



**AgEcon** SEARCH  
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

*The World's Largest Open Access Agricultural & Applied Economics Digital Library*

**This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.**

**Help ensure our sustainability.**

Give to AgEcon Search

AgEcon Search  
<http://ageconsearch.umn.edu>  
[aesearch@umn.edu](mailto:aesearch@umn.edu)

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

# Revitalizing Asia's Irrigation:

*To sustainably meet tomorrow's food needs*



**IWMI**  
International  
Water Management  
Institute



Funded by:





# Revitalizing Asia's Irrigation:

*To sustainably meet tomorrow's food needs*





## Credits

### Lead authors:

Aditi Mukherji (IWMI)

Thierry Facon (FAO)

### Other authors:

Jacob Burke (FAO)

Charlotte de Fraiture (IWMI)

Jean-Marc Faurès (FAO)

Blanka Füleki (IWMI)

Mark Giordano (IWMI)

David Molden (IWMI)

Tushaar Shah (IWMI)

Mukherji, A.; Facon, T.; Burke, J.; de Fraiture, C.; Faurès, J.-M.; Füleki, B.; Giordano, M.; Molden, D.; Shah, T. 2009. Revitalizing Asia's irrigation: to sustainably meet tomorrow's food needs. Colombo, Sri Lanka: International Water Management Institute; Rome, Italy: Food and Agriculture Organization of the United Nations.

/ irrigated farming / food security / irrigation management / participatory management / water users associations / public sector / private sector / farmer managed / irrigation systems / surface irrigation / pumps / groundwater irrigation / water productivity / models / reservoirs / canals / tanks / irrigation programs / climate change / water conservation / Asia /

ISBN 978-92-9090-709-1

Copyright © 2009, by IWMI and FAO. All rights reserved.

Cover image shows seedlings growing in a rice paddy.

Photo credits: All photos [www.iStockphoto.com](http://www.iStockphoto.com) unless otherwise stated.

Editorial consultant: Carolyn Fry

Designer: Mario Bahar, Gracewinds Advertising

Cartographer: John Plumer

Printer: Gunaratne Offset Ltd.

The views expressed in this paper are the views of the authors and do not necessarily reflect the views or policies of the Asian Development Bank (ADB), or its Board of Governors, or the governments they represent. ADB does not guarantee the accuracy of the data included in this paper and accepts no responsibility for any consequence of their use. Terminology used may not necessarily be consistent with ADB official terms.





## CONTENTS

### MAIN MESSAGES AND RECOMMENDATIONS 01

### INTRODUCTION 05

### TRENDS IN ASIAN IRRIGATION 08

#### Past trends in Asian irrigation

Irrigation has long been 'big business' in Asia  
Irrigated land has expanded rapidly since the 1960s  
Irrigation developments boosted rural growth and reduced poverty  
But with considerable costs to the environment

#### What drives changes in irrigation?

Demographics, diets and diversification  
Food and energy prices and policies  
Water and land scarcity, and environmental pressures

#### Emerging trends in Asian irrigation

Large-scale surface irrigation is shrinking or under-performing  
Groundwater and pumped irrigation is booming  
PIM and IMT initiatives have not yet lived up to expectations  
Climate change and variability as future threats

### FORECASTING FUTURE FOOD NEEDS AND WATER DEMAND 24

#### How will Asia feed its swelling population?

Squeezing value from water and land  
Is making better use of rainfall possible?  
What about boosting international trade?  
Increasing yields from irrigated land is the key

### MAKING IRRIGATION PERFORM BETTER 29

#### A continent in transition

Strategy 1: Modernize yesteryear's schemes for tomorrow's needs  
Strategy 2: Go with the flow by supporting farmers' initiatives  
Strategy 3: Look beyond conventional PIM/IMT recipes  
Strategy 4: Expand capacity and knowledge  
Strategy 5: Invest outside the water sector

#### In conclusion

### REFERENCES 39

## Acknowledgements

The authors would like to thank the following contributors for their help and comments during compilation of this publication:

Deborah Bossio, International Water Management Institute (IWMI)  
M. Gopalakrishnan, International Commission on Irrigation and Drainage (ICID)  
R. P. S. Malik, International Water Management Institute (IWMI)  
K. Palanisami, International Water Management Institute (IWMI)  
Thomas Panella, Asian Development Bank (ADB)  
Effendi Pasandaran, Indonesian Agency for Agricultural Research and Development (IAARD)  
Vadim Sokolov, Scientific-Information Center of Interstate Coordination Water Commission of Central Asia (SIC ICWC)  
Khim Sophanna, Cambodian Center for Study and Development in Agriculture (CEDAC)  
Diana Suhardiman, International Water Management Institute (IWMI)  
Philippus Wester, Wageningen University  
Jinxia Wang, Center for Chinese Agricultural Policy (CCAP), Chinese Academy of Sciences (CAS)  
Dennis Wichelns, International Water Management Institute (IWMI)  
Zhanyi Gao, Department of Irrigation and Drainage, China Institute of Water Resources and Hydropower Research (IWHR)

The authors would also like to thank Ashok Gulati of the International Food Policy Research Institute (IFPRI), Sagith Ibatullin of International Fund for Saving the Aral Sea (IFAS), Kazakhstan, Herath Manthrithilake of IWMI (Central Asia office), To Trung Nghia of the Ministry of Agriculture and Rural Development of Vietnam, Sylvain Perret of Asian Institute of Technology (AIT), Thailand, Zailah Selamat of the National Hydraulic Research Institute of Malaysia (NAHRIM), Malaysia, and Ganesh Shivakoti of AIT, Thailand, along with all other participants, for their valuable inputs during and after the workshop "Trends and Transitions in Asian Irrigation: What are the Prospects for the Future" held at the FAO Regional Office for Asia and the Pacific, Bangkok, from January 19-21, 2009.

## Project

This project is a collaboration between many authors and contributors from numerous institutes, led by IWMI and FAO through KnowledgeHubs. KnowledgeHubs is a regional network of organizations whose mission is to deliver state-of-the-art knowledge-based products and services that meet the practical needs of countries, institutions and society in the Asia-Pacific region. IWMI leads the knowledge hub on Irrigation Service Reform in this network. This booklet was developed in partnership with FAO as a first product of the hub and provides guidelines for revitalizing Asia's irrigation sector.


For more information, visit <http://waterknowledgehub.iwmi.org/>

## Donors

This project was funded by the Asian Development Bank.







Ending hunger, given Asia's swelling population, increasing urbanization and climate change, presents a huge challenge for farmers. With land and water resources stretched, they must double their output from existing cultivated areas. Irrigation systems will be vital to help meet future food needs and reverse past environmental degradation, even given higher yields from rainfed agriculture. However, the irrigation sector must first be revitalized to unlock its potential, by introducing innovative practices and changing the way it is governed and managed.





## MAIN MESSAGES AND RECOMMENDATIONS

### Why is irrigation important in Asia?

#### Asia contains 70% of the world's irrigated area ...

Irrigated agriculture has been at the heart of rural growth in Asia. Here, 34% of cultivated land is irrigated, as compared to only 10% in North America and 6% in Africa.

#### ... and irrigation was key to the success of the Green Revolution ...

Despite forecasts of famine and starvation, most Asian countries became food self-sufficient in the 1970s and 1980s, thanks to the Green Revolution. Timely and reliable water supplies, greater cropping intensities, high-yielding varieties of seeds and doses of fertilizers pushed up productivity.

#### ... this helped alleviate poverty and boost rural growth.

In South Asia, cereal production rose by 137% from 1970 to 2007 with only a 3% increase in the amount of land used. In East and Southeast Asia, agricultural productivities more than tripled and rural poverty declined rapidly. Studies show that, depending on the stage of development, agricultural growth is often more effective at alleviating poverty than growth in other sectors. Irrigation developments are often instrumental in achieving high rates of agricultural growth.

### Does Asia still need to invest in irrigation?

#### Asia needs to feed a growing population ...

Feeding the extra 1.5 billion people who will live on the continent by 2050 will require more food than the region currently produces. Experts estimate that demand for food and animal feed crops will double during the next 50 years. Growing this extra food will require better management of existing irrigated lands, since opening up new frontiers is constrained by lack of land and water resources.

#### ... secure livelihoods and alleviate poverty ...

In spite of progress made in recent decades some 700 million Asians, mostly concentrated in South Asia, live on less than US\$1 per day. The Asian Development Bank (ADB) estimates that roughly half of Asia's population will still be rural in 2030. Therefore, farming will continue to provide livelihoods and food security for many people.

#### ... within the limits of natural resources ...

There is very little scope for expanding arable land in most regions of Asia, so developing extensive





new irrigation schemes is not a solution. Similarly, there are clear limits in most places on the amount of additional water that can be used for agriculture.

### **... while limiting stress to the environment.**

The need to produce more food is prompting renewed interest in Asia's irrigation. However, this must be done in a way that conserves the vital environmental services that wetlands, rivers and other ecosystems provide.

### **Boosting the performance of irrigated agriculture will be critical.**

Investments to raise yields and productivity from irrigated land must be key elements of a strategy to produce the extra food needed, while safeguarding the environment from additional stresses. Alternative options, such as upgrading rainfed farming and increasing international trade in food grains, must also contribute, but they will need to be supplemented by a significant increase in production from irrigated agriculture.

## **Will past irrigation schemes be effective in future?**

### **Irrigation was key to raising productivity 50 years ago ...**

Irrigation, from large-scale surface schemes and private groundwater supplies, played an important role in raising productivity during the Green Revolution. The increase in food production outpaced population growth and helped alleviate poverty.

### **... but the face of Asia is changing fast.**

Asia is now a very different place to what it was in the 1960s and 1970s. Rural people have more opportunities to work outside agriculture, and increasing urbanization has boosted wealth for many.

### **Wealthier city dwellers have new dietary demands ...**

Wealth influences dietary choices and diets affect water use. Providing the foods that people now demand requires shifts in agriculture. In many places, such as China, the demand for meat is increasing. Producing food for a meat- or milk-based diet requires more water than for a vegetarian one. Meanwhile, growing a range of crops requires a different irrigation regime than that needed to supply water to large areas planted with one or two cereals.

### **... which are providing farmers with opportunities.**

The shift from rural to urban living has provided farmers with more options. Some have chosen to quit farming for city-based jobs, while others have opted to become part-time farmers. Those remaining in the agricultural sector have taken advantage of improved access to markets to diversify their activities and produce the higher-value niche crops urban residents demand.



### **Meanwhile, state-built irrigation schemes are under-performing ...**

The large-scale, centrally managed irrigation schemes of the past were not designed to be demand-driven or provide the reliable, flexible and equitable year-round water service that modern farming methods require. Beset with problems of inappropriate design, poor maintenance, salinity and waterlogging, many large-scale schemes are currently in decline across Asia. Efforts by many national governments to rehabilitate them are ongoing but the results are, at best, mixed.

### **... forcing farmers to invest on their own.**

With poor service provision and a lack of effective management, farmers have taken irrigation into their own hands by pumping water from aquifers, rivers and drains. Privately sourced, pumped groundwater now represents the bulk of irrigation in large parts of South, East and Southeast Asia. Many farmers are investing in on-farm storage ponds to augment their supply and gain greater control over their water supplies.

## **What is the best way forward for Asian irrigation?**

### **Irrigated agriculture still offers huge opportunities ...**

There is considerable scope to increase food production, enhance livelihoods and reduce poverty in existing irrigated areas. However, realizing this potential will require new approaches to investing in infrastructure, reforming institutions and building capacity.

### **... but only innovative strategies will unlock the potential gains.**

Future irrigation systems will need to be efficient and flexible to meet the demands of many sectors including farming, fishing, domestic use and energy supply. The managers of irrigation systems will need to find ways to generate more value from ecosystem services and halt environmental degradation. They must also enable farmers to respond to challenges posed by volatile market conditions and climate change.







## Recommended strategies

### **Strategy 1: Modernize yesteryear's schemes for tomorrow's needs**

In Asia, most irrigation schemes have operated for 30 to 40 years. Surface irrigation schemes across Asia have become underused, poorly maintained and inefficient. Many would benefit from being modernized, by being redesigned, operated and managed for a range of uses. For example, surface irrigation schemes could be used to recharge aquifers or fill intermediate storage structures, such as farm ponds, providing farmers with greater reliability and control. Meanwhile, flexible and responsive management will be vital for mitigating against, and adapting to, climate change. Tomorrow's managers will need to look beyond the confines of the irrigation system and start managing operations within entire river basins. This will involve allocating water to multiple uses and to meet environmental targets.

### **Strategy 2: Go with the flow by supporting farmers' initiatives**

While the area of surface irrigation has remained stagnant or been shrinking, farmers in South, East and Southeast Asia have raised yields using locally adapted irrigation technologies to scavenge water from surface sources, wastewater and groundwater. There are opportunities for investors to identify successful initiatives and direct funds towards schemes emulating farmers' methods. New models are needed for managing groundwater in areas where this pump-based 'atomistic' irrigation has largely replaced centralized surface irrigation.

### **Strategy 3: Look beyond conventional PIM/IMT recipes**

Efforts to reform large-scale irrigation schemes by transferring management to farmers have had less-than-expected success throughout Asia. Many believe the private sector could help irrigation entities improve water delivery. For example, irrigation departments could outsource irrigation services, create public-private partnerships or provide incentives for irrigation officials to act as entrepreneurs in publicly managed operations. Such actions could help to mobilize funds, increase efficiency and improve the provision of water services but are, as yet, rare and largely untested.

### **Strategy 4: Expand capacity and knowledge**

If new approaches are to be successful, investors will need to direct funds towards training existing staff, attracting new talent through forward-thinking curricula and realistic remuneration packages, as well as building the capacity of all stakeholders (including the irrigation bureaucracy). Initiatives might include updating engineering courses in universities, conducting in-depth training workshops for farmers and irrigation officials, or revamping irrigation departments to empower their workforces.

### **Strategy 5: Invest outside the irrigation sector**

The irrigation sector is embedded within Asia's wider political economy and is, therefore, affected by external forces. Policies and programs that influence agriculture, both directly and indirectly, come to drive developments in irrigation. Framing policies to ensure external influences on the water sector are properly understood and planned is one way to indirectly influence irrigation performance.

## INTRODUCTION

One and a half billion more people will live in Asia by 2050, as the region's population swells to five billion. With land for agricultural and irrigation expansion limited in most parts of the continent, Asian countries urgently need to boost productivity from existing farmlands. Asia contains 70% of the world's 277 million hectares (mha) of irrigated land. Making these existing irrigation systems work more efficiently and, where possible, investing in new irrigation infrastructure, will be critical for meeting future food demands. This will not be an easy task, as Asia's natural water resources are already stretched and climate change is likely to bring greater variability in rainfall and runoff, generating uncertainty.

During the 1960s, when Asian populations faced famine and starvation, new technologies, fertilizers, pesticides, high-yielding varieties of seeds and reliable irrigation water supplies helped the region's economies shift from being in food deficit to generating a surplus in less than a decade. Between 1961 and 2002, the irrigated area in Asia more than doubled as governments sought to achieve food security, improve public welfare and generate economic growth. Investments in irrigation provided the key to unlocking Asia's agricultural potential at that time. For example, in South Asia, cereal production rose by 137% from 1970 to 2007. This was achieved using only 3% more land.<sup>3</sup>

Irrigation contributed in a number of ways. It enabled farmers to increase yields and cropping intensities, stabilize production by providing a buffer against the vagaries of weather, and create employment in rural areas. Irrigated areas accounted for only 34% of the arable land, yet they produced 60% of the total food grains in Asia. Irrigated agriculture was also key to alleviating poverty. Rural poverty in intensively irrigated areas, such as the states of Punjab and Haryana in India, became much lower than in predominantly rainfed states, such as Orissa and Madhya Pradesh.

Since the Green Revolution, as this period came to be known, the world has moved on. Urbanization has gathered pace across Asia, offering some farmers opportunities to quit agriculture in favor of city-based jobs or to become part-time farmers. Urbanization is accompanied by greater wealth, and also changing dietary aspirations. More people are now choosing to eat fewer cereals and consume more fruit, vegetables, meat and milk. The increasing number and size of cities has helped farmers by providing greater access to markets at home and abroad. As a result, the incentive for farmers to produce lucrative niche crops has never been higher. Today, many prefer to grow fruit and vegetables in addition to cereal crops.

The irrigation systems of the 1960s and 1970s were predominantly designed to water cereals (mainly rice and wheat) as Asia sought to achieve food self-sufficiency. Over time, farming systems

<sup>3</sup> All statistics, unless otherwise stated, are downloaded from FAO's FAOSTAT (<http://faostat.fao.org>) or AQUASTAT (<http://www.fao.org/INR/WATER/AQUASTAT/main/index.stm>)





became more complex in response to changing socioeconomic conditions. However, the irrigation schemes failed to adapt to the changing needs of farmers and were soon performing below their potential. There were attempts to reform these systems by sharing responsibility for their management with agricultural communities (a process that is often termed Participatory Irrigation Management [PIM] or Irrigation Management Transfer [IMT]). However, these PIM/IMT interventions failed to live up to their potential.

Faced with such challenges, farmers in many parts of Asia have opted to take irrigation into their own hands. Millions of small-holders have invested in pumps so they can extract water from shallow aquifers whenever they choose. The trend has changed the face of Asian irrigation from being one of centralized state-controlled irrigation to that of individual-centered irrigation, dominated by farmer-owned boreholes and pumps. This, in turn, has led to problems such as over-exploitation of groundwater in certain pockets. The boom in individual irrigation has happened despite some governments investing heavily to rehabilitate surface irrigation schemes. India, for example, has spent some US\$58 billion to rehabilitate old canal systems and construct new ones during the last five decades or so.



The pressing problem of how to feed Asia's growing population, coupled with higher food prices, is prompting renewed interest in irrigation. Based on in-depth research and consultation with experts, this study recommends five investment strategies:

- Modernize yesteryear's schemes for tomorrow's needs
- Go with the flow by supporting farmers' initiatives
- Look beyond conventional PIM/IMT recipes
- Expand capacity and knowledge
- Invest outside the irrigation sector

At a time when environmental concerns have never been greater, future investments in irrigation will require decision-makers to minimize disruptions to natural water flows, biodiversity and ecosystem services. Planners will also need to embrace forecasts for climate change. Climate variability is set to influence how existing drainage and irrigation systems function, as well as affecting overall agricultural water management. Asia presently uses some 73% of the 2,664 cubic kilometers (km<sup>3</sup>) of water the world withdraws annually for agriculture. Its challenge is to produce enough food to feed its future population, in an unpredictable climate, without having a detrimental effect on precious land and water resources.







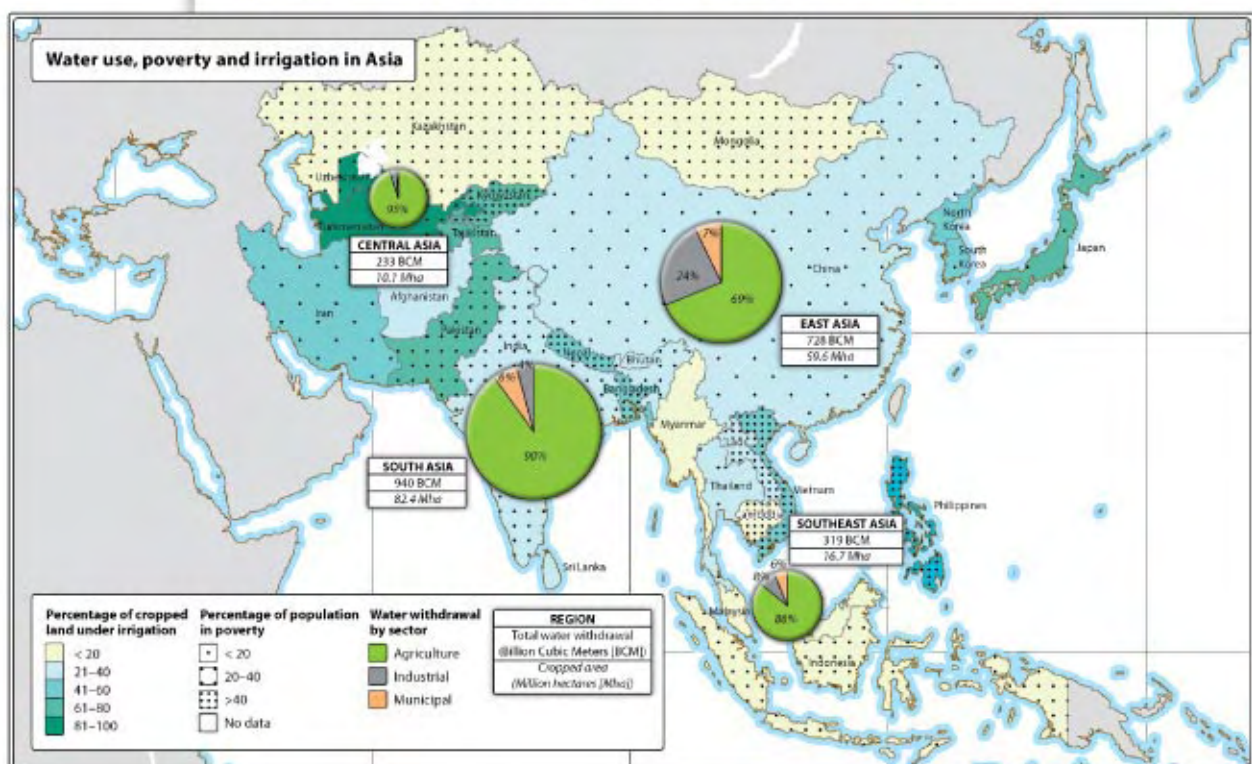


## TRENDS IN ASIAN IRRIGATION

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 predominantly agricultural while others have become industrialized. There are developed 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 shows how the area of irrigated lands, annual average water withdrawals and levels of poverty vary. In absolute numbers, South Asia is responsible for the largest amount of irrigated land and water withdrawals, followed by East Asia, Southeast Asia and Central Asia. In percentage terms, Central Asia is the most intensively irrigated part of Asia.<sup>2</sup>

**Figure 1.**

**Agriculture is the primary user of water resources across Asia.  
The most heavily irrigated lands lie in the heart of Central Asia.**



<sup>2</sup> South Asia : India, Pakistan, Bangladesh, Nepal, Sri Lanka, Bhutan, Maldives and Afghanistan  
 East Asia : China, Japan, Mongolia, North Korea and South Korea  
 Southeast Asia : Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Thailand and Vietnam  
 Central Asia : Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan

## Past trends in Asian irrigation

### Irrigation has long been 'big business' in Asia

Asia accounts for 70% of the world's irrigated area (Table 1) making irrigation 'big business' on the continent. The Indus Basin irrigation system in Pakistan is the world's largest contiguous scheme, with an area of 17 mha. The Ganges Basin in India, the Yellow River Basin in North China, and the Central Asian Republics similarly support some of the largest irrigation schemes in the world. These serve as granaries, feeding the people of their host nations and regions. Although there is not much scope for expanding the irrigated area, almost all countries in Asia report some difference between the area of land with potential for irrigation and that currently with infrastructure installed. For example, India reports an irrigation potential of 113 mha against an actual irrigated area of 57 mha. This gap is narrower in China, where 58 mha of the 64 mha deemed suitable for irrigating, already have schemes in operation. By contrast, in Southeast Asia there is a large gap between the potential area of 44 mha and the currently irrigated area of 17 mha.

**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						
	Area irrigated (million hectares)			Area irrigated as a percentage of cultivated land (%)		
Year	1980	1990	2003	1980	1990	2003
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	21.1	21.6	23.2	8.6	8.8	9.9
Oceania	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

One third of Asia's cropland is watered artificially, making it the most intensively irrigated continent in the world. Between 1961 and 2003, the area of irrigated land in Asia more than doubled, with an average annual growth rate of 2.6% (Figure 2). In 2003, South Asia accounted for the bulk of irrigated land (82.4 mha), followed by East Asia (59.6 mha), Southeast Asia (16.7 mha) and Central Asia (10.1 mha). Since the late 1980s, the rate of expansion has generally slowed but recently in India and

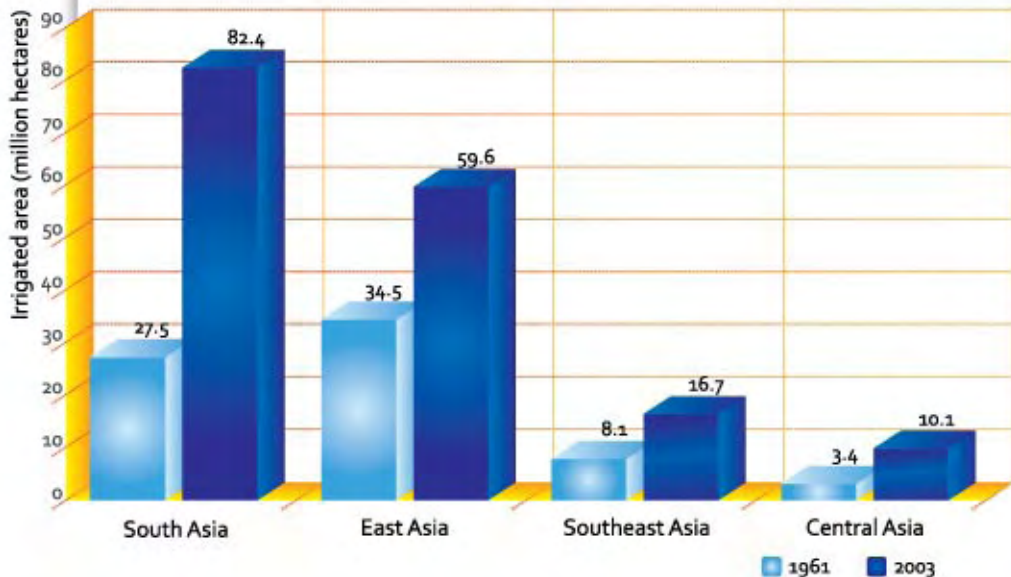




China it has begun to increase again. In Central Asia, neglect of surface irrigation schemes since the end of the Soviet era has led to their deterioration and there has been very little investment in new irrigation infrastructure.

Figure 2.

Changes in irrigated area in Asia, 1961-2003.



### Irrigation developments boosted rural growth and reduced poverty

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.

### But with considerable costs to the environment

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 monocropping, pollution of water bodies and soils from fertilizers, and resistance of insects to pesticides. Improperly designed irrigation schemes caused salinization and waterlogging in some places and declining groundwater levels in others. Irrigation introduced in

upstream locations often affected downstream biodiversity, particularly natural fisheries. The World Wildlife Fund's (WWF) Living Planet Index shows that freshwater species have declined in line with the expansion of irrigation. To avoid such negative impacts from future irrigation ventures, irrigation managers must find technological fixes (say, by changing designs), and political solutions (for example, by introducing new environmental policies).

## What drives changes in irrigation?



Photo courtesy of: Sanjini de Silva

### Demographics, diets and diversification

Drivers of change in the irrigation sector usually lie within the broader political economy and overall developmental thinking. Demographic shifts, in particular, are an important driver of change. Asia's population continues to grow, but at lower rates than before. At the same time, more and more of Asia's inhabitants are opting to live in cities. By 2025, 52% of East Asia's, 53% of Southeast Asia's and 45% of South and Central Asia's populations are predicted to be urban. This is presenting opportunities for farmers. Some are leaving agriculture in favor of higher-paid jobs and others are becoming part-time farmers. Many are taking advantage of improved access to national and international markets. Being able to reach new buyers means some farmers can now grow lucrative 'niche' crops, instead of staples (Figure 3). As rural livelihoods become increasingly diversified and mobile, irrigation schemes will have to adapt to become more flexible.

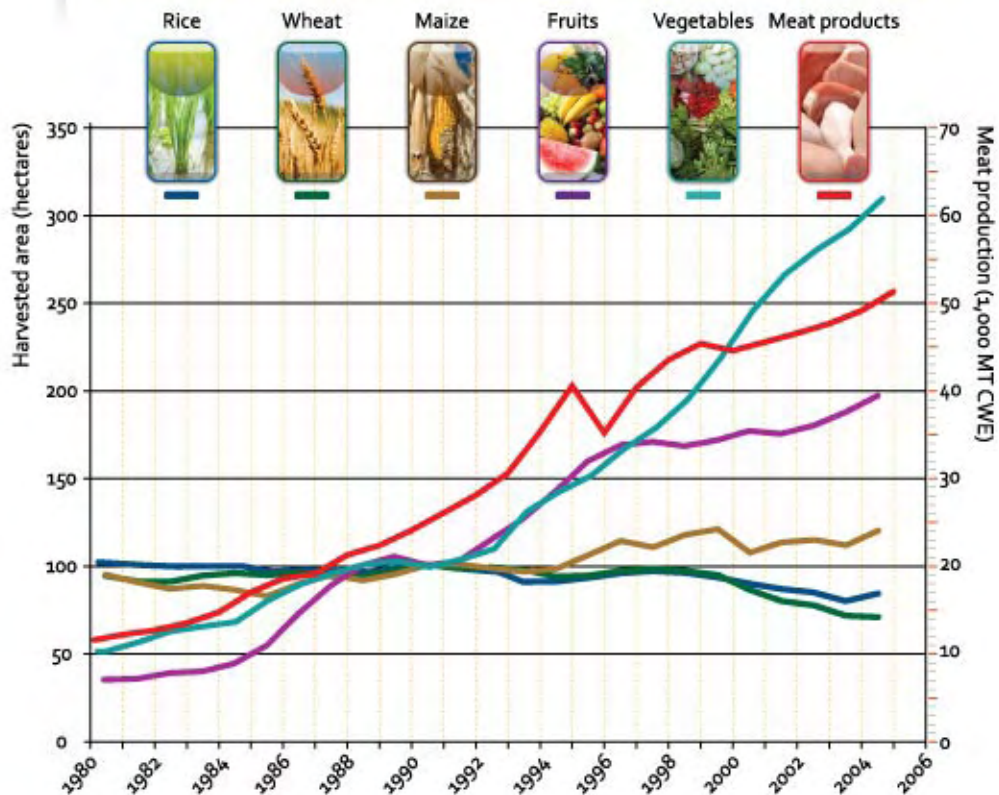
Wealthy city dwellers generally demand a richer, more varied diet than poorer rural communities. In Asia, per-capita consumption is rising and only forecast to level off in 2030. As people become richer, they are choosing to eat fewer cereals and consume more fruit, vegetables, milk and meat. Growing the wide selection of crops to meet this demand means farmers need greater reliability and flexibility from their irrigation systems. Producing food for a meat-based diet, meanwhile, requires much more water than for a vegetarian one. Meat consumption in China has more than doubled in the past 20 years and is expected to double again by 2030.





**Figure 3.**

**Evolution of the harvested area and meat production in China, 1980–2005.**



### **Food and energy prices and policies**

Historically, increased investments in irrigation have tended to lower food prices, while low food prices have discouraged new irrigation investments (see Figure 4, overleaf). Between the mid-1970s and 2007, global cereal prices remained relatively low. As a result, public investments in irrigation declined. However, the total irrigated area continued to grow, mostly through individual actions by farmers. The phenomenon of many farmers investing in tube wells and pumps to obtain water from shallow and deep aquifers is referred to as 'atomistic' irrigation.

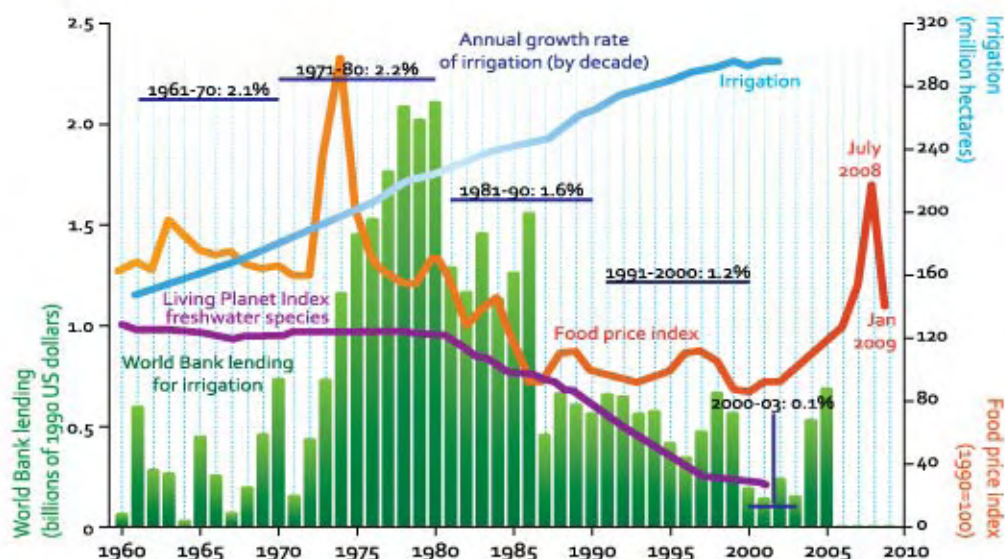
During 2007 and 2008, food prices suddenly increased, prompting widespread panic. Analysts attribute the price hike to decreased stockpiles of food grains and resulting export bans, rising energy prices, increased biofuel production, high demand for wheat, milk, meat and oil, the declining value of the dollar, speculation in the futures markets, plus underinvestment in agricultural research, technology and rural infrastructure, especially irrigation. Although food prices have subsequently fallen, long-term projections published by the United States Department of Agriculture (USDA) indicate that both food and oil prices will rise again after a slump in 2009/10 and food prices will remain above historical levels. Water scarcity will increasingly contribute to food price volatility.



**Figure 4.**

**Increased investments in irrigation in the 1970s and 1980s led to a decline in food prices.**

*Source: Comprehensive Assessment of Water Management in Agriculture (2007)*



Such forecasts, coupled with growing population pressures and negative experiences when importing food from other countries during crises, are prompting many Asian countries to strive for food self-sufficiency. National policies also strongly influence food prices and investments in irrigation. For example, India's actions aimed at achieving food self-sufficiency resulted in very large food surpluses in 2003–04. Once these surpluses were off-loaded onto the world markets, prices slumped. When global prices shot up in 2007, India's reserve had dwindled and in response the government banned exports of most rice products. Other countries in East and Southeast Asia took similar actions. This led to a further rise in international rice prices. Multilateral trade agreements, such as those created under the World Trade Organization (WTO), can also profoundly affect food pricing and agricultural production in developing countries.

Food prices tend to be closely interlinked with energy prices. High energy prices push up the costs of fertilizer, fuel for irrigation pumps and transportation of goods to markets, and thereby squeeze farmers' profits. Climate-change policies and high fossil-fuel prices have begun having another impact, by increasing demand for biofuels. One major corn grower, the USA, has diverted substantial quantities of corn to biofuel production, prompting food crises. Food policies, especially national food pricing and subsidy policies, affect decisions taken by farmers on which crops to grow. This is because they influence incentive structures, which, in turn, can affect water-provision policies. For example, in water-scarce Pakistan and the Indian Punjab, farmers still opt to grow water-intensive rice and wheat because they receive high prices due to government food procurement policies.



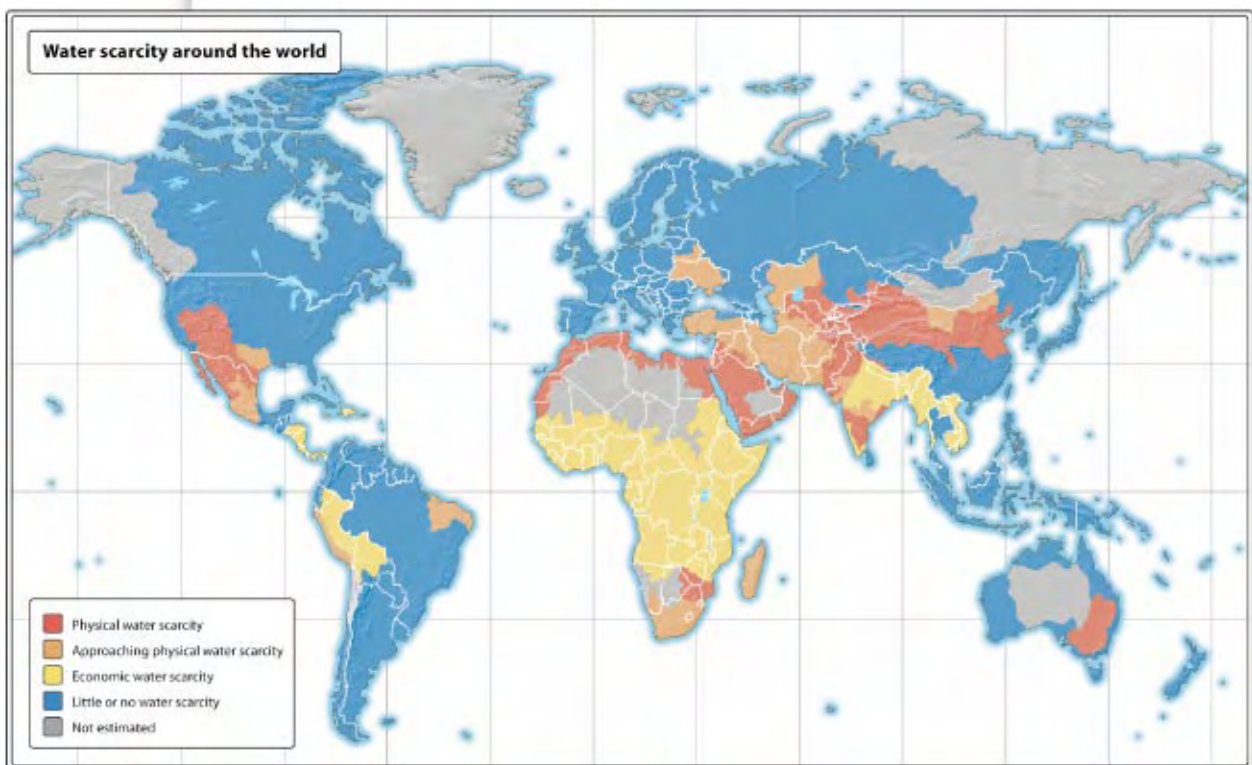
## Water and land scarcity, and environmental pressures

As demands on water supplies are increasing, supplies are becoming scarcer (Figure 5). According to the *Comprehensive Assessment of Water Management in Agriculture* (2007), a fifth of the world's people, more than 1.2 billion, live in areas of physical water scarcity, where there is not enough water to meet everyone's daily needs. Meanwhile, 1.6 billion people live in economically water-scarce basins, where human capacity or financial constraints, poorly conceived irrigation infrastructures and inefficient management are affecting the quality and quantity of water available for productive uses. For

**Figure 5.**

**Large parts of the world suffer from physical and economic water scarcity.**

Source: *Comprehensive Assessment of Water Management in Agriculture* (2007)



### Definitions and indicators

- **Little or no water scarcity.** Abundant water resources relative to use, with less than 25% of water from rivers withdrawn for human purposes.
- **Physical water scarcity** (water resources development is approaching or has exceeded sustainable limits). More than 75% of river flows are withdrawn for agriculture, industry and domestic use (accounting for recycling of return flows). This definition, relating water availability to water demand, implies that dry areas are not necessarily water scarce.
- **Approaching physical water scarcity.** More than 60% of river flows are withdrawn. These basins will experience physical water scarcity in the near future.
- **Economic water scarcity** (human, institutional and financial capital limit access to water, even though water in nature is available locally to meet human demands). Water resources are abundant relative to water use, with less than 25% of water from rivers withdrawn for human purposes, but malnutrition exists.



example, excessive withdrawal of water is having a negative impact on the river basins of the Yellow River, Aral Sea tributaries, Ganges and Indus. Meanwhile, pumping of groundwater by farmers in China and India is causing water tables to drop 3 meters (m) per year in some areas.

Land is also at a premium. Presently in Asia, there are 0.16 hectares (ha) of land per person available for growing food. This is only 60% of the world average, which stands at 0.26 ha per person. The growth of cities and increasing industrialization mean there is little scope to expand the area being farmed. Even if the area presently under irrigation in Asia remains unchanged, and the population growth rate continues on its present downward trend, the total number of inhabitants will continue to grow. This means the amount of arable land available per person will shrink in the future.

Environmental concerns have begun to influence public thinking and limit funds available for projects that may have damaging environmental impacts. Taking protective actions has yet to become widely practiced. However, international lenders are less likely to support large, environmentally disruptive irrigation schemes than they were in the past. Although some large irrigation projects may be justified for their developmental potential, and implemented using internally generated funds, national governments will also become increasingly concerned about environmental impacts in the years to come. Conservationists, decision-makers and the public need to recognize that making existing irrigation less harmful to the environment will be costly and require funding.

## Emerging trends in Asian irrigation

### Large-scale surface irrigation is shrinking or under-performing

In Asia, in general, and South Asia, in particular, the area of land irrigated by large-scale surface schemes has been declining since the early 1990s. Often, the main reason for the decline is poorly maintained infrastructure that does not cater to farmers' needs. The Indian sub-continent has the largest area under surface irrigation. However, small surface structures, notably tanks in southern India and Rajasthan, *kerezes* in Pakistan and Iran, *kuhls* in the Himalaya, and *ahar-pyne* systems in southern Bihar, have been dwindling in size and numbers since the 1950s. Sri Lanka bucks the trend seen elsewhere in South Asia. Here, canal irrigation schemes seem to function satisfactorily and contribute to the nation's goal of rice self-sufficiency.

Elsewhere in the region since the 1990s, even large public irrigation systems have been losing area. Between 1994 and 2001, India and Pakistan together lost more than 5.5 mha of canal-irrigated areas, despite very large investments in rehabilitation and new projects. Some of these areas were lost due to irrigation-induced soil salinity and waterlogging. In Central Asia, too, large-scale surface irrigation schemes designed to meet the needs of a highly centralized and planned economy have shrunk since the Soviet Union collapsed in the early 1990s. In East and Southeast Asia, the situation is better, but the present performance and future sustainability of irrigation projects is of concern.





## Groundwater and pumped irrigation is booming

Although surface irrigation is shrinking across Asia, the overall area being irrigated is expanding. This is because old community and government-managed schemes are rapidly giving way to atomistic irrigation. Millions of smallholders are now watering their crops by means of a mechanical pump, well and rubber or PVC pipes. This 'water-scavenging' economy is most visible in South Asia and on the North China Plains; here pump irrigation has begun to dominate not only dry land areas but also regions where public and community irrigation underpinned agriculture until the 1980s (Figure 6). In some pockets of Asia, particularly the Indus Basin and river basins of Southeast Asia, much of the groundwater is used in conjunction with surface water, with or without prior planning, but across the rest of South Asia and on the North China Plains, the sole use of groundwater has become the norm.

**Figure 6.**

**Atomistic irrigation has boomed across large parts of Asia.**

*Source: Based on various IWMI projects*



A booming low-cost Chinese pump industry is supporting the explosion of water-scavenging irrigation. The Chinese have pared the weight and cost of pumps to a fraction of their competitors' products and now export some four million each year. In India, more than 60% of the nation's irrigation now comes from atomistic pump irrigation, despite ongoing investment in surface irrigation. This is an official estimate of the Government of India; other estimates suggest a much bigger role for pump irrigation.



What atomistic irrigation is able to do, which public and community schemes are unable to match, is help farmers to keep up with changing agricultural practices by providing them with a reliable, timely and adequate supply of irrigation water.

### PIM and IMT initiatives have not yet lived up to expectations

In recent years, NGOs, donors and governments have sought to reverse the decline in large-scale irrigation schemes by emulating the structures of traditional irrigation communities. They have attempted to accomplish this by handing some responsibility for managing irrigation back to farming communities. The process has become known as Participatory Irrigation Management (PIM) or Irrigation Management Transfer (IMT). Table 2 lists the socio-technical environment of Asia's irrigation systems and reviews the conditions under which conventional PIM/IMT is likely to succeed. It also underscores the core strategies needed to unlock value from irrigated agriculture across Asia.

**Table 2.**

**The socio-technical environment of Asia's surface irrigation systems and the implications for the success of conventional PIM/IMT reforms.**

	Central Asia	South Asia	Southeast Asia	China
State's revenue interest in irrigated agriculture	High	Low	Low	Low
State's capacity to enforce discipline in irrigation systems	Some to high	Low	Low	High
Government compulsory 'levy' of irrigated crops	Yes	No	No	Not any more
Spread of pump irrigation within irrigation commands	Low	Very high	High	High
Population pressure on farm land	Low	Very high	High	High
Ease of exit from farming	Low	Some	High	High
Chances of success of conventional models of PIM/IMT	High	Low	Low to medium	Low to medium
Core strategy for unlocking value	Improvise on estate-mode of irrigation farming with PIM or entrepreneurial model in distribution	Adapt surface irrigation systems to support and sustain atomistic irrigation	Modernize irrigation systems to support dry-season rice and diversified farming	Experiment and evaluate to build on the incentivized contractor model for fee collection.

This strategy has achieved only modest successes in terms of performance and sustainability. While some PIM/IMT programmes in developed countries were successful, those in developing nations have not produced fruitful results. The authors of a review of the literature on PIM/IMT suggested that it has worked in situations where irrigation has been central to a dynamic, high-performing agriculture, where benefits from managing the system outweighed the costs of management.





In most of Asia, transferring management from bureaucratic irrigation systems to farmers' groups has neither significantly improved productivity, operation and maintenance, nor has it produced other net benefits. Exceptions are limited to a few NGO-supported or donor-driven PIM initiatives across Asia. Consequently, many experts now believe there is a need to look beyond conventional PIM/IMT recipes. Infrastructure, management and operation issues have been neglected during the reform process and this has contributed to poor performance. This highlights the importance of addressing both 'hardware' and 'software' issues when planning irrigation management reforms.



### Climate change and variability as future threats

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 Intergovernmental Panel on Climate Change's (IPCC) 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,









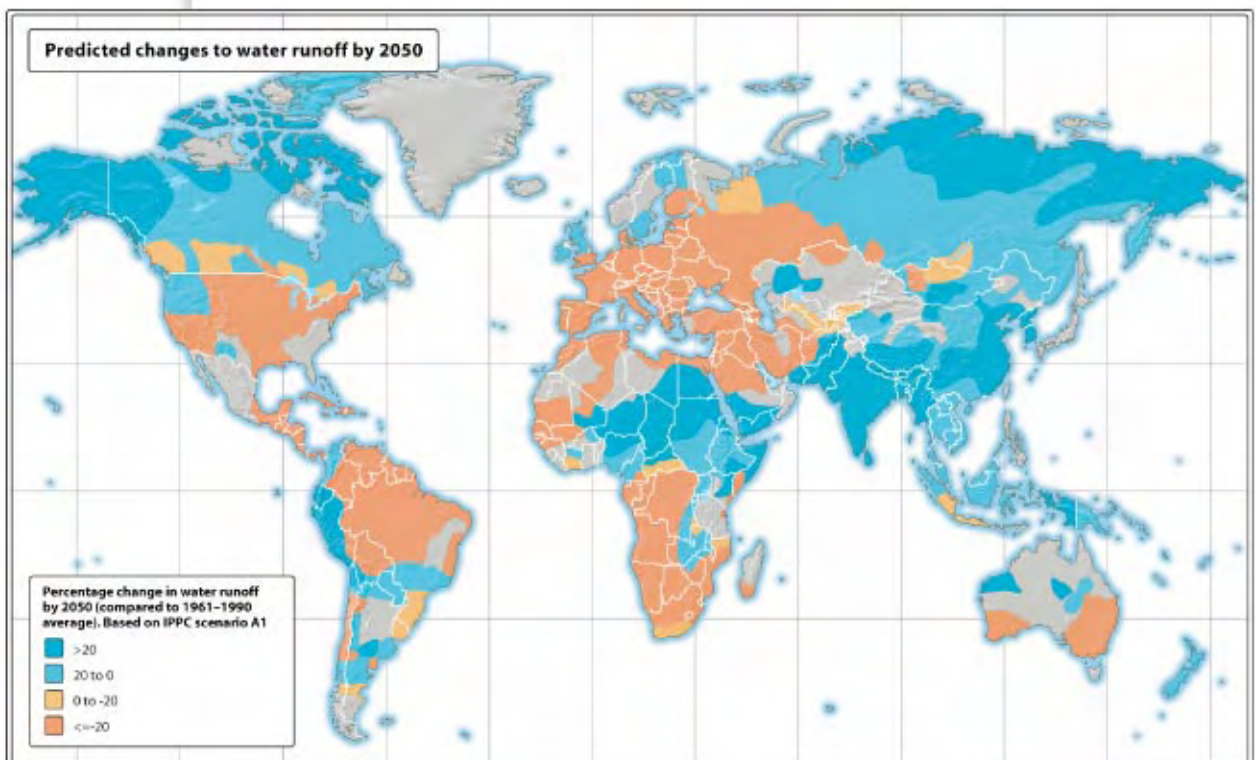
experts predict climate change will exacerbate water scarcity in large areas that are already suffering from water stress and high population densities. However, some places are likely to lose out while others benefit. The increased evaporation from climate change may increase the amount of irrigation water required in Southeast Asia by as much as 15% (Döll 2002). Meanwhile, in Central Asia, land suitable for growing crops (Fisher et al. 2006) may expand.

Most of Asia's rivers originate in the Himalayan mountains. Scientists forecast that melting of mountain glaciers due to 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% for every 1°C rise in temperature (Fischer et al. 2002). Figure 7 shows the predicted changes to runoff by 2050. Planners must consider modernizing existing irrigation systems and improving how they are managed to adapt to a more variable climate. Actions such as investing in new infrastructure, using groundwater aquifers for storing water, and making more efficient use of water in rainfed and irrigated farming will help communities adapt to climate change.

**Figure 7.**

**Large parts of the world will experience reduced run-off by 2050.**

*Source: Arnell (2003)*





## Challenges facing Asia's irrigation sector

### Central Asia: Region in transition

As a major wheat and cotton producer, Central Asia is critical to global agriculture. It has some of the largest irrigation systems in the world but the issues, challenges and opportunities it faces differ from those affecting other parts of the continent. The end of centralized control following the break up of the Soviet Union in 1991 left a vacuum that the newly independent states have struggled to fill. One response has been the 'de-collectivization' of agriculture to give farmers greater autonomy. However, this policy has created large numbers of small farmers operating in irrigation systems designed for small numbers of large farms. Planners have since promoted water user associations (WUAs) as a means to address the incongruity.

Long-term financial viability of the new system has been hampered by the state's continued control of some key farming decisions and farmers often being paid below-market prices. Also, much of the technical expertise and financial support farmers once relied on in state-managed agriculture has migrated and not been replaced. Consequently, existing irrigation infrastructure is deteriorating due to a lack of adequate maintenance. Central Asia is one of the only regions in the world where agricultural groundwater use is decreasing, due to technical constraints. The creation of new states, meanwhile, means many river basins, and even some irrigation canals, now span international boundaries. Effective transboundary institutions have not yet evolved to manage competing national goals and their impacts on how much, and when, water is available for irrigation.

### Southeast Asia: Rice production must rise

Rice provides food and work for many of Asia's rural people, especially in the wet paddy zones of Southeast Asia. Here, rice production needs to increase but with a major expansion of the area under paddy unlikely, the extra grain will have to come from presently irrigated areas through gains in productivity. On the island of Java, in Indonesia, the area under rice paddy cultivation in older irrigation schemes is shrinking, mainly due to urbanization. This, along with deforestation, demographic pressures and variability from climate change is leading ecosystems in major river basins to become degraded, a phenomenon called 'Java Syndrome'.

Early efforts to improve irrigation performance in Southeast Asia's paddy fields concentrated on improving the efficiency with which water was used. Since the 1980s, governments have overwhelmingly emphasized institutional reforms in the form of PIM/IMT, seeing this kind of action as a way out of managing financially unviable systems. With little attention given to improving how irrigation systems are designed and operate, farmers have not experienced any tangible improvements in water delivery since the reforms.

Appraisals of large and medium-scale irrigation systems by FAO and partner agencies in eight Asian countries show that irrigation systems are performing well-below their potential. A lack of discipline







and capacity within the institutions that manage water delivery mean policies are not being adequately implemented. However, the findings show that many problems can be traced back to inappropriate designs, difficulties in controlling and operating the systems, flaws in operation strategies, and an inability for systems to adapt to changes in farmers' needs. If these issues are addressed, there is every chance the required improvements in water delivery service can be achieved.

### South Asia: Opportunities for groundwater use

South Asia is the poorest and most populous region in Asia. The region not only hosts some of the oldest irrigation systems in the world, such as the Grand Anicut and Cauvery schemes, but is also home to some of the largest, including the Indus Basin irrigation system and Bhakra Nangal canal scheme. However, the area irrigated by these systems stagnated through the 1990s and has been declining since 2001. Meanwhile, groundwater irrigation has expanded rapidly to become the mainstay of irrigated agriculture across the region. Farmers now use around 250 km<sup>3</sup> of groundwater annually, nearly half the total volume used worldwide each year. Today, groundwater irrigation is a vital tool for maintaining livelihoods and food security for the poor, as well as an engine of economic growth.

These benefits have come at a cost. Groundwater has been over-exploited, especially in arid and semi-arid regions and those with hard rock aquifers. The groundwater economy in the region is closely linked to the energy economy. In India, for example, electricity for pumping groundwater is subsidized, yet large areas such as Eastern India still depend on diesel pumps for drawing groundwater. The result is a paradox; a farmer pumping water from a depth of 5 m using a diesel pump in eastern Uttar Pradesh, Bihar or West Bengal will pay almost US\$0.10–US\$0.20/cubic meter (m<sup>3</sup>) while a farmer in water-scarce Gujarat extracting groundwater from a 100 m depth may pay as little as US\$0.05/m<sup>3</sup> due to subsidized electricity. So, the region faces the dual challenge of controlling over-exploitation of groundwater in western, northwestern and southern parts of the sub-continent, while boosting groundwater irrigation in the eastern parts. Current efforts aim to improve irrigation management by reforming energy policies and introducing community schemes to replenish groundwater (see box on groundwater recharge in Saurashtra on page 33). However, the extent to which these measures will counter the depletion of groundwater have yet to be analyzed.







Photo courtesy of: Alex Benwell, [www.alexbenwell.co.uk](http://www.alexbenwell.co.uk)





## FORECASTING FUTURE FOOD NEEDS AND WATER DEMAND

Scientists agree that feeding another 1.5 billion people by 2050 will require more land and water. However, it is neither clear what additional resources will be needed nor is it obvious what the best strategies will be for producing the required extra food. In the following studies, researchers from IWMI and FAO sought to answer these questions.

### How will Asia feed its swelling population?

The policies and investment strategies chosen to increase food production and feed Asia's swelling population will affect water use, poverty and the environment. In this study, IWMI researchers identified four potential ways to produce the required amounts of food.

These are:

- Investment in irrigated agriculture
- Upgrading rainfed farming
- Trade in agricultural commodities
- A judicious combination of all three strategies

Given the high spatial and temporal variability of rainfall across Asia, augmenting rainfed farming alone will not be adequate to grow the extra food Asian people will need by 2050. While, in theory, trade in food commodities could meet the extra food requirements, it is a politically unpopular solution especially after the recent food crisis of 2007/08. Therefore, the researchers deemed investments in irrigated agriculture to be the best possible strategy for meeting future food demands.

### Squeezing value from water and land

FAO estimated that agricultural production will need to increase by 70% globally and by 100% in developing countries in order to cope with the 40% increase in world population. Both IWMI and FAO projections predicted an increase in arable land, irrigated area and water withdrawals in order to increase agricultural production by improving productivity of crops.

Researchers at IWMI used the WATERSIM model to generate scenarios showing how the production of food, water use and irrigation requirements might change in the future, given certain economic and environmental conditions. For the purpose of the study, the results are aggregated into South and East Asia. The overall findings suggest that:

- Farmers will need to divert between 10 and 57% more water to agriculture in South Asia by 2050 and between 16 and 70% in East Asia. The figures depend on whether optimistic or pessimistic assumptions are made.
- The range in predictions for how much cropped areas will need to expand ranges from 3 to 18% for South Asia and from 10 to 34% for East Asia.



### **Simulating supply and demand: IWMI and FAO**

Researchers at IWMI used the WATERSIM model to explore key links between water, food security and the environment. This model comprises a 'food demand and supply' module and a 'water supply and demand module'. It divides the world into 125 major river basins and 115 economic regions (mostly single countries with a few regional groupings of nations). These intersect to form 282 food-producing units. At basin level, the hydrologic components of water supply, use and outflow must balance. At a global level, food demand and supply are balanced by international trade and changes in commodity stocks. The model makes repeated calculations at basin, region and globe scales until conditions of hydrologic and economic equilibrium are met.

The FAO projections on land use and yield growth took crop production projections for 2030 and 2050 from the 2006 FAO study, *World Agriculture: Towards 2030/2050*, as the starting point. The crop production projections were based on demand and trade forecasts. Projected crop production, area harvested and yields were derived through several iterations using existing FAO data. This entire exercise was based on expert judgement, and was not merely an extrapolation of trends. However, neither the IWMI, nor FAO projections, took into account climate change and variability.

FAO projections found there would be very limited scope for expanding arable land in South and East Asia, while there would be a modest expansion in areas equipped for irrigation from 81 to 86 mha in South Asia from the base year of 2005 to 2050, and from 85 to 97 mha in East Asia during the same time period. In South Asia, irrigation water withdrawals would increase from 819 km<sup>3</sup> in 2005 to 906 km<sup>3</sup> in 2050 and they would increase from 714 to 793 km<sup>3</sup> in East Asia during the same time period. The main source of growth during this period would come from yield increases in much of Asia, especially in South and Southeast Asia where there is a considerable gap between current and potential yields.

### **Projected water and food demand in India**

Using the PODIUMSIM model, IWMI scientists projected India's food and water needs to 2025. Under a business-as-usual (BAU) scenario, they projected that India's water demand would increase from 680 billion cubic meters (BCM) in 2000 to 900 BCM by 2050, an increase of 32%. The model also forecast that groundwater withdrawals would increase to 423 BCM in 2050, an increase of over 84% from 2000. As a result, groundwater levels in 10 major river basins in India would decline considerably by 2050, though groundwater use efficiency would improve during this period. The scientists also projected that the gross irrigated area in the country would increase from 76 to 117 mha during the period 2000 to 2050 and the share of groundwater would increase from 43 to 70 mha. On the food supply side, the model predicted that while there would be overall surpluses of grain crops, there would be production deficits of oilseeds, which would need to be imported. Overall, it showed that with a modest increase in crop-water productivity, future water needs for crops could be accommodated without stretching water resources. Much of the additional water demand in the BAU scenario comes from the industrial and domestic sectors and these demands, too, could be met without compromising agricultural water needs through modest increases in crop and crop-water productivity.

*Source: Amarasinghe et al. 2007*







### Is making better use of rainfall possible?

WATERSIM projections show that given favorable prices and incentives, rainfed cereal yields could more than double in South Asia from 1.4 to 2.9 tonnes/ha by 2050. In East Asia, where just over half the value of the region's food already derives from land watered by the rain, the growth would be more modest, rising from 2.6 to 4.8 tonnes/ha. Under this optimistic scenario, an increase of 13% in the rainfed area would be enough to provide all the additional demand for cereal in South Asia by 2050. In East Asia, the area would have to expand by 39%, due to the higher demand for cereal for livestock feed and slower yield growth. In South Asia, 94% of the land that is suitable for farming is already cultivated, so the scope for expansion is limited unless marginal lands are exploited.

### What about boosting international trade?

When a country imports food, it 'saves' the amount of water it would have taken to grow those crops at home. In theory, world food demands could be met through international trade without worsening water scarcity or requiring new irrigation infrastructure. However, this would require both South and East Asia to import a quarter of their cereal needs by 2050. With high food prices forecast for the near future, buying food from abroad is a politically unacceptable option for many nations. More importantly, a very large number of people in Asia depend on agriculture for their livelihoods. If fewer crops were to be grown on the continent, there would need to be alternative jobs for farmers or opportunities for them to migrate elsewhere. Therefore, relying exclusively on international trade for food grains is unlikely to be a politically acceptable option.

A recent development, somewhat akin to food trade, is for counties to lease or buy tracts of land overseas on which to grow food or fuel crops. The International Food Policy Research Institute (IFPRI) reported in 2009 that between 15 and 20 mha of farmland in poor nations have been sold, or were under negotiation for sale, to foreign entities since 2006. Acquiring land abroad is a way of securing water supplies, as water rights are often included in purchase or lease agreements (Figure 8, overleaf).





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

**Countries are buying up land abroad to ensure their future food security**

**Countries owning land in other countries**

- South Korea
- China
- Saudi Arabia
- United Arab Emirates
- Japan
- India

**Amount of land owned (hectares)**

1,000,000  
100,000  
10,000  
1,000

**Land Ownership Data:**

Country	Land Owned (hectares)
South Korea	2,306,000
China	2,090,796
Saudi Arabia	1,882,500
U.A.E.	1,282,500
Japan	304,352
South Korea	2,306,000

Asia grows 90% of the global rice supply, mostly on irrigated land. Although irrigation has been in decline for a decade, rising demand for food and anticipated changes to climates are encouraging donors and policymakers to reconsider its potential value. IWMI researchers generated two scenarios using the WATERSIM model, one emphasizing the expansion of irrigated land, and the other focusing on improving yields in order to investigate the role of irrigated agriculture in meeting future food demands (Table 3).



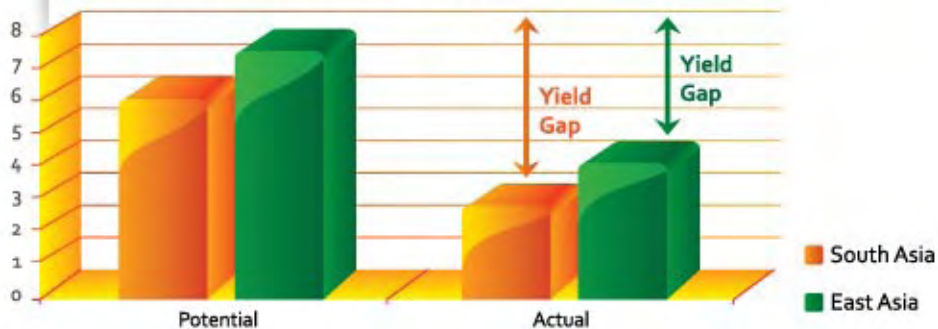


The yield-improvement scenario was aimed at obtaining 'more crop per drop' from presently irrigated lands. Under these circumstances, 80% of the gap between actual and potential irrigated cereal yield could be bridged (Figure 9). These conditions would result in South's Asia's yield doubling from 2.7 to 5.4 tonnes/ha and East Asia's increasing by 70% from 4.0 to 6.8 tonnes/ha. Achieving these improvements in yields would require greater water supplies to existing irrigated areas, as greater transpiration from plants is a precondition for boosting yields. The scenario envisaged a 12 and 4% increase in irrigated land area in South and East Asia respectively, along with a 29 and 26% increase in diversions of water to farmland.

**Figure 9.**

**Irrigated cereal yields under different irrigation scenarios (tonnes per hectare)**

Source: Based on IWMI's WATERSIM calculations



The models show that, while increasing yields from rainfed agriculture and boosting food trade could contribute to meeting Asia's future food demands, increasing production from irrigated farmland remains a necessity. Therefore, there is an essential need to focus on irrigation. There is substantial potential for improving the performance of existing irrigated areas, particularly in South Asia, where more than 50% of the harvested area is irrigated and yields are low. Three-quarters of the additional food supply required in Asia by 2050 can be met by improving productivity in this way. In South Asia, all additional demand for cereal can be met by improving yields from irrigated land, although it would require extra water withdrawals.

**Table 3.**

**Results of irrigated yield improvement and area expansion scenarios.**

Note: Negative numbers signify imports.

	South Asia					East Asia				
	2000	2050 Yield scenario	Growth (%)	2050 Area scenario	Growth (%)	2000	2050 Yield scenario	Growth (%)	2050 Area scenario	Growth (%)
Irrigated cereal yield (tonnes/hectare)	2.7	5.4	100	4.1	52	4.0	6.8	70	5.6	40
Irrigated area (mha)	104	115	11	135	30	116	121	4	170	47
Net cereal trade (% of demand)*	7	0		2		-5	-6		-4	



## MAKING IRRIGATION PERFORM BETTER

### A continent in transition

Asia has one of the most extensive irrigation infrastructures in the world, much of it constructed in the 1960s and 1970s when the priority was to produce more cereal crops to avert famine. Since then, Asian economies have changed in myriad ways and irrigation systems have evolved from being single-function to multi-function ones. The Asian countries are now at varying levels of development. The agricultural sectors of Asian countries can be largely classified as being at one of three stages: those that derive their revenue largely from activities outside agriculture, such as Malaysia; nations where farming is mostly geared towards producing crops for export, such as the former Central Asian Republics; and countries where agriculture still remains the main source of rural livelihoods, such as Bangladesh, Nepal, Cambodia and Vietnam. Strategies for developing irrigation and drainage need to be targeted according to the stage of development (Table 4).

**Table 4.**

**Policies needed to adapt infrastructure to current and future needs.**

Agricultural strategy and stage of development	Agricultural and economic situation	Most appropriate strategy
Focus outside agriculture  Developed economies	<ul style="list-style-type: none"> <li>• Highly diversified agriculture</li> <li>• Competition for water and land</li> <li>• High environmental awareness</li> <li>• Rapid urbanization and shifts in diets</li> <li>• Assuring minimum food self-sufficiency is still a stated goal</li> </ul>	<ul style="list-style-type: none"> <li>• Adapt large-scale systems originally designed for cereal production to high-value farming</li> <li>• Encourage private investments and conjunctive use</li> <li>• Improve water productivity</li> <li>• Ensure full cost recovery</li> <li>• Invest in reuse of wastewater</li> </ul>
Export-oriented agriculture  Intermediate/transition economies	<ul style="list-style-type: none"> <li>• On the way to diversification, though cereal crops still dominate</li> <li>• Quick demographic transition</li> <li>• Export earnings from agriculture a major source of revenue</li> </ul>	<ul style="list-style-type: none"> <li>• Stabilization of area under cereal cultivation</li> <li>• Emphasis on smaller schemes dedicated to producing high-value crops</li> <li>• Emphasis on financial viability of schemes</li> <li>• Adopt water-saving technologies</li> </ul>
Agriculture dependent  Developing economies	<ul style="list-style-type: none"> <li>• Alleviating poverty and achieving food security are stated goals</li> <li>• Few alternative livelihood options</li> <li>• High population pressure</li> </ul>	<ul style="list-style-type: none"> <li>• Concentrate on producing cereals</li> <li>• Develop new infrastructure through strong government support</li> <li>• Source external funding for developing new infrastructure and modernizing existing schemes</li> </ul>



Future investments in the irrigation and drainage sector need to take into account the changing socioeconomic conditions across Asia. Based on research and expert consultations, this paper highlights five main strategies for future investments in irrigation.

### Strategy 1: Modernize yesteryear's schemes for tomorrow's needs

In many places, the large-scale surface irrigation systems developed in the past are underused, poorly maintained and inefficient. There is substantial scope for unlocking value from earlier investments. Sometimes, this is possible simply by improving operations but in most cases it requires modernizing the existing hardware to better meet the needs of users. Modern designs, when effectively managed, provide flexible and reliable water supplies to meet the changing demands of farmers. Sometimes, blending modern design principles with existing irrigation infrastructure provides a cheaper but effective way for improving the performance of an irrigation scheme (see the case study on Deduru Oya in Sri Lanka, overleaf).

Pressurized systems (pipes, sprinklers and drip systems), and even levelled fields, can be very precise. Allocating water supplies for multiple uses, such as drinking water, industry, livestock rearing, fisheries and natural ecosystem functions, is a good way to increase efficiency. For example, storage ponds created by farmers to help them control water deliveries could also be used to develop fisheries. These could boost family nutrition as well as providing additional income. Sri Lanka is planning to take this approach with its newly constructed Rambukkan Oya irrigation project.





### **Blending ancient technology with new: Deduru Oya Reservoir Project, Sri Lanka**

A new irrigation project in the Deduru Oya Basin in Sri Lanka aims to capitalize on existing irrigation infrastructure while improving the reliability of supplies to farmers. Farmers living in the basins presently depend on rainwater that collects in 3,000 artificial lakes, or tanks, but they frequently face water shortages. The tanks form part of an ancient irrigation system developed under the direction of King Mahasena between 277 and 304 AD.



Photo courtesy of: Arosha Ranasinghe

The Government of Sri Lanka has begun building a dam, with the aim of capturing and storing the 1,600 million cubic meters (MCM) of runoff that is generated by rainfall during the wet season. A 33 kilometer (km) canal will supply water to a 1.5 megawatt (MW) powerhouse, as well as to existing and new farming areas in the Deduru Oya and Mee Oya basins. Meanwhile, a 44 km canal will supply the existing tank cascade system by connecting all the reservoirs, thereby ensuring they are constantly replenished. Similar examples operate in the Tanbraparani Basin in Tamilnadu, where numerous tanks get supplied from a storage reservoir.

### **Strategy 2: Go with the flow by supporting farmers' initiatives**

With large surface irrigation schemes failing to respond to the needs of farmers, many small-holders have installed their own irrigation infrastructure to overcome deficiencies in water supplies and insure themselves against possible risks of crop failure. For example, they have installed pumps to withdraw groundwater or devised innovative ways to store water so they can tap supplies when they need them. These actions, taken largely by individuals or small groups, sometimes have negative consequences such as over-extraction of water and resources being shared unfairly. Nonetheless, these activities also have large positive impacts, such as increasing crop productivity and helping farmers boost their incomes. Investments supporting initiatives that increase the volume of 'crop per drop' without impinging on the rights of others will be crucial. In some cases, existing irrigation infrastructure can be used to deliver water to intermediate water storage structures (see case studies on India and China, opposite) or may be used to recharge groundwater (see case study on India, page 33).







## **Making canal irrigation more flexible and reliable:**

### **Farm storage tanks in India and China**

The Indira Gandhi Nehru Pariyojna (IGNP) scheme was set up to irrigate large areas of the Thar Desert, which covers two-thirds of Rajasthan. Under the 'waraband' system, water is allocated to canals on a weekly rotation, with each canal receiving water for a week and then drying out for a week. Although the system promotes equity, the timing of water supply is often mismatched for critical periods of crop growth. As the area irrigated by the IGNP expanded over time, the frequency of water supplies decreased. Farmers' acted to overcome unreliable water supplies in the project area by building intermediate water storage tanks called 'diggies'. An average 'diggie' is about 900 square meters ( $m^2$ ) with a storage capacity of  $3,160 m^3$ . The farmers use sprinklers to distribute water from the diggies, with each sprinkler covering around 0.41 ha of irrigable land. Overall, farms now irrigate 27% more than before construction of the diggies. Benefits include an increase in the rental value of land and a doubling in the value of output from farms in the Kharif season. There is potential across India to improve the reliability of water supplies through similar storage mechanisms.



Photo courtesy of Upali Amarasinghe

Farmers in one of the major canal commands of China's Zanghe Irrigation System, meanwhile have also received declining water deliveries in recent decades, as dam supplies have been increasingly diverted to hydropower, cities and industry. They have responded by building small storage structures in their fields. The ponds are recharged by a mixture of return flows from irrigation and runoff from catchment areas within the irrigated area. The structures enable farmers to maintain crop areas and water use despite receiving reduced waters from the canal system. However, reservoir supplies are still important to farmers during dry seasons. This model could be developed by incorporating management of small storage structures within canal irrigation operations. Actions might include developing operational procedures that explicitly take advantage of these ponds. With the reuse of water a prevalent feature of modern irrigation, the system could be transposed to other locations with similar rainfall regimes and topography.



### **Boosting water supply:**

#### **Groundwater recharge movement in Saurashtra, India**

The increasing scarcity of groundwater prompted a mass movement for well-recharge and water conservation in Saurashtra, Gujarat, India. The main catalyst was a religious teacher of the Swadhyaya Pariwar Hindu religious group, who was subsequently joined by other sects of Hinduism and scores of NGOs. The campaign started in the mid-1980s in response to a severe drought. The campaigner's slogan was "the rain on your roof, stays in your home; the rain on your field stays in your field; the rain in your village, stays in your village." The movement caught popular attention and by 1995 had prompted many NGOs to examine the potential of recharging groundwater supplies. In the early 2000s, the Government of Gujarat launched a dam water-harvesting scheme, under which the government contributed 60% of the resources required to build the dam and the community contributed the rest. In 2007, the Government of India launched a program for recharging wells. While the mass movement for water harvesting in Saurashtra has not been rigorously assessed, studies shows these actions reduce vulnerability by securing winter irrigation.

*Source: Van Steenberg and Shah (2003)*

### **Strategy 3: Look beyond conventional PIM/IMT recipes**

Problems of low efficiency, poor operation, deferred maintenance, high fiscal burden on governments and unreliability, plague large-scale surface water irrigation schemes. In response, farmers in many parts of Asia have chosen to vote with their feet by either abandoning, or reducing their dependence on, poorly performing schemes. However, billions of dollars have already been invested in these large-scale systems and they still offer a huge opportunity for increasing food production and securing livelihoods.

Since the mid-1980s, when problems began emerging within the publicly managed irrigation and drainage sector, governments have attempted to make reforms, largely through PIM and IMT. Since farmers were the biggest stakeholders in irrigation, the idea was that they might do a better job of running the systems through WUAs. However, after more than 20 years of experimentation with PIM/IMT, results are at best mixed; there have been only a handful of fully successful cases. Attention is increasingly being paid to alternative types of reforms.



*Photo courtesy of Carolyn Fry*





One alternative to PIM/IMT gaining acceptance is to involve the private sector in publicly managed irrigation and drainage schemes. Such initiatives offer a means for governments to offload fiscal and administrative burdens, without placing the responsibility entirely on the shoulders of unprepared and unwilling farmers. Often termed Public-Private Partnerships (PPP), these involve finding a viable 'third party' between farmers and governments. This could be a public entity, such as a reformed or financially autonomous government agency. Alternatively, it might be private, such as a contracting firm or WUA turned into a private corporation or a farmers' company.

Such PPPs have been running within the water and sanitation sector for two decades, but are less widespread in the irrigation sector, especially in Asia. A part of the PPP could involve unbundling management of large irrigation canal systems into, for example, reservoirs, main canals and distribution networks, in a way similar to reforms that have taken place in the power sector. It seems likely that PPPs could be useful in mobilizing financing, implementing investment programs and improving the water delivery service. However, they are as yet largely untested in Asia. China has experimented with using private contractors with some success (see box below). Sri Lanka has also experimented with a farmer-managed irrigation company (see box, overleaf). Experiences in Mali, France and New Zealand also support the idea that the private sector can efficiently manage irrigation systems and collect water charges, even in the absence of formal WUAs.

### **Contracting out irrigation services and saving water: Examples from China**

China's irrigation reforms are based around creating profitable water businesses for the long-term financial sustainability of the project. A study of 51 villages, located within four large irrigation schemes in the Yellow River Basin in China, indicate that China has been largely successful with its 'bounded service provider' model, which aims to create water-saving incentives for water managers. Water managers from the local WUA or contract management arrangement receive a basic fee but can increase their incomes by saving water. The lower the village requirement for water, the more they earn. The researchers, from the Center for Chinese Agricultural Policy and IWMI, found that water use per hectare is lower in villages with incentivized management of large irrigation schemes by as much as 40%. This saving does not significantly reduce yields of major crops including rice and maize.

China has also made significant achievements in saving water used for agriculture, thanks to institutional and technological innovations. Between 1980 and 2004, while the total volume of water being used by the country rose by 25%, the amount allocated to irrigation remained at 340–360 BCM. At the same time, the irrigated area increased by 5.4 mha, food production capacity increased by 20 million tonnes and 200 million people gained food security. In the past decade, China's irrigation water use per hectare dropped from 7,935 to 6,450 m<sup>3</sup> nationwide.

*Source: Wang et al. (2007)*



### Building on innovation: Farmer-managed irrigation in Sri Lanka

The Ridi Bendi Ela People's Farmer Company was established in 1998 as a pilot experiment in Irrigation Management Transfer, by the Ministry of Irrigation and Water Resources, Sri Lanka. The goal of the pilot project was to hand over irrigation system operation and maintenance to the newly formed system-level farmer organization (SLFO). The SLFO, in turn, contracted a newly formed farmer company to undertake these tasks. The farmer company was formed under the Companies Act with the farmers as the shareholders. It was designed to be multi-functional, with goals to diversify small-holder agriculture and generate income by offering credit, training and marketing through public-private partnerships. The long-term aim was to progressively reduce the government subsidy as farmer shareholders became sufficiently financially sound to shoulder the operation and maintenance responsibilities. In the year 2000, under a tripartite agreement between the government, the farmer organization and the farmer company, the irrigation system below the reservoir and the main sluice was leased to the SLFO and the farmer company for 36 months.

The initial result of this innovative experiment was impressive: the dry season cultivation area was expanded by 2,000 acres (1 acre = 0.404 hectare), and water consumption was significantly reduced. Under intensive drought in 2003-2004, when crops were destroyed in this region, this irrigation system still managed to cultivate 4,300 acres. There was a marked decline in catchment head-to-tail disparities and water conflicts among farmers reduced significantly. The farmer company undertook microcredit programs, began seed paddy production and started propagating traditional and nearly-extinct rice varieties. They also entered into commercial agreements with private dairy and poultry companies. In 2006, the government ended the tripartite agreement and the irrigation-related activities were divested from the company. The company continues to function marginally, performing a few non-irrigation-related activities.

*Source: Namika Raby, personal communication*

### Strategy 4: Expand capacity and knowledge

For any of these strategies to work, investors must direct funds towards boosting capacity and knowledge within institutions. The challenges faced by the irrigation sector today and in the future, differ greatly from those that were faced in the past (Figure 10). To achieve the desired aims of ensuring people have enough food to eat, reducing poverty and benefiting from the services that healthy ecosystems provide, Asia will need to start thinking differently about how water is used. For example, as well as surface irrigation supplies, decision-makers need to consider the contribution of rainfall and groundwater, envisage agriculture as an ecosystem, and embrace the importance of gender by acknowledging the roles played by women in rural economies that depend on irrigation.

Changing existing mind-sets will require training. This will demand investment in programs to reform and develop institutions that manage irrigation so that existing staff members embrace

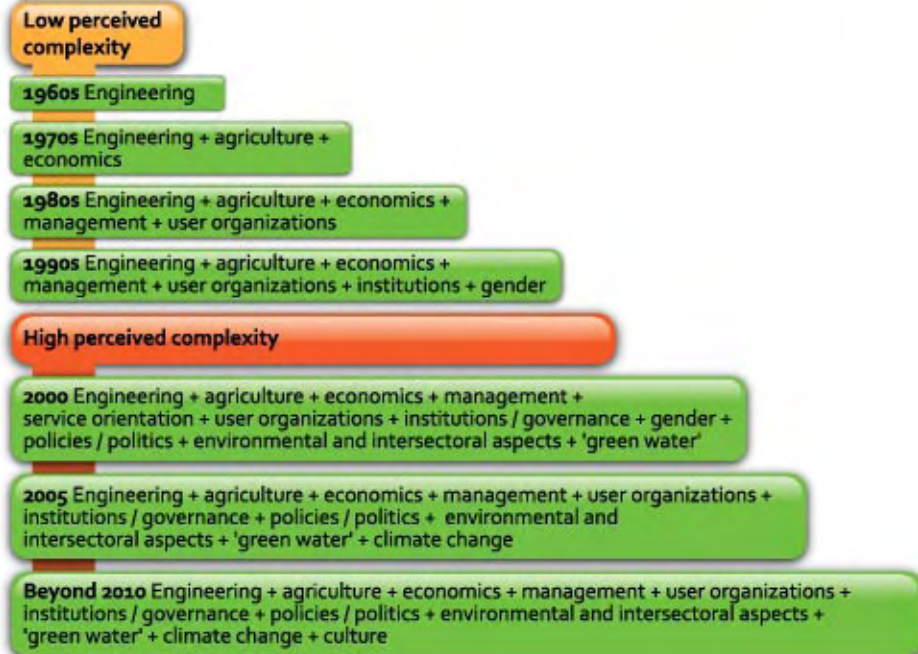




**Figure 10.**

**Over the years, managing irrigation has become a complex affair.**

*Source: Huppert (2008)*



new ways of thinking. It will also require investments aimed at attracting and retaining talented new irrigation engineers and administrators. Actions might include commissioning research so that institutions keep in touch with the realities on the ground, using this research to develop up-to-date and informative curricula to attract a new generation of irrigation specialists, and training them on how to adapt existing irrigation schemes for multiple uses to obtain greater value per drop. Central Asia and parts of newly liberalized Southeast Asia (Laos and Cambodia, for example), desperately need trained people to manage irrigation systems and adapt them to changing rural circumstances.

### **FAO's MASSCOTE: Encouraging irrigation staff to modernize**

The FAO has initiated a programme to train engineers and managers on how to modernize irrigation systems. This programme, called MASSCOTE (Mapping System and Services for Canal Operation Techniques), sets out new guidelines for using service-oriented management to make irrigation schemes function better. The idea is to drive through change at system, state, regional and global levels. For example, MASSCOTE was introduced in Karnataka, India, in 2006. Since then, staff members have shifted their focus from being supply-oriented to service-oriented and they have improved the way in which they target investment planning. A state-level workshop on irrigation policy is now planned to discuss how best to revise irrigation legislation so systems can be successfully modernized.









### Strategy 5: Invest outside the water sector

Although this report focuses on irrigation, the sector forms part of the larger political economy of Asia. In future, instead of being proactive as it was in the 1960s and early 1970s, the irrigation sector will become increasingly reactive to external forces. Developments in irrigation will be driven by policies and programmes that influence agriculture directly (subsidies, taxes, trade policies and genetic research) and indirectly (energy policies, labor laws, rural finance, land tenure, environmental policies, strategies to alleviate poverty and transboundary resource issues). For example, investing to reform agricultural policy in Central Asia may be more effective at rejuvenating irrigation services than funding aimed specifically at renovations to the physical infrastructure. Similarly, in India, investing in electricity sector reforms would have a profound influence on groundwater use and may even halt its over-exploitation in certain places. Investments in rural infrastructure such as roads, markets and electricity will help to maximize returns from investments in irrigation (see box, below). Understanding the links between sectors, and encouraging communication and collaboration among them, will be crucial for meeting future irrigation and drainage challenges.

#### National Rural Employment Guarantee Act, India

Launched by the Ministry of Rural Development, the National Rural Employment Guarantee Act (NREGA) is the flagship program of the Government of India. It is aimed at enhancing the livelihoods and financial security of households in rural areas by providing at least 100 days of guaranteed wage employment in a financial year to every household whose adult members volunteer to do unskilled manual labor. In 2007–2008, 33.9 million households benefited from employment opportunities offered by 330 districts across India. While the main purpose of NREGA was to generate employment in rural areas, it did this through initiatives such as creating features for water harvesting, renovating traditional water bodies, developing land and boosting rural communication links. According to a financial statement released by the Government of India, 64% of all investments were geared towards creating assets for conserving water and creating small-scale irrigation infrastructure. In the financial year of 2007–2008, water storage facilities totalling 130 MCM were created by digging new ponds, building percolation tanks and constructing small check dams. Approximately 66,000 ha became irrigated during this time.

### In conclusion

Today, Asian irrigation is at a crossroads. The need to produce more food is prompting new interest in investments in the sector, but innovative methods are required to reverse the degradation that has resulted from years of neglect. As this report shows, Asia is a diverse continent and different strategies will be needed to achieve this goal in different places and under varying economic, political and geographic conditions. However, there are great opportunities for irrigation to once more help farmers improve productivity. If Asian irrigation can become better at meeting the needs of farmers, within the uncertainties of rainfall and runoff presented by climate change, it will play a vital role in preventing Asia's future population from going hungry.



## REFERENCES

### IWMI-FAO-ADB Background papers

de Fraiture, C. Looking ahead to 2050: Scenarios for water and food in Asia.

Faurès, J.-M.; Mukherji, A. Trends and Drivers in Asian Irrigation.

Füleki, B.; Mukherji, A.; Molden, D.; Giordano, M. Institutional reforms in irrigation management in Asia: Options for the future.

Shah, T. Reform or Morph: Unlocking value in Asian Irrigation.

Wichelns, D.; Facon, T. Irrigation in Asia: Investment options for the future.

For links to these papers, please visit: <http://waterknowledgehub.iwmi.org/index.htm>

Amarasinghe, U. A.; Shah, T.; Turral, H.; Anand, B. K. 2007. India's water future to 2025-2050: Business-as-usual scenario and deviations. Colombo, Sri Lanka: International Water Management Institute. 47p. (IWMI Research Report 123)

Arnell N. 2003. Effects of IPCC SRES emissions scenarios on river runoff: A global perspective. *Hydrology and Earth System Sciences* 7(5): 619-641. EGU Journals (online).

Comprehensive Assessment of Water Management in Agriculture. 2007. Water for food, Water for life: A Comprehensive Assessment of Water Management in Agriculture. London: Earthscan ([www.earthscan.com](http://www.earthscan.com)), and Colombo: International Water Management Institute.

Döll, P. 2002. Impact of climate change and variability on irrigation requirements: A global perspective. *Climatic Change* 54(3): 269-293.

Fischer, G.; Shah, M.; Velthuisen, H. V. 2002. Climate change and vulnerability. In a special report prepared as a contribution to the World Summit on Sustainable Development. Laxenburg, Austria: IIASA Special Publications.

Fischer, G.; van Velthuisen, H.; Shah, M.; Nachtergaele, F. O. 2006. Global agro-ecological assessment for agriculture in the 21st century: Methodology and results. CD-ROM. Laxenburg, Austria: International Institute for Applied Systems Analysis (IIASA); Rome, Italy: Food and Agriculture Organization of the United Nations.

Huppert, W. 2009. Coping with complexity: Innovative approaches to an emerging issue in agricultural water management. Rome: International Fund for Agricultural Development.

Van Steenberghe, F.; and Shah, T. 2003. Rules rather than rights: Self-regulation in intensively used groundwater systems in Llamas, R & E. Custodio (eds) *Intensive use of groundwater: Challenges and opportunities*, Rotterdam, Netherlands: A. A. Balkema. pp.241-256.

Wang, Jinxia; Jikun Huang; Zhigang Xu; Scott Rozelle; Intizar Hussain; Eric Biltonen. 2007. Irrigation management reforms in the Yellow River Basin: Implications for water saving and poverty. *Irrigation and Drainage Journal* 56: 247-259.









Asia-Pacific  
Water Forum  
*KnowledgeHubs*

[www.iwmi.org](http://www.iwmi.org)

IWMI Headquarters:  
127, Sunil Mawatha,  
Pelawatte, Battaramulla,  
Colombo, Sri Lanka.

Telephone +94-11 2880000  
Fax: +94-11 2786854  
Email: [iwmi@cgiar.org](mailto:iwmi@cgiar.org)  
Web: [www.iwmi.org](http://www.iwmi.org)

