supply to support largely diversifying and high value agriculture. The agricultural sector in Asia can be largely classified into three different stages (Facon, 2009). These are ones in which focus is now largely outside agriculture (e.g. Malaysia), where agriculture is mainly geared towards exports (Central Asian Republics) and where agriculture still remains the main source of rural livelihoods (e.g. Bangladesh, Nepal, Vietnam). These also largely correspond to wider socio-economic development in these countries. Needless to say, I&D sector strategies need to be different in these countries. Table 4 (adapted from Facon, 2009) sums up strategies and policies needed to adapt existing infrastructure to cater to current and future needs.
Table 4 Level of agricultural development and I&D sector strategy

<table>
<thead>
<tr>
<th>Agricultural strategy and stage of development</th>
<th>Agricultural and economic situation</th>
<th>Desired strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus outside agriculture</td>
<td>Highly diversified agriculture</td>
<td>Adapt large scale systems originally designed for cereal production to high value farming</td>
</tr>
<tr>
<td>Developed economies</td>
<td>Competition for water &amp; land</td>
<td>Encourage private investments and conjunctive use</td>
</tr>
<tr>
<td></td>
<td>High environmental awareness</td>
<td>Improve water productivity</td>
</tr>
<tr>
<td></td>
<td>Rapid urbanization and shifts in diets</td>
<td>Ensure full cost recovery</td>
</tr>
<tr>
<td></td>
<td>Assuring minimum food self sufficiency still a stated goal</td>
<td>Invest in re use of waste water</td>
</tr>
<tr>
<td>Export oriented agriculture</td>
<td>On the way to diversification, though cereal crops still dominate</td>
<td>Stabilization of area under cereal cultivation</td>
</tr>
<tr>
<td>Intermediate/transition economies</td>
<td>Quick demographic transition</td>
<td>Emphasis on smaller schemes</td>
</tr>
<tr>
<td></td>
<td>Export earnings from agriculture a major source of revenue</td>
<td>dedicated to high value crop production</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Emphasis on financial viability of schemes</td>
</tr>
<tr>
<td>Agriculture dependent</td>
<td>Poverty alleviation and food security are stated goals</td>
<td>Adopt water saving technologies</td>
</tr>
<tr>
<td>Developing economies</td>
<td>Little alternative livelihood options</td>
<td>Concentrate on cereal production</td>
</tr>
<tr>
<td></td>
<td>High population pressure</td>
<td>New infrastructure through strong government support</td>
</tr>
</tbody>
</table>

Adapted from Facon, 2009

The nature of the challenge will determine the extent to which the existing systems can be adapted to the future needs. For example, reliability and timeliness of irrigation water supply will be crucial in ensuring both increased food grains production and high value crops. In addition, for high value crops, on demand pressurized irrigation systems would be at premium. Adoption of modern water saving technologies (e.g. drip and sprinkler irrigation) and re use of treated or partially treated waste water would provide windows of opportunity for achieving higher water productivity in high value agricultural systems faced with water scarcity. Challenges posed by climate change would necessitate investments in increased water storage structures, be it surface storage or groundwater storage. In India, already a substantial part of rural development investments are geared towards creation of small distributed storage structure throughout the country side and groundwater recharge is receiving increased attention – both from the national government and from the international donors and farmer communities. The future challenges, as this report has been emphasized all throughout, would be multi dimensional. Therefore, adapting existing irrigation structures to future needs, in many instances, would involve incorporating multi-functionality (e.g. irrigation and hydro-power generation, or irrigation and flood control or irrigation and waste water re use) in previously single function irrigation infrastructure. An important step towards adapting current irrigation infrastructure to future needs would be carefully assess the systems present 'de-facto' mode of functioning and understand how this serves the interests of the users (farmers) and the irrigation agencies and modernize the schemes based on such understanding.

Investments in irrigation management reforms would also be crucial in adapting present irrigation infrastructures to meet future demands. This will involve investments in not only up gradation of the physical infrastructure, but also investments in ‘software’, such as capacity building of the irrigation agency staff and practical training for existing water users associations. Investment in professionalization of irrigation management through continuous in-service training program could be a good strategy in this regard. Similarly, another important investment strategy could be to improve data collection and monitoring capability of the national irrigation agencies. Thus software investments would be just as crucial as hardware investments.
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