IFA AGRICULTURE CONFERENCE

Optimizing Resource Use Efficiency for Sustainable Intensification of Agriculture

Kunming, China
27 February – 2 March 2006

ENSURING AGRICULTURAL WATER SUPPLIES IN A WORLD OF COMPETING DEMAND

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"Ensuring Agricultural Water Supplies in a World of Competing Demand"

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1. INTRODUCTION[1]

Water is essential for growing food; for household water uses, including drinking, cooking, and sanitation; as an input into industry; for tourism and cultural purposes; and for its role in sustaining the earth's ecosystems. However, growing national, regional, and seasonal water scarcities in much of the world pose severe challenges for national governments and international development and environmental communities. Challenges of growing water scarcity are heightened by the increasing costs of developing new water, the degradation of soil in irrigated areas, the depletion of groundwater, increasing water pollution and the degradation of water-related ecosystems, and wasteful use of already developed water supplies, often encouraged by the subsidies and distorted incentives that influence water use (Rosegrant, Cai and Cline 2002). Further challenges lie ahead as global climate change proceeds with the most adverse impacts predicted for developing-country farmers (IPCC 2001).

The paper describes the roles of irrigated agriculture, examines the consequences of changes in future water demand under a business-as-usual scenario at the global and regional levels on agricultural water supplies and food production, and presents potential avenues to maintain agricultural water supplies under growing water competition.

2. THE ROLES OF IRRIGATED AGRICULTURE

Irrigated agriculture is worldwide the major user of freshwater. During the mid-1990s, about 80 percent of global and 86 percent of developing-country water consumption was accounted for by agriculture. The development of irrigated agriculture has played a major role in boosting agricultural yields and outputs that have made it possible to feed the world's growing population; and has helped maintain food production levels and contributed to price stability through greater control over production and scope for crop diversification.

[1] This paper draws on Ringler, C., M. Rosegrant, X. Cai, and S. Cline. Auswirkungen der zunehmenden Wasserverknappung auf die globale und regionale Nahrungsmittelproduktion. Zeitschrift für angewandte Umweltforschung (ZAU) (Journal for Environmental Research). Jg. 15/16 (2003/2004), H. 3-5, pp. 604-619. The IMPACT-WATER model, used for combined water and food projections in this paper, has been jointly developed by IFPRI and IWMI. For comments and questions, please send an email to c.ringler@cgiar.org

In developing countries, irrigation development has been particularly vital in achieving food security, especially as an important component of the Green Revolution technology package, both locally, through increased income and improved health and nutrition, and nationally, by bridging the gap between production and demand. The important role of irrigation for increased agricultural production and enhanced crop productivity has been well documented, particularly for Asia (see, for example, Mellor 1985; Barker et al. 2004; Rosegrant, Kasryno, and Perez 1997, and many others).

Study results have been mixed regarding the impact of irrigation on poverty alleviation, however, with results varying depending on the scale of analysis, region studied, and methodology chosen (Bhattarai and Narayanamoorthy 2003). According to Lipton, Litchfield, and Faurès (2002), it is important to look at the larger impacts of irrigation investments, ranging from enhanced yields and incomes of small-scale farmers, to increased employment of landless laborers, and reaching the urban poor via lower food prices and possibly reduced rural-to-urban migration. Moreover, irrigation systems often serve many other rural water uses, including rural domestic water supplies, household gardens, livestock, fishing, recreation, and other enterprises. These irrigation water uses are particularly important for women and marginalized social groups (e.g. pastoralists or fishers) (Bakker et al. 1999).

Although the achievements of irrigation in ensuring food security and improving rural welfare have been impressive, past experiences also indicate that inappropriate management of irrigation has contributed to adverse environmental outcomes, including excessive water depletion, pollution of freshwater resources, and waterlogging and salinization of formerly productive crop areas. While irrigation has contributed to water scarcity, water pollution, and ecosystem degradation, it has also helped conserve large areas of forest and other land: In the group of developing countries, 38 percent of the cereal harvested area that is irrigated accounted for 59 percent of cereal production. In developed countries, where irrigation plays a smaller role, 18 percent irrigated cereal area contributed 23 percent of total cereal production (Rosegrant, Cai and Cline 2002).

In addition to the fundamental role of water in food security, water is also essential for drinking and household uses, as an input into industrial production, and for environmental and ecosystem services. Access to safe drinking water and sanitation is critical in terms of health—particularly for children. Unsafe drinking water contributes to many health problems in poor countries. About 4 billion incidents of diarrhea occur annually, resulting in 2.2 million deaths, mainly children under the age of 5 (WHO/UNICEF 2000). For more than one billion people across the globe, safe water is unavailable in sufficient quantities to meet minimum levels of health and income. Contaminated water supplies also impact the health and productivity of people through consumption of unsafe food and water.

Although the domestic and industrial sectors use far less water than irrigated agriculture, the growth in water consumption in these sectors has been rapid. Globally, withdrawals for domestic and industrial uses grew four-fold between 1950 and 1995, compared to just over a doubling for agricultural uses (Cosgrove and Rijsberman 2000).

3. INCREASING PRESSURE ON AGRICULTURAL WATER SUPPLIES UNDER BUSINESS AS USUAL

The business as usual (BAU) scenario of the combined water-food projections model IMPACT WATER, which simulates both water supply and demand and food supply and demand over a period of 30 years provides some insights into the impact of increasing competition for water resources on agriculture (for more details, see Rosegrant, Cai, and Cline 2002). The BAU scenario—as implied by its name—projects the likely outcomes for water and food if recent past trends in many drivers are broadly maintained, and current policies for water investments, water prices, and management are continued.

A continuation of trends implies little increase in irrigated area expansion due to stagnating or slowly declining real prices for agricultural commodities, limited remaining suitable areas for irrigation development, declining investment levels, and increased land degradation levels. Due to slow expansion in area, food production growth will be based primarily on increases in yield; but crop yield growth will also continue to slow. The slowdown in growth in public investment in public agricultural research and rural infrastructure over recent decades, the high yield levels already achieved during the Green Revolution for wheat and rice, as well as the existing high levels of fertilizer use in many regions are all factors that will make future yield increases more difficult. Growing competition for water supplies might make water scarcity the major limiting factor for both area and yield growth.

By 2025, the global population might well increase to 7.9 billion, of whom more than 80 percent will live in developing countries, and 58 percent in rapidly growing urban areas (UN 1999). In response to population growth and rising incomes, cereal demand worldwide is expected to increase by 46 percent between 1995 and 2025, and in developing countries by 65 percent. Demand for meat products is expected to increase even faster, at 56 percent, including a more than doubling of consumption in the developing world (Rosegrant, Cai and Cline 2002).

Half of the future growth in cereal production is expected to be met from irrigated agriculture. Moreover, more affluent diets will translate into greater demand for other water-intensive crops, such as sugarcane and horticultural crops. However, the continued rapid growth of domestic and industrial water use and the growing recognition of environmental demands for water, together with the high cost of developing new water resources, and rapidly growing water pollution levels, could threaten the water supplies required to meet growing food demands, increasing the specter of combined food and water crises, particularly for vulnerable developing countries and regions.

Total global water withdrawals in 2025 are projected to increase by 22 percent above 1995 withdrawals, to 4,772 km^3. Projected withdrawals in developing countries are expected to increase 27 percent over the 30-year period to 3,507 km^3. Together, annual consumption of water for domestic, industrial, and livestock uses will increase dramatically, rising by 62 percent or 225 km^3 from 1995 to 2025, principally in developing countries. Irrigation water consumption, however, will only increase by 4 percent globally to reach 1,492 km^3 in 2025. While irrigation accounted for approximately 80 percent of global water consumption in the mid-1990s, this share is expected to decline to 72 percent by 2025, given the rapid increases in non-irrigation demands. Changes will occur faster in the group of developing countries (Figure 1).

Additional results of the BAU scenario are shown in Table 1. While in the group of developing countries, water consumption per capita is projected to decline by 21 percent to reach 242 m^3 per year, consumption is expected to slightly increase in the group of developed countries. This decline can either be achieved by a net reduction or increased efficiency of water use. In developing countries, water consumption will increase particularly for domestic and industrial uses, whereas irrigation consumption will decline on a per capita basis. The water-scarce region of West Asia and North Africa had, on average, the highest per capita water consumption in 1995, while Sub-Saharan Africa, featured the lowest consumption level. Of particular importance for global food security is the projected absolute decline in irrigation water consumption in China and the United States—which, together with India, are the largest cereal producers. The reasons for projected declines in irrigation water consumption are important. While projected declines in the United States are due to increased efficiency of irrigation water use, lack of water resources constrain China's future irrigation water development.

One of the most well-known indicators for water scarcity is the share of water withdrawals in total renewable water resources (UN 1997). Figure 2 presents this indicator for 1995 and projected for 2025. Of particular note are the increasing water shortages in the West Asia/North Africa region. However, such aggregate indicators sometimes mask more than they reveal. Northern China, for example, is among the most arid areas in the world. This is evidenced by the multi-billion dollar projects by the Chinese Government to divert water from the relatively abundant southern region to the drier north to quench the thirst of such metropolises as Peking and Tianjin, among others, and to enhance the water-related ecosystem services of entire regions.

Another important conclusion from this graph is that Sub-Saharan Africa only uses a small share of available water resources. Therefore, the low per capita water consumption levels in that region (presented in Table 1) are not due to a lack of water resources but instead due to a lack of investment in water infrastructure and irrigation as well as a lack of purchasing power and demand.

Implications for Crop Yields and Food Production

Water scarcity is an important contributor to slowing crop yield growth. Rosegrant, Cai and Cline (2002) show this using a relative crop yield index, which compares model calculated crop yields with potential non-water stressed yields. The relative crop yield index for irrigated cereals in developing countries is expected to decline from 0.86 in 1995 to 0.75 in 2021-25 under BAU, that is, actual yields will only be 75 percent of potential yields without water stress, on average. This represents an annual loss in crop yields forgone due to increased water stress of 0.68 tons per hectare in 2025, or an annual loss of cereal production of 130 million tons, equivalent to the annual rice crop in China in the late 1990s. At the same time, yield increases and better irrigation practices are projected to increase cereal yields in developing countries from an average of 3.3 tons per hectare in 1995 to 4.6 tons per hectare in 2025, while rainfed cereal yields are projected to increase from 1.5 tons per hectare, on average, to 2.1 tons per hectare. Rainfed production is expected to maintain its share in total cereal production over the projections period (see also Table 2).

In the group of developed countries, where rainfed agriculture is generally more important than irrigated agriculture, rainfed cereal yields in 1995 reached 3.2 tons per hectare, similar to irrigated yield levels achieved in the group of developing countries. In these countries, the share of rainfed agriculture in total cereal production is expected to slowly decline from 77 to 74 percent over the projections period.

Consequences for Global Cereal Trade and Imports

While food production is set to increase in developing countries, the increase will not be sufficient to meet rapidly increasing and more diversified food demands. Under the BAU scenario, net cereal imports in developing countries will increase from 107 million tons in 1995 to 245 million tons in 2025 (see also Figure 3). So-called "hot spots" for food trade gaps occur in Sub-Saharan Africa, where cereal imports are projected to more than triple by 2025 to 35 million tons, and in the West Asia/North Africa region, where cereal imports are projected to increase from 38 million tons in 1995 to 83 million tons in 2025. The reliance on water-saving cereal imports makes economic and environmental sense in water-scarce regions, but must be supported by enhanced nonagricultural growth. It is highly unlikely that Sub-Saharan Africa could finance the projected level of imports internally; instead international financial or food aid would be required. Failure to finance these imports would further increase food insecurity and pressure on water resources in this region.

Due to the relatively slow growth in food production, international agricultural commodity prices are expected to decline more slowly, especially when compared with the decline of the past 20 years. Prices for maize are expected to slightly increase due to rapid increases in cereal feed demand.

4. ENSURING AGRICULTURAL WATER AND FOOD UNDER GROWING COMPETITION

Role of Virtual Water Trade

By substituting cereal and other food imports for irrigated agricultural production (so-called imports of virtual water), countries can effectively reduce their agricultural water use (Allan 1996). Virtual water is defined as the volume of water used to produce agricultural or other commodities. For crop production, it can be measured as crop water depletion, calculated as effective precipitation and irrigation water use. Global water savings take place when agricultural exporters are more water efficient than importers whereas global irrigation water savings occur when exporters produce agricultural products under rainfed conditions while importers would have used irrigation water to produce the same agricultural commodities.

Rosegrant, Cai and Cline (2002) use the IMPACT-WATER model to project virtual water flows for cereals to 2025. In 1995, 7 percent of total crop evaporation and 5 percent of irrigation water depletion was used to produce cereal crops for export.

By 2025, total crop evaporation increases to 8 percent, while irrigation water depletion remains at 5 percent. The United States, Canada, Argentina, Australia and the European Union—chiefly rainfed cereal producers—remain the major cereal exporters. Moreover, while in 1995, approximately 20 percent of cereal trade was from water-abundant to water-deficit areas, this share is expected to increase to 38 percent by 2025. Instead of water scarcity, other factors, such as subsidies and trade arrangements are more likely to determine trade outcomes. For the group of developing countries, the increase in developing-country cereal imports by 138 million tons between 1995 and 2025 is equivalent to saving 147 km^3 of water at 2025 water productivity levels, or 8 percent of total water consumption and 12 percent of irrigation water consumption in developing countries in 2025.

Increasing Water Use Efficiency

The scope for increasing water use efficiency in agriculture is large—simply because agriculture uses the largest volumes of water. At the same time, enhancing water use efficiency in an appropriate manner is a highly complex task. Conserving water ideally should be achieved without adversely impacting third parties who rely on return flows or downstream water reuses; without taking water simply away from farmers, thereby reducing crop yields and farm incomes; without causing long-term adverse impacts on water quality and farm soils; and taking into account the full scarcity value of water for all ecosystem services this resource provides.

Water productivity can be defined as crop yield per cubic meter of water consumption including effective rainfall and, in irrigated environments, water diverted from surface or groundwater. Water productivity varies from region to region and from crop field to crop field, depending on many factors such as cropping patterns and agroclimatic conditions, irrigation technology and field water management, land and infrastructure, and input applications, including labor, fertilizer, and machinery. According to Cai and Rosegrant (2003), water productivity of rice ranges from 0.15 kg per m^3 to 0.60 kg per m^3, while productivity of other cereals, which consume less water than rice, ranges from 0.2 kg per m^3 to 2.4 kg per m^3. For both rice and other cereals, water productivity is lowest for Sub-Saharan Africa. Based on area and yield growth projections and projections of additional water development, productivity of water is expected to increase significantly between 1995 and 2025. For the group of developed countries, water productivity is expected to increase from 1.0 kg per m^3 to 1.4 kg per m^3 for cereals other than rice and for the group of developing countries, from 0.6 kg per m^3 to 1.0 kg per m^3 (Table 3).

Both the increase of crop yield and improvement in water application and basin-wide efficiencies contribute to the increase in water productivity, but the major contribution comes from crop yield increase. Moreover, water productivity of irrigated crops is higher in developing countries, while productivity of rainfed crops is higher for the group of developed countries.

5. CONCLUSİON AND OUTLOOK

Under the BAU scenario, the world in 2025 is subject to much stronger food and water shortages, compared with today. The resources available for irrigated agriculture increase very little—and even decline on a per capita basis—whereas withdrawals by industry and households increase rapidly. The danger is that poor countries and regions, and particularly the vulnerable populations in these countries will fall behind regarding the access to both food and drinking water. At the national level, these countries will need to increase food imports, in order to balance the gap between supply and demand. At the local level, the combination of water and food poverty can lead to chronic poverty and malnutrition and, at the same time, endanger social stability.

Thus, the question remains how the access to water and food for the poorest population can be secured today and particularly in the future. This will require significant increases in investments on both the food and water supply side, but more importantly, water policy, management and institutional reforms are needed. These include incentives to conserve on water and improve the efficiency of water use in existing systems through water management and policy reform; and to improve crop productivity per unit of water and land through integrated water management and agricultural research and policy efforts, including crop breeding and water management for rainfed agriculture.

Virtual water trade, while conserving some irrigation water and precipitation use, is unlikely to play a major role in making significant agricultural water supplies available given current trade and subsidy regimes. However, with growing scarcity, water savings through cereal imports will play increasingly important roles in the West Asia/North Africa region.

Both the increase in crop yield and reduction in water depletion through enhanced crop water management contribute to increased water productivity, but the major contribution comes from the increase in crop yield. Therefore, investments in agricultural infrastructure and agricultural research might have higher pay-offs than other water-saving investments, in order to make sufficient water available for agricultural production in the next 25 years.

There is significant scope for improvements in the irrigation sector at technical, institutional and managerial levels. Drip irrigation, sprinklers, and the conjunctive use of surface and groundwater, and other technologies such as computer monitoring of crop water demand are all technical improvements that can help improve water use efficiency. The establishment of effective water rights and water user associations, as well as the introduction of water pricing are all improvements to the institutions influencing water resources. Demand-based irrigation scheduling and improved maintenance of irrigation infrastructure are aspects of improved irrigation management that should be considered, and together with yield improvements will likely bring about the largest improvements for maintaining agricultural water supplies.

The Challenge Program on Water and Food, a research program under the Consultative Group on International Agricultural Research, is working on crop yield enhancement, direct irrigation sector policies, and more generally, trade and subsidy policies, and institutional arrangements affecting agriculture in order to improve agricultural water supplies and food security.

A large part of the world is facing severe water scarcity, especially developing countries. But the water crisis is not hopeless. The precise mix of water policy and management reforms and investments, and the feasible institutional arrangements and policy instruments to be used, must be tailored to specific countries and basins. They will vary based on level of development, agroclimatic conditions, relative water scarcity, level of agricultural intensification, and degree of competition for water. But these solutions are not easy, and they take time, political commitment (for the negotiation of fair trade agreements, for example), and financial resources. Therefore, reform processes in the water sector should start today.

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Table 1: Per capita consumption of water in various sectors and regions

	Population		Irrigation water consumption		Domestic consumption		Industrial consumption		Total consumption	
	1995	2025	1995	2025	1995	2025	1995	2025	1995	2025
	(Mio.)		*(m^3/cap/year)*							
Asia	3185	4363	289	214	25	36	15	21	333	276
Latin America	476	689	186	141	38	45	38	43	276	247
Sub-Saharan Africa	532	1111	95	57	18	22	2	2	117	84
West Asia/ North Africa	335	564	363	243	21	23	14	15	403	288
Developing countries	4408	6616	264	184	25	33	14	18	308	242
Developed countries	1251	1288	217	215	47	53	76	88	352	371

Note: Data are for consumption (i.e. water that cannot be reused). Values for 1995 have been assembled for IMPACT-WATER from various sources; values for 2025 are model calculations.
Source: calculated from Rosegrant, Cai, und Cline (2002).

Table 2: Rainfed and Irrigated Cereal Production, 1995 and 2025

Region/Country	Irrigated production		Rainfed production		Share rainfed production	
	1995	2025	1995	2025	1995	2025
	(million tons)				*(percent)*	
Asia	493	769	233	323	32	30
Latin America	31	55	86	167	74	75
Sub-Saharan Africa	7	16	59	122	89	89
West Asia /North Africa	35	53	48	67	58	56
Developed countries	186	275	608	775	77	74
Developing countries	557	886	425	678	43	43
World	742	1161	1033	1453	58	56

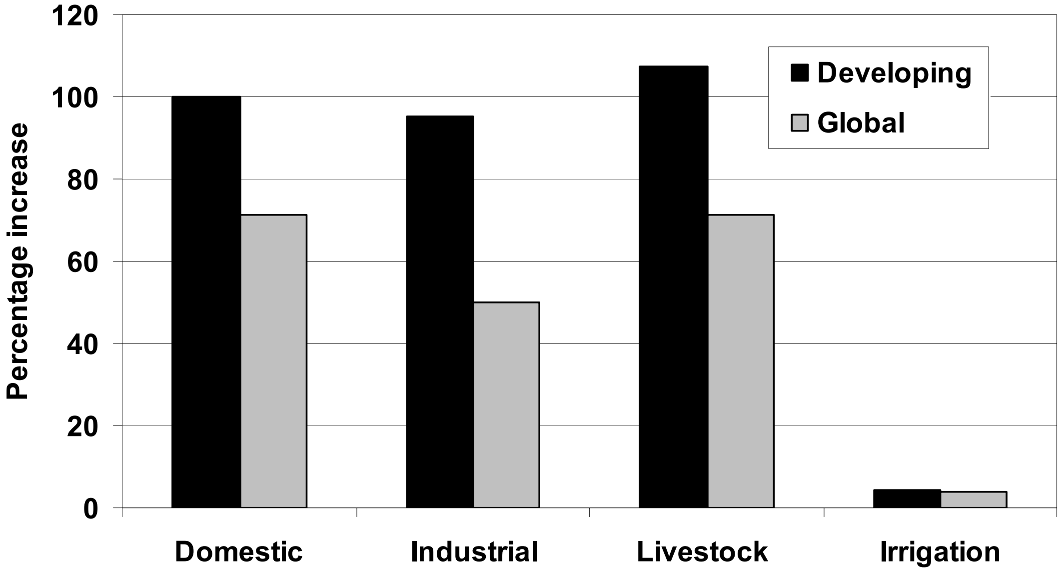
Note: Values for 1995 have been assembled for IMPACT-WATER from various sources; values for 2025 are model calculations.
Source: Rosegrant, Cai, und Cline (2002).

Table 3: Estimated and Projected Values of Water Productivity and Water Use for Rice and Other Cereals, 1995 and 2025

	Estimated	Projected
	1995	**2021-25**
Rice		
Water Productivity (kg/m^3)		
Developing Countries	0.39	0.53
Developed Countries	0.47	0.57
Water Use per hectare (m^3/ha)		
Developing Countries	8,580	8,445
Developed Countries	10,200	9,730
Other Cereals		
Water Productivity (kg/m^3)		
Developing Countries	0.56	0.94
Developed Countries	1.00	1.32
Water Use per hectare (m^3/ha)		
Developing Countries	5,720	5,260
Developed Countries	4,430	4,530

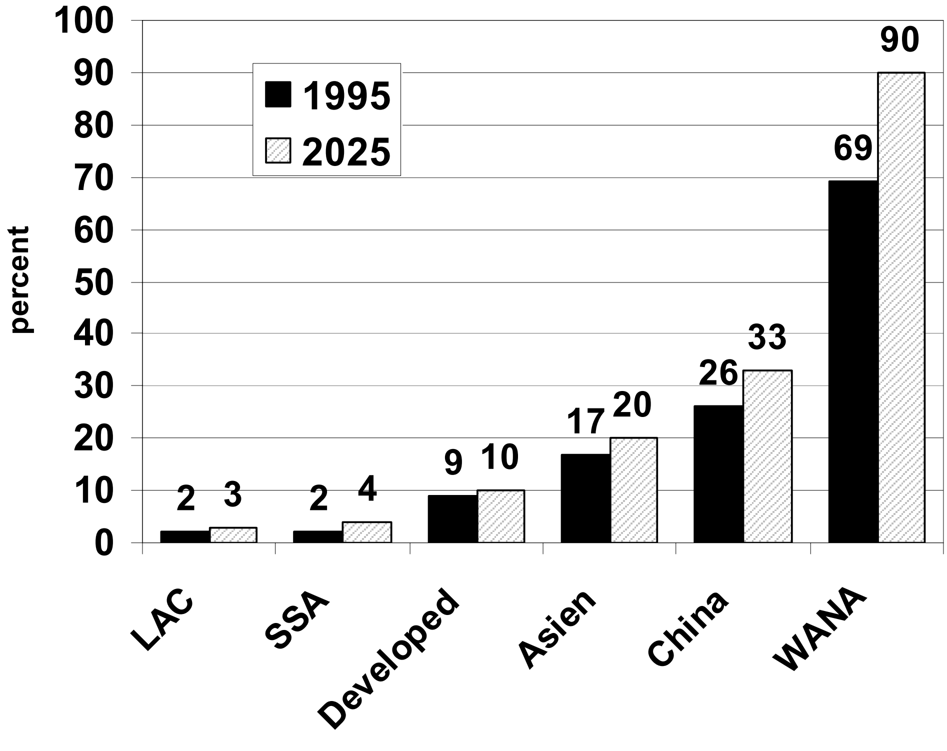
Source: Cai and Rosegrant (2003).

Figure 1: Projected Increase in Water Consumption by Sector, 1995-2025



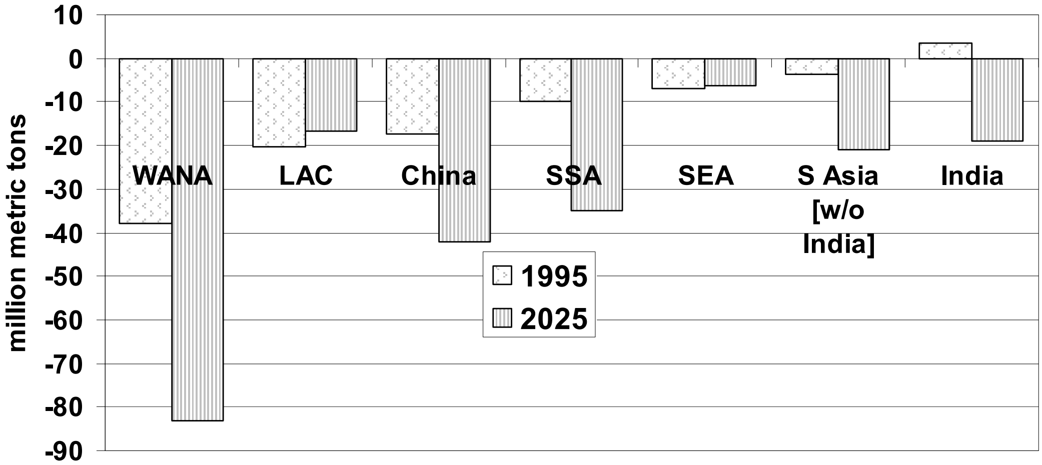
Source: Based on Rosegrant, Cai and Cline (2002).

Figure 2: Water Withdrawals as a Share of Renewable Water Resources, 1995 and 2025 (percent)



Note: LAC = Latin America; SSA = Sub-Saharan Africa; WANA = West Asia and North Africa.
Source: Based on Rosegrant, Cai, und Cline (2002).

Figure 3: Net Cereal Imports in Countries and Regions, 1995 and Projected 2025



Source: Based on Rosegrant, Cai, und Cline (2002).