Challenge Program on
Water and Food
Background Paper 5

Policies and Institutions for Sustainable Water Resource Management: A Research Agenda

Mark W. Rosegrant, with contributions from
Sonia Davila-Poblete, David Dawe, Howard Elliot, Mingsarn Kaosa-ard,
Ruth Meinzen-Dick, K. Palanisami, Prabhu Pingali,
Madar Samad, Brent Swallow and Aaron Wolf

.

INTRODUCTION

The world faces severe and growing challenges to sustain water quality and meet the rapidly growing demand for water resources. New sources of water are increasingly expensive to exploit, limiting the potential for expansion of new water supplies. With nearly one-half of the world's cereal production and almost 60 percent of cereal production in developing countries produced on irrigated lands, productivity growth in irrigation is essential—and the productivity of rainfed agriculture must simultaneously be boosted. At the same time, the quality of the land and water resource base must be sustained in the face of mounting pressure from waterlogging, salinization, groundwater mining, and water pollution. Pollution of water from industrial effluents, poorly treated sewage, and runoff of agricultural chemicals, combined with poor household and community sanitary conditions, is a major contributor to disease and malnutrition, particularly among children. Furthermore, the poor, women, and other disadvantaged groups have unequal access to water in many regions. Incentives and policies need to be developed to achieve access by all claimants on the resource. Water is subsidized in all sectors, reducing incentives to conserve water and threatening the financial viability of needed future investments. Finally, transboundary water issues have the potential for escalating into conflicts that will disrupt development and harm ecosystems.

These water challenges, if not successfully met, will threaten future prospects for sustainable poverty alleviation and food security. Meeting these challenges requires improved basic and applied knowledge on how policies and institutions influence poverty and ecosystems through water management and development. The objective of this research theme of the Challenge Program on Water and Food is to improve incomes, alleviate poverty, and enhance food security in an environmentally sustainable manner through policies and institutions that lead to more effective water management and development and increased food production. The goals of the research under this theme are: (1) to understand the impact of alternative policies and institutions on water supply and demand, poverty and income, water quality and water-related ecosystems and food production and food security. Relevant policies and institutions include those that directly affect water resource allocation, and also broad trade and macroeconomic policies, investment and finance and environmental policies. (2) To utilize this understanding to assist national governments, stakeholders in developing countries, NGOs, and international organizations to develop policies and institutions for effective and sustainable water management and development that contributes to poverty alleviation and food security.

This paper discusses in detail the critical water challenges that must be addressed by policies and institutions and summarizes some of the policy and institutional alternatives that can help address these challenges. The paper then outlines a research agenda in the form of key research questions that must be answered in order to understand and enhance the impacts of policy and institutions on income generation, poverty, water and environmental quality, and food security through improved water management and development.

GLOBAL WATER SUPPLY AND DEMAND

Global water availability statistics give a false sense of security, because water is abundant globally, but scarce locally. The total amount of water on the earth is 1,360 million cubic kilometers (km^3), 97 percent of which is in the oceans. There are 37 million km^3 of freshwater, three-fourths of which is in glaciers and icebergs. About 8 million (M) km^3 of freshwater are stored in groundwater, and lakes and rivers account for only 200,000 km^3.

Renewable freshwater is provided by the 110,000 km^3 of annual rainfall over land, of which 70,000 km^3 is evaporated, and 40,000 km^3 is transformed into runoff that can replenish rivers, lakes, and groundwater aquifers. Much of this runoff is immediately lost to floods, leaving an estimated 9,000-14,000 km^3 of reliable runoff annually. Given global water withdrawals of 3,906 km^3 estimated for 1995 and estimated consumptive water use of around 1,600 km^3 (Rosegrant, Cai and Cline 2002), even this fraction of available water would be adequate to meet growth in demand for the foreseeable future, if supplies were distributed equally across the world's population.

But freshwater is distributed unevenly across the globe. Per capita water availability is highest in Latin America and North America, while Africa, Asia and Europe have far less water per capita. However, these regional figures also hide the huge variability in water availability. Freshwater is poorly distributed across countries (Canada is blessed with 120,000 cubic meters (m^3) per capita per year of renewable water resources; Kenya has 600 m^3; and Jordan 300 m^3); across regions within countries (although India has adequate average water availability of 2,500 m^3 per capita, the state of Rajasthan has access to only 550 m^3 per capita per year); and across seasons (Bangladesh annually suffers from monsoon flooding followed by severe dry season water shortages).

Thus, water scarcity is region-, locale- and season-specific. Many countries and regions already face crucial water shortages that cause reductions in income, and impose severe limits on economic growth and lead to local and international conflicts. When does water scarcity become a serious problem? Various indices have been utilized to measure water stress. The *criticality ratio*, which is the ratio of water withdrawals for human use to renewable resources, has been estimated globally and projected to 2025 (Alcamo et al. 1999). Utilizing this approach, it is estimated that 4 billion people, more than one-half of the world's population, will be living in countries facing high water stress (criticality ratio greater than 40 percent) by

2025. Because of the expansion in area subjected to stress, and especially owing to population growth in existing water scarce areas, the number of people living in areas where water resources are under high stress therefore nearly doubles from the 2.1 billion figure in 1995 (Alcamo et al. 1999).

Depleting supplies relative to population will be accompanied by strong growth in the demand for water, especially for domestic and industrial water uses. Total global water withdrawals are expected to increase by 23 percent over the period from 1995 to 2025. Withdrawals in developing countries are projected to experience a proportionally larger increase, with total water withdrawals increasing by 28 percent over this 30-year period. Growth of consumptive use of water for non-irrigation purposes is set to increase dramatically over the period. The domestic sector, the largest user of non-irrigation water, shows a considerable increase in consumptive use of 75 percent globally between 1995 and 2025. Livestock use of water is expected to have a similar percentage increase over the period of 72 percent, while industry use will increase by an estimated 42 percent globally. Consumptive use by irrigators will increase at a lower rate of 4 percent over the period, although the absolute increase is similar to that of the other sectors due to the dominance of the irrigation sector in total water use (Rosegrant, Cai and Cline 2002).

As is evident from the above projections, water availability for irrigation may be threatened in many regions by rapidly increasing nonagricultural water uses in industry, households and the environment. A portion of the growing demand for water must be met through new investments in irrigation and water supply systems and through improved water management. Also, some potential exists for the expansion of nontraditional sources of water supply. However, in many arid or semiarid areas—and seasonally in wetter areas—water is no longer abundant, and the high economic and environmental costs of developing new water resources pose limits to supply expansion. Therefore, new supplies may not be sufficient to meet growing demands. As a result, the role of water withdrawals in irrigated agriculture and food security has been receiving substantial attention in recent years. Whether water availability for irrigation—together with feasible production growth in rainfed areas—will provide the food needed to meet the growing demand and improve national and global food security remains a crucial and urgent question for the world. Changes in water policies at regional and national levels as well as investments in both supply expansion and research into new technologies, including water harvesting and crop breeding, will be critical in determining the extent to which future food demands are met.

WATER AND FOOD: FUTURE POLICY AND INSTITUTIONAL CHALLENGES

National, regional and seasonal water scarcity in developing countries pose severe challenges for national governments and the international development community. The challenges of growing water scarcity are exacerbated by the increasing costs of new water; wasteful use of already developed water supplies; degradation of soil in irrigated areas; depletion of groundwater; threats to water-related ecosystems; water pollution and degradation of water-related ecosystems; subsidies and the distorted incentives that govern water use; inequitable water access by women, the poor, and disadvantaged groups; and threats of transboundary conflicts at national and international levels.

INCREASING COSTS OF NEW WATER

New sources of water are increasingly expensive to exploit, limiting the potential for expansion of new water supplies. In India and Indonesia, the real costs of new irrigation have more than doubled since the late 1960s and early 1970s; in the Philippines, costs have increased by more than 50 percent; in Sri Lanka, they have tripled; and in Thailand they have increased by 40 percent. The result of these increases in costs, together with declining cereal prices, is low rates of return for new irrigation construction.

In Africa, irrigation construction costs have been even higher than in Asia, due to numerous physical and technical constraints. The average investment cost for medium and large-scale irrigation with full water control was estimated at US$8,300/ha in 1992 dollars (FAO 1992). However, the average cost of irrigation systems in Sub-Saharan Africa will increase to US$18,300 if the typically high indirect costs of social infrastructure, including roads, houses, electric grids, and public service facilities are included (Jones 1995).

A particularly active debate concerns the future of large dams. In addition to increasing financial costs, the development of new dams often imposes high environmental and social costs, including dislocation of people displaced from dam and reservoir sites. The controversy over the Narmada Valley Development Program in western India is illustrative of the issues that need to be resolved if large-scale irrigation projects are to play a role in future water development. The Narmada project includes 30 large dams, 135 medium-sized ones, and 3,000 small ones, and covers an area from the watersheds of the Narmada river in Madhya Pradesh and Maharashtra in central India through Gujarat on the west coast and on to arid regions in Rajasthan. The main dam in the project is the Sardar Sarovar, which is designed to provide domestic water to 40 million people, generate 1,200 MW of electric power, and irrigate 1.8 million ha of land (Seckler 1992). These benefits are large, but the environmental and human costs of the construction of the dam are also large. The reservoir to be created by the Sardar Sarovar dam would flood 37,000 hectares of forest and farmland and displace nearly 100,000 people, mostly poor tribal villagers. An additional 80,000 ha of land will be utilized for the construction of the distribution network, affecting, in various degrees, another 140,000 people (Berger 1994). Assessment of large-scale dams should include a comprehensive accounting of costs and benefits, and if projects proceed they must employ equitable, realistic and practical methods for compensating those who are negatively affected. Future construction of large-scale dams will require balanced development approaches acceptable to diverse constituencies.

The cost of supplying water for household and industrial uses is also increasing rapidly. In Amman, Jordan the average incremental cost of water from groundwater sources has been US$0.41 per cubic meter. However, with shortages of groundwater, the city has begun to rely on surface water, pumped with a lift of 1,200 m from a site 40 km from the city, at an average incremental cost of US$1.33/ m^3. Future schemes are estimated to cost US$1.50 per cubic meter. In Shenyang, China, the cost of new water supplies will nearly triple from US$0.04 to US$0.11 per cubic meter between 1988 and 2000 because pollution of the current groundwater source will require a shift to water conveyed by gravity from a surface source 51 km from the city. In Yingkou, China, pollution of the water supply source has forced a shift to a new source that increased the average incremental cost from about US$0.16/ m^3 to US$0.30/m^3. In Lima, Peru, the average incremental cost to meet short- and medium-term needs has been US$0.25/$m^3$. However, because of depletion of the presently used aquifer, to meet long-term urban needs, a transfer of water from the Atlantic watershed is being planned, at an estimated average incremental cost of US$0.53/$m^3$. In Mexico City, water is being pumped over an elevation of 1,000 m into the Mexico Valley from the Cutzamala River through a pipeline about 180 kilometers long, at an average incremental cost of US$0.82/$m^3$. This is almost 55 percent more than the cost of the previous source, the Mexico Valley aquifer (World Bank 1993).

WASTEFUL USE OF EXISTING WATER SUPPLIES

One of the most important challenges is to generate water savings from existing agricultural, household and industrial uses. Water use efficiency in irrigation in much of the developing world is typically in the range of 25 to 40 percent, while in urban supply systems, "unaccounted for water" (much of which is direct water losses) is often 50 percent or more in major metropolitan areas in developing countries. These inefficiencies seem to imply the potential for huge savings from existing uses of water.

The potential for water savings is not as dramatic in all regions or delivery systems as implied by these efficiency figures because much of the water "lost" from systems is reused elsewhere within the river basin. However, the scope for water savings and economic gains from improvements in river basin water use efficiency still appears to be large in many basins.

A particularly difficult challenge will be to improve the efficiency of agricultural water use to maintain crop productivity growth while at the same time allowing reallocation of water from agriculture to urban and industrial uses. Since irrigated area accounts for nearly two-thirds of world rice and over one-third of world wheat production, growth in irrigated output per unit of land and water is essential to feed growing populations. At the same time, because of the limited number of cost-effective new sources of water, the rapidly growing household and industrial demand for water will need to come increasingly from water savings in irrigated agriculture, which generally accounts for 80 percent of water diverted for use in developing countries. Moreover, water savings in agriculture, to truly contribute to reducing water scarcity, should be accompanied by improved efficiency in urban and industrial use.

DEGRADATION OF IRRIGATED CROPLAND

The past decade has seen a significant degradation of existing irrigated cropland. Although data is limited and definitions of damaged area vary considerably, estimates of annual global losses of agricultural land due to waterlogging and salinization span from lower estimates in the range of 160,000-300,000 ha (Barrow 1991) to high estimates of 1.5 million ha (Kovda 1983), with most of the waterlogging and salinization in irrigated croplands of high production potential.

Global estimates of the total area affected by salinity but still in production also vary considerably. El-Ashry (1991), Rhoades (1987), and Kayasseh and Schenck (1989) estimate that salinity seriously affects productivity in 20 to 30 million ha of irrigated land. Barrow (1991), however, estimated that in the late 1980s roughly 30 to 46 million ha was in a poor state due to salinization. Thus, although estimates vary significantly, degradation of irrigated area is a significant and growing problem and will further increase the pressure on existing irrigated production.

GROUNDWATER DEPLETION

Groundwater is depleted when pumping rates exceed the rate of natural recharge. While mining of both renewable and non-renewable water resources can be an optimal economic strategy, it is clear that groundwater overdrafting is excessive in many instances. Overdraft or mining of groundwater at a rate higher than recharge increases pumping lifts and costs due to the lowered water table, causes land to subside (sometimes irreversibly damaging the aquifer), and induces saline intrusion and other degradation of water quality in the aquifer.

In parts of the North China Plain, groundwater levels are falling by as much as one meter per year. In the western state of Gujarat, overpumping in the coastal areas has caused saltwater to invade the aquifer, contaminating village drinking supplies (Postel 1993). At the same time, in a number of regions in India, water tables have been falling at average rates of 2 to 3 m per year due to the growing number of irrigation wells. The resultant depletion of groundwater aquifers has some analysts predicting that 25 percent of India's harvest may be placed at risk in the coming years (Brown 2000; Gleick 2000).

Fossil aquifers, which are typically deep underground, and which receive little or no recharge, are being utilized for irrigation in some of the arid regions of the world. Pumping of fossil water constitutes water mining, one-time extractions from a depletable reserve. Egypt is irrigating 17,000 ha of cropland from fossil aquifers, and has plans to increase these areas several-fold (Abu-Zeid, 1992). Three-fourths of Saudi Arabia's water supply comes from non-renewable ground water sources, and this share is expected to rise. Finally, groundwater pumping in Saudi Arabia exceeds estimated recharge more than five-fold.

INADEQUATE ACCESS AND PARTICIPATION BY THE POOR, WOMEN AND UNDERPRIVILEGED

Access to safe water is crucial for poor residents around the world, particularly those in water-scarce countries. Often women, the poor, and disadvantaged groups, including minorities and indigenous peoples, have unequal access to water, which can lead to even greater increases in poverty. Women are often at a particular disadvantage regarding access to water, which has a significant impact on household water security as women take many of the household water use decisions. Household water is primarily collected by women, making the burden of carrying heavy buckets of water from standpipes or wells to the home a significant issue. The use of the time and energy required to haul the water takes away from time that could otherwise be spent caring for children or earning income. Women also often take important decisions related to irrigation water use for family gardens and water use for livestock.

Availability of water for irrigation is fundamental in ensuring the ability to grow enough crops to feed the eight hundred million food-insecure people in the developing world. Irrigation can play an important role in poverty reduction, as many poor residents around the globe live in rural areas and depend upon agriculture for both food and income. Also irrigation is used for a large portion of agriculture production. Other potential benefits to poor communities include increased food security, increased incomes to farmers, decreased food prices and greater employment. Unfortunately, it has been found that many of these benefits accompanying irrigation cannot be realized by poor farmers in low-productivity areas that are also those most vulnerable to water shortages. Some factors that prevent achieving the full potential of irrigation water supply include: (1) managerial and institutional factors contributing to poor performance of irrigation systems, (2) physical factors related to the environment or the irrigation system design, (3) economic factors including lack of credit, lack of inputs and access to markets and smaller landholdings and (4) socio-cultural factors such as insecure land tenure and gender bias (Hussain, Yokoyama and Hunzai 2001).

In addition to the importance of irrigation water for food security, access to safe drinking water and sanitation are critical in terms of maintaining health, particularly for children. Unsafe drinking water can contribute to many health problems in poor countries, such as the 1 billion or more episodes of diarrhea that occur annually in developing countries. For an excess of one billion people across the globe, safe water is unavailable in sufficient quantities required to meet minimum levels of health and income. Contaminated water supplies may also impact health through food consumption, as untreated wastewater or contaminated surface water is often used for irrigation in poor communities. Outbreaks of cholera and typhoid in Chile during the early 1990s have been linked to the use of untreated wastewater on vegetable crops.

Perhaps even more fundamental than the lack of access to water is the lack of access to decision making processes for water development and allocation. Evidence from previous projects has shown that new water projects are more likely to be used when women are consulted during their development. New water facilities in Indonesia, Guatemala, and Togo were not used by women due to improper design and other problems arising from a lack of prior consultation with women users. Some projects have begun to consult with women users, however, as evidenced in Sri Lanka, where an irrigation project was designed to make clean water available to women for domestic use (FAO 2000). While there has been some improvement and much policy discussion of gender issues related to water (particularly irrigation), there is still a gap between this discussion and action (van Koppen 2002). Increased participation in transparent decision-making by all stakeholders, and particularly those who are currently disadvantaged, would foster an enabling environment for the poor, women and underprivileged groups.

THREATS TO ECOSYSTEMS, INCREASING POLLUTION AND DECLINING WATER QUALITY

In addition to its value for direct human consumption, water is integrally linked to the provision and quality of ecosystem services. On the one hand, water is vital to the survival of ecosystems and the plants and animals that live in them. On the other hand, ecosystems regulate the quantity and quality of water. Wetlands retain water during high rainfall and release it during dry periods and purify it of many contaminants. Forests reduce erosion and sedimentation of rivers and recharge groundwater (Bos and Bergkamp 2001). Ecosystem services can be defined as the conditions and processes through which ecosystems sustain and fulfill human life, including the provision of food and other goods (Carpenter et al. 2002). Ecosystem services are generally not traded in markets, have no price, and therefore are not properly valued in economic decision-making, but they are essential for human life and welfare.

Important interlinked categories of ecosystem services include:

- Providing food, freshwater and other biological products (including fiber, biochemicals/medicine, fuels and energy, and non-living materials)
- Supporting regulation functions (including soil formation, nutrient cycling, waste treatment, climate regulation, atmospheric composition, flood and erosion control, and pollination) and organization and structure (including biodiversity, landscape interconnections and structure, and space)
- Enriching cultural life, recreation and tourism (Carpenter et al. 2002)

But water and the ecosystems it supports are under increasing threat, leading to deterioration in the quality and quantity of ecosystem services. Half of the world's wetlands have been lost due to diversion of water and conversion into agricultural and other land uses (Bos and Bergkamp 2001).

Moreover, a growing number of the world's rivers, lakes and groundwater aquifers are being severely contaminated by human, industrial and agricultural wastes. High withdrawals of water, and heavy pollution loads have already caused widespread harm to a number of ecosystems. This has resulted in a wide range of health effects in which humans have been harmed by waterborne illness and through the consumption of food from contaminated ecosystems. Rising human demands will put increasing pressure on ecosystems. As more water is withdrawn for human uses, there is increasing need to make certain that an adequate water supply to wetlands, lakes, rivers and coastal areas are maintained to ensure the healthy functioning of ecosystems (UN 1997).

Pollution of water from industrial effluents, poorly treated or untreated domestic and industrial sewage, runoff of agricultural chemicals and mining wastes is a growing problem. The main contaminants found in water include detergents (soaps and solvents); pesticides; petroleum and other derivatives; toxic metals (e.g. lead and mercury); fertilizers and other plant nutrients; oxygen-depleting compounds (e.g. wastes from canneries, meat-processing plants, slaughterhouses, and paper and pulp processing); and disease causing agents responsible for hepatitis and infections of the intestinal tract such as typhoid fever, cholera and dysentery (Anton 1993).

Water-related diseases place an excessive burden on the population and health services of many countries worldwide, and in particular on those in developing countries (WHO 2000). According to the UN, 3.3 billion illnesses and 5.3 million deaths are caused annually by unsafe water on a global scale (UN 1999). There have been some significant improvements in water quality, however, particularly due to governments and industry response to citizen-applied pressure for cleanups. Most developed countries have begun treating an increasing part of their municipal sewage, and a number of their industries are reducing discharges of many toxic substances. As a result, there have been reduced risks to human health, and improvements in the health of some wildlife species (UN 1997).

Unsafe drinking water, combined with poor household and community sanitary conditions, is a major contributor to disease and malnutrition, particularly among children. Contaminated wastewaters are often used for irrigation, creating significant risks for human health and well-being. In São Paulo, the contaminated waters from the Tiete river are used to irrigate vegetables downstream. In Chile, 62,000 ha of vegetables are irrigated from watercourses downstream from Santiago's sewage outflow (Anton 1993). Only 217 of 3119 towns in India have partial (209) or full (8) sewage treatment facilities. Rivers in India often have astronomical coliform counts—the Yamuna river leaving New Delhi receives 200 million litres of untreated sewage per day, with coliform counts of 25 million organisms per 100 milliliters, compared to safe level for drinking water of 100 organisms per 100 milliliters (Clarke 1993). Worldwide, one billion people are without clean drinking water and 1.7 billion have inadequate sanitation facilities.

SUBSIDIES, DISTORTED INCENTIVES, AND POOR COST RECOVERY

The main objectives of water pricing include: 1) creation of incentives for efficient water use, 2) cost recovery in the water sector, and 3) financial sustainability for urban water supply systems and irrigation, including the ability to raise capital for expansion of services to meet future demand. However, none of these objectives are met in most developing countries. Both urban and rural water users are provided with large subsidies on water use; irrigation water is essentially unpriced; in urban areas the price of water does not cover the cost of delivery; and capital investment decisions in all sectors are divorced from management of the resource. In Mexico during the mid-1990s the annual subsidy for operations and maintenance of water systems (that is, not including capital costs) was one-half of one percent of the gross domestic product, far more than was spent on the agricultural research system (Rosegrant, Gazmuri and Yadav 1995). Annual irrigation subsidies are estimated at US$0.6 billion in Pakistan, US$1.2 billion in India, and US$5.0 billion in Egypt (Bhatia and Falkenmark 1993).

In the mid-1980s, average irrigation subsidies in six Asian countries covered an average of 90 percent or more of total operating and maintenance (O&M) costs (Repetto 1986). During the 1990s, subsides have declined somewhat as most countries worldwide have officially adopted the stated goal of full recovery of O&M costs. No country in either the developed or the developing world has fully eliminated subsidies, however, and progress on this front has been uneven, with Chile and South Africa implementing particularly innovative programs. Despite these ongoing reforms, O&M cost recovery remains dismal in most major irrigators. In Pakistan, for example, the gap between O&M expenditures and recoveries in the Punjab region was 62 percent in 1994-1995, increasing to 74 percent in 1995-1996, while the Sindh region performed even worse with only 88 percent in 1995-1996 (Dinar, Balakrishnan, and Wambia 1998).

Subsidies often worsen, rather than improve equity. In most countries, water subsidies disproportionately benefit the better off—mostly urban water users connected to the public system and irrigated farmers. Therefore, the urban poor, who must rely on water vendors, often pay many times more for water than the generally better-off residents who receive subsidized water from the public systems. The equity impacts are worsened even more when subsidies are financed from regressive taxes.

Low water charges and poor cost recovery risk the efficient maintenance of existing water infrastructure as well as the additional investments on future water development projects and encourage wasteful use of irrigation water (Saleth 2001).

Irrigation water pricing for full capital cost recovery in existing systems appears unlikely in most of the developing world (even developed countries have rarely attempted full capital cost recovery for irrigation), but pricing to cover O&M costs and capital asset replacement or depreciation costs appears feasible. Even recovery of O&M costs would require a major reform in pricing policy, monitoring and enforcement. In developing countries, the recovery of irrigation O&M ranges from 20-30 percent in India and Pakistan to 75 percent in Madagascar, and depreciation is virtually uncovered (Dinar and Subramanian 1997).

TRANSBOUNDARY WATER DISPUTES

International basins cover 45 percent of the land surface of the earth, affect about 40 percent of the world's population and account for approximately 80 percent of global river flow (Wolf 2001). These basins have certain characteristics that make their management especially difficult, the most notable of which is the tendency for regional politics to regularly exacerbate the already difficult task of understanding and managing complex natural systems.

River basins and groundwater aquifers that cross international boundaries present increased challenges to effective water management, and hydrologic needs are often overwhelmed by political considerations. While the potential for paralyzing disputes are especially high in these basins, the record of violence is actually greater within the boundaries of a nation. Water resources have contributed to tensions between competing users around the globe, mostly at the intra-national level, generally between tribes, water-use sectors, or states/provinces. Examples of internal water conflicts range from interstate violence and death along the Cauvery river in India, to California farmers blowing up a pipeline meant for Los Angeles, to much of the violent history in the Americas between indigenous peoples and European settlers. While these disputes can and do occur at the sub-national level, the human security issue is subtler and more pervasive than violent conflict. As water quality degrades—or quantity diminishes, over time—tensions can spill across boundaries, and the overall effect on the stability of a region can be unsettling.

Wolf (2001) points out that a general pattern has emerged for international basins over time. Riparians of an international basin implement water development projects unilaterally, first on water within their territory, in an attempt to avoid the political intricacies of the shared resource. At some point, one of the riparians, generally the regional power, will implement a project that impacts at least one of its neighbors. The goal of the project might be to continue to meet existing uses in the face of decreasing relative water availability (for example, Egypt's plans for a high dam on the Nile, or Indian diversions of the Ganges to protect the port of Calcutta) or to meet new needs reflecting new agricultural policy (such as Turkey's GAP project on the Euphrates). These projects which impacts one's neighbors can, in the absence of relations or institutions conducive to conflict resolution, become a flashpoint, heightening tensions and regional instability, and requiring years or, more commonly, decades, to resolve. Meanwhile, all the while water quality and quantity degrades to where the health of dependent populations and ecosystems are damaged or destroyed.

POLICIES AND INSTITUTIONS FOR WATER AND FOOD: THE RESEARCH CHALLENGE

In response to these challenges, policies and institutions must evolve to: (1) maintain growth in irrigated and rainfed agricultural production; (2) facilitate efficient intersectoral allocation of water, likely to include transfers of water out of agriculture; (3) reverse the ongoing degradation of the water, irrigated land, and water-related ecosystems, including the watershed, irrigated land base, and water quality; (4) increase incomes and enhance and safeguard the rights of poor and socially-excluded groups to domestic and irrigation water supplies; (5) improve the effectiveness of water use in rainfed agricultural areas, including less favorable and dryland areas; and (6) better management of conflicts over water use.

Five broad areas of policies and institutions that affect the future of water and food will be considered here: (1) economy-wide policies that influence water resource demand, supply, and quality, including globalization, trade and macroeconomic policy, agricultural output and input pricing and taxation policies; (2) public investment and financing of irrigation and water supply; (3) policies and institutions for water allocation at the river basin and irrigation system levels; (4) water quality and environmental policies and institutions; and (5) transboundary water policies and institutions.

Several core research questions cut across these categories, and research must fundamentally address these crosscutting issues, including:

- What is the impact of alternative policies and institutions on income and poverty, with particular emphasis on the income of the poor, women and disadvantaged groups?
- What is the impact of alternative policies and institutions on supply and demand for water in agriculture, household and industrial uses?
- What are the impacts of alternative policies and institutions on food production and food security?
- What is the impact of alternative policies and institutions on water-related ecosystems, including forest-water interactions and wetlands; and on water

quality, including agricultural effluents such as fertilizer and pesticides, and household and industrial water pollution?

In addition to these meta-questions, there are specific priority research questions within each of these categories of policies and institutions. The key issues and research questions in each of the categories of policies and institutions are addressed in the following sections.

GLOBALIZATION, TRADE, MACROECONOMIC AND SECTORAL POLICIES

The process of globalization, which includes increased integration across countries through liberalized trade, financial flows, technology flows and information flows, can generate significant economic benefits for developing countries. But globalization and economic liberalization also carry with them risks of economic and political instability, worsening inequality and vulnerability of the poor, and the loss of agricultural production and income to other countries that subsidize their own agricultural producers. Developed-country agricultural trade policies that protect their own farmers impose significant costs on developing-country agriculture. A simulation of the elimination of agricultural subsidies and trade barriers based on the international model for policy analysis of agricultural commodities and trade (IMPACT) global food supply and demand model, shows that trade liberalization would generate significant net economic benefits. Taking into account the benefits to producers and consumers and the tax savings due to removals of subsidies, liberalization of trade for the sixteen commodities included in the model would generate global benefits of US$35.7 billion in 2020. Both developed regions and developing regions benefit, with the former gaining US$14.2 billion and the latter US$21.5 billion (Rosegrant et al. 2001).

Trade and macroeconomic policies and activities can affect water and related natural resources both directly and indirectly. Currency devaluations and fiscal incentives can directly contribute to deforestation and deterioration of the upper watershed by promoting exports of timber and other agricultural products. Indirect impacts are those arising from the interaction of one environmental input directly affected by a policy with another environmental input (for example, water quality can deteriorate due to policies affecting deforestation, through increased runoff). Macroeconomic and trade policies can also have positive effects in promoting sustainable and equitable water resource use.

For example, a potential benefit from expanded international trade that has received considerable attention is trade in virtual water. The strategy of substituting food imports financed by urban and commercial growth for irrigated agricultural production (so-called imports of "virtual water") is a possible strategy for reducing agricultural water helping to alleviate water scarcity and other problems in many countries (Allan 1996). The virtual water concept is based on the principle of comparative advantage in international trade. Water-scarce countries, such as much of the Middle East, have a disadvantage in growing water-intensive crops such as cereals, and could improve water availability by increasing their reliance on imports. Countries with relatively plentiful water, such as Vietnam, Thailand and Myanmar in turn have a comparative advantage in exporting water-intensive crops, like rice, to water-scarce countries. Maize is exported from the USA largely because it can be grown without irrigation due to the exceptionally favorable agroclimatic conditions of the "corn belt." This principle also holds for trade within countries. For example, it has been estimated that Egypt could save nearly 10 percent of its scarce water supplies, for example, by replacing sugarcane production in the very hot south with cool season sugar beet production in the north (IWMI 2000).

Sectoral policies, such as agricultural taxation and input and output price policy also profoundly influence farmer decisions regarding water use and related cropping decisions. In much of Asia, for example, government interventions in cereal markets, especially through crop price support and input subsidies, provided farmers incentives to produce water-intensive rice at the expense of other, less water-intensive commodities.

Subsidies on inputs other than water can also profoundly influence the utilization and quality of water. In addition to highly subsidized irrigation water, Asian farmers benefited from cheap fertilizers, pesticides and credit. Input subsidies that keep input prices low directly affect crop management practices at the farm level; they reduce farmer incentives for improving input use efficiency, that often requires farmer investment in learning about the technology and how best to use it. In addition to inducing increased use, subsidized fertilizer prices have tended to favor the use of nitrogen fertilizers over other nutrients, creating soil fertility imbalances. High rates of fertilizer use in some regions are causing nitrate leaching or runoff and eutrophication that cause excess growth of algae, oxygen depletion and increased fish mortality.

Subsidized energy prices have been one of the primary causes for groundwater overdraft in parts of India, as noted above. In most states power is provided at a flat rate based on pump capacity, while in some (e.g. Tamil Nadu and the Punjab), it is provided free of charge. As a result, power consumption in agriculture has grown dramatically in recent years and estimates suggest that it exceeds 40 percent of total energy use in many states (Foster et al. 2000).

More generally, trade, macroeconomic, and sectoral policies influence water use and quality through changes in the level of aggregate economic activity, changes in the composition of each sector to output and changes in production technology. The aggregate output effect tends to increase water use and water pollution, but the technology and intersectoral composition effects may either add to or dampen the impact of increased overall activity (Strutt and Andersen 2000). In a general equilibrium model analysis for Indonesia, Strutt and Andersen (2000) found that Uruguay trade round implementation would reduce water demand and water pollution, due mainly to changes in intersectoral composition (including reductions in rice production and production of paper products).

In addition to these factors, economy-wide political effects, such as induced institutional change due to changes in economic policies can have a major impact on water and other resource use and degradation rates. The political economy effects could be negative if companies respond to liberalization by actively shifting manufacturing to countries with weak environmental regulation, or if countries weaken regulations to attract business. On the other hand, economic liberalization can induce improvements in environmental regulation and enforcement and increase the stock of knowledge, innovations, and capital to meet these standards (Jansen 2001; Logsdon and Husted 2000). Jansen's (2001) assessment of the impacts of North American free trade agreement (NAFTA) on Mexico in a general equilibrium model with endogenous institutional change shows that the net pollution impact of NAFTA is likely to be beneficial or only slightly negative.

In addition, when water resources support an economic sector that is relatively large within the overall economy (such as in Egypt), development in the water sector can have significant feedback effects of environmental change on the economy as a whole. Trade policy impacts in turn are also partly dependent on the prevailing water allocation policies. For example, Diao and Roe (2002) show that trade liberalization in Morocco would induce a strong positive investment and growth response, and a reallocation of water and land resources to the production of fruit and vegetable crops, for which Morocco has a strong comparative advantage. However, trade reform alone reduces the returns to farmers in previously protected cereal crops. But trade liberalization combined with creation of a water user-rights, market not only compensates for the losses of farmers due to the trade reform, but also raises the efficiency of water allocation and hence benefits the economy as a whole.

Given the wide-ranging impacts of globalization, trade, and economy-wide policies on water resource utilization and policy, a better understanding of these impacts is essential. Key research issues include:

- What is the relationship between global and national policies and water sector policies and how can they be effectively coordinated?

- To what extent can imports of virtual water through food imports be utilized to conserve water domestically and achieve water and food security goals?
- What is the impact of developed-country agricultural trade and macroeconomic policy on water and food supply and demand, food security and livelihoods in developing countries?
- How can globalization and trade and economic liberalization be managed to best enhance environmental policy and the regulation of water quality and water-related ecosystems?
- How can globalization and trade and economic liberalization be managed to best encourage technological and institutional change in water use that improves efficiency of water use and water quality and water-related ecosystems?
- How can the participation, rights and access to water of the poor, women, and socially excluded groups be established and safeguarded in the processes of global and national demographic, economic and political change that are shaping the developing regions?

INVESTMENT AND FINANCING FOR IRRIGATION AND WATER SUPPLY

As discussed above, low water prices and high subsidies for capital investment and operations and maintenance threaten the financial viability of irrigation and urban water supply. This problem is particularly serious due to the huge future needs of financial resources for these sectors. Various estimates of additional investment costs to achieve global water security and to extend water supply and sanitation services to currently uncovered citizens are quite significant. The Agenda 21 report of the Rio Conference on Environment and Development in 1992 estimated additional investments to achieve water security to be approximately US$56 billion per year. Water supply and sanitation cost estimates reported in the Vision 21 report were a total of US$225 billion over 25 years if more appropriate technologies were used – although this estimate did not include additional costs to be incurred at the community and household levels (WSSCC 1999). The World Water Vision document estimates costs in the range of $180 billion globally for urban water supply and sanitation and an additional US$180 billion for industrial water supply and wastewater treatment over the period from 1995-2025. They estimate that costs for increasing food production by an additional 40 percent (the amount required to end hunger) would be an additional US$550 billion when including increased investments in irrigation and research in more productive water use (Cosgrove and Rijsberman 2000).

The allocation of investment across sectors is also a crucial issue. Recent analysis in China and India indicates that increased public investment in many less-favored rainfed areas may have the potential to generate competitive if not greater agricultural growth on the margin than comparable investments in many high-potential irrigated areas, and could have a greater impact on the poverty and environmental problems of the less-favored areas in which they are targeted (Fan, Hazell and Thorat 1998; Fan, Hazell and Haque 2000; Fan, Zhang and Zhang 2000). If this finding holds true in other countries, then additional investments in less-favored areas may actually give higher aggregate social returns to a nation than additional investments in high-potential areas.

Moreover, new sources of water are increasingly expensive to exploit, and development of new dams often imposes high environmental and social costs, including dislocation of persons displaced from dam and reservoir sites. In order to guide policy makers, available estimates of total investment requirements must be carefully refined for individual countries and regions, the most effective allocations across different types of investments and different regions must be assessed, and appropriate methods for the financing of needed investments must be determined. Important research issues include the following:

- To what extent can and should full capital and/or operations and maintenance costs be recovered from water users and other beneficiaries in each sector?
- What water pricing and water rights policies and institutions will best contribute to appropriate levels of cost recovery and to economic and social valuation of water that will provide incentives for efficient and effective water use in each sector?
- What should be the relative role of private and public investment for expansion and maintenance of irrigation, water supply and sanitation systems?
- How should investments be allocated, directly for water development, or rather in water-related or water-supporting sectors, including agricultural research and other types of physical infrastructure and social investments such as education, health and nutrition?
- What should be the allocation of investments among irrigated, rainfed and dryland agriculture, livestock, fisheries and other agro-ecosystems?
- What should be the future investment in dams, taking into account the benefits and financial, social and environmental costs of dam building?

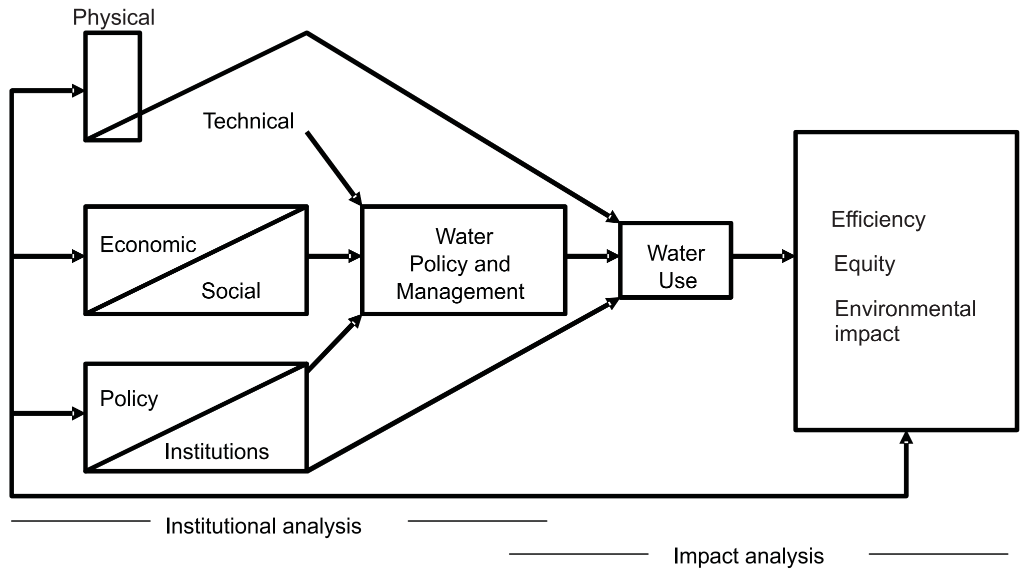
WATER POLICIES AND INSTITUTIONS AT THE RIVER BASIN AND IRRIGATION SYSTEM LEVELS

At the river basin and irrigation system level, reform of water policies and institutions will be increasingly important for meeting new water demands by saving of water in existing uses, for increasing the economic benefits from water use, and for improving the quality of water and soils. Despite the growing pressure for water policy reform due to growing water scarcity, increasing competition for water within and across sectors, and declining water and soil quality, essential questions regarding the feasibility, implementation costs, and likely impacts of reform of water allocation mechanisms and policy in developing countries have not been answered. The research at the basin and system level will seek answers to these questions by addressing the policies and institutions that influence water resource allocation.

Alternative mechanisms for water resource allocation mechanisms can be broadly characterized as: (1) administrative allocation by public agencies; (2) user-based allocation, such as community-managed systems and farmer-managed irrigation districts; (3) market allocation based on scarcity pricing or markets in tradable water rights; and (4) mixed systems that incorporate elements of these basic types of systems. These allocation systems should not be seen as static, and each of these allocation systems can include scope for negotiation, particularly to deal with changing situations or fluctuations in water availability.

In order to understand the performance and potential for improvement of water resource allocation, it is necessary to understand the evolution of the existing systems of allocation. This part of the analysis will assess how the physical, socioeconomic, and policy environments affect the institutions and laws that govern water allocation. The conceptual framework for this analysis is illustrated in figure 1. The underlying conditions are seen to affect the choice of water allocation mechanisms and institutions. Water allocation, in conjunction with a range of conditioning factors, affects water use patterns, which in turn determine the outcomes, and outcomes have a feedback effect on the environment. The conditioning factors are broadly defined to include: (1) physical and technical factors, including quantity and quality of water supply, soils, terrain, and water application and measuring technology; (2) economic and social factors, including markets, landholding size, population density, and heterogeneity of social background; and (3) policy and institutional factors, including water rights, pricing, regulations, capacity of government agencies, organizational density and legal frameworks.

Figure1. Policies and institutions at river basin and irrigation system: Conceptual framework.



The outcomes for water use can then be examined in terms of efficiency, equity, and environmental impact. Over time, these outcomes change the conditioning environment through processes such as salinization, siltation, industrial water pollution, technological change, crop diversification and trade, industrialization, migration and population growth, social differentiation, changes in legislation and institutional change.

Corresponding to this conceptual framework, research must address both institutional issues and the impact of policies, including: (1) analysis of the nature and performance of water allocation mechanisms, with particular reference to (a) the role of physical/technical, social/economic, and policy/institutional environments in shaping allocation systems; (b) the nature of water rights and other property rights, laws, informal and formal contracts, contracts, different forms of property rights and institutions in alternative water allocation systems; and (2) analysis of the impact of water allocation on agricultural productivity, consumer welfare, industrial productivity and resource degradation. Specific research questions to be addressed are summarized in the following sections.

Determinants of Water Allocation Mechanisms

- What are the characteristics and determinants of existing water allocation mechanisms?

- How do underlying factors and forces (economic and political development, agricultural intensification, technology, resource base and water scarcity) influence the evolution and effectiveness of rules, procedures and policies for water allocation?

Water Rights

The nature and effectiveness of water rights is an important determinant of the performance of water allocation under administrative, market-based, or user-based systems. In many cases, lack of well-defined and secure water rights systems increases the vulnerability of poorer, politically and economically weaker water users under water allocation and reallocation practices. Clarifying and strengthening rights can play an important role in improving water allocation equity and efficiency, while a lack of effective water rights systems creates major problems and inequities for managing increasingly scarce water. Improved water rights and allocation practices can raise water productivity, enhance livelihoods, and better optimize benefits from existing and new investments in the sector. Key research questions include:

- What is the nature and role of water rights under alternative water allocation systems?
- What are the processes by which water rights are recognized or conferred, and how do these processes influence access by the poor, women, landless and other underprivileged social groups?
- What is the relative effectiveness of customary versus formal legal water rights and can legal water rights that capture the resilience and flexibility of customary rights be developed?
- What are the benefits and costs of making water rights tradable?

Transaction Costs

A fundamental determinant of the effectiveness of water allocation is the level of transaction costs incurred in the allocation process. Transaction costs occur in any process of water allocation, and particularly during the process of water *reallocation* among individuals and sectors that will increasingly occur due to increasing demand. Transaction costs include (a) the cost of identifying beneficial opportunities for transferring water, (b) the costs of negotiating or administratively deciding on the water transfer, (c) the cost of monitoring possible third-party effects and other externalities, (d) the infrastructure cost of actually conveying the water and monitoring the transfers, (e) the infrastructure and institutional cost of mitigating, or eliminating possible third-party effects and externalities, and (f) resolution of conflicts that arise during water reallocation (see below for more on conflict resolution). The main research issues here are:

- What is the level of transaction costs under different policies, institutions and mechanisms for water resource allocation?
- What institutional mechanisms are most effective in minimizing the associated transaction costs?

Conflict Resolution

The conflicts that arise from water allocation are dynamic, driven by growing water scarcity, climate variability, changing technical knowledge and new societal values on water and the environment. Water conflicts are broadly multicultural, involving urban and rural ways of life and ethnically and culturally diverse groups. With physical uncertainties and diverse values, there is a premium on legal, economic and technical information. The role of information is complex because parties to the conflict have differing perceptions regarding the legal rights involved, the technical nature of the problem, the cost of solving technical problems, and the allocation of costs among stakeholders (Colby and d'Estree 2000).

Conflict resolution mechanisms include litigation, market transactions, political maneuvering, direct bargaining among disputants, and alternative dispute resolution mechanisms such as mediation, consensus building and other forms of assisted negotiations and arbitration (Colby and d'Estree 2000). Bruns and Meinzen-Dick (2000) argue that alternative dispute mechanisms that emphasize negotiations among all concerned parties are the most effective means for conflict resolution, because they ensure that all points of view are heard, local knowledge is utilized and that the decisions are politically acceptable and implementable. Understanding the most effective conflict resolution techniques under different cultural, political, and economic systems will be essential as pressure grows to transfer water. Among the most important research issues on conflict resolution are the following:

- What conflict resolution methods are most effective under alternative underlying conditions?
- What is the role of public policy in improving the capability of local and user-oriented groups to participate in negotiations to resolve conflict?
- What are the transaction costs of alternative methods for conflict resolution?
- To what degree do different methods for conflict resolution provide access and protection to the poor, women or other disadvantaged groups?

Impacts on Access and Poverty

- How can the rights and access of the poor to water be established and safeguarded during the processes of demographic, economic and political change that are shaping the developing regions?
- What are the barriers to access for the poor and marginalized under existing policies and institutions for water, and how can these be overcome?
- How can water policies and institutions be designed to create an enabling environment for the participation of the poor, women, landless and underprivileged social groups?
- How can water policies and institutions be designed to improve access for the poor, women, landless, and underprivileged social groups to water for irrigation and household uses, livestock, fishing and micro-enterprises?
- What is the role of public and private user-based interventions in improving access to water for the poor?
- What is the impact of privatization and water markets on the poor?

Impacts on Agricultural Production and Water Quality

- What are the impacts of alternative water allocation mechanisms on farmer water use, choice of inputs, investments, productivity of water, food production and income?
- How effective are alternative water allocation mechanisms in reducing agricultural effluents and industrial pollution and protecting wetlands and other water-related ecosystems?

Impacts on Intersectoral Water Demand

- How do alternative water allocation mechanisms balance the allocation of water across sectors, including agriculture, environment, domestic and industrial sectors?
- What valuation tools can be developed and utilized to inform the trade-offs among multiple uses of water and to assist stakeholders in negotiating sharing agreements?

POLICIES AND INSTITUTIONS FOR WATER QUALITY AND ENVIRONMENTAL SUSTAINABILITY

Trade, macroconomic, sectoral, and water allocation policies and institutions that influence the quality of water and related environmental resources were discussed in some detail above. Policies and institutions that directly deal with water quality and those that affect the incentives for use of resources that interact with water resources, including forest policies and wetland protection policies, are also critically important. World Bank (1997) summarizes policy approaches for managing natural resources that are directly applicable to water resources. The typology includes using markets, creating markets, using environmental regulations and engaging the public. Table 1 summarizes alternative environmental policy instruments according to this typology.

Table 1: Environmental Policy Instruments

	Policy Instruments			
Approach	Using Markets	Creating Markets	Using Environmental Regulations	Engaging the Public
Resource Management and Pollution Control	- Subsidy reduction - Environmental taxes - User fees - Deposit-refund systems - Targeted subsidies	- Property rights/ decentralisation - Tradable permits/ rights - International offset systems	- Standards - Bans - Permits and quotas	- Public participation - Information disclosure

Source: World Bank, 1997

In the case of water pollution, markets have been used in order to place environmental taxes on emissions (wastewater discharge fees in Brazil, China, Eastern Europe, Korea, Mexico, the OECD and the Philippines); to implement user fees for services (sewage charges in Brazil, Chile, China, Colombia, Malaysia, Indonesia, Mexico, Singapore and Thailand); and to implement targeted subsidies (tax relief and subsidized credit for environmental investments in Brazil, Chile, China, Colombia, Ecuador, India, Korea, Mexico and the Philippines). The use of markets is also beneficial in the establishment of performance bond and deposit-refund systems. The existence of the deposit or bond helps to ensure that that the financial costs of noncompliance are sufficiently high so that firms and individuals take the necessary steps to protect the environment, such as replanting forests after harvest, or correctly disposing waste products as in Japan and Taiwan.

Markets may also be created to deal with water pollution in the form of property rights and tradable permits or rights, such as tradable wastewater discharge permits. Although currently no examples of market creation for water pollution permits have been implemented in developing countries, several countries have created markets for air pollution. Tradable emission permits were implemented in Chile, the Czech Republic, Poland and Kazakhstan, while carbon offsets have been implemented in Argentina, Latin America, Norway, Poland, Russia and the US. International offset systems are another example of creating environmental markets. Offset systems extend the notion of a market for environmental resources across boundaries, permitting firms and institutions to meet environmental objectives by purchasing abatement wherever on the globe it is cheapest.

Environmental regulations have been put into place for water pollution in the form of standards in many countries, for example, in the form of wastewater standards in China, India, Indonesia, Korea, Malaysia, the OECD, the Philippines and Singapore. Quotas are another type of environmental regulation that has been implemented to control water pollution. Industrial wastewater discharge quotas have been used in the Bahamas, China, Colombia and the OECD.

Finally, the public can be engaged to act on water pollution and related environmental degradation through information disclosure and public participation. Public disclosure programs, in the form of eco-labeling, have been tested in Bangladesh, Indonesia and the Philippines to allow consumers to make more informed choices and enable them to demand more environmentally friendly goods and services. Public participation in the development and implementation of environmental policy can be crucial in developing the political will to take effective action on the environment, and is being used increasingly in the developing world.

Key research questions in the area of environmental policies and institutions for water and related resources are directly analogous to the research questions on institutions and impact that are described above for water allocation at the river basin and policies. The key research questions can by summarized by the following points:

- What is the influence of underlying conditions, including the physical/technical, social/economic and policy/institutional environment, on the effectiveness of alternative environmental policy instruments?
- Who should bear the costs of pollution, and how can the costs of pollution treatment and abatement be equitably allocated and effectively administered under alternative environmental policy systems?

- What are the impacts of direct environmental policies, such as environmental taxes and subsidies, effluent markets, and regulatory and quota-based restrictions, on water quality and water-related ecosystems?

TRANSBOUNDARY WATER POLICY AND INSTITUTIONS

River basins and groundwater aquifers that cross national or sub-national (state and provincial) boundaries present major challenges to effective water management. Water resources have contributed to tension and conflict between competing users around the globe, at both international and intra-national level, including between nations, tribes, water-use sectors, or states and provinces. The primary challenge is to get ahead of the "crisis curve," and to help develop institutional capacity and a culture of cooperation in advance of costly, time-consuming crises, which in turn threaten lives, regional stability and ecosystem health.

The main objective of research on this topic is to understand the institutional mechanisms by which international waters are shared. An "institution" might be as formal as a treaty-empowered joint management body, or as loose as a set of unofficial understandings on joint principles. These arrangements have both prevented and resolved conflicts (to various degrees of success) and, occasionally, have been the source of conflicts themselves.

Within this context, it must be remembered that, just as nations are a compilation of all of their components, so too do international institutions reflect all of the myriad actors and forces involved, even peripherally, in the issue of shared waters. As such, institutional research requires an understanding of (1) national policies and their influences on international politics; (2) non-governmental actors and their interests in impacting decision-making; (3) the sustainability and resilience of the institutional structure; and (4) the impact transboundary management has on the physical environment.

This research will investigate the mechanisms by which transboundary waters are shared, including institutions, allocation mechanisms and processes for conflict prevention and resolution. Key research questions include:

- Do identifiable indicators exist which might help predict future water conflict?
- How can international and national institutions, civil society organizations, water user organizations, and NGOs help prevent future conflict and assist in transboundary negotiations?
- What is the relative effectiveness of integrated watershed management and bilateral, coordinated management structures in transboundary water management?

- What is the potential for transboundary negotiation utilizing market-oriented approaches that emphasize equitable allocation of the economic returns to water, rather than allocation of quantities to water?
- How can agricultural development, rural livelihoods, and food security concerns best be integrated into international river basin agreements?
- How can water quality, environmental concerns and social concerns, including health and nutrition, best be integrated into transboundary river basin agreements?

Conclusion

The research agenda summarized here will provide a comprehensive assessment of the policies and institutions that influence water resource management and development. The research spans the key levels of analysis, from international to economy-wide, river basin, and irrigation system, with a fundamental emphasis throughout on how policies and institutions influence the incentives and rights of individual water users. The research will contribute not only to building a comprehensive knowledge base on the impacts of alternative policies and institutions, but also to actively develop and implement policies and institutions for effective and sustainable water management and development that contributes to poverty alleviation and food security.

Literature Cited

Abu-Zeid, M.; and D. Seckler. eds. 1992. *Roundtable on Egyptian eater policy*. Proceedings of a seminar on Egyptian water policy, sponsored by the Water Research Center, the Ford Foundation, and Winrock International at the hotel Helnan International Palestine in Alexandria, Egypt, April 11–13.

Alcamo, J.; T. Henrichs; and T. Roesch. 1999. *World water in 2025: Global scenarios of Water Use and Availability: An application of waterGAP 1.0*. Germany: University of Kassel, Center for Environmental Systems Research.

Allan, J.A. 1996. Water security policies and global systems for water scarce regions. In *ICID (International Commission on Irrigation and Drainage), 16th Congress on Irrigation and Drainage, Cairo, Egypt, 1996: Sustainability of Irrigated Agriculture- Transactions, Vol. 1E*, Special Session: the future of irrigation under increased demand from competitve uses of water and greater needs for food supply - R.7; Symposium:management information systems in irrigation and drainage. New Delhi, India: ICID. 117–132.

Anton, D. 1993. *Thirsty cities - Urban environments and water supply in Latin America*. Ontario, Canada: International Development Research Centre.

Barrow, C. J. 1991. *Land degradation: Development and breakdown of terrestrial environments.* Cambridge: Cambridge University Press.

Berger, T. The independent review of the Sardar Sarovar projects 1991-1992. *Water Resources Development* 10(1): 55-66.

Bhatia, R.; and M. Falkenmark. 1993. *Water resource policies and the urban poor: Innovative approaches and policy imperatives.* Water and Sanitation Currents UNDP (United Nations Development Programme) -World Bank Water and Sanitation Program. Washington, D.C.: The World Bank.

Bos, E.; and G. Bergkamp. 2001. Water and the environment. In *Overcoming Water Scarcity and Quality Constraints, 2020 Focus* 9, ed. R.S. Meinzen-Dick and M.W. Rosegrant. Washington, D.C.: International Food Policy Research Institute.

Brown, L. 2000. *Falling water tables in China may soon raise food prices everywhere*. World Watch Institute. Earth Policy Alerts. http://www.earth-policy.org/Alerts/Alert1.htm.

Bruns, B. R.; and R.S. Meinzen-Dick. 2000. Negotiating water rights: Implications for research and action. In *Negotiating Water Rights*, ed. B. R. Bruns and R.S. Meinzen-Dick. Washington, D.C.: International Food Policy Research Institute.

Carpenter, S.; P. Pingali; E. Bennett; and M. Zurek. 2002. Millenium ecosystem assessment. Scenarios Working group. Background document for the meeting in February 2002 in Tlaxcala, Mexico.

Clarke, R. 1993. *Water the international crisis*. Cambridge, Massachussetts: The Michigan Institute of Technology Press.

Colby, B.; and T.P. d'Estree. 2000. Economic evaluation of mechanisms to resolve water conflicts. *International Journal of Water Resources Development* 16(2): 239-251.

Cosgrove, W.J.; and F.R. Rijsberman. 2000. *World water vision: Making water everybody's business*. London: World Water Council.

Dinar, A. T.; K.Balakrishnan; and J. Wambia. 1998. *Political economy and political risks of institutional reform in the water sector*. Policy Research Working Paper. Washington, D.C.: The World Bank.

Dinar, A.; and A. Subramanian. 1997. *Water pricing experiences: An international perspective*. World Bank Technical Paper No. 386. Washington, D.C.: The World Bank.

Diao, X.; and T. Roe. 2002. Can a water market avert the "double-whammy" of trade reform and lead to a "win-win" outcome?" *Journal of Environmental Economics and Management*, forthcoming.

El-Ashry, M. T. 1991. Policies for water resource management in semi-arid regions. *International Journal of Water Resources Development* 7(4): 230–236.

Fan, S.; L. Zhang; and X. Zhang. 2000. *Growth and poverty in rural China: The role of public investments*. Environment and Production Technology Division Discussion Paper No. 66. Washington, D.C.: International Food Policy Research Institute.

Fan, S.; P. Hazell; and T. Haque. 2000. Targeting public investments by agroecological zone to achieve growth and poverty alleviation goals in rural India. *Food Policy* 25(4): 411-428.

Fan, S.; P. Hazell; and S. Thorat. 1998. *Linkages between government spending, growth and poverty in rural India*. Research Report 110. Washington, D.C.: International Food Policy Research Institute.

FAO (Food and Agriculture Organization of the United Nations). 2000. *Crops and drops*. Rome, Italy.

FAO. 1992. *Water for sustainable food production and rural development - UNCED agenda: Targets and cost estimates.* Rome, Italy.

Foster, S.; J. Chilton; F. Cardy; M. Schiffler; and M. Moench. 2000. *Groundwater in rural development: Facing the challenges of supply and resource sustainability*. World Bank Technical Paper No. 463. Washington, D.C.: The World Bank.

Gleick, P. 2000. The changing water paradigm-A look at 21st century water resources development. *IWRA (International Water Resource Association)* 25 (1), March.

Hussain, I.; K. Yokoyama; and I. Hunzai. 2001. Irrigation against rural poverty: An overview of issues and pro-poor intervention strategies in irrigated agriculture in Asia. In *Proceedings of National Workshops on Pro-Poor intervention strategies in Irrigated Agriculture in Asia*, ed. I. Hussain, I. Biltonen and E. Biltonen. Colombo, Sri Lanka: International Water Management Institute.

IWMI (International Water Management Institute). 2000. *Water supply and demand in 2025*. Colombo, Sri Lanka.

Jansen, H. 2001. Induced institutional change in the trade and environment debate. *Environmental and Resource Economics* 18: 149–172.

Jones, W. I. 1995. *The World Bank and irrigation*. Washington, D. C.: The World Bank.

Kayasseh, M.; and C. Schenck. 1989. Reclamation of saline soils using Calcium Sulphate from the Titanium in industry. *Ambio* 18(2):124–127.

Kovda, V. A. 1983. Loss of productive land due to salinization. *Ambio* 12(2): 91–93.

Logsdon, J.M.; and B. W. Husted. 2000. Mexico's environmental performance under NAFTA: The first 5 years. *Journal of Environment and Development* 9(4): 370-383.

Postel, S. 1993. Water and agriculture. In *Water in Crisis A Guide to the World's Fresh Water Resources*, ed. P. H. Gleick. New York: Oxford University Press.

Repetto, R. 1986. *Skimming the water: Rent-seeking and the performance of public irrigation systems*. Research Report No. 4. Washington, D.C.: World Resources Institute.

Rhoades, J. D. 1987. *The problem of salt in agriculture*. Yearbook of Science and the Future. Chicago: Encyclopedia Britannica.

Rosegrant, M.; R. Gazmuri Schleyer; and S. Yadav. 1995. Water policy for efficient agricultural diversification: Market based approaches. *Food Policy* 20(3), June.

Rosegrant, M.W.; X. Cai; and S.A. Cline. 2002. *Global water and food: Prospects to 2025*. Washington, DC: International Food Policy Research Institute.

Rosegrant M.W., M.S. Paisner, S. Meijer, and J.Witcover. 2001. *Global Food Projections to 2020: Emerging Trends and Alternative Futures.* Washington D.C International Food Policy Research Institute.

Saleth, R.M.. 2001. Water pricing: Potential and problems. In *Overcoming Water Scarcity and Quality Constraints, 2020 Focus* 9, ed. R.S. Meinzen-Dick and M.W. Rosegrant. Washington, D.C.: International Food Policy Research Institute.

Seckler, David. T*he Sardor Sarovar Project in India*. A Commentary on the Report of the Independent Review. Center for Economic Policy Studies Discussion Paper No. 8. Winrock International Institute for Agricultural Development, July 1992.

Strutt, A.; and K. Anderson. 2001. Will trade liberalization harm the environment? The case of Indonesia to 2020. *Environmental and Resource Economics* 17: 203–232.

WHO (World Health Oranization). 2000. *WHO guidelines for drinking water quality training pack*. Rome, Italy: WHO.

UN (United Nations).1999. http://www.unu.edu/hq/rector_office/press-archives/press99/wwaterday.pdf.

UN. 1997. *Comprehensive assessment of water resources and water availability in the world.* I. A. Shiklomanov .ed Geneva : WMO. http://www.un.org/esa/sustdev/freshwat.htm

van Koppen, B. 2002. *A gender performance indicator for irrigation: Concepts tools and applications*. Research Report 59. Colombo, Sri Lanka: International Water Management Institute.

Wolf, A. ed. 2001. *Conflict prevention and resolution in water systems*. Cheltenham, U.K.: Edward Elgar.

World Bank. 1997. *Five years after Rio: Innovations in environmental policy.* Environmentally sustainable development and monographs series No.18. The International Bank for Reconstruction and Development. Washington, D.C.: The World Bank.

World Bank. 1993. *Water resources management*. A World Bank policy paper. Washington, D.C.: The World Bank.

WSSCC (Water Supply and Sanitation Collaborative Council). 1999. *Vision 21: A shared vision for water supply, sanitation and hygiene and a framework for future action*. Geneva: WSSCC.