WATER POLICIES AND AGRICULTURE

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This paper is extracted from the Special Chapter on Water Policies and Agriculture, published in *The State of Food and Agriculture*, 1993. It is primarily intended for agricultural policy-makers, water managers, researchers, students, development planners and agricultural project donors. It is meant to help us reflect on the way water resources are managed at present; to contribute to the discussion on sustainable water use; and to stimulate thinking, research and change. Decisions made in this decade regarding how water is used will have a profound effect on our future supplies.

The full text of the Special Chapter consists of four sections. The first section gives an overview of world water resources and briefly discusses the key issues: scarcity, quality and health.

The second section stresses the need to integrate the water sector with the national economy and analyses the physical, economic and social aspects of water. It then provides a conceptual foundation for understanding the circumstances under which water policies either work or fail. Section II also assesses the advantages and disadvantages of broad alternative approaches to public water policy.

Section III examines how policy analysis is applied to water resource planning, including both supply-side (physical and hydrological) and demand-side considerations. It discusses the advantages and disadvantages of various policy options for urgent water policy issues related to surface water and groundwater.

The fourth and final section reviews three specific policy issues in irrigated agriculture: declining growth and investment trends; the difficulties imposed by irrigation-induced environmental degradation; and efforts to reform managerial/administrative systems.

Only extracts from Sections I and II are reproduced in this document.

WATER POLICIES AND AGRICULTURE

I. Water resource issues and agriculture

INTRODUCTION AND OVERVIEW

An interesting observation arising from the preparation of this year's special chapter on water and agriculture is how difficult it is to generalize about water. Almost any statement requires qualification. For example, while we can say that water is one of the most abundant resources on earth, we know that less than 1 percent of the total supply is reliably available for human consumption. Water is a liquid, for the most part, but it can also be a solid and a vapour. Drinking-water is certainly essential for human survival but water-related illnesses are the most common health threat in the developing world. An estimated 25 000 people die every day as a result of water-related sicknesses.[1]

One statement, however, needs no qualification: human existence depends on water. The geosphere, the atmosphere and the biosphere are all linked to water. Water interacts with solar energy to determine climate and it transforms and transports the physical and chemical substances necessary for all life on earth.

In recent years, water issues have been the focus of increasing international concern and debate. From 26 to 31 January 1992, the UN system sponsored the International Conference on Water and the Environment (ICWE) in Dublin, Ireland. The ICWE called for innovative approaches to the assessment, development and management of freshwater resources. In addition, the ICWE provided policy guidance for the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in June 1992. UNCED highlighted the need for water sector reforms throughout the world.In 1993, the World Bank issued a comprehensive policy paper defining its new objectives for the water sector. FAO recently established an International Action Programme on Water and Sustainable Agricultural Development (ISA-WASAD). Likewise, the UNDP, WHO, UNICEF, WMO, Unesco and UNEP are all coordinating or participating in special programmes related to water resources.

Other international, national and local organizations are becoming more active in water issues. The 1990 Montreal meeting, "NGOs Working Together", focused attention on drinking-water supply and sanitation. The Canadian International Development Agency, the French Ministry of Cooperation and Development, the German Agency for Technical Cooperation (GTZ), the United Kingdom's Overseas Development Administration and the United States Agency for International Development (USAID) have recently developed water resource strategies for foreign assistance.

The message highlighted by all these efforts is that water is an increasingly scarce and valuable resource. Of principal concern is our failure to recognize and accept that there is a finite supply of water. The consensus is that the growing water scarcity and misuse of freshwater pose serious threats to sustainable development.

[1] UNEP. 1991. *Freshwater pollution*. UNEP/GEMS Environmental Library. No. 6. Nairobi.

Competition among agriculture, industry and cities for limited water supplies is already constraining development efforts in many countries. As populations expand and economies grow, the competition for limited supplies will intensify and so will conflicts among water users.

Despite water shortages, misuse of water is widespread. Small communities and large cities, farmers and industries, developing countries and industrialized economies are all mismanaging water resources. Surface water quality is deteriorating in key basins from urban and industrial wastes.

Groundwater is polluted from surface sources and irreversibly damaged by the intrusion of salt water. Overexploited aquifers are losing their capacity to hold water and lands are subsiding. Cities are unable to provide adequate drinking-water and sanitation facilities. Waterlogging and salinization are diminishing the productivity of irrigated lands. Decreasing water flows are reducing hydroelectric power generation, pollution assimilation and fish and wildlife habitats.

At first glance, most of these water problems do not appear to be directly related to the agricultural sector. Yet, by far the largest demand for the world's water comes from agriculture. More than two-thirds of the water withdrawn from the earth's rivers, lakes and aquifers is used for irrigation. As competition, conflicts, shortages, waste, overuse and degradation of water resources grow, policy-makers look increasingly to agriculture as the system's safety valve.

Agriculture is not only the world's largest water user in terms of volume, it is also a relatively low-value, low-efficiency and highly subsidized water user. These facts are forcing governments and donors to rethink the economic, social and environmental implications of large publicly funded and operated irrigation projects. In the past, domestic spending for irrigation dominated agricultural budgets in countries throughout the world. For instance, since 1940, 80 percent of Mexico's public expenditures in agriculture have been for irrigation projects. In China, Pakistan and Indonesia, irrigation has absorbed over half of agricultural investment. In India, about 30 percent of all public investment has gone into irrigation.[2]

A significant portion of international development assistance has also been used to establish irrigation systems. Irrigation received nearly 30 percent of World Bank agricultural lending during the 1980s. Spending commitments for irrigation by all aid agencies exceeded $2 billion per year in the past decade.

Once established, irrigation projects become some of the most heavily subsidized economic activities in the world. In the mid-1980s, Repetto[3] estimated that average subsidies to irrigation in six Asian countries covered 90 percent of the total operating and maintenance costs. Case-studies indicate that irrigation fees are, on average, less than 8 percent of the value of benefits derived from irrigation.

Despite these huge investments and subsidies, irrigation performance indicators are falling short of expectations for yield increases, area irrigated and technical efficiency in water use. As much as 60 percent of the water diverted or pumped for irrigation is wasted.[4] Although some losses are inevitable, in too many cases this excess water seeps back into the ground, causing waterlogging and salinity. As much

[2] R. Bhatia and M. Falkenmark. 1992. *Water resource policies and the urban poor: innovative approaches and policy imperatives*. Background paper for the ICWE, Dublin, Ireland.

[3] R. Repetto. 1986. *Skimming the water: rent-seeking and the performance of public irrigation systems*. Research Report No. 4. Washington DC, WRI.

[4] FAO. 1990. *An International Action Programme on Water and Sustainable Agricultural Development*. Rome.

as one-quarter of all irrigated land in developing countries suffers from varying degrees of salinization.[5] Moreover, stagnant water and poor irrigation drainage escalate the incidence of water-related diseases, resulting in human suffering and increased health costs.

Today, agriculture is often unable to compete economically for scarce water. Cities and industries can afford to pay more for water and earn a higher economic rate of return from a unit of water than does agriculture. (For economists, water flows uphill to money.) For the first time in many countries, agriculture is being obliged to give up water for higher-value uses in cities and industries. Irrigators in some areas are now asked to pay for the water they receive, including the full cost of water delivery. In other areas, new regulations require farmers to pay for polluting streams, lakes and aquifers.

The irony is that irrigated agriculture is expected to produce much more in the future while using less water than it uses today. At present, 2.4 billion people depend on irrigated agriculture for jobs, food and income (some 55 percent of all wheat and rice output is irrigated). Over the next 30 years, an estimated 80 percent of the additional food supplies required to feed the world will depend on irrigation.[6]

These developments are placing enormous pressure on agricultural policy-makers and farmers. Throughout the world, governments assume the prime responsibility for ensuring food security and, because food depends increasingly on irrigation, food security is closely linked with water security. Between 30 and 40 percent of the world's food comes from the irrigated 16 percent of the total cultivated land; around one-fifth of the total value of fish production comes from freshwater aquaculture; and current global livestock drinking-water requirements are 60 billion litres per day (forecasts estimate an increase of 0.4 billion litres per year). Food security in the next century will be closely allied to success in irrigation.

Irrigation can help make yield-increasing innovations a more attractive investment proposition but it does not guarantee crop yield increases. The overall performance of many irrigation projects has been disappointing because of poor scheme conception, inadequate construction and implementation or ineffective management. The mediocre performance of the irrigation sector is also contributing to many socio-economic and environmental problems, but these problems are neither inherent in the technology nor inevitable, as is sometimes argued.

Irrigation projects can contribute greatly to increased incomes and agricultural production as compared with rain-fed agriculture. In addition, irrigation is more reliable and allows for a wider and more diversified choice of cropping patterns as well as the production of higher-value crops. Irrigation's contribution to food security in China, Egypt, India, Morocco and Pakistan is widely recognized. For example, in India, 55 percent of agricultural output is from irrigated land. Moreover, average farm incomes have increased from 80 to 100 percent as a result of irrigation, while yields have doubled compared with those achieved under the former rain-fed conditions; incremental labour days used per hectare have increased by 50 to 100 percent. In Mexico, half the value of agriculture production and two-thirds of the value of agricultural exports is from the one-third of arable land that is irrigated.

Irrigation is a key component of the technical package needed to achieve productivity gains. In the future, as high levels of costly inputs are added to crop-

[5] Ibid.

[6] International Irrigation Management Institute. 1992. *Developing environmentally sound and lasting improvements in irrigation management: the role of international research*. Colombo, Sri Lanka, IIMI.

land to sustain yield increases, the security and efficiency of irrigated production will become even more important to world farming. Water will no longer be plentiful and cheap. It will be scarce, expensive to develop and maintain and valuable in use. The prospect of high-cost water may at first seem to be another problem looming for low-income economies. However, the high cost will be an incentive to use water more efficiently. The single most important factor limiting the adoption of proven irrigation and drainage technology is the low cost of water. Moreover, if farmers have opportunities for higher-value uses and can make profits, both governments and farmers will invest in irrigation.

This water dilemma – to produce more in a sustainable way with less water – points to the need for demand management mechanisms to reallocate existing supplies, encourage more efficient use and promote more equitable access. Policy-makers need to establish a structure of incentives, regulations, permits, restrictions and penalties that will help guide, influence and coordinate how people use water while encouraging innovations in water-saving technologies.

In the past, supply-side approaches dominated water resource management practices. Water itself was physically managed through technical and engineering means that captured, stored, delivered and treated water. However, the era of meeting growing demand by developing new supplies is ending. In our present-day water economy, resource management is shifting away from the goal of capturing more water towards that of designing demand- and user-focused approaches that influence behaviour.

WORLD WATER RESOURCES

Every day the hydrological cycle renews the world's freshwater resources through evaporation and precipitation. The average annual rainfall over land is 110 000 km^3, but some 70 000 km^3 evaporate before reaching the sea. The remaining 40 000 km^3 are potentially available for human use. Global freshwater consumption is currently around 4 000 km^3, only 10 percent of the annual renewable supply.

These numbers suggest that plenty of water is available for human use but a closer look reveals a more complicated situation. The 40 000 km^3 of available water are distributed very unevenly and two-thirds of it runs off in floods. That leaves around 14 000 km^3 as a relatively stable supply. A substantial share of this supply should be left to follow its natural course in order to safeguard wetlands, deltas, lakes and rivers.[7] For example, 6 000 km^3 of water is needed to dilute and transport the estimated 450 km^3 of waste water now entering the world's rivers each year.[8] Without substantial investment in waste water treatment and more effective regulation, even more water will have to be diverted to dilute and transport wastes.

Precipitation, withdrawals and availability of water vary widely around the world. Table 1 demonstrates regional changes in per caput water availability since 1950 and shows forecasts for 2000. Per caput availability is highest in Latin America and lowest in North Africa and the Near East while withdrawals are highest in North America and lowest in Africa. Per caput water availability in Europe and North America is not expected to change greatly by 2000 while Asians, Africans and Latin Americans will face less per caput water availability as their populations continue to grow.

At present, Asia accounts for over one-half of the world's water withdrawals. Figure 1 illustrates regional water consumption during the past century. Forecasts to the year 2000 suggest that Asia will consume 60 percent of the world's water, followed

[7] S. Postel. 1992. *Last oasis: facing water scarcity*. New York, Norton.

[8] See footnote 1, p. 1.

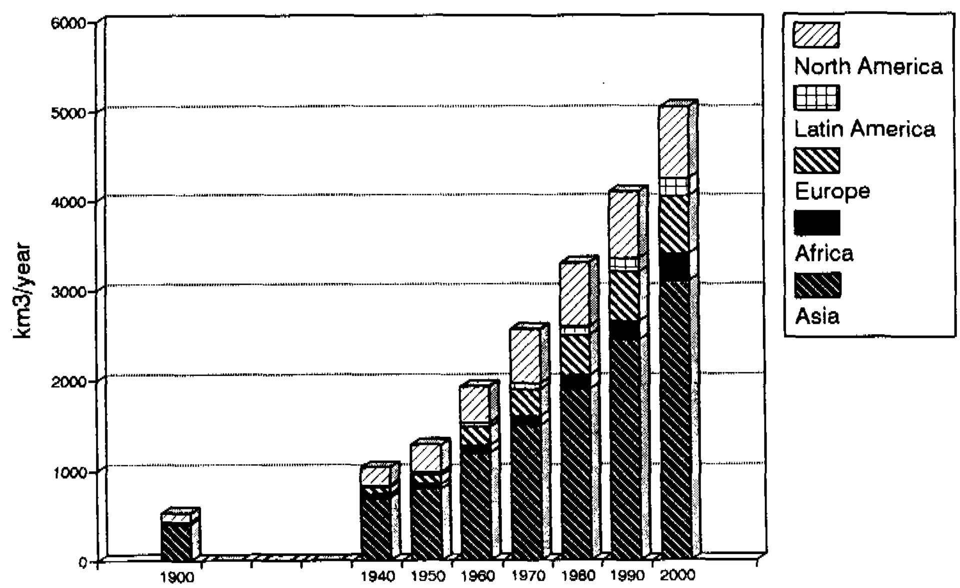
TABLE 1

Per caput water availability by region, 1950-2000

Region	1950	1960	1970	1980	2000
			'000 m^3		
Africa	**20.6**	**16.5**	**12.7**	**9.4**	**5.1**
Asia	**9.6**	**7.9**	**6.1**	**5.1**	**3.3**
Latin America	**105.0**	**80.2**	**61.7**	**48.8**	**28.3**
Europe	**5.9**	**5.4**	**4.9**	**4.4**	**4.1**
North America	**37.2**	**30.2**	**25.2**	**21.3**	**17.5**

Source: N.B. Ayibotolo. 1992. *The world's water: assessing the resource.* Keynote paper at the ICWE, Dublin, Ireland.

FIGURE 1
Water consumption by region, 1900-2000



by 15 percent in North America, 13 percent in Europe and less than 7 percent in Africa. Latin America's share of world water consumption is forecast to be less than 5 percent in 2000, although the region's consumption has nearly quadrupled since 1950.

Water scarcity

Human actions bring about water scarcity in three ways: through population growth, misuse and inequitable access.[9] Population growth contributes to scarcity simply because the available water supply must be divided among more and more people. Every country has a more or less fixed amount of internal water resources, defined as the average annual flow of rivers and aquifers generated from precipitation. Over

[9] T.F. Homer-Dixon, J.H. Boutwell and G.W. Rathjens. 1993. Environmental change and violent conflict. *Sci. Am.* (February).

TABLE 2

Countries predicted to have scarce water resources in 2000

Country[1]	Population in 2000	Water availability	
		Internal renewable water resources	Water resources including river flows from other countries
	(millions)	*(—m^3 per caput—)*	
Egypt	**62.4**	**29**	**934**
Saudi Arabia	**21.3**	**103**	**103**
Libyan Arab Jamahiriya	**6.5**	**108**	**108**
United Arab Emirates	**2.0**	**152**	**152**
Jordan	**4.6**	**153**	**240**
Mauritania	**2.6**	**154**	**2 843**
Yemen	**16.2**	**155**	**155**
Israel	**6.4**	**260**	**335**
Tunisia	**9.8**	**384**	**445**
Syrian Arab Republic	**17.7**	**430**	**2 008**
Kenya	**34.0**	**436**	**436**
Burundi	**7.4**	**487**	**487**
Algeria	**33.1**	**570**	**576**
Hungary	**10.1**	**591**	**11 326**
Rwanda	**10.4**	**604**	**604**
Botswana	**1.6**	**622**	**11 187**
Malawi	**11.8**	**760**	**760**
Oman	**2.3**	**880**	**880**
Sudan	**33.1**	**905**	**3 923**
Morocco	**31.8**	**943**	**943**
Somalia	**10.6**	**1 086**	**1 086**

[1] A number of other countries with smaller populations, e.g. Barbados, Cape Verde, Djibouti, Malta, Qatar and Singapore, are also included in the water-scarce category.
Source: FAO calculations based on World Bank/WRI data.

time, this internal renewable supply must be divided among an increasing number of people, eventually resulting in water scarcity.

When annual internal renewable water resources are less than 1 000 m^3 per caput, water availability is considered a severe constraint on socio-economic development and environmental protection. Table 2 lists the countries where per caput internal renewable water availability will fall below 1 000 m^3 by the end of this decade. Most countries facing chronic water scarcity problems are in North Africa, the Near East and sub-Saharan Africa. Countries with less than 2 000 m^3 per caput face a serious marginal water scarcity situation, with major problems occurring in drought years. By the end of the 1990s, water availability is expected to fall below 2 000 m^3 per caput in more than 40 countries.

In many countries, while scarcity is less of a problem at a national level, serious water shortages are causing difficulties in specific regions and watersheds. Notable examples include northern China, western and southern India and parts of Mexico.

People also bring about water scarcity by polluting and overusing existing supplies. Box 1 describes some of the pressing water pollution issues. This type of scarcity can be regarded as the consumption of the resource's "capital". For instance, an aquifer represents resource capital, providing what is generally a renewable source of water ("income") that can be tapped for human consumption. Sustainable use of the aquifer leaves the capital intact so that future generations can continuously use the renewable portion or income. If pumping is greater than recharge, the aquifer is depleted and the capital is consumed.

Overuse of groundwater has become a major problem in China, India, Indonesia, Mexico, the Near East, North Africa, Thailand, the western United States and many island countries where seawater intrusion results. The overpumping of aquifers not only results in a water source that is too depleted to serve as a supply, it may also cause the land above the aquifer to settle or subside, resulting in widespread structural damage in extreme cases. Bangkok and Mexico City are well-known examples.

Finally, a shift in access or distribution patterns may concentrate water resources among one group and subject others to extreme scarcity. In many cities of the developing world, large numbers of people depend on water vendors and may pay 100 times as much as the rate of public utilities (see Table 3). Numerous recent studies document that large numbers of urban poor

TABLE 3

Ratio of prices charged by vendors to prices charged by public utilities in selected countries

Country	City	Ratio
Bangladesh	**Dacca**	**12-25**
Colombia	**Cali**	**10**
Côte d'Ivoire	**Abidjan**	**5**
Ecuador	**Guayaquil**	**20**
Haiti	**Port-au-Prince**	**17-100**
Honduras	**Tegucigalpa**	**16-34**
Indonesia	**Jakarta**	**4-60**
	Surabaja	**20-60**
Kenya	**Nairobi**	**7-11**
Mauritania	**Nouakchott**	**100**
Nigeria	**Lagos**	**4-10**
	Onitsha	**6-38**
Pakistan	**Karachi**	**28-83**
Peru	**Lima**	**17**
Togo	**Lomé**	**7-10**
Turkey	**Istanbul**	**10**
Uganda	**Kampala**	**4-9**

Source: R. Bhatia and M. Falkenmark. 1992. *Water resource policies and the urban poor: innovative approaches and policy imperatives.* Background paper for the ICWE, Dublin, Ireland.

pay much higher prices and a much larger share of their income for water than families with access to a city water system.[10] The poorest families in some large cities spend up to 20 percent of their income on water. When the cost is so high, these families use little water for washing and bathing, which results in serious health problems.

World water use

The early civilizations of Asia, Africa and Latin America organized cooperative efforts to develop river valleys for irrigated agriculture. Through irrigation technology, societies controlled and manipulated natural water supplies to improve crop production. The result was often reliable and ample food supplies which led to the creation of stable agricultural villages, the division of labour and economic surpluses.

Many scholars still argue whether irrigation technology facilitated political control and development of the state or whether political developments led to advancement of the technology. No matter the direction of cause and effect, no one disputes the

[10] See footnote 2, p. 2.

TABLE 4

Sectoral water withdrawals, by income group

Country income group	Annual withdrawals per caput	Withdrawals by sector		
		Agric.	Ind.	Dom.
	(..m^3..)	(...... % ......)		
Low-income	386	91	5	4
Middle-income	453	69	18	13
High-income	1 167	39	47	14

association of development with control over water use.

In today's world, agriculture still accounts for the majority of human water use. Globally, around 70 percent of water withdrawals are for agriculture. Domestic and industrial uses consume the remaining 30 percent.[11] Water uses differ greatly depending on access, quantity, quality and socio-economic conditions. For example, Table 4 illustrates that agricultural water use is higher as a proportion of total water use in the low-income countries (91 percent) than in the high-income group (39 percent). Nevertheless, on a per caput basis, the high-income countries use more water for agricultural purposes than the low-income countries.

The trends in world water use during this century are presented in Figure 2. Overall, global water consumption has increased almost tenfold. Agriculture's share, which was 90 percent in 1900, will have dropped to an estimated 62 percent by 2000. During this same period, industrial consumption will have grown from 6 percent to 25 percent, while consumption by cities will have increased from 2 percent to nearly 9 percent. By the year 2000, around 35 percent of available water supplies will be in use, compared with less than 5 percent at the beginning of the century.

[11] Domestic uses include drinking-water supplies, private homes, commercial establishments, public services and municipal supplies.

BOX 1
WATER AND POLLUTION

The quality of water from different sources varies widely. Precipitation absorbs gases from the atmosphere and removes particles from the air. When the precipitation strikes the ground it becomes surface water runoff or enters the ground. The surface water flows into larger and larger channels, ponds, lakes and rivers until some of it reaches the sea. Along its course, surface water picks up both organic and mineral particles, bacteria and other organisms as well as salts and other soluble substances. The water in lakes and swamps sometimes acquires odours, tastes and colours from algae and other organisms and from decaying vegetation.

Since ancient times, heavy metals from mining and pathogens from cities have caused serious, although localized, contamination. Since the industrial revolution, water pollution problems have become first regional, then continental and now global in nature. Much water is polluted when it is used in industry and agriculture or for domestic purposes. Mining is the major cause of metal contamination, whereas other industries contribute to acidification. The intensification of agricultural activities has led to the contamination of groundwater by fertilizers and other chemicals. Moreover, irrigation projects often cause a rapid rise in the level of groundwater, which leads to waterlogging and soil salinity.

Since 1977, UNEP's and WHO's Global Environmental Monitoring System (GEMS) has been working with Unesco and WMO to develop a global water quality monitoring network. More than 50 water variables are monitored to provide information on the suitability of water for human consumption and for agricultural, commercial and industrial use. Recent assessments have found that the main water pollutants are: sewage, nutrients, toxic metals and industrial as well as agricultural chemicals.

Conclusions drawn from the GEMS assessment include: the nature and level of freshwater pollution strongly depends on socio-economic development; the most common water pollutant is organic material from domestic sewage, municipal waste and agro-industrial effluent; and the high water nitrate levels found in western Europe and the United States are a result of the nitrogen fertilizers and manure used for intensive agriculture. The GEMS assessment also noted a dramatic increase in the use of fertilizers in developing countries, particularly where intensive irrigation allows for double or triple cropping.

Other conditions highlighted in the GEMS report include deforestation, eutrophication, suspended particulate matter (SM) and salinity.

Deforestation, i.e. the clearing of land for agriculture and urban development, often leads to water contamination. When the soil is stripped of its protective vegetative covering, it becomes prone to erosion. This in turn leads to higher water turbidity, because of the increased amounts of suspended matter, to nutrient leaching and to a decreased water-retention capacity of the soil.

There is also concern about the destruction of wetlands, which destroys the habitat of many species and removes natural filter mechanisms, permitting many common pollutants to reach water supplies.

Eutrophication is the enrichment of waters with nutrients, especially phosphorus and nitrogen. It can lead to enhanced plant growth and depleted oxygen levels as this plant material decays. It is not always a human-induced problem, but is often linked to organic waste and agricultural runoff. Today 30 to 40 percent of the world's lakes and reservoirs are eutrophic. Not all intervention has been successful, but eutrophication can be reversible if mid- and long-term strategies are enacted. Laws and measures introduced to reduce tripolyphosphates (used mostly in detergents) and to remove phosphorus from waste water have had positive effects.

SM consists of materials that float in suspension in water. There are three main sources of SM: natural soil erosion, matter formed organically within a water body and material produced as a by-product of human activity. SM settles on the sediment bed and forms deposits in rivers, lakes, deltas and estuaries. Evidence of human-induced SM from Roman and Mayan times has been discovered in lake beds, implying that this was one of the first types of water pollution. River damming affects the amount of SM flowing from rivers to the oceans because reservoirs act as effective sinks for SM. An estimated 10 percent of the global SM discharge to the sea is trapped in reservoirs. Approximately 25 percent of the water currently flowing to the oceans has been previously stored in a reservoir. Damming can also greatly modify water quality; waters flowing out of reservoirs not only have reduced SM quantities, they are also depleted of nutrients and are often more saline, which consequently has detrimental effects on downstream agriculture and fisheries.

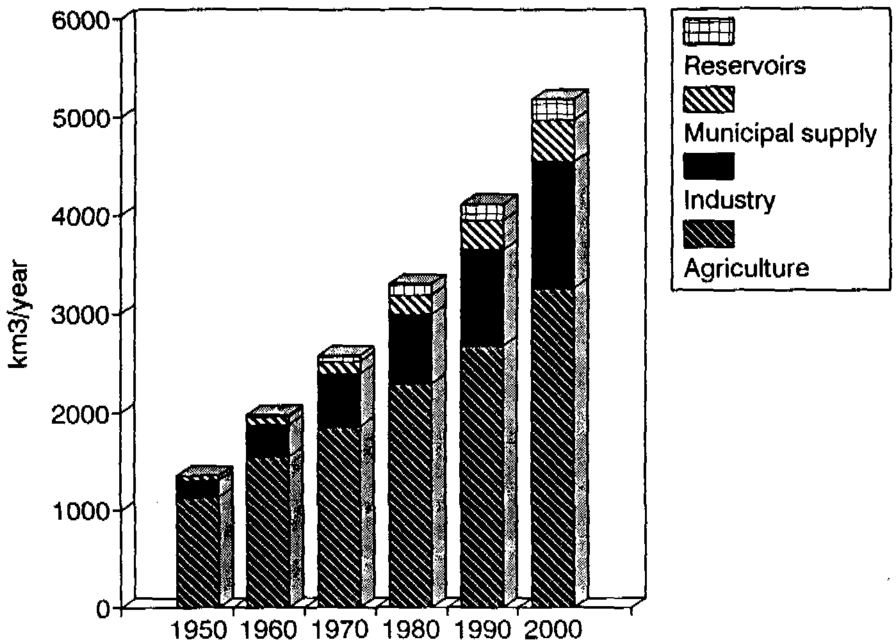
Salinity is a significant and widespread form of freshwater pollution, particularly in arid, semi-arid and some coastal regions. The primary cause of salinization is a combination of poor drainage and high evaporation, rates which concentrate salts on irrigated land. Salinity can adversely affect the productivity of irrigated crops and is also detrimental to industrial and household water users. It is not a new phenomenon; salinization of soil and water in the flood plain of the Tigris and Euphrates Rivers contributed to the decline of the Mesopotamian civilization some 6 000 years ago. The estimated global gross area of irrigated land is 270 million ha. About 20 to 30 million ha are severely affected by salinity while an additional 60 to 80 million ha are affected to some degree. Waterlogged soil, which aggravates the problem of salinity, is usually caused by overwatering and a lack of proper drainage systems. Runoff from agricultural areas fertilized with manure and chemicals pollutes watercourses and groundwater by increasing levels of nutrients.

The present level of water pollution warrants that steps be taken to control further contamination of water resources. More serious action needs to be taken in water resource management, waste water treatment and the provision of safe public water supplies. In developed and developing countries there should be controls and regulations regarding the treatment and recycling of industrial effluents, while efforts must be made to replace harmful products and ban dangerous pesticides.

There is compelling evidence that at least 20 to 30 percent of the water currently used in households and industries can be saved by adopting appropriate regulatory and policy instruments (tariffs, quotas, groundwater extraction charges). The twin benefits of clean water and reduced demand can be obtained if the recycling or reuse of water is encouraged in industries through pollution control legislation and economic incentives (water tariffs based on economic costs, effluent charges and low-interest loans for effluent/sewage treatment plants). Similar savings may be possible in irrigated agriculture by investments in canal lining, by encouraging less water-intensive crops (through relative output prices) and by raising irrigation rates.

Source: UNEP. 1991. *Freshwater Pollution*. UNEP/GEMS Environmental Library, No. 6, Nairobi.

FIGURE 2
World water consumption according to use (Note: Consumption by reservoirs is through evaporation.)



Source: I.A. Shiklomanov. 1990. Global water resources. *Nat. Resour.* 26:34-43.

Water quantity and quality requirements also differ widely depending on the type of use. Net agricultural requirements are especially large in relation to other uses. For instance, around 15 000 m^3 of water are normally sufficient to irrigate 1 ha of rice. This same amount of water can supply: 100 nomads and 450 head of stock for three years; or 100 rural families through house connections for four years; or 100 urban families for two years; or 100 luxury hotel guests for 55 days.[12]

Industry requires large amounts of water, but most of it is recycled back into the water system. The major problem is that much of this water is returned polluted with wastes, chemicals and heavy metals. Over 85 percent of total withdrawals by industry are recycled as waste water.[13]

Domestic water demand is moderate in comparison with agriculture and industry but its quality requirements are high. Domestic and municipal water uses include drinking, washing, food preparation and sanitation.

Water and health

Two of the most troubling domestic water supply issues for policy-makers are access and health. Nearly one billion people in the world are without clean drinking-water.

[12] I. Carruthers and C. Clark. 1983. *The economics of irrigation.* Liverpool, Liverpool University Press.

[13] D.B. Gupta. 1992. The importance of water resources for urban socioeconomic development. In *International Conference on Water and the Environment: Development Issues for the 21st Century.* Keynote Papers. Dublin, Ireland.

Providing easier access to safe drinking-water significantly improves health conditions. Personal hygiene increases when water availability rises above 50 litres per day (which generally means that it must be delivered to the house or yard). An estimated 1.7 billion persons contend with inadequate sanitation facilities. The lack of sewage collection and treatment is a major source of surface and groundwater pollution.

Health officials identify five categories of disease related to water: i) water-borne diseases (typhoid, cholera, dysentery, gastroenteritis and infectious hepatitis); ii) water-washed infections of the skin and eyes (trachoma, scabies, yaws, leprosy, conjunctivitis and ulcers); iii) water-based diseases (schistosomiasis and guinea-worm); iv) diseases from water-related insect vectors such as mosquitoes and blackflies; and v) infections caused by defective sanitation (hookworm).

The World Bank's *World Development Report 1992* estimates that providing access to safe water and adequate sanitation could result in two million fewer deaths from diarrhoea among young children and 200 million fewer episodes of diarrhoeal illnesses each year.

Water as a strategic resource

Water, even when plentiful, is frequently drawn into the realm of politics. Domestic laws and well-established customs can help resolve water-related disputes at national and village levels but international law has not developed fast enough to deal with the growing number of water-related conflicts between many countries and regions. In 1989, Egypt's then Minister of State for Foreign Affairs, Boutros Boutros-Ghali, declared: "The national security of Egypt is in the hands of the eight other African countries in the Nile basin."[14] As Postel notes, Mr Boutros-Ghali's statement highlights the importance of water to Egypt's economy as well as the advantage upstream countries have over downstream neighbours.

The increasing value of water, concern about water quality and quantity, and problems of access and denial have given rise to the concept of resource geopolitics or "hydropolitics". In this context, water joins petroleum and certain minerals as a strategic resource. Its increasing scarcity and value will only intensify the prevalence of water politics and relevant international conflicts.

Several countries depend heavily on river flows from other countries. Botswana, Bulgaria, Cambodia, Congo, Egypt, the Gambia, Hungary, Luxembourg, Mauritania, Netherlands, Romania, the Sudan and the Syrian Arab Republic all receive over 75 percent of their available water supplies from the river flows of upstream neighbours. More than 40 percent of the world's population lives in river basins that are shared by more than one country.

Along with land and energy sources, water has been the focus of disputes and, in extreme cases, even wars. The division of the Indus waters and its tributaries among India and Pakistan provided a salutary warning example. War was only just avoided in the early years of independence by a binding agreement, backed by massive international aid, to build two huge water storage dams and a system of canals. Water could then be channelled to the areas of Pakistan that were deprived of water when some of the Indus tributaries were diverted into Indian territory.

The costs to all parties of this settlement were high but certainly less than the human and financial costs of a conflict. Many other international rivers, including the Nile, Euphrates, Ganges and Mekong, are prospective risk points for disputes. The future of the Jordan waters is already an integral component of regional peace talks and illustrates how complicated hydro-politics can be. The fact that groundwater

[14] See footnote 7, p. 4.

BOX 2
THE INTERNATIONAL CONFERENCE ON WATER AND THE ENVIRONMENT: DEVELOPMENT ISSUES FOR THE 21ST CENTURY

The International Conference on Water and the Environment (ICWE) was held in Dublin, Ireland from 26 to 31 January 1992. The conference provided the major input on freshwater problems for UNCED, convened in Rio de Janeiro, Brazil, June 1992. The ICWE was attended by 500 participants from 114 countries, 38 NGOs, 14 intergovernmental organizations and 28 UN bodies and agencies.

The major work of the ICWE was undertaken by six working groups which addressed:

- Integrated water resources development and management;
- Water resources assessment and impacts of climate change on water resources;
- Protection of water resources, water quality and aquatic ecosystems;
- Water and sustainable urban development and drinking-water supply and sanitation;
- Water for sustainable food production and rural development and drinking-water supply and sanitation;
- Mechanisms for implementation and coordination at global, national, regional and local levels.

The two main outputs of the conference are the Dublin Statement and Report of the Conference, which set out recommendations for action based on four guiding principles. First, the effective management of water resources demands a holistic approach linking social and economic development with the protection of natural ecosystems, including land and water linkages across catchment areas or groundwater aquifers; second, water development and management should be based on a participatory approach that involves users, planners and policy-makers at all levels; third, women play a central part in the provision, management and safeguarding of water; and, finally, water has an economic value in all its competing uses and should be recognized as an economic good.

resources are also involved in the talks adds another dimension of difficulty.

THE WATER SECTOR AND NATURAL RESOURCE POLICY

In January 1992, the ICWE concluded that scarcity and misuse of freshwater pose a serious and growing threat to sustainable development and protection of the environment.[15] The conference emphasized that human health and welfare, food security, economic development and ecosystems are all at risk, unless water and land resources are managed more effectively in the future.

To address water problems at local, national and international levels, the ICWE recommended a range of development strategies and policies based on four principles (see Box 2). While the conference participants readily agreed on the wording of the first three principles, the fourth provoked a long and contentious debate. Principle 4 declares that water has an economic value in all its competing uses and should be recognized as an economic good.

For many, it is difficult to reconcile the concept of water as an economic good with the traditional idea of water as a basic necessity and human right. Older elementary economic textbooks explain this conceptual puzzle - why diamonds, which have so little utility, are expensive while freshwater, which is so essential to life, is cheap. More recent texts leave water out of these vignettes. Like fresh air, water was once considered a classic free good; now that it is growing scarce, while not yet expensive, it is at least acknowledged to be valuable.

[15] *The Dublin Statement and Report of the Conference*. 1992. ICWE, Dublin, Ireland.

Scarcity is one of the most important issues in considering the various socio-economic tradeoffs in allocating water among different users. Allocation policies and decisions determine who will have access to water and under what conditions, and what impact this will have on society and the economy.

The cheapness of water is often more apparent than real. It is a free good not because water provision is without cost obviously this is far from true but because governments have chosen to charge less than full costs for water services for one or more reasons.[16] These subsidies are now coming under scrutiny. The ICWE's final report acknowledges that failure in the past to recognize water's economic value and the real cost of service provision has led to wasteful and environmentally damaging uses. Moreover, the conference report states that managing water as an economic good is an important way of achieving efficient and equitable use, as well as encouraging the conservation and protection of scarce water resources.

It is in this context that the ICWE and UNCED called for a new approach to the assessment, development and management of freshwater resources. The proposed approach involves the management of freshwater as a finite and vulnerable resource and the integration of sectoral water plans and programmes within the framework of national economic and social policy.[17]

[16] Water may be considered a "free" good in the form of rain, but when this free good is captured and delivered to customers by canal, pipe or other means, it becomes a water service. There is generally much less resistance to water service fees than there is to water charges.

[17] UN. 1992. Protection of the quality and supply of freshwater resources: application of integrated approaches to the development, management and use of water resources. Chapter 18, Agenda 21, *Report of the United Nations Conference on Environment and Development.*

A more integrated and broader approach to water sector polices and issues is important because of water's special nature as a unitary resource.

Rainwater, rivers, lakes, groundwater and polluted water are all part of the same resource, which means global, national, regional and local actions are highly interdependent.[18] Water use in one part of the system alters the resource base and affects water users in other parts.

Dams built in one country frequently reduce river flows to downstream countries for years afterwards, thereby affecting hydroelectric and irrigation capacity. When a city overpumps a groundwater supply, streamflows may be reduced in surrounding areas; when it contaminates its surface water, it can pollute groundwater supplies as well. Some human actions at local levels may contribute to climate change, with long-term implications for the hydrological system worldwide.

Water policies, laws, projects, regulations and administrative actions often overlook these linkages. Governments generally tend to organize and administer water sector activities separately: one department is in charge of irrigation; another oversees water supply and sanitation; a third manages hydropower activities; a fourth supervises transportation; a fifth controls water quality; a sixth directs environmental policy; and so forth.

These fragmented bureaucracies make uncoordinated decisions, reflecting individual agency responsibilities that are independent of each other. Too often, government planners develop the same water source within an interdependent system for different and competing uses (see Box 3). This project-by-project, department-by-department and region-by-region approach is no longer adequate for addressing water issues.

[18] P. Rogers. 1992. *Comprehensive water resources management: a concept paper.* Policy Research Working Paper Washington DC, World Bank.

BOX 3
FRAGMENTED PLANNING AND WATER RESOURCES IN SOUTHERN INDIA

The World Bank's water resources management policy paper presents several examples from South India to illustrate the kinds of problem caused by fragmented decision-making. The Chittur River's highly variable flows have traditionally been diverted at many points into small reservoirs to irrigate the main rice crop. The diversion channels are large enough to accommodate flood flows following the monsoon rains. Thus, when a storage dam was constructed, the uppermost channel was able to absorb virtually all the regulated flow. The upper tanks now tend to remain full throughout the year, concentrating benefits and adding to evaporation losses. The more extensive lower areas have reverted to uncertain rain-fed cultivation, and total agricultural value added has decreased. Construction of the storage dam without adequate considerations of downstream users or the existing storage capacity of the basin is one example of how individual project development in isolation can cause significant economic losses.

The construction of the Sathanur Dam on the Ponnani River in Tamil Naduto serve a left bank command area deprived productive delta areas of irrigation water. While the rights of downstream irrigators are recognized in the dam operating rules, most of the regulated flow is diverted upstream; water losses have greatly increased in the wide sandy bed and no surface water has reached the sea for twenty or more years. Continued spills in about 50 percent of all years were used to justify the subsequent construction of the right bank command, further aggravating shortages in the delta and leading to continual conflicts between the two Sathanur commands. Meanwhile, additional storage dams on upstream tributaries are adding to evaporation losses in what was already a fully developed basin. Irrigation in the productive delta has declined further and the Sathanur commands in turn are suffering. The high-value crops that were once grown on the main river are being replaced by cultivation on less productive lands, served by tributaries that are more variable than the main river.

The Amaravati River, a tributary of the Cauvery, is the most disputed major river in India. In the absence of a Cauvery agreement, Karnataka (the upstream riparian state) has steadily developed large irrigation schemes, depriving the delta (Tamil Nadu's rice bowl) of its accustomed supplies. Meanwhile, Tamil Nadu has been developing the Amaravati. As at Sathanur, water releases are made from the Amaravati Dam for the traditional areas, but these are far downstream and the substitution of regulated flood flows has encouraged the development of private pumps along the river bank. Even though the new electric connections have now been banned, little can be done to control illegal connections or diesel pumps and, consequently, little water now reaches the lowest commands, let alone the Cauvery. Meanwhile, new storage dams are being constructed on tributaries both in Kerala and Tamil Nadu, further depriving not only the old lands but also the new lands and the pump areas.

Source: World Bank. 1993. *Water resources management: a policy paper.*

To help resolve the growing number of water resource issues, policy-makers are increasingly being called on to review and explain the conditions, problems and progress in the overall water sector. This integrated approach requires water managers to understand not only the water cycle (including rainfall, distribution, ecosystem interactions and natural environment and land-use changes), but also the diverse intersectoral development needs for water resources.

The next section further explores this important concept of linking the water sector with the national economy and provides a conceptual basis for understanding the role of economic policy-making.

II. Water resources: economics and policy

In early civilizations, water played a relatively simple role. It was needed for transportation and drinking and it provided a fishing and hunting source. Over time, sedentary agricultural societies evolved and water use became more important. Families began settling near springs, lakes and rivers to supply livestock and crops with water, gradually developing technologies to divert water for irrigation and domestic purposes. Babylonian, Egyptian, Hittite, Greek, Etruscan, Roman, Chinese, Mayan, Incan and other empires constructed water delivery systems such as long aqueducts to carry water to large cities.[19] In fact, until the middle of the twentieth century, most societies were able to meet their growing water needs by capturing reliable and relatively inexpensive sources.

When water is plentiful relative to demand, water policies, rules and laws tend to be simple and only casually enforced. As populations grow and economies expand, water sectors evolve from an "expansionary" phase to a "mature" phase.[20] At a certain point during the expansionary phase, the financial and environmental costs of developing new water supplies begin to exceed the economic benefits in the least productive (marginal) uses of existing supplies. The reallocation of existing supplies, rather than the capture of unclaimed supplies, then becomes the least costly method to maximize benefits.

A water sector in the "mature" phase is characterized by rising marginal costs of providing water and increasing inter-dependencies among users. In this phase conflicts over scarcities and external costs arise. (External costs result when one user interferes with another's supply, e.g. when an upstream user pollutes a river and raises costs for downstream users.) These conflicts eventually become so complex that elaborate management systems are needed to resolve disputes and allocate water among different users and economic sectors.

Developing effective water sector policies is troublesome for a number of reasons. First, water has unique physical properties, complex economic characteristics and important cultural features that distinguish it from all other resources.[21] Second, water resource management is administratively complicated because it involves legal, environmental, technological, economic and political considerations.[22] In most societies, political considerations dominate decisions on water resource use. Nonetheless, most policy options are framed and discussed in economic terms.

This section attempts to provide a conceptual basis for understanding water policy interventions while examining the circumstances under which water policies work or fail. It comprises three parts: the

[19] V. Yevjevich. 1992. *Water Int.*, 17(4): 163-171.

[20] A. Randall. 1981. Property entitlements and pricing policies for a maturing water economy. *Aust. J. Agric. Econ.*, 25:195-212.

[21] R.A. Young and R.H. Haveman. 1985. Economics of water resources: a survey. *In* A.V. Kneese and J.L. Sweeney, eds. *Handbook of natural resources and energy economics*, Vol. II. Amsterdam, Elsevier Science Publishers.

[22] For example, water resource management depends on the government's ability to establish an appropriate legal, regulatory and administrative framework. In fact, markets are based on a system of enforceable private property rights. Private water markets require secure and transferable property rights, including the right to exclude other users.

BOX 4
ECONOMIC POLICIES AND WATER USE IN THE SYRIAN ARAB REPUBLIC

After struggling throughout the 1980s, the Syrian economy has performed well over the past few years. The end of a two-year drought allowed agriculture and agro-industries to recover in 1991. During the drought, the government was forced to import large quantities of wheat and barley, thereby draining foreign currency reserves. In addition, the lower water levels meant a reduction in hydropower generation, increasing the need for thermal power and, in turn, lowering crude oil exports.

Two of the Syrian Arab Republic's major national development objectives are: achieving food self-sufficiency to reduce dependency on imports; and expanding agricultural exports to earn more foreign exchange. To support these objectives, the government has invested 60 to 70 percent of the entire agricultural budget in irrigation over the past ten years.

Several factors explain this special attention for irrigation development. The irrigated area comprises only 15 percent of the cultivated land yet produces over 50 percent of the total value of agricultural production. A large part of wheat production as well as all major industrial crops, including cotton tobacco and sugarbeet, are produced on irrigated farms. Production on the remaining rain-fed area, representing 85 percent of the total area, varies greatly from year to year.

At present, agriculture accounts for around 85 percent of the country's water consumption, but competition is increasing. During the 1980s, industrial water demand increased by nearly 900 percent. Current projections suggest that water requirements will be two to three times greater by 2010.

The government's effort to promote food self-sufficiency has produced a second generation of water-related problems. To encourage growth in agricultural production and enhance rural incomes, interest rates, seeds, fertilizers, pesticides, transport and energy prices are subsidized. The government also establishes purchase prices and buys industrial crops, major cereals and feedgrains. For example, the 1992 domestic wheat price was almost twice the international price.

These policies are contributing to the proliferation of wells in the Syrian Arab Republic. Digging wells to pump groundwater accounts for 80 percent of the newly irrigated land since 1987. With irrigation, farmers obtain higher yields, more stable production and greater profit. Since water is free, the only investment expense required is the well and the pumping gear – a one-time fixed cost. Farmers obtain subsidized credit to purchase subsidized fuel for operating imported pumps purchased with overvalued currency (an implicit subsidy). With these economic opportunities, most farmers want to dig wells or pump surface water.

Other current economic pressures are also influencing farmers' decisions to dig wells and expand irrigation. For example, as incomes in urban areas increase, consumers are demanding more fruit and vegetables. At the same time, recent changes in trade and exchange rate policies are making Syrian agricultural products more competitive in regional markets. Farmers who inititally planned only on supplementary irrigation for winter wheat are finding summer vegetables and irrigated fruit production increasingly profitable.

first examines the relationship between the water sector and the overall economy; the second explains the social, physical and economic nature of water; the third assesses the advantages and disadvantages of broad alternative approaches to public water policy and also reviews policy issues related to the economic organization of water resource management.

LINKING THE WATER SECTOR WITH THE NATIONAL ECONOMY

Economic policy-makers tend to confront policy issues one at a time, stating policy objectives in single dimensional terms. This approach presents difficulties because a policy aimed at achieving a single objective usually has unintended and unrecognized consequences. Water managers and policy-makers need to assess the entire range of government interventions to understand fully the economic, social and environmental impacts on a given sector, region or group of people.

Improving water resource management requires recognizing how the overall water sector is linked to the national economy. Equally important is understanding how alternative economic policy instruments influence water use across different economic sectors as well as between local, regional and national levels and among households, farms and firms. For too long, many water managers have failed to recognize the connection between macro-economic policies and their impact on, for example, technical areas such as irrigation.

Macroeconomic policies and sectoral policies that are not aimed specifically at the water sector can have a strategic impact on resource allocation and aggregate demand in the economy. A country's overall development strategy and use of macroeconomic policies - including fiscal, monetary and trade policies - directly and indirectly affect demand and investment in water-related activities. The most obvious example is government expenditures (fiscal policy) on irrigation, flood control or dams. A less apparent example is trade and exchange rate policy aimed at promoting exports and earning more foreign exchange. For example, as a result of currency depreciation, exports of high-value, water-consuming crops may increase. If additional policy changes reduce export taxes, farmers are provided with an even greater incentive to invest in export crops as well as in the necessary irrigation (see Box 4).

National development strategies can directly influence water allocation and use in other ways. In the case of a food self-sufficiency strategy, the government may subsidize water-intensive inputs to encourage farmers to produce more rice. By providing financial incentives for rice producers, the government is influencing the demand for water and private irrigation investment through price policies.

Apart from the direct effects on water use resulting from such price policies, the increased demand for irrigation water also has intersectoral, intrasectoral, distributional and environmental implications. The agricultural sector is provided with an economic advantage in access to water *vis-à-vis* the industrial sector (intersectoral); water used for rice gains an economic advantage over water used for other crops (intrasectoral); rice producers with more land and access to water gain over those with less land and water (distributional); and increased pesticide and fertilizer use are likely to affect water quality (environmental).

Sectoral policies affect water use and allocation in non-agricultural sectors in a variety of ways. For example, in the western United States, 70 to 80 percent of the region's water yield results from snowmelt from the high-elevation forests, many of which are under public jurisdiction. Water yields are significantly affected by timber harvest policies on these lands. Rangeland management policies on lower elevations also alter vegetation conditions and thus affect the rate of evapotranspiration, in turn affecting streamflow and groundwater recharge.[23] In such cases, it is important for downstream city water managers to recognize, understand and become involved in the decisions of other sectors such as livestock and forestry.

With the continuing importance of structural adjustment and stabilization programmes, many developing countries are implementing fundamental changes in macroeconomic and sectoral polices. Typical adjustment programmes call for a greater reliance on markets, more open trade, fiscal austerity and a phasing out of producer and consumer subsidies (input and product markets). Budget-reducing measures imply increased competition between and within sectors for funding new water projects. In these situations, the overall economic, social and environmental implications of choices must be carefully addressed. For example, when governments must choose between financing either irrigation projects or hydroelectric power projects, there is an additional social opportunity cost of the irrigation water in countries that are dependent on imported energy sources. At the same time, when water scarcity keeps some farmers on uneconomical lands such as steep watersheds, the country suffers twice: once in terms of reduced production compared with what would be possible with irrigation; and again in terms of erosion and resource depletion, with erosion possibly shortening the life of existing waterworks.[24]

In most countries, pressure has increased not only to modify investment allocations but also to recognize and accommodate new demands for water. The direct implications for water managers include fewer capital investments in new water projects, the elimination of irrigation subsidies, increased efforts to recover its cost and more emphasis on demand management to improve the efficiency of existing supplies.

THE SOCIAL, PHYSICAL AND ECONOMIC NATURE OF WATER

Policy-makers throughout the world treat water as more than a simple economic commodity. Because water is essential to life, they often reject competitive market allocation mechanisms. Many societies believe that water has special cultural, religious and social values. Boulding observed that "the sacredness of water as a symbol of ritual purity exempts it somewhat from the dirty rationality of the market".[25] In many cultures, goals other than economic efficiency play an unusually large role in selecting water management institutions. Some religions, such as Islam, even prohibit water allocation by market forces.

The international community recognizes that access to water is a basic human right. The ICWE asserted that "...it is vital to recognize first the basic right of all human beings to have access to clean water and sanitation at an affordable price".

The connection between water and human life is most dramatic in arid regions, where crop irrigation is essential to food production. In Egypt, little food can be grown without the help of the Nile for irrigation. However, the focus on water's special status tends to obscure the fact that, in most societies, only a tiny fraction of

[23] B. Saliba, D. Bush, W. Martin and T. Brown. 1987. Do water market prices appropriately measure water values? *Nat. Resour. J.*, 27 (summer).

[24] D.W. Bromley, D.C. Taylor and D.E. Parker. 1980. Water reform and economic development: institutional aspects of water management in the developing countries. *Econ. Dev. Cult. Change*, 28(2).

[25] K.E. Boulding. 1980. The implications of improved water allocation policy. *In* M. Duncan, ed. *Western water resources: coming problems and policy alternatives.* Boulder, Colorado, Westview.

water consumption is actually for drinking and preserving life. In fact, a large portion of urban water is used for convenience and comfort. In the arid western United States, per caput water withdrawal by households frequently exceeds 400 litres per day, about half of which is used to irrigate lawns and gardens. Most of the remainder is for flushing toilets, bathing and washing cars. Another important influence on water resource policy is societies' partiality for technical solutions. In most countries, water management is typically relegated to the engineering domain. Indeed, most water managers are engineers, who are trained to solve technical problems. As inadequate public policies are increasingly blamed for water-related problems, a strong case is emerging for emphasizing human behaviour as an additional component of water systems.

Physical attributes of water

Water has two additional features that further complicate management efforts: bulkiness and mobility. The value per unit of weight tends to be relatively low (placing water among the commodities that are termed "bulky"). Unlike petroleum, the costs of transporting and storing water are generally high relative to its economic value at the point of use. In crop irrigation, the water applied may yield additional economic values of less than $0.04 per tonne of water. Water is also difficult to identify and measure because it flows, evaporates, seeps and transpires. This evasive nature means that exclusive property rights, which are the basis of a market economy, are hard to establish and enforce.

Many water management problems are site-specific and so elude uniform policy treatment. While water consumption and quality require-ments are tied to local populations and development levels, local water availability usually changes with climatic variations throughout the year and over longer cyclical swings. These supplies may be highly variable and unpredictable in time, space and quality. In regions throughout India, for instance, most rainfall is concentrated during a three-month period and there are large year-to-year variations. In addition, forecasts of significant global climate change - attributable to both natural and human causes - raise concerns about longer-term supply trends (See Box 5).

Water projects that attempt to compensate for extreme seasonal variations such as floods and droughts frequently require enormous investments. The economies of size are so large in these cases that unit costs continue to exceed the range of existing demands. This is a classical "natural monopoly" situation in which a single supplying entity is the most economically efficient organizational arrangement.

On the other hand, most economies of size for pumping groundwater are achieved at relatively small outputs and multiple suppliers can therefore operate efficiently. However, aquifers are usually hydraulically linked with rivers or streams - part of a river's volume may come from underground flows and rivers may replenish groundwater stocks. This hydraulic linkage is affected when an aquifer is heavily pumped. A lowered groundwater table may draw water from a connected stream, reducing its flow to surface water users. Box 6 describes the special policy concerns related to aquifers.

Aquifer management is often complicated by the aggregate impact of the actions of many individuals. Even though each individual may have a negligible impact when taken alone, the sum total can be of major importance. One example is the rapid spread of tube well irrigation in South Asia. One tube well has little effect on the total water supply, but thousands of tube wells can quickly deplete an aquifer. Establishing effective policies to regulate these many small, scattered decision-makers is exceedingly difficult.

Economic attributes of water use

Water provides four types of important economic benefits: commodity benefits;

BOX 5
CLIMATE CHANGE, WATER RESOURCES AND AGRICULTURE

To date, research is not able to provide clear conclusions about the prospective impacts of climate change and global warning. Among the potential impacts of climate change is its effect on the hydrological cycle and water management systems. For instance, increases in floods and droughts causes increased frequency and severity of disasters. Relatively small changes can cause severe water resource problems, especially in semi-arid regions and humid areas where demand or pollution has led to water scarcity.

The statement adopted by the Second World Climate Conference, held in Geneva in 1990, concluded that the design of many costly structures to store and convey water, from large dams to small drainage facilities, is based on analyses of past records of climatic and hydrological parameters. Some of these structures are designed to last from 50 to 100 years or even longer. Records of past climate and hydrological conditions may no longer be a reliable guide for the future. The possible effects of climate change should be considered in the design and management of water resource systems.

Data systems and research must be strengthened to predict water resource impacts, detect hydrological changes and improve hydrological parameterization in global climate models.

Agricultural impacts could be significant but researchers are uncertain whether global agricultural potential will increase or decrease. Increases in drought risk are potentially the most serious effect of climate change on agriculture. Disease and pest patterns, raised sea levels and storm surges are additional problems. It does appear that many areas will have increased precipitation, soil moisture and water storage, thus altering patterns of agricultural ecosystems and other water uses.

Source: WMO/UNEP/FAO/ Unesco/ ICSU. 1990. Second World Climate Conference. Geneva; and UNEP. 1992. *The state of the environment.*

waste assimilation benefits; aesthetic and recreational benefits; and fish and wildlife habitats. Individuals derive commodity benefits from water by using it for drinking, cooking and sanitation. Farms, businesses and industries obtain commodity benefits by using water in productive activities. These commodity benefits represent private good uses of water which are rivals in consumption (e.g. one person's or industry's water use precludes or prevents its use by others). Government policies and regulations that concentrate on improving market access and competition are important means for improving the productive and allocative efficiency of the commodity uses of water.

The second and increasingly important economic benefit of water is waste disposal. Water bodies have a significant, but ultimately limited, assimilative capacity, meaning that they can process, dilute and carry away wastes.

Recreation and aesthetic benefits and fish and wildlife habitats were once regarded as luxury goods outside the concern of governments. Today, these two types of benefit are gaining increased attention. In developed countries, more and more people are focusing their recreational activities around lakes, rivers and seas. In developing nations, as incomes and leisure time grow, water-based recreation is becoming increasingly popular and an adequate supply of good-quality water helps provide a basis for attracting the tourist trade. Examples are cruises on the Nile in Egypt and visits to the Iguazú Waterfalls on the Brazil-Argentina border. Likewise, information and knowledge about how humans have an impact on ecosystems have raised concern about the fish and wildlife

BOX 6
AQUIFER OVERDRAFT

An aquifer is a geological formation, actually or potentially containing water in its pores and voids. Aquifers consist of the porous rock or soil media (sand, gravel or rock materials) within which water is collected and through which it flows. Moisture from rain or snow that escapes evaporation collects in streams as surface water or seeps into the ground. Soil water not taken up by plants seeps downwards until it reaches the water-saturated zone. Water in aquifers is called groundwater. Groundwater deposits are economical to use for human purposes if they are close to the surface (and thereby inexpensive to pump) and are of good quality.

Aquifers vary greatly in their nature and extent. The quantity, quality and ease of extraction can be determined accurately only after extensive exploration. Underground geology varies widely and is expensive to map. Aquifers may be very thin or hundreds of meters thick; some are local in character, while others extend for hundreds of kilometres. The Ogallala-High Plains Aquifer in the central-western United States underlies more than 10 million ha over six states.

Relative to surface water, groundwater moves very slowly – in some cases only a few metres per year. While aquifers may have accumulated over thousands of years, modern pumping devices can easily exhaust them more rapidly than the natural recharge rate. It is also possible to divert surface water to artificially recharge an existing aquifer and make it available for future use.

Aquifer status reports from many parts of the world suggest that all is not well with our groundwater resources. Symptoms of management problems begin with pumping rates that exceed the natural recharge. Primary symptoms are: an exceedingly rapid exhaustion of groundwater stocks and the consequent increase in pumping costs; the intrusion of poorer-quality water into the deposit being exploited; salt water intrusion from rapid pumping near seacoasts; and mineralized deposits interspersed with better-quality water.

Subsidence of overlying lands is another adverse impact of aquifer overexploitation. As water is withdrawn, the soil and rock particles comprising the aquifer are compressed into a smaller volume and, consequently, crack the earth's surface. This results in damages to buildings, roads, railroads, etc. Another consequence of overpumping may be the interruption of flows in neighbouring wetlands and streams; deprived of their water source, they are reduced in size or may dry up altogether. Other adverse effects from overpumping result when residential or farmers' wells dry up because of the presence of larger and deeper wells.

From a broad perspective, aquifer exploitation can bring about either or both of two types of social dilemma. First, overdraft is an example of a class of resource problems, usually called "common pool" problems.[1] A common pool resource can be defined by two characteristics. The first is subtractibility (meaning that a unit of resource withdrawn by one individual is not available to another individual user). The second is high cost of excluding potential beneficiaries from exploiting the resource. Fugitive or mobile resources, such as water, petroleum or migratory fish and wildlife, are typical examples of resources with high-exclusion costs.

Common pool problems or dilemmas arise when individually rational resource use leads to a non-optimal result from the perspective of the users as a group. Three conditions are necessary to produce a common pool resource dilemma: first, large numbers of users withdraw the resource; second, the actions and characteristics of the individual users and the extraction technology bring about suboptimal outcomes from the group's viewpoint; third, there must be an institutionally feasible strategy for collective resource management that is more efficient than the current situation.[2]

The roots of the problems associated with common pools are found in the inadequate economic and institutional framework within which the resource is exploited.[3] Common pool resources have been typically utilized in an "open access" framework, within which resources are used according to a rule of capture. When no one owns the resource, users have no incentive to conserve for the future and the self-interest of individual users leads them to overexploitation. The characteristics of the economic institutions governing their use is the fundamental issue in managing common pool resources.

The second type of social dilemma associated with groundwater exploitation is the imposition of external costs or externalities. In the presence of significant externalities, the calculation of costs and benefits by exploiters do not yield a collectively optimal rate of exploitation.

[1] R. Gardner, E. Ostrom and J.M. Walker. 1990. The nature of common pool resources. *Rationality and Society*, 2:335-358.

[2] Ibid; and E. Ostrom. 1990. *Governing the commons: evolution of institutions for collective action*. Cambridge, UK, Cambridge University Press.

[3] R.A. Young. 1993. Aquifer overexploitation: economics and policies. *Proc. 23rd Conference of the International Association of Hydrogeologists*, Santa Cruz, Spain.

benefits provided by water. Fish and wildlife habitats are related to both commodity and recreational uses.

Waste assimilation and recreational and aesthetic values are closer to being public goods than private goods. Public goods are non-rivals in consumption - one person's use does not preclude use by others. For example, enjoyment of an attractive water body does not deny similar enjoyment to others. Non-rival goods require large amounts of resources to exclude unentitled consumers from using the good. Exclusion costs are frequently very high for water services such as flood control projects and navigation systems. Goods and services that are non-rivals in consumption are normally better suited to public sector interventions, including ownership, provision and regulation.

ECONOMIC ORGANIZATION OF THE WATER SECTOR: MARKETS OR GOVERNMENTS?

Most countries rely on a mix of market policies and direct government interventions to manage water resources. Each system has its own advantages and disadvantages.

A competitive market has the potential to efficiently allocate resources (water supplies) among competing demands. Producers and consumers acting in their own self-interest arrive at the price at which available supplies are allocated. Private producers, guided by prospective profit, seek to buy inputs as cheaply as possible, combine them in the most efficient form and create products that have the highest value relative to cost.

Consumers' incomes, tastes and preferences influence expenditure patterns, which encourage firms to produce the commodities people are willing and able to buy. Prices are forced upwards for the commodities most desired, and producers allocate resources in the direction of the greatest potential profits. The firms producing desired goods most efficiently are rewarded by profit while the unsuccessful are eliminated, so production occurs at the least cost. However, the needs of potential consumers with limited income may not be met at all or only partially.

While the private market has the potential to produce the maximum private-valued bundle of goods and services, the public sector also plays an important role. Public actions incorporate a broader range of social goals than the private sector. The public sector can ameliorate income inequalities, promote development in disadvantaged regions, regulate private activities that harm the environment and control other undesirable effects of a private, profit-oriented monopoly.

Market failures

If water as a commodity, or the economic system in which water is used, meets the preconditions for a market system, government interventions can be minimized. In competitive markets, government's primary role is to emphasize "incentive structures" and to establish "rules". Some of the most important rules are the laws governing the establishment of property rights and the enforcement of contracts.

Market economies experience shortcomings called market failures.[26] Market failures occur when incentives offered to individuals or firms encourage behaviour that does not meet efficiency criteria (or more generally, because efficiency or economic criteria fails to satisfy national social welfare criteria). In these cases, the public sector may intervene to influence water provision and allocation. Market failures affecting water resources include externalities, public goods and natural

[26] C. Wolf. 1988. *Markets or governments; choosing between imperfect alternatives.* Cambridge, MA, Massachusetts Institute of Technology Press.

monopolies. In other cases, even efficient markets may not meet societies' equity criteria so public intervention is necessary to compensate for distributional inequity.

Externalities are inherent in water sector activities. An example is the detrimental effect of saline return water flows (caused by irrigation) on downstream water users. Another example is the waterlogging of downslope lands through inefficient irrigation practices. Most irrigators do not normally consider the external costs they impose on others, so governments attempt to protect affected individuals through regulations, taxes, subsidies, fees or technical standards. For instance, irrigation practices can be regulated by setting and enforcing standards to control salinity and waterlogging.

In recent years, the "polluter pays" principle has attracted increased attention in industrialized countries (and to a lesser extent in developing countries). This principle requires producers to pay the "full" cost of their production process, including externalities such as polluting water.

Water storage projects and flood control programmes represent examples of *public goods*. The market does not adequately supply public goods because private entrepreneurs cannot easily exclude non-paying beneficiaries and capture a return on investment. For example, it is not possible to exclude people living along a river from the benefits of a flood protection plan on that river.

A firm that experiences decreasing costs throughout its range of production is easily able to dominate the entire market and become a *natural monopoly* (a common situation in the water sector). Decreasing costs imply increasing returns; thus, the first firm to begin production can always underprice new entrants. Urban water supply systems, hydropower plants and canal irrigation projects are subject to this type of market failure. Unregulated monopolies can restrain production and charge excessive prices; they also have little incentive to innovate. A water supplier acting as a natural monopoly has the power to impose exorbitant costs - even economic ruin - on its customers.

Public regulation or public ownership can mitigate the undesirable effects of a private, profit-oriented monopoly. When increasing returns exist, the lowest-cost production is that of a single producer. Society is likely to benefit by regulating or owning the monopoly rather than by encouraging competitive suppliers. More than one competitive supplier would present much higher distribution costs.

While free competition is viewed as the most efficient system for allocating resources, potential market imperfections can accentuate income disparities. Societies' public welfare goals often incorporate a broad range of social objectives. Primary among these is ameliorating income inequalities between members of the society and sometimes among political subdivisions or regions. In these situations, the government may direct investment and subsidies towards specific regions or groups. Water projects provide important investment strategies both for human welfare (drinking-water and food supplies) and for infrastructure to support economic development.

Government failure

Even in the event of market failures, public sector interventions or non-market approaches may not lead to the socially optimum solution. In many cases, non-market responses to market failures lead to less than optimal outcomes. In particular, some government agency performance incentives result in a divergence from socially preferable outcomes (both in terms of allocative efficiency and distributional equity criteria). The problem areas relevant to water sector services are:

- *"Products" are hard to define*. The outputs of non-market activities are difficult to define in practice and to measure independently of the inputs that produced them. Flood control or amenity benefits of water storage reservoirs are examples of water system outputs that are hard to measure.

- *Private goals of public agents.* The internal goals, or "internalities", of a public water agency as well as the agency's public aims provide the motivations, rewards and penalties for individual performance. Examples of counterproductive internal goals include budget maximization, expensive and inappropriate "technical-fix" solutions and the outright non-performance of duties. In addition, agencies may adopt high-tech solutions, or "technical quality", as goals in themselves. For example, they may recommend sprinkler or drip irrigation systems when other less expensive but reliable methods are more economical. Finally, irrigation agency personnel may be persuaded, by gifts or other inducements, to violate operating rules for a favoured few.[27]

- *Spillovers from public action.* Public sector projects can also be a major source of externalities. Salinity and waterlogging of downslope lands can occur just as easily from inappropriately managed public irrigation projects as from private irrigators.

- *Inequitable distribution of power.* Public sector responsibilities, however noble their intent, may not be scrupulously or competently exercised. Yet the monopoly control of water supplies by public agencies provides certain groups or individuals with so much power over the economic welfare of water users that procedures to protect those of limited influence should be of prime importance.

[27] R. Wade. 1982. The system of administrative and political corruption: land irrigation in south India. *J. Dev. Stud.*, 18:287-299.

Economic structure and irrigation

For many years, the economic systems in a number of developing countries discriminated against agriculture through policies such as high levels of protection for domestic manufacturing sectors, overvalued exchange rates and taxes on agricultural exports. Most developing countries today are at some stage of structural reform, attempting to adjust and transform their economies towards a more liberal economic trade regime - modifying government involvement and increasing market influence.

The developing world's recent record in consolidating macroeconomic stability with solid economic growth is very mixed. Where success is evident, most of the economic transformation has taken place at the macro level and much remains to be done to effect the consequent adjustments at the micro level, i.e. at the level of water users.

Even with widespread acceptance of the need for macroeconomic price policy reforms for all other sectors since the early 1980s, the dominant supporting actions for agriculture have been non-price policies. For non-agricultural sectors, the new policy mix includes minimizing state involvement in the pricing and marketing of inputs and outputs, privatization and limiting government borrowing.

Despite the irrigation sector's often being sheltered or even benefiting from the effects of these economic policy reforms, government subsidy cuts are inevitably affecting the scope and efficiency of agricultural support services. In most countries, there is a pressing need to discuss how various policy options, including both public interventions and market-oriented, private sector activities, may assist the irrigation sector in the process of economic reform.