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IRRIGATION AND WATER RESOURCES IN LATIN AMERICA AND THE CARIBBEAN: CHALLENGES AND STRATEGIES

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ABSTRACT

Latin America and the Caribbean are relatively well endowed with water resources. However, population growth and rapid urbanization are putting considerable pressure on water available for irrigation. Local and regional water scarcity problems are exacerbated by severe water quality problems; and wastewater is frequently used for irrigation. Moreover, prospects for new investments into irrigation development appear limited.

This paper examines the factors underlying irrigation development in Latin America and the Caribbean, reviews the water supply situation, and describes trends in water demand and irrigated agriculture. The overall water management in the region is assessed, and recent trends in investments in the water sector, with a focus on large-scale irrigation systems, are analyzed.

The paper concludes that in this context of accelerating demand and declining irrigation investments, new water development is not the primary solution to water resource challenges in the region. Much greater attention is needed on water policy and management reform to improve the efficiency and equity of irrigation and water supply systems. In order to pay for future investments, irrigated agriculture needs to produce high-value crops for both local consumption and exports into competitive world markets. Policies to officially transfer management responsibilities from agencies to farmers - and to privatize urban water supply and sanitation - are increasingly important. The complex tradeoffs across sectors and across water uses can best be managed through integrated water management at the river basin level—but developing appropriate institutions for intersectoral water allocation remains an important challenge under the fragmented management structure in most of Latin America and the Caribbean. Thus, the challenges for water policymakers in the region are great, but a strategy that focuses on river basin management, irrigation management transfer and privatization, and market-based water allocation can effectively address these challenges.

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1. INTRODUCTION

Latin America and the Caribbean (LAC) are relatively well endowed with natural resources. The region has 15 percent of the global land area, but 24 percent of the forest or woodland, 20 percent of the agricultural land, 11 percent of the inland water area and all but two countries have direct access to a major fishing area. Moreover, 30.8 percent of the available global water supply is concentrated in the region, but only 8.6 percent of the world's population. But water resources are distributed highly unequally in LAC, with more than one-half of the renewable water supply for the region concentrated in one river, the Amazon.

Moreover, the population in LAC has been growing rapidly, at 2.17 percent per year during 1967-96, from 244 million people in 1966 to almost double to 475 million by 1997. The population is expected to continue to grow, albeit at a lower rate (1.25 percent annually), to almost reach 700 million people by 2025. The distribution of the population places additional pressure on water resources: 60 percent of the population is concentrated in the 20 percent of the land area that has only 5 percent of the renewable water resources (WMO/IDB 1996). In LAC, as elsewhere, agriculture is the major user of freshwater. However, the large and growing proportion of the population living in urban areas in LAC will put considerable pressure for continued transfers of water out of agriculture to supply the growing urban centers in the region. In 1995, about 78 percent of the population in South America was living in urban areas, and it is expected that by 2025 88 percent of the population will be concentrated in urban centers. In most of Central America, the proportion of urban population is expected to reach 60-80 percent, depending on the country (WRI 1996).

Water scarcity problems will be exacerbated by severe water quality problems. 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 in LAC. Contaminated wastewaters are frequently used for irrigation. For example, about 90,000 ha of agricultural land in the Tula Valley, Mexico, is irrigated with wastewater from Mexico City, and 62,000 ha of vegetables are grown using water from three watercourses located downstream from Santiago's sewage outflow. Only 41 percent of the urban population is linked to sewerage systems, and over 90 percent of wastewater is discharged into the environment with no treatment. As a result, there is widespread contamination of the water bodies into which urban sewage is discharged resulting in easy transmission of diarrhea and other diseases through water or food.

The prospects of continued population growth and increasing urbanization will pose severe challenges for the region’s water resources and irrigation development. Moreover, a primary reliance on water supply augmentation is not a viable strategy: a number of factors will limit water investments in the region. Escalating construction costs for dams and related water supply and irrigation infrastructure, limited government budgets for large-scale investments, low and declining prices of staple cereals, declining quality of land available for new irrigation, and increasing concerns over the environmental and negative social impacts of large-scale irrigation projects have led to declines in irrigation investments. Moreover, declining investment in irrigation has been accompanied by a decline in the quality and performance of irrigation systems.

With limited contributions from supply augmentation, the water challenges in LAC must be met primarily through reform of water management. This reform process will be difficult, because water management in LAC has had serious shortcomings, with fragmented management across water-using sectors, and provision of heavy subsidies to water users. In Mexico, for example, annual subsidies for operations and maintenance (O&M) of water systems (that is, not including capital costs) were one-half of one percent of gross domestic product in the early 1990s, far more than was spent on the agricultural research system (Rosegrant and Gazmuri Schleyer 1996). Current water policies often do not encourage conservation of water and preservation of water quality in irrigation or municipal and industrial uses; on the contrary, in much of LAC water management contributes to the problems that it should instead be solving.

In the remainder of this paper, factors underlying irrigation development are examined, the water supply situation, including quantity and quality is reviewed, and trends in water demand and irrigated agriculture are described. The overall water management in LAC is assessed, and recent trends in investment in the water sector, with a focus on irrigation facilities, are analyzed. Based on these analyses, challenges and strategies for water management in LAC are identified.

2. FACTORS UNDERLYING IRRIGATION DEVELOPMENT IN LAC

Trends in the larger economy, the contribution of agriculture to the national economies, trends in agricultural exports, and the share of people employed in agriculture are all important factors underlying the development of irrigation and other water uses in the region. Table 1 shows total GDP and growth in GDP during 1967-96 for countries in LAC. Brazil is by far the largest economy in the region with a GDP of US$724 billion (at constant 1995 prices). Mexico and Argentina's economies were slightly less than half of Brazil's; the GDP of Chile, Colombia, Peru, and Venezuela ranged from US$60 billion to US$80 billion; and all other LAC economies had a GDP below US$20 billion in 1995. Besides the island state Barbados (and the Bahamas), per capita income was highest in Argentina (US$8,076 at constant 1995 prices), followed by Uruguay (US$5,663), Brazil (US$4,427), and Chile (US$4,176). Per capita income was lowest in Haiti (US$370), Nicaragua (US$458), Honduras (US$702), Guyana (US$744), Suriname (US$784), and Bolivia (US$906) in 1995.

The path of economic development undertaken by most of LAC until recently was characterized by an Import Substitution Industrialization (ISI) policy that started in the 1960s. The agriculture sector was neglected and/or exploited in favor of a heavily subsidized domestic industrial sector. The industrial development of Latin America was limited to central regions of the largest countries, and basically concentrated in large, highly industrialized megacities (of which the largest are Mexico City, São Paulo and

Buenos Aires). The debt crisis of the 1980s, triggered by the two oil shocks of the 1970s, led to a long-term recession in many of the countries of the region; and the import substitution policy was abandoned. Most LAC countries only recovered in the 1990s from the heavy debt burden and large government deficits of the debt crisis, and have since embarked on increased trade liberalization and export-oriented strategies and have revived their agricultural sectors. GDP growth in the 1990s was thus much more

Table 1 Total gross domestic product and growth in gross domestic product

	Total GDP		**Growth in GDP**				
	1966	**1996**	**1967-82**	**1982-96**	**1982-89**	**1989-96**	**1967-96**
	(million 1995 US$)		***(percent per year)***				
Argentina	146,050	294,199	2.60	2.11	-0.20	4.48	2.36
Barbados	862	1,743[/a]	3.05	1.20[/b]	2.89	-1.11[/b]	2.23[/b]
Belize	119	601	5.94	5.15	5.49	4.82	5.56
Bolivia	..	6,991	..	2.12	0.14	4.14	..
Brazil	164,663	723,622	7.05	2.82	3.26	2.38	4.99
Chile	17,948	63,720	2.26	6.60	5.14	8.09	4.34
Colombia	21,283	82,179	5.16	4.01	3.81	4.21	4.60
Costa Rica	2,523	8,969	4.65	3.89	3.79	3.98	4.28
Dominican Republic	2,843	12,800	7.03	3.39	3.07	3.72	5.26
Ecuador	4,333	18,295	7.06	2.63	2.15	3.11	4.90
El Salvador	5,042	9,674	1.19	3.15	1.08	5.27	2.13
Guatemala	5,014	15,090	4.74	2.58	1.15	4.02	3.69
Guyana	457	618[/a]	1.10	0.36[/b]	-2.92	5.12[/b]	0.77[/b]
Haiti	2,127	2,707	2.68	-0.99	0.06	-2.02	0.89
Honduras	1,325	4,089	4.37	3.12	3.08	3.15	3.76
Jamaica	2,710	4,108	1.03	1.69	2.11	1.28	1.35
Mexico	92,487	300,955	6.15	1.73	0.88	2.59	3.99
Nicaragua	1,645	2,371	1.35	-0.42[/c]	-2.70	2.31[/c]	0.52[/c]
Panama	2,628	8,106	4.97	2.32[/c]	-0.40	5.59[/c]	3.73[/c]
Paraguay	2,037	9,096	7.12	2.94	2.73	3.16	5.08
Peru	29,493	60,540	3.31	1.59	-0.66	3.88	2.47
Trinidad & Tobago	2,217	5,492	5.81	0.04	-1.47	1.57	2.98
Uruguay	10,624	18,996	1.96	2.23	0.94	3.52	2.09
Venezuela	38,582	76,905	2.52	2.11	1.44	2.78	2.32

Note: [/a] Values are for 1995; [/b] Growth rates are up to 1994 (instead of 1996); [/c] Growth rates are up to 1995; Growth rates are three-year centered moving averages.
Source: WDI 1999.

vigorous than during the so-called lost decade of the 1980s. Macroeconomic fundamentals are now solid in most of the region, but growth performance remains volatile (Pfeffermann 1998). However, even under the new model based on liberalization and integration that emerged in the 1980s, LAC continues to fail to fully recognize the renewed role of agriculture and rural areas, in the context of integration and globalization, and how important both are for the rest of the economy and society as a whole (Escudero Columna 1999).

Nevertheless, due to the deep recession of the 1980s, only eight out of 25 countries achieved economic growth in excess of 4 percent per year during the last 30 years: Belize, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, and Paraguay. Several Central American countries and Caribbean islands did not achieve growth in excess of 1.5 percent per year, including Guyana, Haiti, Jamaica, and Nicaragua. The other LAC countries achieved growth of about 2 percent per year during 1967-96. The growth pattern varies significantly by country. In virtually all economies that achieved considerable growth during 1967-96, growth plunged from high levels of 6 to 7 percent per year during 1967-82 to 3-5 percent annually thereafter. Growth resumed in many of the LAC countries during 1989-96, but not all countries in the region have reached the rates of growth achieved during 1967-82.

As can be seen in Table 2 and Figure 1, in 1966, the share of agriculture in GDP was already under 30 percent in most LAC countries. Moreover, in several countries, including Argentina, Chile, and Venezuela, and the smaller states of Suriname and Trinidad and Tobago, the share of agriculture in GDP was already at or below 10 percent by 1966.

During the following 30 years, the share of agriculture in GDP declined very slowly in most LAC countries, there was some convergence in the trends, and agriculture continued to contribute more than 10 percent to GDP in most LAC countries. Over the 30-year period, the contribution of agriculture to GDP dropped by about half in Brazil (to 8 percent), Colombia (to 11 percent), Ecuador (to 12 percent), Honduras (to 22 percent), and Mexico (to 6 percent); and by about 60 percent in Peru (to 7 percent) and Uruguay

Table 2 Agriculture, value added

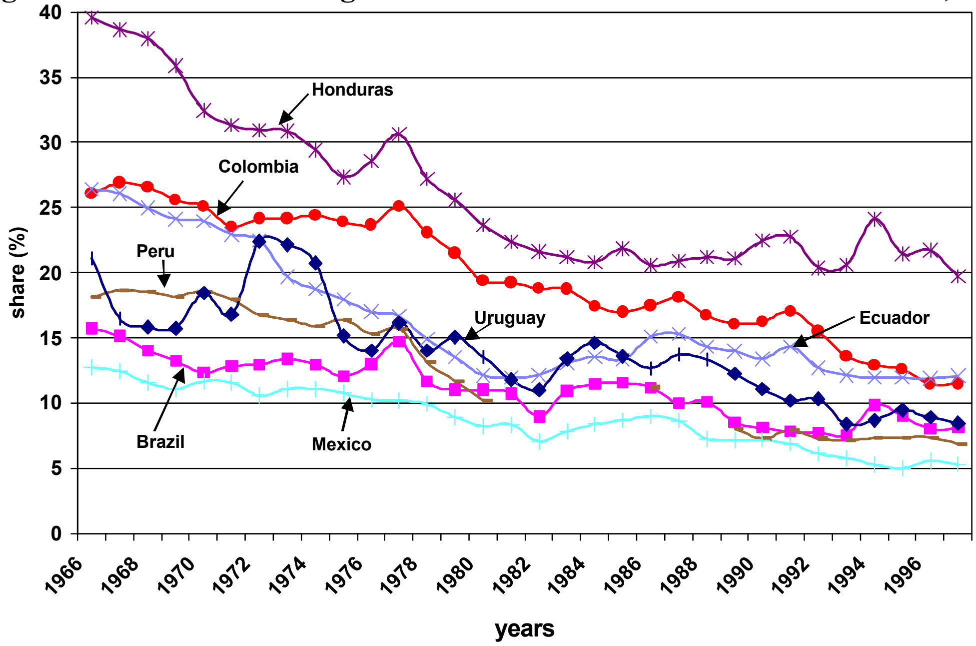
	1966	1975	1980	1985	1990	1996
	(% of GDP)					
Argentina	10.28	6.58	6.35	7.63	8.12	6.92
Barbados	19.62	13.33	9.91	6.24	5.21	..
Belize	..	..	27.44	20.38	21.70	21.40
Bolivia	..	..	..	..	15.40	16.20
Brazil	15.73	12.07	11.01	11.54	8.10	7.98
Chile	8.89	6.58	7.23	7.39	8.24	8.03
Colombia	26.03	23.89	19.36	16.99	16.24	11.46
Costa Rica	23.18	20.34	17.80	18.87	15.94	15.56
Dominican Republic	21.91	21.47	20.15	13.10	13.42	12.93
Ecuador	26.38	17.94	12.13	13.33	13.41	11.90
El Salvador	..	..	..	..	17.10	12.94
Guatemala	28.51	28.05	24.84	25.85	25.88	24.06
Guyana	21.69	31.11	23.35	26.83	38.08	..
Haiti	..	..	..	..	33.25	31.42
Honduras	39.58	27.33	23.67	21.85	22.44	21.71
Jamaica	9.61	7.36	8.22	7.52	6.47	8.32
Mexico	12.71	10.76	8.23	8.66	7.18	5.58
Nicaragua	23.53	22.42	23.32	23.66	31.06	34.17
Panama	..	..	9.57	8.83	10.49	8.20
Paraguay	35.68	36.91	28.62	28.93	27.78	23.73
Peru	18.13	16.39	10.22	..	7.27	7.36
Suriname	9.34	7.91	9.14	9.13	11.20	..
Trinidad & Tobago	5.00	3.33	2.17	2.25	2.56	1.84
Uruguay	21.10	15.15	13.53	13.60	11.10	8.88
Venezuela	5.60	5.03	4.84	5.79	5.40	4.24

Note: Agriculture comprises value added from forestry, hunting, and fishing, and crop and livestock production.
Source: WDI 1999.

(to 9 percent). In the rest of LAC, the contribution of agriculture to GDP has stabilized or even increased.

In 1996, Brazil was the largest exporter of agricultural products in the region, followed by Argentina, and Mexico. Other major exporters include Chile, Colombia, Costa Rica, and Ecuador. Most of these countries have rapidly increased their export volume during the last three decades, from relatively small levels in 1966 (see Figure 2). Thus, contrary to the trends in the contribution of agriculture to GDP, there has been a rapid increase in agricultural exports in the region (see Table 3). Sixteen out of 26

Figure 1 Contribution of agriculture to GDP in selected LAC countries, 1966-97

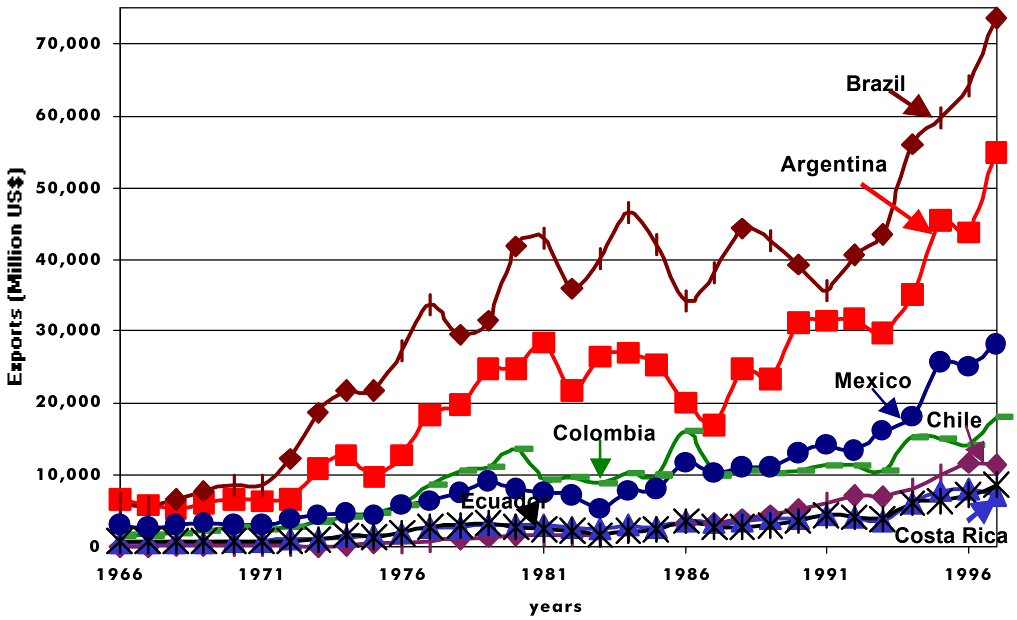


Source: WDI 1999.

countries achieved annual growth in agricultural exports at or above 10 percent during 1967-82, with Chile as the frontrunner. However, in most countries, growth in exports decelerated substantially during 1982-96. Exceptions include Mexico, where the entrance into NAFTA as well as strong investments in irrigation induced rapid growth in agricultural exports; and Bolivia, Ecuador, Jamaica, Peru, Venezuela, and Trinidad & Tobago. In these countries, reforms in the agricultural sector and trade liberalization only started during the 1980s. Moreover, growth in agricultural exports resumed in several LAC countries during the early 1990s, with growth doubling or more for most of the larger exporters, including Argentina, Brazil, Colombia, Costa Rica, Ecuador, Peru, and Uruguay.

Between 1995 and 2025, world cereals trade is projected to increase by 72 percent, from 172 million metric tons to 297 million metric tons, and world meat trade by a rapid 128 percent from 8 million metric tons to 18 million metric tons. In 1995, LAC imported 20.4 million metric tons of cereals and exported 0.5 million metric tons of meat products. By 2025, it is expected to still import 19 million metric tons of cereals and to

Figure 2 Agricultural exports of selected LAC countries, 1966-97



Note: Export values are deflated with 1990 G-5 MUV.
Source: FAOSTAT. 1999.

triple exports of meat products to 1.5 million metric tons (IFPRI 1999). There is little doubt that LAC has the natural resource base to boost cereal and livestock production substantially in addition to projected values. However, even the baseline simulation outcomes of the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) presume a continuation in the trends of investments in agricultural research, irrigation, and other production-enhancing strategies. As will be shown in later sections, the trends in irrigated agriculture reflect a substantial decline in the volumes and levels of investment. The share of LAC in future trade in agricultural commodities will also depend, in great part on its enabling environment for agriculture, including the outcomes of the new trade negotiations under the WTO, and the trade liberalization under all bilateral trade agreements in the region, like NAFTA, CARICOM, MERCOSUR, Andean Community of Nation (CAN), and the Central American Common Market (CACM).

Table 3 Exports of agricultural products and growth in exports

	Total agr. exports *(million US$)*[a/]		Growth in agr. exports *(percent per year)*				
	1966	**1996**	**1967-82**	**1982-96**	**1982-89**	**1989-96**	**1967-96**
Argentina	6,580	43,667	10.24	4.60	0.47	8.90	7.48
Barbados	118	462	3.84	5.25	2.14	8.46	4.52
Belize	41	558	11.53	6.10	6.96	5.25	8.87
Bolivia	43	1,555	12.26	14.64	14.27	15.01	13.40
Brazil	6,205	64,016	13.22	3.66	0.80	6.61	8.50
Chile	126	11,756	18.50	14.45	15.59	13.32	16.53
Colombia	1,736	14,224	11.40	3.80	1.80	5.83	7.66
Costa Rica	487	8,005	11.39	7.70	4.67	10.82	9.59
Dominican Republic	540	1,758	10.50	-2.95	-5.85	0.03	3.79
Ecuador	768	7,279	6.74	9.37	5.72	13.15	8.01
El Salvador	611	2,246	9.46	0.72	-6.52	8.51	5.15
Guatemala	840	5,762	10.64	4.09	0.61	7.69	7.43
Guyana	213	1,119	6.29	4.48	-2.25	11.68	5.42
Haiti	133	120	5.38	-4.59	-3.63	-5.55	0.44
Honduras	524	2,168	9.90	-0.09	3.30	-3.36	4.96
Jamaica	411	1,353	3.44	5.32	5.18	5.45	4.34
Mexico	3,115	25,155	5.51	10.25	8.45	12.08	7.77
Nicaragua	504	1,457	7.52	-0.70	-7.31	6.39	3.47
Panama	181	1,347	11.04	1.86	1.84	1.89	6.51
Paraguay	146	3,550	14.03	7.77	15.72	0.37	10.97
Peru	796	2,825	2.19	6.65	2.86	10.59	4.32
Suriname	26	202	12.95	-0.35	-1.01	0.30	6.32
Trinidad & Tobago	155	842	3.72	8.67	6.35	11.04	6.08
Uruguay	585	4,938	11.28	4.29	2.01	6.62	7.85
Venezuela	146	2,022	6.20	13.27	12.09	14.47	9.56

Note: [a/] deflated with 1990 G5-MUV deflator; Agricultural exports as defined in FAOSTAT. G5-MUV deflator has been applied to nominal export values. Growth rates are three-year centered moving averages.
Source: FAOSTAT 1999 (Agriculture and Food Trade Domain).

The share of the economically active population in agriculture declined by about half in LAC during the last 30 years (Table 4). The proportion of people working in agriculture dropped most rapidly in the island states and in Brazil and Venezuela (by 62 percent and 67 percent, respectively). The share of labor in agriculture declined by about half in Colombia, Costa Rica, Ecuador, Honduras, Mexico, Nicaragua, and Trinidad & Tobago. However, although the contribution of agriculture to GDP has declined substantially over the last 30 years, agriculture still plays an important role in the employment of the LAC population, with an average share of the economically active population in agriculture of 22 percent. The proportion of the population employed in agriculture is particularly high in the poorer LAC economies of Bolivia (45 percent), Guatemala (49 percent), Haiti (65 percent), Honduras (35 percent), and El Salvador (31 percent). Thus, with large populations employed in agriculture in the low-income economies of LAC, investments in irrigation and agriculture more generally and improvements in water management, in particular, can have substantial impacts on rural poverty alleviation.

Table 4 Share of economically active population in agriculture

	1966	**1975**	**1980**	**1985**	**1990**	**1996**
			(%)			
Argentina	17.82	14.49	12.95	12.54	12.15	10.66
Barbados	20.65	13.59	9.82	8.33	6.98	5.15
Bolivia	55.16	53.94	52.81	49.87	46.85	45.25
Brazil	50.44	41.90	36.67	29.99	23.28	19.13
Belize	39.39	41.03	39.53	35.29	34.48	31.94
Chile	26.59	22.48	20.92	19.83	18.79	16.93
Colombia	47.90	42.79	40.48	33.54	26.62	22.80
Costa Rica	45.96	38.79	34.93	30.33	26.02	22.39
Dominican Rep.	54.11	39.93	32.46	28.64	24.83	19.64
Ecuador	54.63	45.59	39.80	36.55	33.25	28.67
El Salvador	58.80	50.07	43.27	39.83	36.28	31.80
Guatemala	63.05	57.52	53.82	53.14	52.39	48.71
Guyana	34.57	29.15	26.80	24.13	21.84	19.26
Haiti	76.60	72.70	70.94	69.35	67.81	64.58
Honduras	69.36	62.23	57.14	49.30	41.41	35.44
Jamaica	36.19	32.13	31.17	27.93	24.74	22.35
Mexico	48.32	40.13	36.28	32.05	27.81	23.88
Nicaragua	55.80	45.39	39.58	34.07	28.64	23.25
Panama	45.33	35.25	28.89	27.57	26.16	22.53
Paraguay	51.54	47.33	44.77	41.85	38.86	36.12
Peru	49.88	44.28	40.30	37.94	35.58	32.28
Suriname	28.09	25.00	23.30	22.03	21.48	19.87
Trinidad & Tobago	19.80	14.84	10.87	10.96	11.34	9.80
Uruguay	19.69	17.68	16.62	15.45	14.28	13.31
Venezuela	28.92	20.16	14.57	13.26	12.02	9.52
TOTAL	45.55	38.80	34.80	30.36	25.81	22.27

Note: The economically active population in agriculture is that part of the economically active population engaged in or seeking work in agriculture, hunting, fishing or forestry.

Source: FAOSTAT 1999 (Population Domain).

All of these trends will influence the future of irrigation development and water resource management in the region. Whereas the decline in the contribution of agriculture to GDP will likely discourage investments in irrigation, the rapid growth of agricultural exports can fuel additional investments in the sector.

3. WATER SUPPLY SITUATION IN LAC

LAC is seemingly well endowed with water resources. South America, Central America and the Caribbean have a combined annual renewable water supply of about 13,120 billion cubic meters (BCM), which represents 30.8 percent of the global total of 42,655 BCM. This generous endowment is shared by 8.5 percent of the world's population that live in the region on 15 percent of the world's land area. Total annual runoff in LAC has been estimated at 771 mm and the total annual discharge of South American rivers into the oceans at 13,724 BCM.

The continental watershed in Latin America is located on the Sierra Madre in Mexico and Central America, and continues over the Andes range down the western coast of South America. It distributes the surface flows towards the Atlantic Ocean, which includes the Gulf of Mexico and the Caribbean Sea (84 percent of the area), and towards the Pacific Ocean (11 percent). The remaining 5 percent of the basins do not have a direct outlet to the sea. The geographical position of the continental watershed in LAC places the largest water systems on the versant of the Atlantic Ocean, including—from north to south—the basins of the Rio Bravo, Rio Grande and the Grijalva-Usumacinta, and in South America the Magdalena, Orinoco, Amazon, Tocantins, Sao Francisco and River Plate.

The Amazon covers 7.1 million square km and has a mean annual flow of 252,000 cubic meters per second. It is the world's largest concentration of surface flow and provides, on its own, one fifth of the world's total volume of freshwater. The Orinoco River has a catchment area of about 1.05 million square km and a mean annual flow of 30,000 cubic meters per second. The River Plate has a drainage basin covering 2.8 million square km mean annual flow of 18,000 cubic meters per second (WMO/IDB 1996).

Most of the rivers in LAC are of pluvial origin and flows vary over the year according to the rainfall pattern. It is estimated that three quarters of the total water flow in Latin America (generated over 56 percent of the territory) comes from international basins, in which the water systems are shared between two or more countries, with several rivers forming territorial limits. Two significant examples are the Amazon basin, which is shared by seven countries, and the basin of the River Plate that covers parts of five countries. To varying degrees, all the countries of the continent share their water resources with their neighbors, whereas the only Caribbean countries that share the same water system are Haiti and the Dominican Republic.

However, the water resources are not evenly distributed across the region, with areas of great abundance and some of the most arid zones of the world. Fifty-three percent of the renewable water supply for the region as a whole comes from one river, the Amazon. In contrast, some desert zones have no surface runoff, except during rare and extreme rainfall events. During 1986-96, annual rainfall in LAC ranged from a low of 550-738 mm in Argentina, Barbados, Chile, and Mexico, to more than 2,000 mm in most of Central America, Colombia, Guyana, and Suriname (Table 5). Rainfall in the region is estimated to be 50 percent above the world average and more than 90 percent of the population in Latin America lives in areas that receive between 500 and 2,000 mm of rainfall annually (ECLAC 1995).

Population is not evenly distributed either, with 60 percent of the population concentrated in the 20 percent of the land area that has only 5 percent of the water resources (WMO/IDB 1996). In most of the Caribbean, for example, high population density is combined with modest runoff leading to low per capita water availability. Water availability is particularly low in Barbados (Table 6). Other countries experiencing low water availability include the Dominican Republic, Haiti, and Peru. On the other hand, Belize, Guyana, Nicaragua, Panama, and Suriname have large water resources in both per ha and per capita terms. In Brazil, low population

Table 5 Average annual rainfall in LAC, 1986-96 (mm)

Country	Rainfall	Country	Rainfall
Antigua and Barbuda	2,515.1	Guatemala	2,719.4
Argentina	552.3	Guyana	2,353.9
Bahamas, The	1,298.0	Haiti	1,493.1
Barbados	552.3	Honduras	1,790.8
Belize	2,372.1	Jamaica	1,980.1
Bolivia	1,047.5	Mexico	738.1
Brazil	1,736.2	Nicaragua	2,179.4
Chile	711.7	Panama	2,596.4
Colombia	2,633.7	Paraguay	1,092.6
Costa Rica	2,842.2	Peru	1,407.9
Cuba	1,293.7	Puerto Rico	1,873.4
Dominica	1,293.7	St. Kitts and Nevis	1,900.1
Dominican Republic	1,388.8	St. Lucia	1,864.4
Ecuador	1,890.1	Suriname	2,267.2
El Salvador	1,711.7	Trinidad and Tobago	1,809.8
French Guyana	2,674.4	Uruguay	1,199.6
Grenada	2,583.3	Venezuela	1,979.9
Guadeloupe	2,707.1		

Source: Based on data supplied by the Climate Impacts LINK Project (UK Department of the Environment Contract EPG 1/1/16) on behalf of the Climatic Research Unit, University of East Anglia.

density and considerable water per ha results in high per capita water availability. On average, Central America and the Caribbean are endowed with about 6,890 cubic meters per capita per year and South America with 38,000 cubic meters per person per year. This compares well with the estimated basic human requirement of roughly 500-1,000 cubic meters per capita per year (depending on the climate of the region, need of irrigation to achieve food security, and level of socioeconomic development). However, due to rapid population growth in the region, water availability on a per capita basis will decline substantially over the next 30 years (WMO/IDB 1996).

Table 6 Water resources in Latin America and the Caribbean

'000 m^3 / ha

> 100			Colombia Costa Rica Ecuador	Bolivia Chile Venezuela	Belize Guyana Panama Suriname
51-100		Guatemala		Brazil	Nicaragua
21-50	El Salvador Jamaica	Argentina Honduras Paraguay Trinidad & Tobago Uruguay			
4-20	Haiti Peru Domin. Rep.	Mexico			
≤ 3	Barbados				
	≤ 3	**4-20**	**21-30**	**31-40**	**> 40**

'000 m^3/cap.

Note: Water resources are annual internal renewable resources. Agricultural area includes arable land and permanent crops.
Source: Adapted and Updated from FAO 1988b (Annex IV). Water availability from WRI 1992. Agricultural area and population: FAOSTAT 1999 (Land and Population Domains).

Water shortages in LAC will worsen over the next few years and decades and reach critical levels in some areas in the near future, due to the fact that most of the population and urban concentration are located in areas with the lowest levels of water resources. In Mexico, for example, just over four-fifths of water resources flow at altitudes below 500 m above sea level, and are concentrated in the south and southeast of the country. However, the main consumption centers, including Mexico City, are located above this altitude in the central and northern parts of the country, where three-fourths of the population live. In the Central American isthmus, 75 percent of the population and towns are located on the Pacific Ocean watershed and the high plateaus of the Sierra Madre. Only 30 percent of the available water resources flow on this versant, however. The situation in South America is similar. In the Andean countries, from Ecuador to Chile, the capitals and main urban centers are concentrated on the Pacific versant, where water resources are limited. On the Atlantic versant the situation is different, since—being the area that is richest in water resources—the regions with the greatest density are found on the coast of the southeastern cone, which stretches from Brazil to Argentina (WMO/IDB 1996).

The Caribbean countries include the members of CARICOM (Antigua and Barbuda, Barbados, Belize, The Bahamas, Dominica, Grenada, Guyana, Jamaica, St. Kitts/Nevis, Saint Lucia, St Vincent and the Grenadines, Suriname, Trinidad, and Tobago) and those of the CARIFORUM group (Haiti, Dominican Republic). Although these countries are typically treated as a homogenous group, they vary in size, population density, and economic development. Water is clearly a constraint to agricultural and economic development in most of the Caribbean. Water availability per capita has been decreasing gradually not only due to growing populations, but also due to rapid increases in demand for additional services related to the tourism sector.

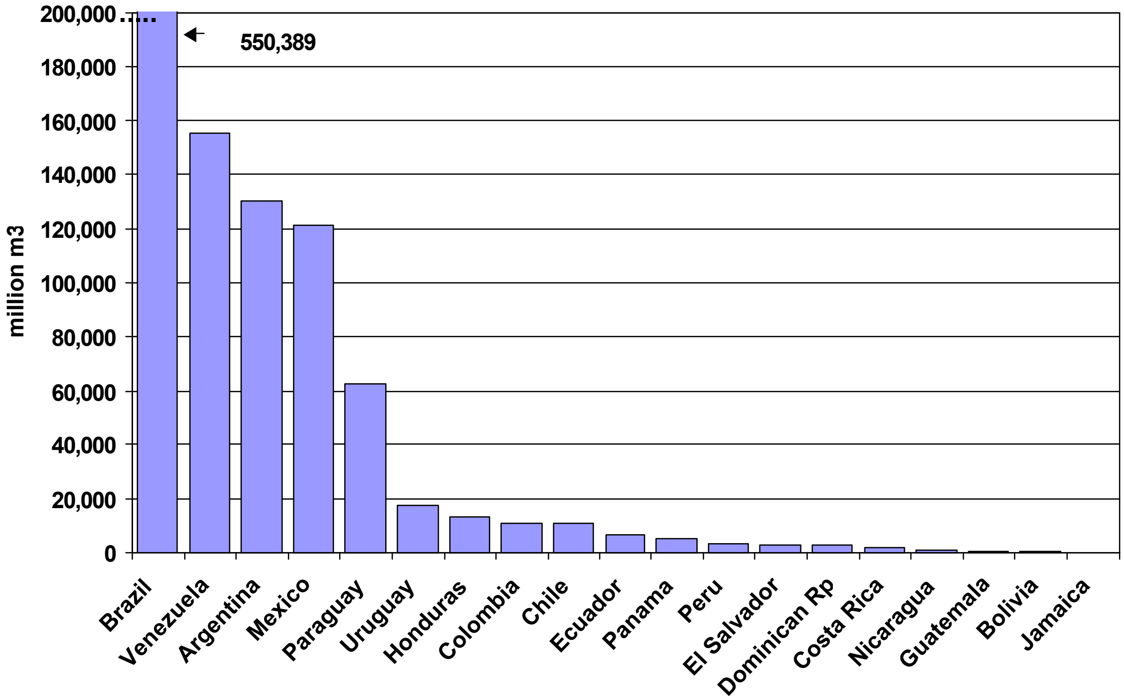
Most island states have very limited internal renewable water resources but still would like to expand irrigated agriculture. The declining world market prices for many basic agricultural commodities combined with other geographic and natural disadvantages, rapid population growth, and lack of internal markets in the island states have led to an increasing diversification into higher-valued export crops that can sustain agricultural incomes. However, these crops need timely and reliable water supplies in the form of irrigation water. Moreover, some island states are single-commodity dependent economies, relying, for example, on banana exports for a considerable share of local GDP. In 1995, for example, Dominica, St. Lucia and St. Vincent depended on bananas directly for 70-90 percent of agricultural exports, more than 10 percent of GDP, and more than 30 percent of employment (backward and forward linkages of the banana trade likely contribute significant additional resources). Additional pressure on water resources is also exerted by the tourism sector, the second-largest exchange earner in most of the Caribbean. Tourism consumes large amounts of freshwater (specifically for maintaining hotel grounds, swimming pools, and golf courses) and produces large amounts of wastewater, particularly in coastal areas. Wastewater generation combined with inadequate treatment facilities and insufficient freshwater poses problems for contamination of surface and groundwater, as well as the near shore environment and can lead to the death of coral reefs.

DAMS AND HYDROPOWER DEVELOPMENT

Total reservoir capacity in LAC is 1,097 billion cubic meters. About half of this capacity is installed in Brazil alone. And Brazil, Venezuela, Argentina, and Mexico combine 87 percent of total reservoir capacity in the region (see also Figure 3). Brazil also has the largest number of dams, 594, closely followed by Mexico with 536 dams (Figure 4). Out of the 1,568 large dams in the region that are registered with the International Commission on Large Dams (ICOLD 1998), almost half have irrigation as one important component and 532 dams in the region have been solely built for irrigation purposes. By far the largest number of dams that have been built with only irrigation in mind are located in Mexico (387 dams). Brazil and Chile rank second and third, with 48 and 46 dams, respectively, whose sole purpose is irrigation. Moreover, 19 large dams in Argentina and 16 dams in Peru are only used for irrigation.

LAC has about 22 percent of the world's potential for power generation (700,000 Megawatts). However, its installed capacity is substantially below that value (153,500 Megawatts). Hydroelectric plants produce 64 percent of total energy, while almost all of the rest (36 percent) is produced at oil-fueled facilities. In 1991, the total amount of energy produced in the region was estimated to be equivalent to 590,000 Gigawatt-hours. Demand is estimated to grow at a rate of about 5 percent per year (WMO/IDB 1996).

Figure 3 Reservoir capacity in LAC, 1998

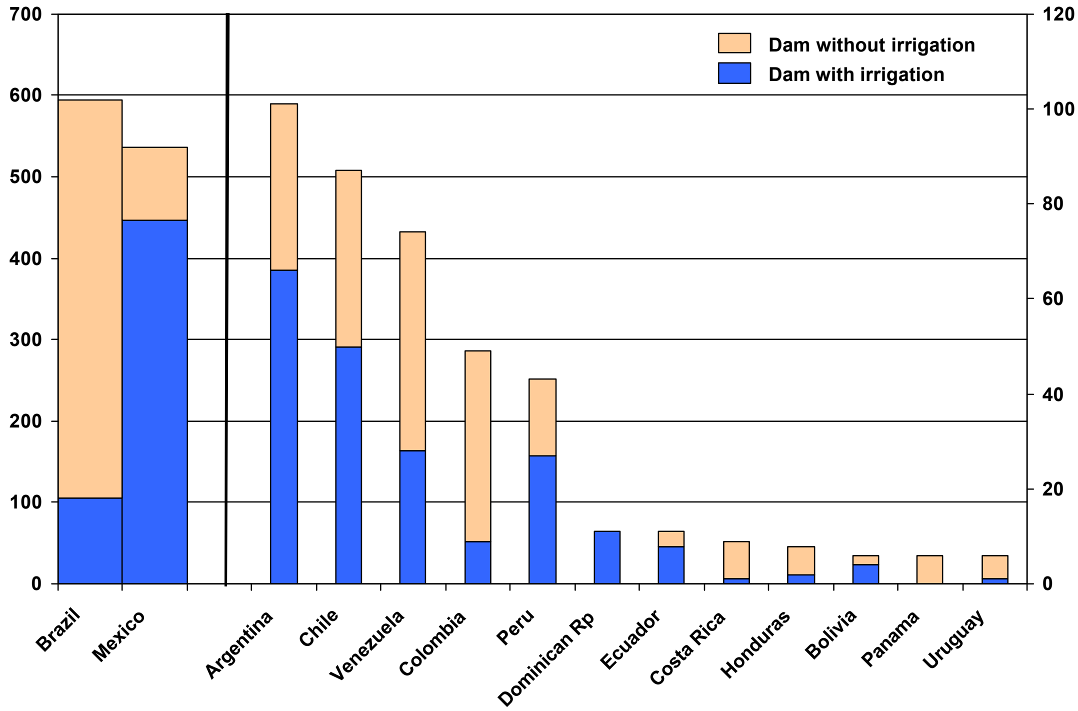


Note: Countries with a reservoir capacity below 50 million m^3 (Guyana, Trinidad & Tobago, Suriname, and Haiti) are not shown.
Source: ICOLD 1998.

WATER SUPPLY AUGMENTATION

This section heavily relies on OAS/UNEP/IETC (1997). With growing demands for water and increasing costs of water supply, a number of LAC countries have ventured into nontraditional water sources for both irrigation and nonagricultural water uses (see Table 7 for an overview of where these technologies are utilized). Rainwater harvesting in the form of rooftop catchment is undertaken in several countries in the region, including Argentina, Barbados, Brazil, Costa Rica, Dominican Republic, Chile, Mexico and Peru and is mainly used for domestic consumption. *In situ* rainwater harvesting—the use of natural or artificial depressions to store rainwater—is carried out in Argentina, Brazil, and Paraguay for crop and livestock production.

Figure 4 Number of dams, with and without irrigation function



Note: Only countries with more than five dams are included.
Source: ICOLD 1998.

Fog collection has been used in the mountainous coastal regions of Chile, Peru, Ecuador, and Mexico with high levels of fog and recurring winds. Fog collectors are made of fine nylon net strung between poles. Water droplets in the fog condense on the net and, when enough have gathered, coalesce and run off into a conveyance system, which carries the water to a storage area. In Chile, costs of fog harvesting have been estimated at US$3 per cubic meter.

Runoff captured from roads can be collected in drainage ditches or street gutters and then transported to cultivation areas. This form of runoff collection has been used in the semi-arid areas of Argentina, Brazil, and Venezuela. Local impoundment and dams are used all over LAC to store water for agriculture, municipal and industrial uses. In

Table 7 Nontraditional water sources used in LAC

Technology	Sector of use [b]			Countries used
	AG	DOM	IND	
Rainwater harvesting				
- Roof catchments	X	X		Argentina, Barbados, Brazil, British Virgin Islands, Costa Rica, Dom. Rep., El Salvador, Guatemala, Haiti, Honduras, Jamaica, Montserrat, Neth. Antilles, Paraguay, St. Lucia, Suriname, Turks & Caicos, US Virgin Islands
- *in situ*	X			Argentina, Brazil, Paraguay
Fog harvesting	X	X	X	Chile, Ecuador, Mexico, Peru
Runoff collection [b]	X	X	X	Argentina, Aruba, Brazil, Chile, Costa Rica, Dom. Rep., Ecuador, Panama, St. Lucia, Suriname, Venezuela
Flood diversion	X			Argentina, Brazil, Venezuela
Water conveyance				
- marine vessels		X		Antigua and Barbuda, Bahamas
- pipelines, aqueducts, water tankers	X	X	X	Costa Rica, Dom. Rep., Ecuador, Jamaica, Panama, St. Lucia
Desalination	X	X	X	Argentina, Bahamas, Brazil, Chile
Wastewater reuse	X		X	Argentina, Barbados, Brazil, Guatemala, Jamaica

Note: [a] AG = Irrigated agriculture and livestock; DOM = Domestic water supply; IND = Industry and mining.
[b] Runoff collection includes paved and unpaved roads and surface and underground structures.
Source: OAS/UNEP/IETC 1997.

Ecuador, costs have been estimated at between US$0.10 and US$2 per cubic meter of water stored; in Argentina, at US$0.60 and US$1.20; in Brazil, a project of 3,000 cubic meters cost US$2,000. In the semi-arid areas of Brazil, artificial aquifers have been created through the construction of underground dams that can store large amounts of water and are less susceptible to evaporation. An underground dam for a drainage area of 1 ha can cost between US$500-1,700, depending on the type of impermeable layer (plastic) used. Flood diversion in the forms of transverse dikes, small-scale diversion structures (*toroba*), and water traps have been used in São Paulo State, Brazil, state of Falcón, Venezuela, and Province of Mendoza, Argentina, respectively.

Water conveyance by marine vessels is typically used for transport of water to water-scarce islands. Barging of freshwater has been used to augment water supplies in Antigua, the Bahamas, and other Caribbean islands. However, this type of freshwater supply is very expensive. Estimated costs of shipping water to the Bahamas are US$1.53 per cubic meter. Water conveyance by pipelines, rural aqueducts, and water tankers are used throughout LAC. Inter-basin transfers with pipelines are used in Jamaica and Panama.

Desalination by reverse osmosis reduces the salt content of seawater or brackish water to below 1,000 milligrams per liter. On many Caribbean islands, desalinated water has become the main source of drinking water. Costs include initial capital investment, energy, replacement parts, and skilled labor to operate the plants. In the Bahamas, production costs range from US$4.60 to US$5.10 per cubic meter. Desalination is also used in some rural areas of LAC. In rural areas of Brazil, reducing salt water levels in the water costs between US$0.12-0.37 per cubic meter. Desalination by distillation is used in the US Virgin Islands, the Netherlands Antilles, and Chile, for example, with costs ranging from US$1.47 per cubic meter in Chile to US$4.31 per cubic meter in the Netherlands Antilles.

Technology for desalination is improving rapidly, but prices remain high relative to the costs of supplying water from other sources. The latest technology has reduced the cost of production (ex-plant) to about US$1.00-2.00 per cubic meter depending on the technology and salt loads in the water (Frederick 1993). Although this is comparable to the costs of new water supplies in some of the most arid areas in LAC, it remains very high compared to costs from alternative sources in most of the region. It must be noted also that, if substantial transportation costs were incurred to pump desalinated water inland, per unit costs would increase significantly. Desalination plants also have high capital and energy costs, and generate substantial wastes, which could cause significant environmental problems. It is likely that use of desalinated seawater in LAC will continue to increase (from a very low base) but that this growth will primarily be for domestic and industrial purposes in the island countries and coastal regions that are very water scarce.

After being used once, freshwater can be used again in the same home or factory (usually called recycling), or collected from one or more sites, treated, and redistributed and used in another location, which is generally called wastewater reuse. Wastewater reuse technologies can produce an effluent suitable for irrigation or industrial purposes.

Treated wastewater is used in resort hotels in the Caribbean islands to irrigate golf courses; and has also been used in Brazil, Chile, and Lima, Peru for agricultural production, and in Brazil as cooling water for mining operations. The largest wastewater reuse effort in LAC likely occurs in Mexico with large-scale use of treated sewage for the irrigation of parks and the creation of recreational lakes. The rate of expansion of wastewater reuse depends on the final quality of the wastewater and on the public's willingness to use these supplies. Although the technology exists to upgrade wastewater for domestic consumption and irrigation, the technology is expensive and consumer resistance has been high.

Only a small fraction of industrial water used for cooling, processing, and other activities is actually consumed. Although the water may be heated or polluted, it can often be recycled within a factory or plant, thereby getting more output from each cubic meter delivered or allocated to that operation. Developed countries have greatly expanded the use of water recycling in industry; a model for what is possible with continued economic growth in LAC. Total industrial water use in Japan reached a high in 1973 and declined by a quarter by 1989. In 1989, Japan produced industrial output of US$77 per cubic meter of water supplied to industries, compared with US$21 per cubic meter in 1965. In the U.S., between 1950 and 1990, total industrial water use fell 36 percent while industrial output increased nearly four-fold (Postel 1992). Pollution control laws have been a primary motivator for industrial water recycling in developed countries. The most cost-effective way to meet specific water quality standards and pollution limits has often been to recycle and reuse water a number of times before discharging it. Pollution control laws have therefore promoted conservation and more efficient water use as well as helped to clean up rivers, lakes, and streams. As LAC countries continue their industrialization, recycling of water can play an important role in conserving water supplies.

The greatest potential for water saving and supply augmentation is likely to be industrial recycling, although wastewater reuse can offer significant and increasing savings as the scarcity value of water increases. Given the relatively high cost of wastewater treatment and transport to agricultural areas, it is likely that wastewater can make up an important share of agricultural water supply only in arid regions where the cost of new water supplies has become very high. Other supply augmentation methods, such as water harvesting and fog harvesting offer both agricultural and environmental benefits in some local and regional ecosystems. However, given the limited areas where such methods appear feasible, and the small amounts of water that can be captured, water harvesting techniques are unlikely to have a significant impact on water scarcity in LAC.

4. WATER QUALITY AND ENVIRONMENTAL AND HEALTH IMPACTS

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 in LAC. The main contaminants found in water include detergents (soaps and solvents); pesticides; petroleum and other derivatives; toxic metals (for example, lead and mercury); fertilizers and other plant nutrients; oxygen-depleting compounds (for example, 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).

Although water is generally abundant in the LAC region, even where rainfall is abundant, access to clean water has been limited by the contamination of water resources. Investments in dams and pipelines to bring water from more remote sources to accommodate a continually increasing urban population have been inadequate. In addition, distribution systems are becoming obsolete, which leads to increasing leakage and other water losses. Reservoir storage capacities are decreasing due to silting; watersheds are being invaded by urban and rural dwellers; and industrialization is leading to declining water quality. In most cities, wastewater is seldom treated. The consequences of this situation can be catastrophic. People are becoming increasingly exposed to health hazards that can affect mortality rates; an example is the cholera outbreak in Peru that spread throughout part of the continent in the early 1990s, with a total number of more than 1.3 million cases resulting in more than 11,000 deaths (PAHO 1997).

ACCESS TO SAFE WATER AND SANITATION

According to recent calculations by the Pan American Health Organization (PAHO), some 333 million people, representing 80 percent of the urban population and 53 percent of the rural population, have access to supply of drinking water and about 285 million, representing 74 percent of the urban population and 30 percent of the rural population, have access to sanitation services. Demand has been especially increasing in urban areas together with growing water pollution and population growth (ECLAC 1995).

In countries like Guatemala, Haiti or El Salvador, less than 20 percent of the population discharge wastewater in septic tanks or closed sewage systems. Others, like Brazil or Argentina, have sewage coverage of more than 60 percent of demand and only in some exceptional cases, like Puerto Rico, the coverage is almost completely satisfied—at 95.7 percent (WMO/IDB 1996).

The water supply and sewerage systems in the rural areas are the least developed and there are no statistical data on the subject in many countries. In the region as a whole, however, the situation is diverse. The focus on rural coverage should be in accordance with the share of people living in rural areas as well as with per capita income, and existing access to water supply and sanitation. Belize, El Salvador, Guatemala, Guyana, Haiti, and Honduras had all more than half of their population living in rural areas; these countries also belong to the poorest in the region, and their access to safe drinking water is relatively low. Rural access to drinking water is also low in Argentina (17 percent) and Bolivia (21 percent) (WHO 1999).

CONTAMINATION OF WASTEWATER AND GROUNDWATER

Water contamination is widespread in the region. There is almost no stream, lake, or groundwater reservoir that has remained untouched by human-made pollution. The largest cities are the ones faced with the largest challenges regarding water quality. Virtually all rivers draining urban wastewaters from the major cities are highly polluted, including the Riachuelo in Buenos Aires (Argentina), the Tietê and Pinheiros in São Paulo (Brazil); the Mapocho River in Santiago (Chile); the Bogotá River in Bogotá

(Colombia); the Almendares River in Havana (Cuba); the Miguelete and Pantanoso Arroyos in Montevideo (Uruguay); and the Guaire River in Caracas (Venezuela).

Contaminated wastewaters are frequently used for irrigation. For example, since the beginning of the century, about 90,000 ha of agricultural land in the Tula Valley has been irrigated with wastewater from Mexico City. In Lima, 2,000 ha of vegetable crops are irrigated with urban wastewaters. In São Paulo, the contaminated waters of the Tietê River are used to irrigate vegetable gardens downstream from the urban core. In Santiago, 62,000 ha of vegetables used to be grown using water from three courses located downstream from Santiago's sewage outflow (Anton 1993). In nearly all of the Caribbean the quality of water resources is declining. In Jamaica, discharges from the rum and bauxite/aluminum industries have polluted both surface and groundwater resources. Saline intrusion is a major constraint to water availability in Antigua and Barbados. This is partially due to intensive agriculture, accelerated land development and deforestation (Fernandez and Graham 1999).

The increasing demand for water for different uses means that surface and underground water reservoirs will continue to be polluted by enormous amounts of organic and inorganic wastes. The situation is worsened by the high dependence of LAC countries on activities related to the primary and secondary sectors, which means that pollution sources will continue to grow in the future. In addition to the negative effects that these activities bring to the environment, this situation poses a large threat to the health of the population in the region.

In LAC, one of the main causes of water pollution is the direct discharge of domestic sewage and industrial effluents. Of these two contaminants, domestic sewage is usually the more important, particularly in large population centers. Although domestic sewage is biodegradable, the input of sewage into the environment in many locations in LAC exceeds the natural decomposition and dispersal capacity of the recipient water bodies leading to significant water degradation. For example, it has been estimated that in Rio de Janeiro, Brazil, 70 percent of the pollutants in the recipient waters around the city are of human origin, while only 30 percent are industrial and organic wastes. Storm-water runoff is a further source of pollution in major urban areas of the region.

Industrial water use in the majority of the countries of LAC accounts for a relatively minor part of total water withdrawals. Locally, however, the share of industrial effluents can be extreme. This phenomenon is due both to the nature of the predominant pollutants and to the fact that their toxicity tends to be very high. The region also has a higher share of industries with potentially noxious effluents than the world as a whole. For example, while the share of Latin America in the world total value added in industry was 5.3 percent (1983), its share (1982) in petroleum refining was 17.7 percent; in the production of other chemicals, 14.7 percent; in the number of beverage industries, 11.4 percent; in food manufacturing, 8.7 percent; in iron and steel basic industries, 7.1 percent; in non-ferrous basic industries, 6.3 percent; and in paper products, 5.4 percent (UN/ECLAC 1990). Moreover, a high proportion of industry and population is concentrated in relatively few regions, such as the Lower Paraná-River Plate area of Argentina and Uruguay, the triangle of Rio de Janeiro/São Paulo/Belo Horizonte in Brazil, and the Mexico City metropolitan region in Mexico.

Many cities, including several large metropolitan centers, such as Mexico City and Havana, as well as the extensive arid and semi-arid areas in much of the region and thousands of rural communities rely on springs and wells for drinking water and irrigation. As a result, groundwater pollution is a cause of particular concern in LAC. Groundwater reservoirs are typically somewhat better protected from contamination than surface sources. However, there are indications that the aquifers of Buenos Aires, São Paulo, and Mexico City, among others, are beginning to suffer the consequences of uncontrolled disposal of wastes. Excessive lowering of water tables is taking place in many cities where pumping is intensive (for example, some suburbs of Buenos Aires, Mexico City, and Lima). In some cases, overpumping has led to saline encroachment (Mar del Plata in Argentina, Nassau in the Bahamas, Santa Marta in Colombia, Havana in Cuba, Lima in Peru, and Coro and Maracaibo in Venezuela) (Anton 1993). In Argentina, saline water intrusion has been reported to threaten coastal areas near the city of Mar del Plata and to have caused the salinization of some aquifers in the area of Buenos Aires.

In Ecuador, the dumping of some 3,300 tons a year of solid wastes has been reported to have impaired the water quality of the Tomebamba and Machánagara rivers.

Direct tipping of solid wastes into water bodies has also been reported in Haiti and the Netherlands Antilles. In Guanabara Bay, Brazil, most of the solid wastes are dumped at the edge of the bay, with the city of Rio de Janeiro alone dumping over 3,000 tons daily. Household solid wastes have also been reported to contribute to water pollution problems in the Caracas Metropolitan Region, Venezuela.

Both Medellín, Colombia, and Santiago, Chile, are characterized by a high level of bacteriological contamination of adjacent water bodies due to a lack of sewage treatment. In Mexico, salmonella poisoning and other gastric problems have been reported to be above the national average among the 1,500,000 people living near the heavily polluted Coatzacoalcos River. The segment of population most affected is usually the low-income groups lacking safe water supply, sewerage facilities or medical services (UN/ECLAC 1990). However, there are signs of increasing investment in wastewater treatment plants, for example, in Chile (Bolelli 1997) and Mexico.

ENVIRONMENTAL IMPACTS OF IRRIGATION

Improper agricultural water use in Latin America is salinizing, waterlogging, and eroding agricultural lands and polluting water for agricultural use. In 1982, salinization affected about 196,550 square km (0.7 percent) of the agricultural soils in Central America and Mexico, and 1,291,630 (7.6 percent) in South America. Most salinization problems originate in inefficient use of water. Argentina and Chile have about 35 percent of their irrigated lands affected by salinity whereas 30 percent, or 250,000 ha, of the coastal region of Peru under irrigation is impacted by this problem. In Brazil 40 percent of the irrigated land in the northeast is affected by salinity as a result of improper irrigation. Natural and man-induced salinity in Cuba covers about 1.2 million ha, the provinces of Guantanamo and Granma being the most affected (Alfaro and Marin 1994).

According to the Mexican Ministry of Agriculture and Water Resources, about 560,000 ha, or 12.4 percent of the country's irrigated acreage, were wholly or partially affected by salinization in 1980, due to the irrigation systems. In Peru, the *Oficina Nacional de Evaluación de Recursos Naturales* surveyed 750,000 ha in 52 coastal valleys and 200 pampas: 250,000 ha in the area surveyed were affected by salinization, 150,000 ha of which also had drainage problems (FAO 1988b).

Drainage problems affect large areas of land in Latin America; in many cases these problems are compounded by salinization. Thus, in Argentina 555,000 ha are in need of drainage. In Peru 60,000 ha in the coastal region and 34 percent of the cultivated lands in the upper jungle (*Ceja de Selva)* - or 150,000 ha - are affected by drainage problems; and in Costa Rica, projects for rehabilitation through drainage exceed 60,000 ha. In spite of the efforts made to control water pollution, the region is experiencing a continuous decline in the quality of water for agricultural use. According to ECLAC (1989), one of the main non-point sources of water pollution is runoff from agriculture. Pollution of water by unloading agro-industry effluent to irrigation watercourses is a growing problem in Mendoza, Argentina (Alfaro and Marin 1994).

There is also a high risk of desertification in about 20 percent of the total area of South America (Argentina: 60 percent, Chile: 45 percent, Bolivia: 25 percent, and Peru: 20 percent). In about one half of this area, the risks are high or very high. Arid and semi-arid lands, which in some countries, including Argentina, Chile, Mexico, and, to a lesser extent, Bolivia and Peru, account for a substantial proportion of the total area of the country have increased as a result of deforestation (FAO 1988b).

Runoff of agricultural chemicals also contributes to water pollution, although this is primarily a localized problem where agricultural input use is high. The consumption of fertilizers in LAC increased rapidly over the last 30 years, from 16 kilogram per ha in 1966 to 62 kilogram per ha in 1996. However, fertilizer application is still below the levels of developed countries. In 1996, the consumption of fertilizers per ha of farmland amounted to 89 kg globally and 113 kg in the United States. However, the experience in LAC is diverse. In a few countries, application rates are extremely low, including Bolivia with 5 kilogram per ha and Haiti with 9 kilogram per ha in 1996. In other countries of the region, however (for example, Chile, Colombia, Costa Rica, El Salvador or Uruguay) the consumption of fertilizers is similar to that of developed countries (FAOSTAT 1999). LAC countries place relatively few restrictions on the use of agricultural chemicals. From the list of agricultural chemicals in the UN publication

'Consolidated list of products whose consumption and/or sale have been banned, withdrawn, severely restricted or not approved by governments,' only 20-25 percent are subject to any restrictions in LAC and the majority of these restrictions are of recent origin.

5. RECENT TRENDS AND PROJECTIONS FOR WATER DEMAND IN LAC

Tables 8-10 give an overview of current and projected water withdrawals and consumption in LAC. As can be seen in Tables 8 and 9, the largest water withdrawals are for agricultural purposes. With the exceptions of Colombia, Trinidad and Tobago, and Venezuela, agricultural withdrawals are more than one-half of total withdrawals, and in many countries, agricultural withdrawals represented more than three-fourths of total water withdrawals (Table 8). For LAC as a region, agricultural water withdrawals represented 63.6 percent of the total in 1990 (Table 9). Based on the projections shown in Table 9 however, the most rapid rise in water withdrawals will be in the industrial and municipal sectors. Water withdrawals in South America are expected to increase by approximately 70 percent between 1990 and 2025. The greatest challenge will be to meet the needs for safe drinking water supply and environmental sanitation in the large urban centers where the concentrations of population and economic activity are among the fastest growing in the world (WMO/IDB 1996).

Reservoir withdrawal will also increase as additional reservoirs are constructed to increase the water supply available and to store water from season to season. Agriculture is even more dominant in the consumptive use of water. For the region as a whole, agriculture consumed 81 percent of total water uses in 1990, but with a projected decline in proportion of total consumption to 69 percent by the year 2025 (Table 10).

Table 11 shows the relationship between water availability and withdrawals at the country level. The island states of Barbados, Cuba, and Dominican Republic as well as Mexico and Peru are particularly vulnerable to water scarcity, with high withdrawals relative to water availability. This constitutes an additional constraint to future irrigation development. Argentina, Chile, El Salvador, Haiti, Jamaica, and Uruguay face medium water pressure. This pressure could intensify if population and economic growth continue to rapidly increase. However, this table can also misleading unless interpreted with care. Even many of the countries in the first column face severe regional, local, and seasonal water shortages in both normal and dry years. Moreover, several of the countries, including Argentina, Bolivia, and Uruguay are highly reliant on transboundary waters from upstream countries (WMO/IDB 1996).

Table 8 Latin America renewable water resources and withdrawals by sector

Country	Annual Internal Renewable Water Resources	Per Capita Annual Internal Renewable Water Resources	Annual Withdrawals (yr of data)	Total Withdr.	Withdr. as Share of Total Water Resources	Annual Withdr. Per Capita	Share Domestic Withdr.	Share Industrial Withdr.	Share Agricult-ural Withdr.
	(km^3)	*(m^3/cap)*		*(km^3)*	*(%)*	*(m^3/cap)*	*(%)*	*(%)*	*(%)*
TOTAL CA	**1,056.67**	**8,084**	**1987**	**96.01**	**9**	**916**	**6**	**8**	**86**
Belize	16.00	69,565	1987	0.02	0	109	10	0	90
Costa Rica	95.00	26,027	1970	1.35	1	780	4	7	89
Cuba	34.50	3,104	1975	8.10	23	870	9	2	89
Dominican Republic	20.00	2,430	1987	2.97	15	446	5	6	89
El Salvador	18.95	3,128	1975	1.00	5	244	7	4	89
Guatemala	116.00	10,033	1970	0.73	1	139	9	17	74
Haiti	11.00	1,460	1987	0.04	0	7	24	8	68
Honduras	55.42	9,015	1992	1.52	3	294	4	5	91
Jamaica	8.30	3,269	1975	0.32	4	159	7	7	86
Mexico	357.40	3,729	1991	77.62	22	915	6	8	86
Nicaragua	175.00	39,203	1975	0.89	1	368	25	21	54
Panama	144.0	52,042	1975	1.30	1	754	12	11	77
Trinidad & Tob.	5.10	3,869	1975	0.15	3	148	27	38	35
TOTAL SA	**9,526.00**	**28,702**	**1995**	**106.21**	**1**	**335**	**18**	**23**	**59**
Argentina	694.00	19,212	1976	27.60	4	1,043	9	18	73
Bolivia	300.00	37,703	1987	1.24	0	201	10	5	85
Brazil	5190.00	31,424	1990	36.47	1	246	22	19	59
Chile	468.00	31,570	1975	16.80	4	1,625	6	5	89
Colombia	1,070.00	28,393	1987	5.34	0	174	41	16	43
Ecuador	314.00	25,791	1987	5.56	2	581	7	3	90
Guyana	241.00	281,542	1992	1.46	1	1,819	1	0	99
Paraguay	94.00	18,001	1987	0.43	0	112	15	7	78
Peru	40.00	1,613	1987	6.10	15	300	19	9	72
Suriname	200.00	452,489	1987	0.46	0	1,192	6	5	89
Uruguay	59.00	18,215	1965	0.65	1	241	6	3	91
Venezuela	856.00	36,830	1970	4.10	0	382	43	11	46

Note: Population numbers are for 1998.
Source: WRI 1998.

Table 9 Water withdrawals by sector in Latin America

Sector	1990	2025
	(billion cubic meter)	
Agriculture	96.7	112.0
Industry	15.9	56.5
Municipalities	28.1	64.5
Reservoirs	11.0	24.0
Total	151.7	257.0

Note: Agriculture includes irrigation and livestock watering. Industrial use includes thermal power plant cooling. Municipal use includes domestic uses in urban and rural areas. Reservoir withdrawals represents the amount of water lost to evaporation in reservoirs.

Source: WMO/IDB 1996.

Table 10 Water consumption by sector in Latin America

Sector	1990	2025
	(billion cubic meter)	
Agriculture	74.2	84.7
Industry	1.2	6.2
Municipal needs	5.0	7.8
Reservoirs	11.0	24.0
Total	91.4	122.7

Note: Consumption includes water used by crops for transpiration or for building plant tissue, water evaporated from land or reservoirs and that part of the water taken for industrial production or community use that is not returned to the river system.

Source: WMO/IDB 1996.

Table 11 Ratio of water withdrawal to water availability

LOW less than 2.5 percent		MEDIUM 2.5 to 10 percent	HIGH over 10 percent
Belize	Guyana	Argentina	Barbados
Bolivia	Honduras	Chile	Cuba
Brazil	Nicaragua	El Salvador	Dominican Republic
Colombia	Panama	Haiti	Mexico
Costa Rica	Paraguay	Jamaica	Peru
Ecuador	Suriname	Uruguay	
Guatemala	Venezuela		

Note: A ratio greater than 10 percent generally indicates that the water resource supply is inadequate and significant investments will be required to increase supply, reduce wasteful demand and develop the water resources management capabilities in the country. The ratios represent both internal and external water supplies available to the country.
Source: WMO/IDB 1996.

6. TRENDS IN IRRIGATED AREA, COSTS AND RETURNS

Irrigation furthers stability through greater control over production and scope for crop diversification. In many developing countries, irrigation constitutes an important element of rural development policies, as it provides higher rural incomes and employment and allows for increased agricultural and rural diversification through secondary economic activities derived from extended and more varied agricultural production (as compared to rain-fed agriculture). In addition, in arid and semi-arid areas, alternatives to irrigated agriculture are rare, and water reallocation can lead to rural-urban migration and abandonment of plots (Fereres and Ceña 1997; Raskin, Hansen and Margolis 1995; Wolter 1997). Thus, irrigation plays a vital role in achieving food security and sustainable livelihoods in developing countries, both locally, through increased income and improved health and nutrition, and nationally, through bridging the gap between production and demand.

The share of area irrigated in LAC of 11 percent in 1996 puts the region in a medium place among the other regions in the world. Developed countries, on average, irrigate 10 percent of their agricultural area, and countries in development 23 percent, and combined they irrigated 18 percent of agricultural area in 1996. In Sub-Saharan Africa, only 3 percent out of the total agricultural area was irrigated in 1996, and in Africa as a whole, 6 percent. In Asia, on the other hand, 33 percent of the agricultural area was equipped for irrigation. The share of LAC is relatively close to that of the United States, where 12 percent of the agricultural area was irrigated in 1996. In most LAC countries, the availability of water for irrigation is not in itself a constraint to the expansion of irrigated area, but in some countries, for example Barbados, Haiti, Jamaica, Mexico, Peru, the expansion of irrigation is rapidly approaching the water potential that can be developed at affordable cost. In addition, the marginal capital cost of irrigation is rapidly increasing in nearly all countries (FAO 1988a).

Tables 12 and 13 show trends in irrigated area over the last 30 years, and Table 14 shows the disaggregation for rainfed and irrigated agricultural production. Growth in irrigated area averaged 2.25 percent per year during 1962-96. The share of agricultural land (arable land and permanent crops) irrigated increased during the same time from 8 percent to 11 percent, a very slow increase. In 1996, irrigated area in LAC stood at about 17 million ha, out of an agricultural area of 155 million ha (FAOSTAT 1999). According to preliminary FAO estimates, 16 percent of the cereal area in LAC was irrigated in 1995 (11 percent of the wheat, 44 percent of rice, 10 percent of maize, 19 percent of barley, and 16 percent of sorghum). In addition, 35 percent of the area planted to sugar cane and 24 percent of the area planted to cotton were irrigated. Irrigated cereal yields were estimated at more than double rainfed cereal yields, and for the region, 28 percent of cereal production is derived from irrigated production (FAO 1999, based on work in progress for Agriculture: Towards 2015/30).

Even though the cropping area has increased substantially—by 47 million ha during the last 30 years—there are still large agricultural areas without irrigation. While countries like Chile, Colombia, Costa Rica, Guyana, Mexico, Peru or Suriname have infrastructure for the irrigation of more than 20 percent of their agricultural land, in other countries, including Argentina, Brazil, Guatemala, Haiti, Honduras, Nicaragua, or Panama, the coverage is less than 10 percent. In 1996, more than a third of the irrigated area (6.1 million ha) was located in Mexico, where about 22 percent of agricultural area is irrigated. Brazil, Argentina, and Peru also have large irrigated areas. Combined, those four countries accounted for three fourths of the total area equipped for irrigation in 1996. The irrigated areas account for between 6 percent (Argentina) and 42 percent (Peru) of agricultural area in these countries. Irrigation is even more important in Suriname, however, where the 68,000 ha irrigated account for 90 percent of agricultural area. On a per capita basis, irrigation is of high importance in Guyana and Suriname, where 0.15 ha and 0.14 ha per capita are irrigated, respectively. The irrigated area—population proportion is also relatively high in Chile, Mexico, and Peru, ranging from 0.07 to 0.09 ha per person. On average, irrigated area per capita—affected by irrigation investments and population growth—was constant over the last 30 years, with substantial increases in Brazil, El Salvador, Suriname, and Uruguay compensated by the rapid declines that occurred in Bolivia, Honduras, and particularly Ecuador.

During the last 30 years, growth in irrigated area was highest in El Salvador—from a small base—and Brazil, at 5.74 percent per year and 5.48 percent annually, respectively. In both countries, irrigated area increased during the 1960s and 1970s and growth has slowed considerably thereafter. Colombia, Costa Rica, Nicaragua, Suriname, and Uruguay all achieved annual growth in irrigated area above 4 percent during the last 30 years. Contrary to the trends in most countries in the region, growth in irrigated area accelerated in Colombia between 1962-82 and 1982-96, an experience that was only replicated by Peru and, to a lesser extent, the Dominican Republic. Bolivia, Chile, Ecuador, Guyana, Honduras, and Jamaica are countries where annual growth in irrigated area was substantially below the regional average. Among these countries, Bolivia and Ecuador stand out with large contractions in irrigated area since the 1980s. Bolivia achieved rapid growth in irrigated area during 1962-82 (3.2 percent per year), but was

Table 12 Trends in irrigated area, 1961-97

	Irrigated area		Growth in irrigated area				
	1966	1996	1962-82	1982-96	1982-89	1989-96	1962-96
	(000 ha)		*(percent per year)*				
Argentina	1,140	1,700	2.29	0.46	0.64	0.28	1.53
Bolivia	75	75	3.19	-3.72	-2.84	-4.60	0.28
Brazil	640	3,169	6.44	4.12	5.20	3.06	5.48
Belize	0	3	..	2.94	0.00	5.96	..
Chile	1,110	1,265	0.76	0.05	0.07	0.04	0.47
Colombia	240	1,051	3.21	6.58	5.29	7.89	4.58
Costa Rica	26	126	5.18	4.15	7.32	1.06	4.75
Dominican Republic	120	259	2.28	2.83	3.63	2.03	2.51
Ecuador	463	240	-0.11	-4.04	-5.27	-2.79	-1.75
El Salvador	20	120	9.47	0.62	1.25	0.00	5.74
Guatemala	45	125	5.01	2.13	2.91	1.37	3.81
Guyana	109	130	1.32	0.24	0.49	0.00	0.88
Haiti	42	90	3.24	1.81	0.67	2.97	2.65
Honduras	66	74	1.20	0.20	0.39	0.00	0.79
Jamaica	24	33	1.97	0.00	0.00	0.00	1.15
Mexico	3,250	6,100	2.47	1.63	1.18	2.07	2.12
Nicaragua	18	88	7.83	0.56	0.63	0.50	4.78
Panama	18	32	3.53	0.96	1.31	0.61	2.46
Paraguay	40	67	3.64	0.63	0.83	0.43	2.39
Peru	1,078	1,753	0.66	2.88	1.76	4.01	1.56
Suriname	20	60	5.93	2.19	4.00	0.40	4.37
Trinidad & Tobago	11	22	3.29	0.33	0.67	0.00	2.06
Uruguay	42	140	5.49	3.51	4.14	2.89	4.67
Venezuela	63	200	4.76	2.04	2.39	1.69	3.63
Total	8,661	16,923	2.46	1.95	1.74	2.16	2.25

Note: Growth rates are three-year centered moving averages.
Source: FAOSTAT 1999 (Land Use Domain).

unable to keep up with expansion in irrigation. As a result, irrigated area that had increased to 140,000 ha in the early 1980s shrank thereafter to 75,000 ha. In Ecuador, irrigated area had been steadily declining since the 1970s. However, the decline accelerated during the 1980s, when the country, as many others in LAC, experienced substantial budgetary constraints. On average, irrigated area as a share of agricultural area increased by 37 percent over the last 30 years. The increase was most rapid in

Table 13 Irrigated area as a share of agricultural land and population

	Irrigated area per agr. area[a]		Irrigated area per capita	
	1966	**1996**	**1966**	**1996**
Argentina	0.049	0.063	0.050	0.048
Brazil	0.020	0.048	0.007	0.020
Chile	0.282	0.550	0.127	0.088
Colombia	0.048	0.237	0.013	0.029
Dominican Rep.	0.113	0.173	0.031	0.033
Ecuador	0.183	0.080	0.087	0.021
Mexico	0.139	0.223	0.073	0.066
Peru	0.411	0.419	0.091	0.073
Average LAC	0.080	0.109	0.036	0.036

Note: a/ Agricultural area includes arable land and permanent crops.
Source: FAOSTAT 1999 (Land Use and Population Domain).

Table 14 Breakdown of area - irrigated and rainfed, 1995, LAC

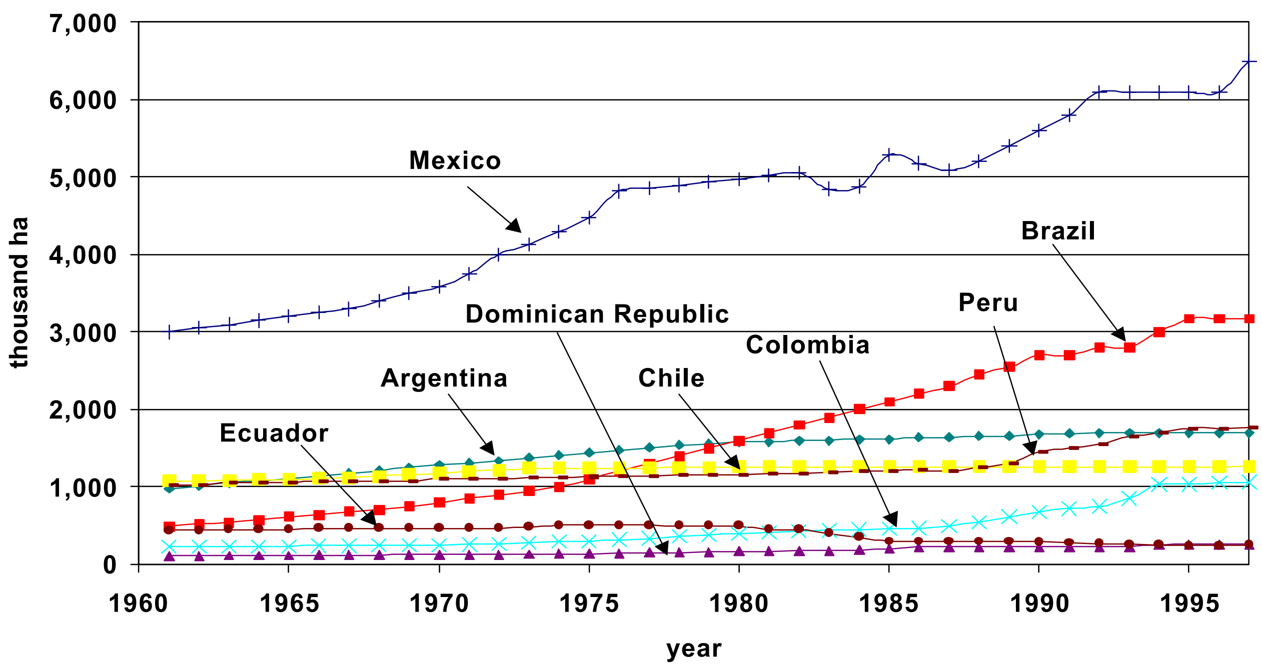
Crop	**Rainfed Area**			**Irrigated Area**			**Total Area**		
	Area	**Yield**	**Prod.**	**Area**	**Yield**	**Prod.**	**Area**	**Yield**	**Prod.**
	000 ha	*kg/ha*	*000 mt*	*000 ha*	*kg/ha*	*000 mt*	*000 ha*	*kg/ha*	*000 mt*
Wheat	8,097	2,048	16,586	1,001	4,186	4,190	9,098	2,284	20,776
Rice	3,732	1,873	6,990	2,971	4,557	13,540	6,703	3,063	20,530
Maize	25,701	2,185	56,149	3,006	4,950	14,878	28,707	2,474	71,028
Barley	734	1,819	1,335	173	1,885	326	907	1,831	1,661
Millet	43	1,288	55	0	0	0	43	1,288	55
Sorghum	2,699	2,330	6,287	496	3,950	1,959	3,195	2,581	8,246
All Cereals	41,764	2,115	88,327	7,688	4,550	34,980	49,452	2,494	123,307
Sugar cane	5,325	56,041	298,399	2,907	71,444	207,692	8,232	61,481	506,091
Cotton	2,048	1,224	2,507	643	2,040	1,312	2,691	1,419	3,819

Source: FAO (1999), based on work in progress for Agriculture: Towards 2015/30.

Colombia, Costa Rica, El Salvador, and Uruguay, all countries with low growth or contraction in agricultural area, and significant expansion in irrigated area. Bolivia, Guyana, Honduras, Paraguay, Peru, and particularly Ecuador have all seen a reduction in their ratio of irrigated area to agricultural area.

Figure 5 shows growth in irrigated area for LAC countries with irrigated area in excess of 200,000 ha. Mexico has by far the largest irrigated area among LAC countries. In Argentina, traditionally, only a small proportion of the agricultural area—about 5 percent—was irrigated. There was also little new irrigation development during the last three decades. Irrigated area increased roughly from 1.0 million to 1.7 million ha over the last 30 years, at 1.5 percent per year with little impact on the relation of irrigated area with respect to overall agricultural area and population. Irrigation development was most rapid during 1967-82, at 2.3 percent per year, and declined thereafter, to 0.5 percent annually. Growth in irrigated area slowed further during the 1990s, to 0.3 percent per year. As there was virtually no growth in agricultural area since the 1980s, irrigated area as a share of agricultural area increased slightly, to 6.3 percent at the beginning of the 1990s.

Figure 5 Irrigated area, major LAC countries, 1961-97



Source: FAOSTAT 1999 (Agriculture and Food Trade Domain).

In Brazil, irrigated area increased by a factor of six during the last three decades, from 0.5 million ha in the early 1960s to about 3,2 million ha in 1996, at an annual rate of growth of 5.5 percent. Growth in irrigated area declined slightly after 1982, from 6.4 percent annually during 1962-82 to 4.1 percent per year during 1982-96. In the early 1990s, however, annual growth was still 3.1 percent, and was thus among the highest in the region. The Brazilian Government has aggressive plans to rapidly increase irrigated area, by a total of 700,000 ha between 1994 and the end of 2002, particularly in the semi-arid Northeast region of Brazil. By the end of 1999, about 582,000 ha will be brought under irrigation with private sector participation. Moreover, all irrigation activities, public and private, will receive technical and institutional support in addition to financial assistance (Government of Brazil 1999). Growth in agricultural area was also extremely rapid in Brazil, and the highest in the region after Paraguay and Nicaragua, more than doubling during the last three decades, from 28 million to 65 million ha. As a result, the share of irrigated area in total agricultural area increased less than expected from growth in irrigated area, from 1.7 percent in 1961 to 4.9 percent in 1996. At the same time, irrigated area per capita almost tripled, from 0.007 ha per capita to 0.02 ha per person.

There has been little expansion in the irrigation sector in Chile during the last three decades, in particular since the mid-1970s. Annual growth averaged 0.47 percent during 1962-96, but declined throughout the period, from 0.76 percent during 1962-82 to 0.07 percent during 1982-89 and 0.04 percent during 1989-96. One of the reasons for this development likely is the establishment of water markets and transferable property rights in water. According to Hearne and Easter (1995), water use efficiency improvements induced by water markets postponed the need of dam and other infrastructure construction projects. The Chilean water law also requires that farmers must contribute substantial funds for construction of new irrigation systems. As a result, only few, particularly profitable systems have been built. Demand for new irrigation was also low due to the steady decline in total agricultural area. This decline in agricultural area actually accelerated, from 0.03 percent per year during 1962-1982 to 3.49 percent per year in 1982-96, and was even more rapid at the beginning of the 1990s, averaging 4.52 percent per year. This rapid decline in agricultural area is a clear indicator of the rapid transformation from an agriculturally based economy to an economy dominated by the manufacturing and service sectors. As a result of this decline in agricultural area, the share of irrigated area in agricultural area actually more than doubled during the last 30 years, from 28 percent in 1961 to 55 percent in 1996, making Chile the country with the largest proportion of irrigated area among the major irrigators in the region. On a per capita basis, on the other hand, there was a slight decline, from 0.13 ha irrigated per capita to 0.09 ha, still the most favorable proportion among the large irrigators.

In Colombia, about 1 million ha are equipped for irrigation, and growth in irrigated area has been rapid during the last three decades, at 4.58 percent per year during 1962-1996. Moreover, growth in irrigated area has been increasing over time, from 3.21 percent per year during 1962-82, to 5.29 percent per year during 1982-89, and finally to 7.89 percent per year during 1989-96. In addition, the area under arable land and permanent crops has been declining in the early 1990s. As a result, irrigated area as a share of arable land and permanent crops has been increasing fourfold, from 4.5 percent in 1961 to 24.0 percent in 1997. Moreover, irrigated area per person more than doubled, from 0.013 ha per person to 0.029 ha per capita.

In the Dominican Republic, irrigated area increased by 2.5 percent per year during 1962-96. Irrigated area doubled from 120,000 ha to 259,000 ha during the same time period. Growth in area equipped for irrigation increased over the last thirty years, from 2.3 percent per year during 1962-82 to 2.8 percent per year during 1962-82. However, in the 1990s, growth in irrigated area slowed down, to 2.03 percent annually. At the same time, the share of irrigated area in agriculture increased, from 11 percent in 1961 to 17 percent in 1997. On a per capita basis, irrigated area was virtually constant, because of the relatively rapid growth in population of 2.5 percent per year during the last 30 years.

Ecuador is the only country in LAC with an irrigated area above 200,000 ha that has experienced a substantial contraction in irrigated area during the last two decades. After increasing slowly from 440,000 ha in 1961 to 506,000 ha in the mid-1970s, irrigated area plunged to 240,000 ha by 1996. Overall, irrigated area declined by 1.8 percent per year, with the largest contraction during 1982-89, at 5.3 percent per year, followed by a leveling off of the decline to 2.8 percent annually in 1989-96. Agricultural area barely increased during the same period, at 0.5 percent per year. As a result, the very high share of irrigated area in total agricultural area of 18 percent in 1961 and 20 percent during the late 1970s dropped to only 8 percent during the early 1990s. Moreover, with a high population growth rate of 2.7 percent per year during the last thirty year, the ratio of irrigated area per capita in 1996 dropped to one fourth of the 1966 level of 0.09 ha per capita.

Mexico accounts for about 35 percent of total irrigated area in LAC. Irrigated area increased rapidly during the last three decades, from about 3.3 million ha in 1966 to more than 6 million ha in 1995, at an annual rate of growth of more than 2 percent per year. However, annual growth slowed down during 1982-96 compared to 1962-82. A closer look at the latter rate of growth however shows some sign of improvement, with growth in 1989-96 at 2.1 percent per year compared to the 1.2 percent annual growth during 1982-89. With population growth at 2.6 percent per year over the last thirty years, irrigated area declined slightly on a per capita basis, from 0.073 ha per capita in 1966 to 0.066 ha per capita in 1996.

In Peru, agricultural area increased rapidly during the last 30 years, from 2.6 million ha in 1966 to 4.2 million ha by 1996. By 1961, the share of irrigated area in total agricultural area was very high, with 0.52 ha out of 1 ha, or more than half of total agricultural area irrigated. Although annual growth in irrigated area was relatively high during 1962-96, at 1.56 percent, and was particularly rapid during the early 1990s (4.01 percent), growth lagged behind the expansion in crop area of 1.98 percent annually, and the share of irrigated area in total agricultural area declined to 0.32 ha in the early 1980s. The ratio recovered to 0.42 ha by 1996, a value close to the 0.41 ha reached in 1966. With rapid population growth, the share of area irrigated per person declined from 0.09 ha to 0.07 ha.

COSTS AND RETURNS TO IRRIGATION INVESTMENT

The performance of irrigation projects in the region has often been disappointing. Of seven projects evaluated by the World Bank after implementation, three, accounting for 48 percent of the investment, were successful. The estimated economic return on investment for the seven projects considered together was about 14 percent. These figures compare unfavorably with success rates and economic rates of return for 58 irrigation projects worldwide evaluated by IBRD in 1980-85, of 90 percent and 18 percent, respectively. For four IDB projects similarly evaluated ex-post, the rates of return were estimated at between 1 percent and 12 percent in three cases, and in only one instance better than 12 percent (FAO 1988b).

A comprehensive World Bank review of its irrigation portfolio worldwide also found relatively low returns to irrigation investment in LAC. The thirteen gravity irrigation projects reviewed had an average internal rate of return of 11 percent, five pump projects had a rate of return of 9 percent, and eight mixed projects had a rate of return of 11 percent. These internal rates of return compare to the average across regions of 14 percent, 17 percent, and 14 percent, respectively. The study also found that projects in LAC have had higher realized capital costs per ha than any region but Africa, and have had the highest rates of cost inflation between the estimated cost during project preparation, and the realized costs measured at the time of post-completion project evaluation. The average capital cost for projects in LAC at project appraisal was US$3,923 per ha, but at the time of project evaluation, the capital costs were US$10,283 (Jones 1995).

Inefficient irrigation contributes to the relatively low returns to investment. Although there are several modern irrigation systems in the region, such as for the irrigation of bananas in Ecuador or of fruit trees in Chile, in too many instances the performance of the existing systems falls below expectations. Field estimates carried out in various irrigation projects in Brazil, for example, with sandy soils and mean wind velocities of 5 meters per second, resulted in average actual and potential water application efficiencies of 40 percent and 60 percent, respectively, for conventional sprinkler systems irrigating plots of 8 ha on average. The average values for localized irrigation, drip and micro-sprayers, were 60 and 80 percent respectively for actual and potential water application. The sources of water losses were mainly excessive length of irrigation time, pipe leakage and surface runoff. The effects of evaporation and wind, and losses due to deep percolation were assumed to be equal for the actual and potential water application efficiencies. Excess irrigation time was the larger source of water losses (10-25 percent for sprinkler systems and 2-10 percent for trickle systems), followed by leakages in the pipe network (Alfaro and Marin 1994).

PRIVATE SECTOR IRRIGATION IN LAC

Latin America possesses a long history of private sector investment in the irrigation sector. Regional governments only decided that the public sector should take responsibility for irrigation development in the 1920s, and it was in the 1940s that these governments decided that irrigation should be under national rather than state or municipal control (ECLAC 1998).

Despite increasing public sector involvement, private irrigation never really disappeared, and it played an important role in a number of LAC countries even at the height of state economic dominance in the 1970s. In Bolivia, Brazil, Chile, Ecuador, and most of Central America, water user associations and individual farmers have been responsible for developing irrigated area in excess of 30 percent of the national total (FAO 1988b). Still, it was not until the debt crisis of the 1980s, and the financial retrenchment that followed, that governments throughout the region shifted much of the responsibility for irrigation development back onto the private sector. With the continued decline in public and international funds for irrigation development (see Section 9), private investment and farmer participation will be increasingly necessary for the realization of further increases in irrigated area and the maintenance and improvement of pre-existing infrastructure. As LAC governments increasingly withdraw from direct involvement in the irrigation sector, however, it is critical that they retain their essential role as regulators and enablers of private investment through credit facilities and technical assistance.

Mexico has long had significant private sector irrigation development. About 30,000 privately owned irrigation units made up 2.9 million ha (two-thirds supplied by groundwater) of Mexico’s total irrigated area of 6.2 million ha even before the reforms initiated by the “Ley de Aguas Nacionales” in 1989 (Gorriz, Subramanian, and Simas 1995). Since the 1989 reforms, the majority of publicly funded irrigation districts have been transferred to users’ associations who exercise full O&M control over secondary irrigation works. By 1996, 2.82 million ha of irrigation infrastructure (87 percent of the total area of irrigation districts) had been transferred to 404,000 users organized into 372 associations and 7 companies (Johnson 1997).

The Mexican reforms have led to dramatic increases in private sector investment in irrigation infrastructure. Private sector and water operator irrigation investment increased from a negligible amount in 1991 to 464 million pesos in 1995 (US$60.71 million). The greatest increases took place between 1993 and 1995, when private sector investment jumped 4.88 percent, from 95 million pesos to 464 million pesos. These private sector investments helped keep total irrigation investments relatively stable over this time period despite a 41 percent decline in federal government investment (CNA 1995). Given the relatively poor performance of much Mexican irrigation infrastructure in the early 1990s, with water conveyance losses in gravity-based schemes at 40 percent, losses in the minor canals at 20 percent, farm level losses of 30-50 percent, and an overall efficiency of only 30 percent, private participation will be essential for the continued development and maintenance of the sector (Gorriz, Subramanian, and Simas 1995). Evidence for the Alto Rio Lerma District shows that improvements in performance are already taking place, as the amount of sediment removed from canals and drains increased more than five times after irrigation management transfer (see also Section 9). Nationwide, irrigation budgets have increased from US$109 million (US$41 million short of the estimated US$150 million needed for sustainable O&M of publicly irrigated land) in 1990 to US$190 in 1993, with user contributions rising from US$40.4 million in 1990 to US$163 million in 1993 (Johnson 1997).

Brazil has also had a long history of private sector involvement in the irrigation sector in all areas of the country outside of the northeast. The private sector has been responsible for approximately 95 percent of Brazil’s irrigation development in southern, southeastern, and western Brazil, and the government has generally provided only minor assistance to private initiatives through credit programs and supporting infrastructure. During the late 1980s, paralleling developments in Mexico during the same time period, the Brazilian government came to the conclusion that its role as instigator, financier, and manager of public schemes in the northeast should be curtailed in favor of greater stress on the government as the facilitator and regulator of privately-financed irrigation in this impoverished region (ODI-IIMI 1990). Between 1986 and 1990, irrigated area in the

Brazilian northeast expanded by 250,000 ha due to large influxes of private investment (Pomerantz and Emanuel 1992).

Chile's system is among the most privatized in Latin America, and Chilean farmers have long had to contribute substantial funds (up to 75 percent) to new pumping and channel irrigation projects, thus limiting construction to those systems that offered high profitability. Government investment in irrigation infrastructure declined at a rate of almost 3.46 percent between 1966 and 1993, with particularly rapid declines in the wake of the revolutionary 1982 water law. The trend seemed to be shifting towards slightly increased government involvement in the sector in the early 1990s, however, as investment increased from US$3.64 million to US$39.39 million between 1989 and 1993 (an increase of 1,082 percent) (Gazmuri Schleyer 1997). Large dams are still publicly funded, but users must pre-approve all construction projects and receive full O&M control after project completion. The results of heightened private sector involvement have been impressive, for while irrigated area declined slightly on a per capita basis between 1966 and 1996 - from 0.13 irrigated ha per capita to 0.09 irrigated ha per capita - agricultural exports rose at a rate of 16.5 percent per year during the same period (Gazmuri Schleyer 1997).

LAC countries without the same history of private sector irrigation involvement as Mexico, Brazil, and Chile have also been forced to encourage private sector investment because of the failure of large-scale hydraulic schemes, albeit at a later date. For example, while the Peruvian government viewed large hydraulic projects as necessary for the storage and diversion of water from the Andean watersheds to the arid coastal region, many of these schemes were not economically viable. In addition, unreliable finance kept a number of projects under construction for many years, and some projects initiated in the 1960s are still not completed. Recognizing the need for enhanced private participation, the government introduced private sector infrastructure investment into irrigation for the first time under Decree 758, passed in 1991. Under the decree, concessions may be granted to both national and foreign companies for the construction, repair, conservation, and operation of public services works (ECLAC 1994). In addition, the 1991 Agricultural Investment Promotion Law (Ley de Promoción de las Inversiones en el Sector Agrario) transferred full responsibility for the management and administration of irrigation systems to farmers. Private sector investments in the Peruvian water sector were projected to account for 36 percent of all investments and 40 percent of investments in the Central Region between 1993 and 1997 (Uruburu Valencia 1993).

Heightened government capacity in its role as regulator and facilitator will be needed if the private sector is to re-emerge as the dominant force in irrigation development in LAC. While water markets have proven themselves the most effective way in which to ensure optimal water allocation, these institutions often do not emerge on their own, and may require public investment in the registration and security of water rights, monitoring of water use, and implementation of measurement systems (Lee and Jouravlev 1998). As discussed further in Section 10, governments must walk a fine line between creating the conditions necessary for a market structure to emerge and intervening harmfully in the efficient functioning of such a market. Governments should only intervene when a clearly sub-optimal outcome has led to clear management problems and non-sustainable use of the water resource, although such discretion is often hard to achieve.

Furthermore, while the private sector has already played a role under relatively unfavorable conditions, credit facilities and technical assistance could further stimulate investment in the irrigation sector. Without government loan guarantees, it is unlikely that the 250,000 additional ha of private irrigation investment in the Brazilian northeast would have materialized (Pomerantz and Emanuel 1992). The Mexican federal government has recently taken direct measures to increase the scale of private irrigation investment. The New Agrarian Act expands the land ceiling for irrigated land from 20 to 100 ha, thus providing an incentive to large private investors (Saleth and Dinar 1999). The Fondo de Inversiün en Infraestructura (FINFRA), established by the Mexican government in 1995, is an infrastructure investment fund mandated to encourage new private sector projects through venture and subordinated capital. It began operations with approximately US$250 million, and will receive funding from privatization proceeds (ECLAC 1998). The Chilean government has also recently increased its subsidies for small-scale infrastructure project investment (Gazmuri Schleyer 1997). Subsidization, however, has come under growing criticism for encouraging investment in non-viable projects with low rates of return.

Since the 1982 water law brought the discipline of the market to Chilean water management, growth in Chilean agricultural production without a concomitant expansion in irrigated area seems to reinforce the point that improvements in the efficiency of existing irrigated area are often more effective than further investment in the expansion of irrigated area.

Governments can play a positive role in partnership with the private sector. In both Chile and Mexico, a federal entity with responsibility for irrigation development—the CNR (Comisión Nacional de Riego) in Chile and the CNA (Comisión Nacional del Agua) in Mexico—has played an important role in facilitating private sector involvement in the irrigation sector. The CNR is charged with ensuring the expansion and improvement of irrigated area. Its main responsibility involves the implementation of the 1985 “Law to Encourage Private Investment in Irrigation and Drainage Works,” under which the state may reimburse up to 75 percent (95 percent for poor farmers) of private investment for construction and rehabilitation of irrigation and drainage works or for mechanical irrigation equipment that increases irrigated area, improves water availability in an area of short supply, or reclaims poorly drained or waterlogged land (ECLAC 1995). Total investment costs cannot exceed US$400,000, with the exception of users’ organizations, which can spend up to US$800,000. Funds are awarded through public competitions organized quarterly by the CNR (ECLAC 1998).

The CNA has played an important role as a technical resource to district irrigation management in Mexico. Each year, the CNA projects overall water availability for the coming season (including groundwater) and provides this information to the district. The CNA also provided the majority of its maintenance equipment to the modules as part of the transfer program, thus empowering them with the tools necessary to maintain ditches and drains (albeit old equipment in many cases) (Johnson 1997). During the ongoing transfer process, the CNA provides financial support through investments for rehabilitation and modernization projects and the acquisition of equipment for district conservation (ECLAC 1998).

While the private sector never really disappeared from the LAC irrigation scene, it is clear that it is becoming an increasingly important force in irrigation development and maintenance as governments pull back their public sectors into an increasingly regulatory role. However, while it is fairly clear that the increasing involvement of the private sector will bring with it mainly positive benefits, it is also clear that a number of issues remain to be resolved as this transition process gathers steam. As irrigation systems place an increasing strain on limited ground and surface water resources, how well will LAC governments regulate water use on the way in and water quality on the way out if they are not directly involved in management? Perhaps more pressingly, as farmers are increasingly asked to pay for irrigation services at cost, how many will find themselves unable to meet their payment obligations? The Alto Rio Lerma District in Mexico experienced a drop in staple crop prices (sorghum, maize, wheat) of approximately 30 percent between 1984 and 1994, and many small private growers and members of the ejidos found themselves hard pressed to pay the water fees necessary to sustain private sector involvement (Johnson 1997). These issues are discussed in more detail in Section 10.

7. NONAGRICULTURAL WATER DEMAND

A large share of the population in LAC lives in cities. It is estimated that the populations of Mexico City and Sao Paulo will soar to 25 million and 22 million respectively, well before the year 2010 (Anton 1993). Until 1930, only three countries (Uruguay, Argentina and Cuba) had the majority of their population living in the urban areas. However, 60 years later, 14 countries had an urban population majority and overall, 71.2 percent of people in Latin America lived in urban areas and in the peripheries of cities. Low service levels are particularly a serious problem in the rapidly expanding peripheries of cities. Cost-effective technologies and innovative strategies are therefore urgently needed. Table 15 summarizes a number of indicators for municipal water consumption and wastewater production in several large metropolitan areas of Latin America. For the cities shown, water consumption (in liters per capita per day) ranges from a low of 43 liters in El Alto, Bolivia, to a high of 630 liters in Buenos Aires, Argentina (Anton 1993). The amount of water wasted and lost in urban distribution systems, homes, commercial establishments, and public facilities is often huge. The average level of unaccounted-for water (UFW) consumed by "illegal" users and lost during distribution in World Bank-assisted urban water projects is about 36 percent. In Santiago, about 28 percent of water remains unaccounted for, and Mexico City, Barranquilla (Colombia), and Lima (Peru) have UFW levels as high as 60 percent. Region-wide in LAC, the average is 34 percent for the well-run urban water supply companies, and from 40-60 percent for the rest (Lee and Jouravlev 1997), compared to 10-15 percent in well-managed systems in developed countries. Although some of this UFW is unreported water use by public agencies or unauthorized private use, much of it is losses into the soil or salt sinks (Bhatia and Falkenmark 1993).

Table 16 shows the principal water sources of major cities in LAC. In the Caribbean region, surface water is scarce, but aquifers (mainly karstic) are often suited for urban supply. In Havana, almost 100 percent of the water supply is drawn from groundwater; other cities using groundwater extensively include Kingston and Montego Bay in Jamaica; San Juan, Puerto Rico; Mérida and Torreón-Gómez Palacios in Mexico; Port-au-Prince, Haiti; Nassau in the Bahamas; and Bridgetown in Barbados. Many cities in volcanic areas are also well situated to draw their water supply from groundwater sources. Guatemala City, Managua (Nicaragua), Mexico City, Quito (Ecuador), and San José (Costa Rica), for example, have important volcanic aquifers that are tapped for their water supply. In fact, Guatemala City, Managua, Mexico City, and San José get most of their water from groundwater reservoirs or related springs, and Quito draws about 40 percent of its water from groundwater sources (Anton 1993). A large number of cities depend partially or totally on alluvial valley aquifers, particularly those in the Andean region. Some examples are Chocabamba, Bolivia; Valencia and Maracay in Venezuela; and Querétaro and San Luis Potosí in Mexico. Groundwater also may become the main source for expansion of urban supply systems in Montevideo in Uruguay; or Recife and Salvador in Brazil (Anton 1993). In Buenos Aires and São Paulo, many of the new

Table 15 Selected indicators for urban water supply and sanitation, major cities in LAC.

City	Country	Population	Share of growth (1990-95)	Share of urban HH connected to water	Share of urban HH connected to sewage	Share of urban HH connected to electricity	Per capita water use	Wastew. generated	Wastew. treated
			(%)	*(%)*	*(%)*	*(%)*	*(l/day)*	*(m^3/sec)*	*(%)*
Buenos Aires	AR	11,802,000	1.2	N/A	N/A	N/A	630[a]	96[a]	N/A
El Alto	BO	726,000	N/A	33	20	83	43	N/A	N/A
La Paz	BO	1,250,000	3.6	55	58	94	73	1	0
Brasilia	BR	1,778,000	2.8	90	74	98	213	N/A	54
Curitiba	BR	2,240,000	3.0	96	75	99	150	5	56
Recife	BR	3,080,000	1.8	79	38	99	100	N/A	52
Rio de Janeiro	BR	10,181,000	1.0	95	87	100	299	34	23
Sao Paulo	BR	16,533,000	1.8	N/A	N/A	N/A	270-293[a]	22	N/A
Santiago	CH	4,891,000	1.7	98	92	94	286	14	2
Bogota	BO	6,079,000	3.0	99	99	99	176	10	N/A
Guayaquil	EC	1,831,000	3.1	80	55	95	261	4	10
Quito	EC	1,298,000	3.0	94	93	100	286-310[a]	2	N/A
Georgetown	GU	150,000	N/A	64	77	85	427	N/A	23
Asunción	PA	1,081,000	3.1	58	10	59	236	1	4
Lima	PE	6,667,000	2.7	70	69	76	211	11	5
Caracas	VE	3,007,000	1.0	N/A	N/A	N/A	300-388[a]	N/A	N/A
Valencia	VE	1,462,000	5.2	90	86	90	N/A	N/A	N/A
Mexico City	MX	16,562,000	1.8	N/A	N/A	N/A	360-527[a]	54	N/A

Source: WRI 1998; [a]Source: Anton 1993.

Table 16 Principal water sources of major cities in LAC

City	Population	Water demand	Surf. water	Ground-water	Surface + Groundwater	Problems
	(million)	*(m^3/sec)*				
Buenos Aires (AR)	12.6 (1995)	85			X	Polluted surface water
Cochabamba (BO)	0.5	0.65 - 0.75			X	
São Paulo (BR)	16.8 (1995)	50-55	X			Contamination, near a divide
Recife (BR)	3.2 (1995)	14.79			X	
Santiago (CH)	4.8 (1995)	20	X			Suspended material, pollution
Bogotá (CO)	5.1 (1995)	17	X			Contamination
Santa Marta (CO)	0.3	1.2			X	
San José (CR)	0.6 (1995)	6.8			X	
Guatemala City (GU)	1.1 (1995)	5		X		Location on divide, lack of water
Mexico City (ME)	22.8 (1995)	50		X		Location on high plateau
Managua (NI)	0.9 (1995)	2.3			X	
Lima (PE)	7.1 (1995)	25 (1990)			X	Saline intrusion, pollution
Montevideo (UR)	1.6 (1995)	5	X			Pollution, limited resources

Source: Anton 1993.

neighborhoods and industries get their water from wells, because their distance from the municipal system and their low population density do not justify the expense of extending municipal waterlines or because the financial resources of the water companies are insufficient to install the connections. When potable groundwater is easily available, fringe communities use this resource, even in cities where surface water is abundant, cheap and of good quality. For example, in Asunción, Paraguay, many industrial factories depend on wells in spite of the good quality and reliability of the river water in the core of the urban area. In 1990, about 30 percent of the water consumed in LAC cities came from nearby aquifers. At the present and projected rate of increase in groundwater extraction, by the year 2020, up to 40 percent of urban water will come from aquifers. At that time, about 850 cubic meters per second will be pumped from the ground to satisfy the requirements of the urban populations of the big cities. This is 3.5 times the present extraction rate (about 260 cubic meters per second) for the whole urban groundwater supply, including only cities with more than 100,000 people. If smaller towns and agricultural areas are included (present rate of use, 2,500 cubic meters per second), it is easy to project the importance of groundwater use in the 21st century.

Several factors have promoted the development of groundwater supplies in some of the urban areas. Surface sources, with typically seasonal or irregular flows, have become increasingly unreliable because of deforestation and degradation of the landscape in the upper basins. Also, various human activities in the Andean highlands have had deleterious effects on the quality of water in the streams flowing toward the plains. Mining has not only devastated landscapes and, therefore, increased erosion and the amount of transported soil material in the streams, but is also a source of a number of toxic substances (for example mercury and cyanide in the widespread gold-mining areas) that may seriously affect the potability of the surface water. The growth of the cities themselves also may make the continued or expanded use of traditional water resources difficult or uneconomical (Anton 1993).

For the Caribbean islands, water is obtained from two sources: reservoirs in the highlands (Kingston, Jamaica; Port-of-Spain, Trinidad and Tobago; and San Juan, Puerto Rico) and aquifers, usually karstic, in the coastal plains (Havana, Cuba; Bridgetown, Barbados; Nassau and New Providence in the Bahamas; Kingston, Jamaica; and along the northern coast of Puerto Rico). Surface water is usually confined to the relatively short rivers descending from neighboring highlands. In some cases, the volume of water is considerable (for example, the Usumacinhta River in Mexico and the San Juan River in Nicaragua), but in others, it is insufficient to meet the requirements of existing cities. Karstic aquifers provide almost all the water consumed in the cities of Mérida (Yucatán, Mexico) and Havana (Cuba).

Table 17 shows the water supply and sanitation costs and tariffs for selected countries in LAC and Table 18 shows the wide variation in efficiency for selected water utilities in Latin America. The provision of water is most expensive in the Bahamas due to the island situation of the country, and cheapest in Central America. Water supply in marginal urban areas and by trucks is significantly more expensive than public connections and only topped by the price of bottled water. The ratio of revenue to operational costs varied from 0.01 (Aguas Corrientes, Argentina, 1991) to 1.67 (DIMA, Chile, 1995), and the wage bill accounted for 12 percent (private enterprises, Chile, 1995) to 72 percent (Peru, 1993/94) of revenues.

The Latin American Office of the World Bank estimated in 1985 that US$92 billion in investment will be required in the water supply and sanitation sector to achieve universal coverage by the year 2000; and the Regional Plan of Investment in Health and the Environment estimated a total investment of US$115 billion during 1993-2004. As can be seen in Section 9, investments by the two largest investment banks in the region, the Inter-American Development Bank and the World Bank, were far below these levels, although the investment volume in this sector has increased steadily. At the same time, the German Government, CIDA (Canadian International Development Agency), the Caribbean Development Bank and other agencies, including JICA (Japan International Cooperation Agency), USAID, UNICEF, and the European Community provided investments in the sector. For the countries that provided full information on sector investments, the mean ratio of external contribution to total investments increased to 45 percent at the beginning of the 1990s, compared to 30 percent in the previous decade (PAHO 1997).

Table 17 Water and sewerage costs and tariffs, LAC

Country	Av. cost of water production		Average tariff		Marginal areas	Truck		Bottled water	Sewerage tariff
	Urban	Rural	Urban	Rural	Urban	Urban	Rural		
				(US$/m^3)				*(US$/l)*	*(US$/m^3)*
Argentina	0.21	0.39	0.28	0.33	-	-	-	0.4	0.18
Bahamas	5.10	6.65	16.50	4.12	-	-	-	0.2	3.84
Bolivia	-	0.32	-	-	-	-	0.60	0.5	0.22
Brazil	0.38	-	0.48	-	0.64	-	-	-	0.64
Costa Rica	0.05	0.05	7.26	5.37	1.63	-	-	1.0	0.99
Dominican Republic	0.40	0.20	0.25	0.10	0.20	0.80	1.00	0.2	0.70
Ecuador	1.83	0.10	1.00	0.10	1.00	1.50	-	-	0.55
El Salvador	0.39	0.05	0.23	0.05	0.11	2.85	2.85	0.5	-
Guatemala	0.14	0.05	0.11	0.10	0.84	2.25	-	0.8	0.02
Haiti	0.35	0.20	0.38	0.10	5.00	3.80	-	0.4	-
Mexico	0.33	0.26	0.16	-	0.07	1.97	1.97	0.3	0.05
Nicaragua	0.19	-	0.23	-	-	-	-	1.3	0.07
Panama	-	-	0.26	0.26	0.19	-	-	-	-
Paraguay	-	-	0.25	0.33	-	-	-	1.2	-
Suriname	0.40	-	0.02	0.07	-	0.10	-	1.0	-
Trinidad & Tobago	-	-	0.19	0.19	-	4.00	4.00	0.4	-
Uruguay	0.41	-	0.86	-	-	-	-	-	-

Source: PAHO 1997.

Table 18 Measures of efficiency for selected water utilities in Latin America

	Revenues/ oper. costs	Wage bill/ revenues	Cove-rage	Hours of operation	Employees/ 1,000 connections	Water losses
Chile (1995)						
- Public Enterprises (avg.)	1.27	0.15	99	23	2.5	31
- Private Enterprises (avg.)	1.21	0.12	100	24	4.9	17
Honduras (1994)						
- SANAA – Tegucigalpa	0.36	0.25	53		13.6	50
- SANAA - Other	0.48	0.43	77	10	5.0	
- Munic. Authorities	0.41	0.29	67	11	4.0	
- DIMA	1.67	0.21	65	22	6.0	37
Mexico (1994)			85			
- Auton. Municipalities				14	6.3	47
- Regulated Municip.				15	5.8	46
- Auton. States				15	5.7	49
- Regulated States				16	5.5	46
Peru (1993/94)			72	14		
- SEDAPAL	1.17	0.19	75	14	2.1	38
- SEDAPIURA	0.86	0.35	81	18	7	55
- Admin. Sullana	0.97	0.32	70		4.4	49
- SEDAQOSQO	1.16		55		5.7	46
Argentina						
- OSN (1985)	0.89	0.57	72		9.6	
- Aguas Argentinas (1994)	1.22	0.39	77		3.6	
- Aguas de Corrientes (1991)	0.01	0.37	66		7.4	61
- Aguas de Corrientes (1995)	0.99	0.35	73		2.6	45
Brazil (1995)						
- SANEPAR	1.08	0.70	99		2.8	28
- CASAN	0.99	0.72	88		3.3	35
- CESAN	1.13	0.67	95		3.6	28
- SABESP	0.99	0.39	94		2.5	36
- CAESB	0.70	0.63	90		3.2	24
- SANESUL	0.71	0.44	94		4.3	47
- EMBASA	1.01	0.61	100		4.2	54
- CAEMA	0.82	0.78	78		8.0	59
- CAGECE	0.84	0.58	74		2.9	39
- CAER	0.40	0.25	99		7.4	43

Source: Spiller and Savedoff 1999.

8. WATER MANAGEMENT IN LAC

In the water laws in most of LAC, there is a clear distinction between public and private rights over water resources: a distinction inherited from the original Spanish and Portuguese legislation and reinforced by the promulgation of Civil Codes drawing heavily on the Napoleonic Code (Lee 1990). The exception was Brazil, where the principal of riparian rights was followed. The 1917 Mexican Constitution created another exception, for although the authority of the states over water resources is weak, the Constitution establishes significant private, or rather *eijido*, rights over water. Despite these differences, without exception the Constitutions of the independent countries of Latin America and the Caribbean establish a clear right of public intervention in water resources (Lee 1990).

In most Latin American countries, responsibility for the management of water resources is shared by several institutions, leading to fragmentation of responsibilities and inefficient management of water resources. Governments in LAC have traditionally been organized on a sectoral basis, so that different government agencies have specialized in activities related to the uses of water resources, including hydroelectricity production, provision of drinking water, and irrigation. Among these, the generation of hydroelectricity is generally the most systematically developed and modern in the countries of the region. The next most developed activities, in terms of managerial systems, are water supply and sanitation services. The least-developed activity managerially has been irrigation. It is also quite common for problems such as water pollution to figure on the agendas of a great many institutions, centralized agencies, municipalities, irrigation departments, water supply companies, and hydroelectric companies, among others (ECLAC 1995).

According to Lee (1990) the water management systems in the region can generally be grouped into three general categories:

- water management systems, which are characterized by the existence of many active public and, in some cases, private institutions with only weak central co-ordination;
- water management systems, which have central coordination of policy, but institutional dispersion of responsibilities for the specific uses of water;
- water management systems with centralization of authority and little or no dispersion of responsibilities either for individual uses or by regions.

When the administration of water resources is divided up among several organizations, and no one organization dominates, then there is typically a weak central coordinating mechanism. Argentina, Bolivia, Chile, Colombia, Guatemala, Paraguay, Uruguay, and Venezuela all fall within this category. Within these systems, there are considerable differences in the degree of centralization and decentralization of decision-making authority and in the territorial units in which the different institutions operate. Often, some functions are decentralized to autonomous public agencies, and other functions are carried out by the private sector, like the management of hydroelectric power generation, public water supply, or irrigation. Territorial decentralization is rare, but characteristic of Colombia, for example. Brazil, Costa Rica, El Salvador, Panama, and Peru all have a stronger central coordination, at both the federal and state levels of government. These countries typically coordinate policies through formal institutions at the inter-ministerial level, which report directly to the President. In the Caribbean, coordination is often carried out through the water supply agency. In four countries - Cuba, Ecuador, Honduras, and Mexico - responsibility for the administration of water resources has been centralized in a single institution (Lee 1990).

The differences in institutional structures among the countries of the region make it difficult to claim that there is one prevailing style of water management or water administration in LAC. The difference in the structures of the water management systems reflects differences in the style of management. In general, water management is characterized by strong public intervention and heavy dependence on technological solutions.

The implementation of the concept of river basin management has been very rare in LAC. During the first decades of construction of water works, there was little interest in multiple water use or "river basin management." Beginning in 1940, commissions (in Mexico) and corporations for the integrated development of river basins (that is, for regional development at the river basin level) were set up. These corporations set out from the construction of water projects to embrace extensive areas under their jurisdiction and to make investments in a number of sectors. During the 1970s, the concept of "watershed management" appeared on the scene, mainly with the aim of reducing the deposition of sediment in existing dams and controlling landslides or flooding (Dourojeanni 1994); see also Section 10 for more recent developments in river basin management.

Box 1 Integrated water resources management in the Caribbean

- **Integration and coordination of water resources management.** Establishment of a national body responsible for formulating policy for the management and comprehensive assessment of water resources; in function of national, social and economic growth trends and the countries' development strategies; and with the participation of the user sectors and the rest of society.
- **Data collection and information management.** Assessment of existing databases for their capacity to provide necessary data for integrated water resources management and strengthening of technical, logistical and financial capacity of national systems in order to improve monitoring, collection and processing of water-related data for decision making.
- **Human resources development.**
- **Strategies to determine social, economic and ecological value of water.** Incentives must be provided to encourage efficiencies in the use of water.
- **Research.** Emphasis on measures to strengthen procedures to monitor and respond to the impacts of national and environmental hazards on water resources.
- **Land use.** Policies to develop land use plans, the regulatory machinery and the necessary measures for enforcement will be important for effective water resources management and conservation.
- **Public education and community awareness.** Effective public education and community awareness program.
- **Networking.** Creation and use of national and regional networks such as the International Water Resources Network (IWRN) as a channel for information sharing and for technology transfer.

Source: Fernandez and Graham 1999.

As in most of LAC, comprehensive water resources assessment is still lacking in many island states of the Caribbean. Jamaica is the only country with a Water Resources Development Master Plan and an Irrigation Master Plan, to guide allocation and development within the sector (Fernandez and Graham 1999). However, promising steps have been taken toward integrated water resources assessment in the Caribbean, as the countries agreed on a plan of action during an IICA (Inter-American Institute for Cooperation in Agriculture), St. Lucia, workshop in 1999 (see also Paulett Iturri 1999 for IICA activities on integrated water resources management). The activities proposed under this plan of action are applicable to integrated water management elsewhere in the region (see Box 1).

9. RECENT TRENDS IN IRRIGATION INVESTMENT IN LAC

DECLINE IN INVESTMENT IN IRRIGATION

Comprehensive data from the Inter-American Development Bank (IDB) and the World Bank (WB), the largest funding agencies for irrigation development in the LAC region,[1] together with more limited data on national government investments, indicate that investments in irrigation—and in the water sector as a whole—have declined steadily over the past fifteen years. During 1961-96, the IDB funded US$28.7 billion of investment in the water sector in Latin America and the WB funded US$20.1 billion (in 1990 constant US$). As can be seen in Figure 6, combined total water sector investments in the region peaked three times during the last 30 years, at US$2.3 in 1974, US$2.5 billion in 1983, and at US$2.4 billion ten years later, but the general trend has been downward since 1983.

Over the full period, 1962-95, investments in the water sector as a whole by the two funding agencies increased at 1.86 percent per year (Table 19, Figure 6). However, the growth in real investment took place in the 1960s and 1970s, with an annual growth of 6.35 percent between 1962 and 1982. Thereafter, investments declined, at 4.68 percent

[1] Bilateral funding agencies, like CIDA, GTZ (Germany), and JICA also account for significant investments in irrigation, but details were not available for this report.

per year during 1982-95. The largest drop in investments occurred during the debt crisis of the 1980s. Funding by the IDB and WB moved in parallel in the first period, with annual growth of 6.60 percent and 5.84 percent, respectively (Figure 7). However, during the 1980s, WB funding was still growing, albeit at a low 1.10 percent per year, whereas IDB investments declined at a rapid 11.71 percent annually during this period. These trends reversed during the early 1990s, with IDB funding picking up again, at 2.70 percent per year, and WB funding declining rapidly, at 8.45 percent annually.

Combined investments in the irrigation sector increased at 4.11 percent per year during 1962-82 and peaked in 1973 at US$977 million (Figures 6 and 8, Table 19). Thereafter, investments declined by 5.90 percent annually. Funding was virtually stagnant during the 1980s and then dropped to negative 12.40 percent per year at the beginning of the 1990s. Again, the trends since the 1980s are reversed for IDB and WB. Whereas the IDB experienced a strong contraction in irrigation sector projects during the 1980s growth in WB investments in irrigation accelerated at 5.68 percent annually during 1982-89 and rapidly declined in the early 1990s (Figure 8). Figure 8 also depicts the volatility in funding during the so-called lost decade of the late 1970s and 1980s. Funding by the WB dropped to a low during the mid-1970s, then increased rapidly until the beginning of the 1980s to decline again until the mid-1980s. As for the IDB, the level of funding increased rapidly after the mid-1970s, and then declined rapidly at the end of the 1970s/beginning of the 1980s. Overall, growth in IDB funding for irrigation declined at 4.03 percent per year during 1962-95, whereas growth in WB funding accelerated at 2.63 percent annually during the same period. In 1986, the WB overtook the IDB as major multilateral funding agency in irrigation in LAC. Figure 9 depicts the trend in the share of funding for irrigation in the overall IDB and WB funding for irrigation. The relative importance of irrigation in IDB water sector funding declined from between 20

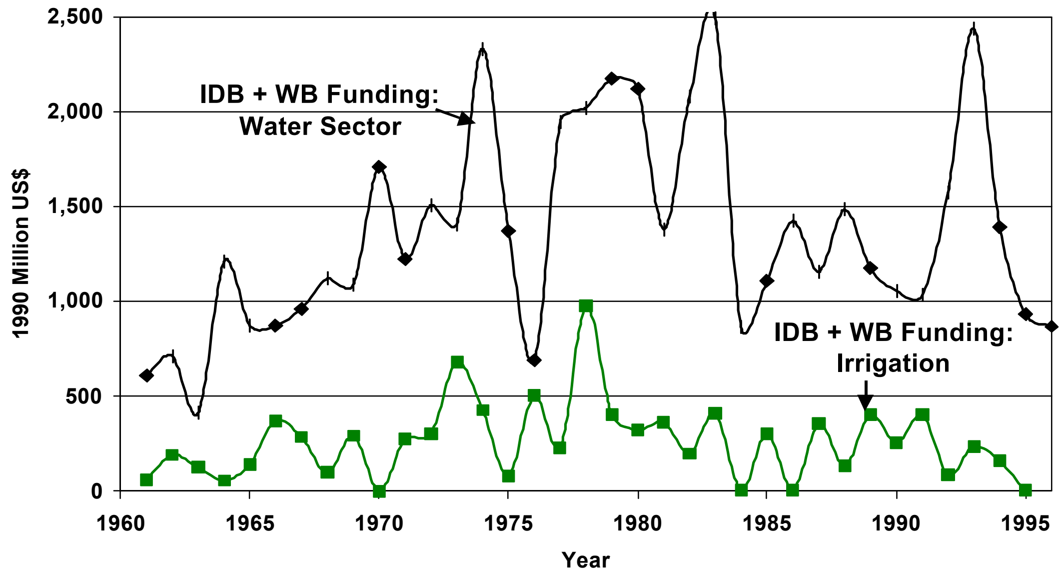
Table 19 Investments by the WB and the IDB in the water sector in LAC, 1961-96

	1962-82	1982-95	1982-89	1989-95	1962-95
	(percent per year)				
Total investments[/a]	6.35	-4.68	-6.51	-2.51	1.86
IDB	6.60	-5.33	-11.71	2.70	1.73
WB	5.84	-3.42	1.10	-8.45	2.09
Irrigation	4.11	-5.90	0.05	-12.40	0.04
IDB	1.46	-11.90	-18.17	-3.98	-4.03
WB	6.95	-3.67	5.68	-13.54	2.63
Hydropower	8.21	-24.57	-11.80	-37.15	-6.13
IDB	15.50	-24.23	-19.50	-29.40	-2.17
WB	-4.84	..	20.39	..	..
Water Supply & Sanitation[/b]	5.55	1.59	-4.16	8.74	3.97
IDB	1.86	4.44	-0.34	10.30	2.87
WB	24.53	-2.33	-8.78	5.77	13.17

Note: Growth rates are three-year moving averages. [/a] Total investments, irrigation, etc. are sum of IDB and WB funding; [b/] for IDB, this component includes, ‘Sanitation’ and ‘Other Water-Quality Related Projects’ for WB, it includes Rural Water Supply, Urban Water Supply, Sewerage, Water Supply and Sanitation adj., and Other Water Supply & Sanitation.
Source: Data provided by IDB and WB.

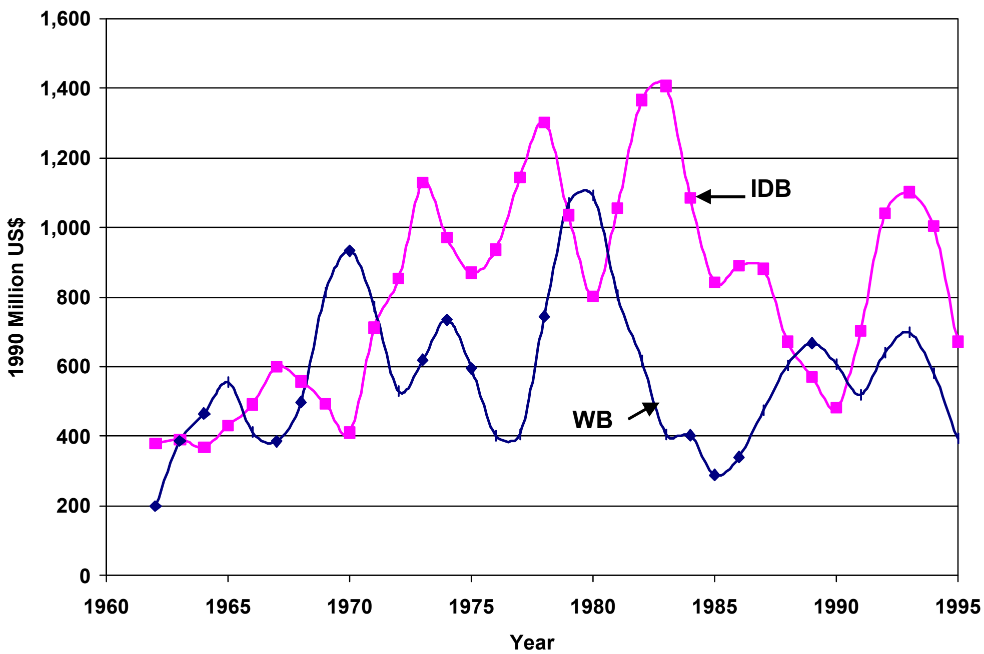
percent and 40 percent during the 1960s and 1970s to a much lower share of 0-20 percent since the beginning of the 1980s. The partial data obtained for the following years seem to support a continuation of this trend. As far as WB funding is concerned, the relationship has been slightly reversed. During the 1960s and up to the beginning of the 1970s, the share of irrigation in the water sector portfolio was relatively minor,

Figure 6 Investments in the water sector and irrigation by IDB and WB, 1962-95



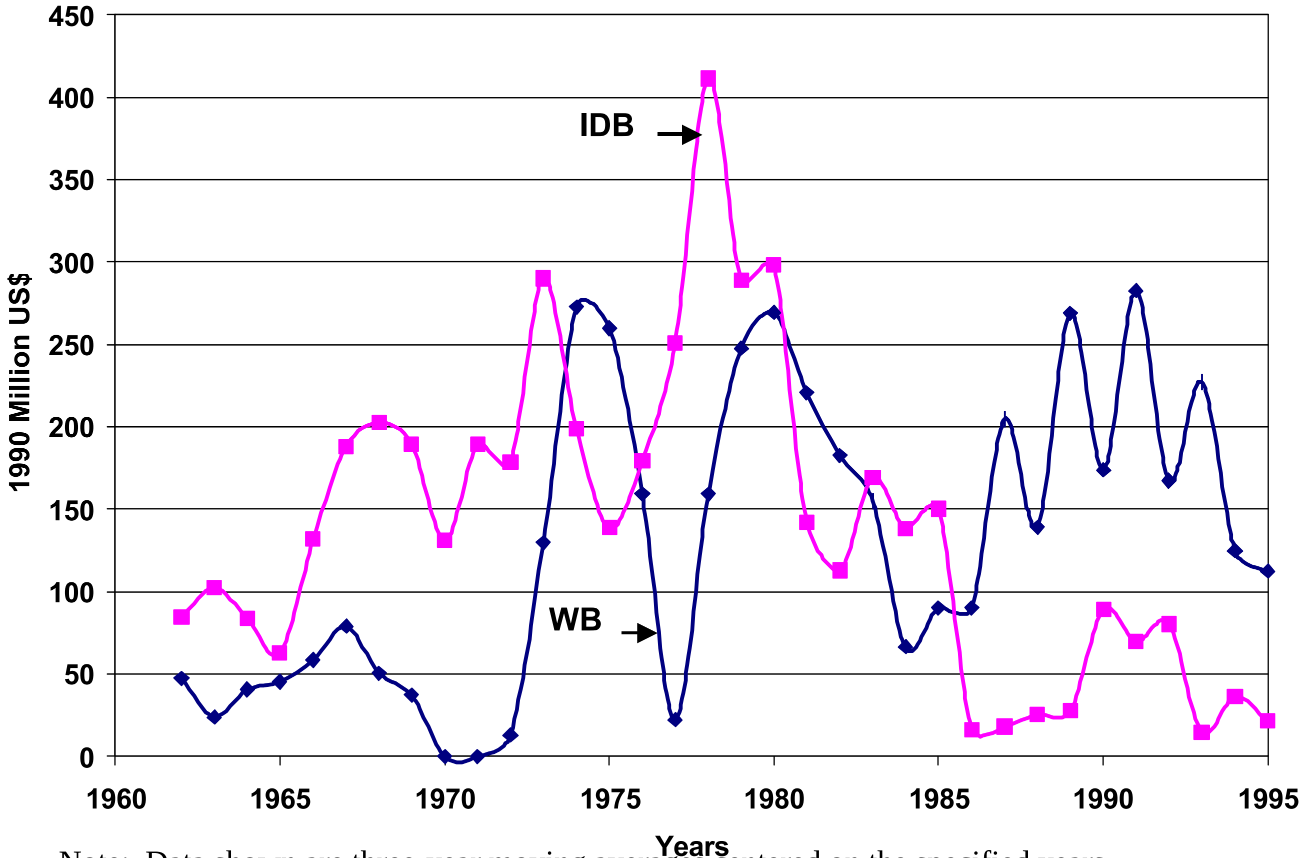
Note: Data shown are three-year moving averages centered on the specified years.
Source: Data provided by IDB and WB.

Figure 7 Investments in the water sector, by IDB and WB, 1962-95



Note: Data shown are three-year moving averages centered on the specified years.
Source: Data provided by IDB and WB.

Figure 8 Investments in irrigation, by IDB and WB, 1962-95



Note: Data shown are three-year moving averages centered on the specified years..
Source: Data provided by IDB and WB.

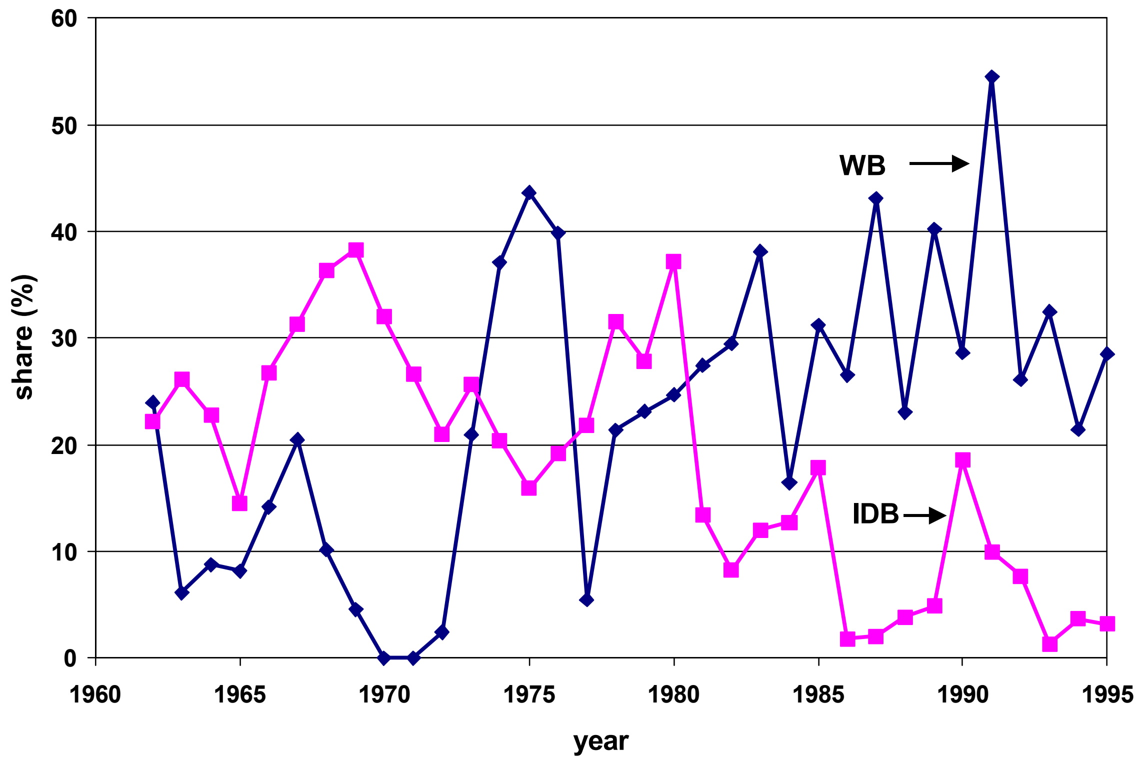
between 0 percent and 25 percent. This was followed by a break in the trend in the mid-1970s with an extremely high proportion in 1975 of 72 percent preceded and followed by several years of low levels of funding for irrigation. Since the 1980s, the share of lending for irrigation in total water sector lending has ranged from 20-45 percent. Moreover, there appears to be a shift from investments into new irrigated areas to rehabilitation and modernization of existing projects, or to a combination of new investment and rehabilitation. However, to examine this trend, the project documents themselves would need to be studied.

The countries receiving the major funding for irrigation from the IDB and WB have been Brazil, Mexico, and Ecuador, with US$5.2 million, US$1.2 million, and US$0.8 million, respectively (in 1990 prices). Mexico alone received 56 percent of all

IDB and WB funding for irrigation, and the three countries together obtained more than three fourths of total irrigation investments by the IDB and WB in the region. Investments by multilateral agencies in Mexican irrigation were concentrated in the 1960s, 1970s, and early 1980s. Irrigation investments in Brazil picked up in the late 1980s and early 1990s (see Figure 10). During 1961-96, Mexico had the largest number of projects funded by the IDB and WB, 53, followed by Brazil and Ecuador, with 12 projects each, and Peru with 10 projects (Figure 11). Trends in investment by multilateral donors are reflected in the development of irrigated area in LAC. The concentration of investment funds and numbers of projects on Mexico fueled the rapid increase in irrigated area in the country, described above. Brazil's rapid increase in irrigated area during the 1980s was likely also furthered through investments financed by the IDB and WB. It is obvious that the bulk of investments in irrigated area were concentrated in those countries that had the largest irrigated areas from the outset as well as significant growth potential and national interest in rapid growth in irrigation. National expenditures in the irrigation sector have generally tracked the decline in international funding, but have often dropped even more dramatically. In Chile, total investment in irrigation declined by 3.46 percent per year between 1965 and 1993. In real terms, annual national investment in irrigation declined from an average of US$75.8 million in 1965-69 to US$18.2 million in 1989-93. In Mexico, public investment in the irrigation sector declined in nominal terms from US$3,600 million in 1981 to US$230 million in 1990 (ECLAC 1998).

Various factors have slowed the expansion in irrigation development. In addition to the increasing capital cost problem and relatively poor performance of existing irrigation, linked to mounting obstacles and the neglect of O&M expenditures, several other financial difficulties have contributed to the decline in irrigation investment. These include increases in interest rates, which greatly affects the cost of irrigation facilities; the decrease in foreign loans, a main source of funding for irrigation development; the policies of budgetary restraints followed by most AC governments; and the increase in energy prices, which in turn sharply increased the cost of pumping and earth-moving operations for construction and land leveling. The financial crisis of the 1980s was

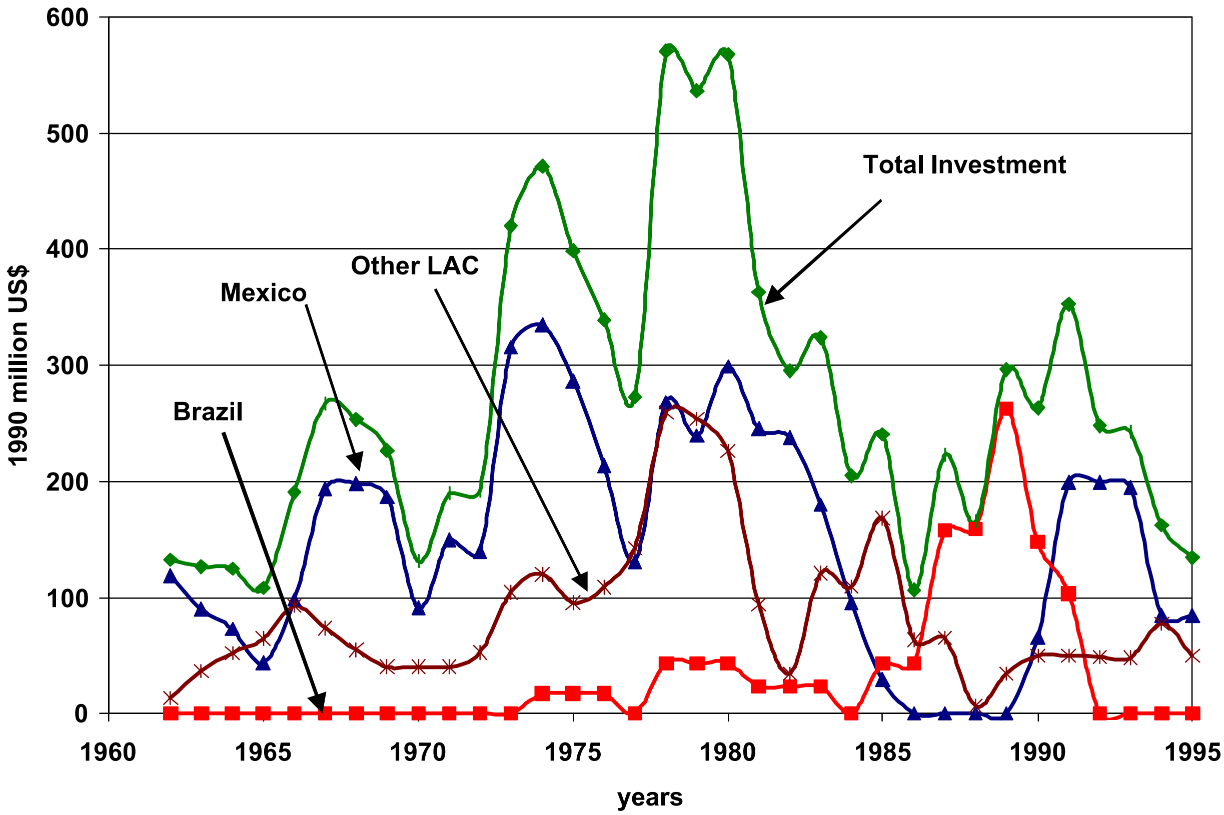
Figure 9 Share of irrigation in IDB and WB water sector portfolio, 1962-95



Note: Data shown are three-year moving averages centered on the specified years.
Source: Data provided by IDB and WB.

a severe deterrent to irrigation development. In addition to the slowdown in capital investment, expenditures on water resource assessment have also declined. In 1990, a detailed analysis was conducted by WMO/UNESCO of the status of Water Resources Assessment in Latin America. The findings of that analysis were that economic circumstances, particularly since about 1983, have severely limited the financial resources available for water resources assessment. Resource management agencies have generally been able to justify allocating resources to project-based data collection, but data collection programs at the national level have deteriorated.

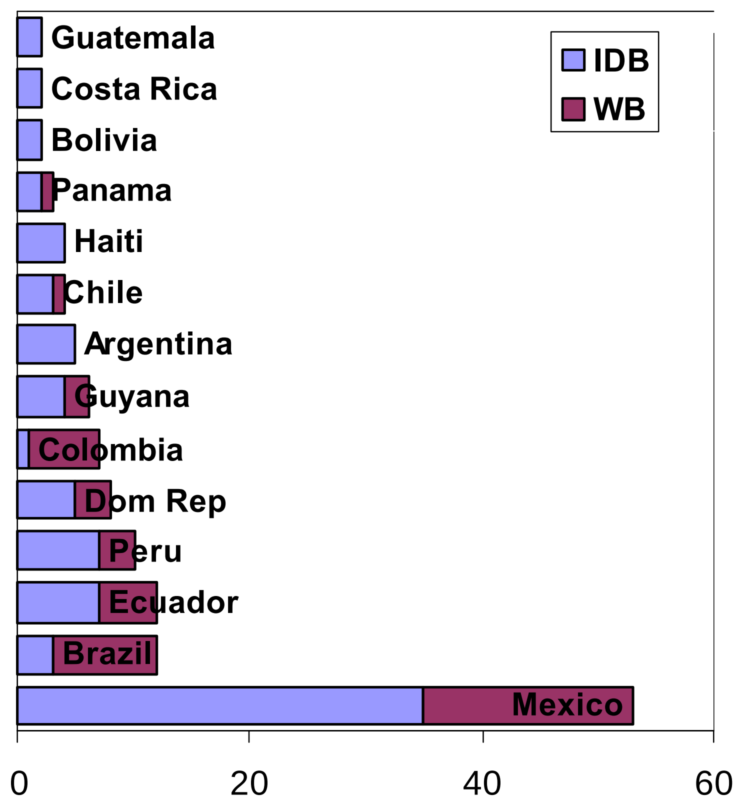
Figure 10 Irrigation investments, IDB and WB, major countries, 1962-95



Note: Data shown are three-year moving averages centered on the specified years.
Source: Data provided by IDB and WB.

The weak demand growth prospects for agricultural commodities, together with financial obstacles and rising marginal costs call for a careful assessment of the role of irrigation in LAC agricultural development. Cost-effectiveness and social and environmental impact are now more important than ever. The actions required to overcome these constraints vary according to country and local circumstances, but some guidelines can be provided. The rehabilitation of saline lands and the modernization or rehabilitation of existing irrigation schemes usually tend to be cheaper and have greater social impact than building new facilities. The economic and social benefits of new

Figure 11 Number of irrigation projects, IDB and WB, 1961-96



Note: Nicaragua, St. Lucia, and Uruguay had one irrigation project funded by WB, and Jamaica and El Salvador one by IDB.

Source: Data provided by IDB and WB.

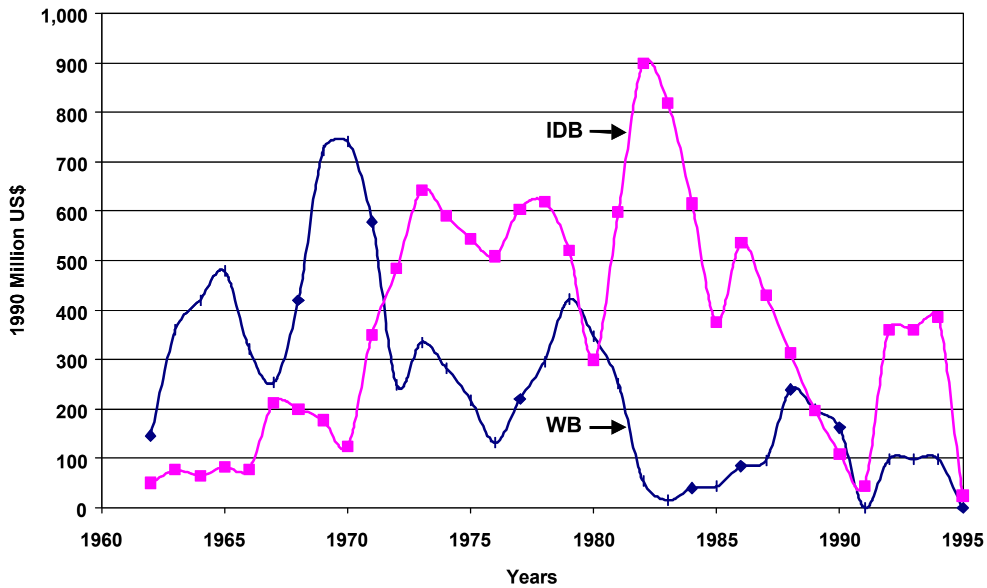
irrigation projects should be calculated as being superior before proceeding. Small irrigation projects in poor areas generally have comparatively greater economic and social impact than larger, more expensive ones. Private sector participation could increase if properly stimulated with credit facilities and technical assistance. Poor control of water distribution, inadequate secondary systems and water metering, and poor training of farmers in irrigation techniques has often led to wasteful use of water in existing schemes and can also lead to secondary high sodium content and alkalinity, making the land very expensive to reclaim (FAO 1988a).

The main constraint on the performance of and future prospects for irrigation development seems to be imposed by the market and price prospects of the crops that may be grown with irrigation, and the high capital costs of irrigation noted above. In order to pay for investments, irrigated lands cannot be used to produce cheap staple foods that can be grown quite satisfactorily in most countries of the region under rainfed conditions. If the project is to be viable, the crop mix to be produced under irrigation must frequently include high-value crops either for the internal market or for export into competitive world markets. Low producer prices give low farm-level returns and consequently reduce the contribution that farmers can make towards O&M. This in turn results in poor maintenance and a deterioration of the irrigation system (FAO 1988b).

Hydropower development, which can provide suitable infrastructure for irrigation, has also received reductions in funding over time by the IDB and WB. Overall funding declined 6.13 percent per year during 1962-95, after a rapid initial growth of 8.21 percent annually during the 1960s and 1970s. Funding has been lowest during the late 1990s (Figure 12).

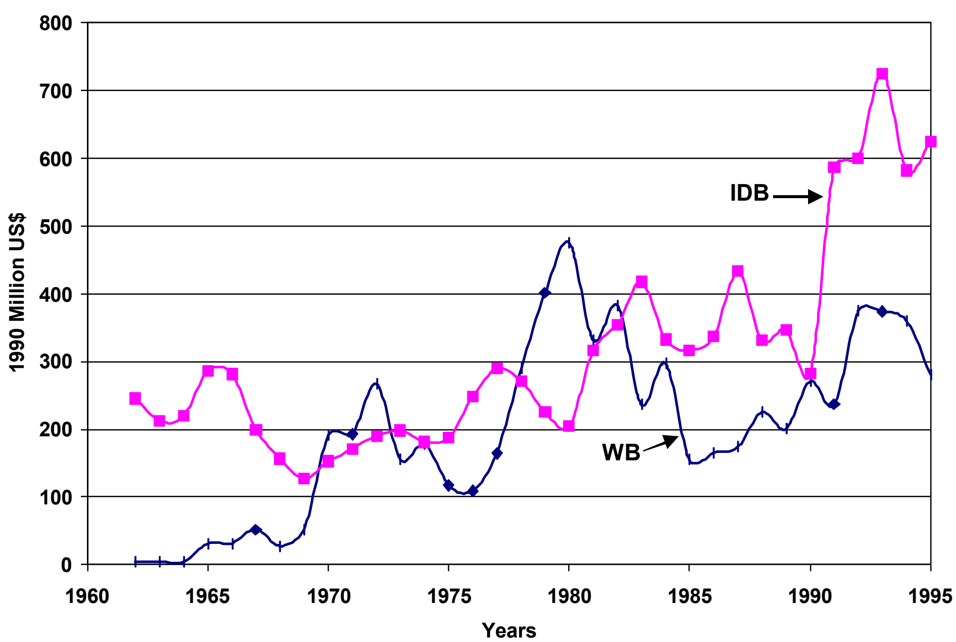
Funding for the urban water supply, sanitation and related sectors, on the other hand, has continued to grow during the last 30 years (with the exception of the debt-crisis years in the 1980s), at 3.97 percent per year during 1962-95 (Table 19, Figure 13). Investments in rural and urban sanitation and sewerage services increased at 5.55 percent annually during 1962-82, and still at 1.59 percent per year during 1982-95. Rates of growth in investment were especially high at the beginning of the 1990s, at 10.30 percent per year in the case of IDB funding, and 5.77 percent per year for WB funding. This sector will likely continue to play a major role in the water sector in the coming decades. Nevertheless, this sector also faces increasing investment costs. In Lima, Peru, the average incremental cost to meet short- and medium-term needs has been $0.25 per cubic meter. However, because of depletion of the presently used aquifer, to meet long-term urban needs, a transfer of water from the Atlantic watershed has been planned, at an estimated average incremental cost of US$0.53 per cubic meter. In Mexico City, water is

Figure 12 Hydropower investments, IDB and WB, 1962-95



Note: Data shown are three-year moving averages centered on the specified years.
Source: Data provided by IDB and WB

Figure 13 Investments in sanitation and other water related areas, IDB and WB, 1962-95



Note: Data shown are three-year moving averages centered on the specified years.
Source: Data provided by IDB and WB.

currently being pumped over an elevation of 1,000 meters into the Mexico Valley from the Cutzamala River through a pipeline about 180 kilometers long, at an average incremental cost of water of US$0.82 per cubic meter, almost 55 percent more than the previous source, the Mexico Valley aquifer (World Bank 1993).

10. CHALLENGES AND STRATEGIES FOR THE FUTURE

Overall, the picture for irrigation and water resources development in the LAC region shows a slowdown in the expansion of irrigated areas, declining investment, rapid increases in demand for nonagricultural uses, increasing development costs and substantial degradation of water and soil quality. These trends pose significant challenges for future water management policy, which can be addressed through two basic strategies: (1) expansion of water availability through investment in new sources of supply; and (2) reforms in water demand management, including efficient reallocation of water to meet increasing demands, improve water quality, and reduce water-related environmental degradation. The future contributions from these strategies are reviewed in the next sections.

Meeting the challenges posed by water scarcity will require highly selective development and exploitation of new irrigation and water supplies. But expansion of new irrigated area is likely to be limited. Investment in irrigation has already been cut substantially, and new investment is not likely to return to previous levels, since irrigation development costs are high and increasing. Most of the best dam sites have been utilized, and the heightened national and international concern over the environmental effects of irrigation projects will make it very difficult to proceed with many possible projects.

Because the potential for expansion of water supplies is limited, reforms in the way water is allocated and utilized must play the primary role in meeting the challenges of water scarcity and water quality in LAC. The most significant required reforms involve changing the institutional and legal environment in which water is supplied and used, to one that empowers water users to make their own decisions regarding use of the resource, while providing correct signals regarding the real scarcity value of water, including environmental externalities. The precise combination of new investments and water management reforms will vary depending on the location, level of institutional and economic development, and degree of water scarcity. But the key elements of appropriate water policy include:

- integrated water management at the river basin level;
- irrigation management transfer and user-managed irrigation;
- water rights, pricing and markets; and
- reform of groundwater management.

Each of these is discussed further below.

RIVER BASIN MANAGEMENT

As was described above, water resource management has generally been highly fragmented in LAC. With increasing water scarcity and competition for use of water, fragmented management is increasingly costly. The realization that fragmented, sector-specific management is no longer sustainable has led to efforts to move toward integrated water resource management at the basin level. The river basin, or watershed, is the hydrologic unit that includes the key interrelationships and interdependencies of concern for water management, as represented, for example, in the linkages between upstream and downstream water users. Competition for limited water resources occurs between different stakeholders/sectors and at different levels: among farmers within an irrigation system; between irrigation systems in the same river basin; between the agricultural sector and other rural uses, such as fisheries or domestic water supply; and more and more often between agricultural and urban and industrial users and uses. Environmental uses also enter the competition. Upland watersheds are source areas for surface and groundwater recharge, while downstream agriculture and urban development are directly dependent on water supplies from the upper watershed.

In many regions, poor management of watersheds through deforestation, the eradication of perennials, and other human interventions in upland areas can lead to soil erosion and decreases in agricultural productivity; siltation of reservoirs and irrigation systems; adverse impacts on fisheries, wildlife, river habitat and recreational water uses; water pollution; flooding of lowland areas, and reductions in water supply for irrigated agriculture, hydropower, industrial and urban uses. The factors shaping the competition for water use at the river-basin scale include economic and population growth; changes in technologies and the environment (including climate change); changes in the social, legal, institutional, and political environment; and changes in the physical, technical, and economic environment. Because of these complex interrelationships, integrated water management at the river-basin level is the foundation for the sustainable management of water resources in LAC.

Although there is a notable absence of institutional frameworks that provide for integrated management of water resources in most of LAC, substantial efforts are being made in this direction. Argentina, Brazil, and Mexico are the three federal countries with experience in river basin management.

In Argentina, River Basin Committees haven been created since the early 1970s. Their main activities then were hydrologic and other water resources-related studies and to develop conjunct activities among the provinces contained in the basin. Most River Basin Committees have not been particularly successful, since agencies at the river basin level have not had the authority to handle financial resources and have been administratively and financially dependent on the federal Government and the various provincial Governments that created them. Moreover, they wore out in the power struggle between the central government and the federal states. Water management in Argentina has historically been strictly sectoral. Water belongs to the states, and there is no water law or river basin law that could regulate basin organizations, although two draft laws on the establishment of river basin authorities are currently under consideration. Nonetheless, valuable experiences with integrated basin management include the International River Plate River Basin Agency, the Bermejo River Regional Corporation (COREBE), the Colorado River Inter-provincial Commission (COIRCO), and the San Roque Lake Riverbasin Committee. COIRCO has been formed after 20 years of negotiation between the five constituting provinces of Mendoza, La Pampa, Río Negro, Neuquén and Buenos Aires. The main functions of the basin authority are the distribution of water among the provinces for domestic water supply, irrigation, hydroelectric power generation, and uses in the mining sector and other industrial sectors (ECLAC 1995; 1999a).

In Brazil, the experiments that are proving to be the most successful in the domain of water resources management are those, which are being carried out at the river basin level (ECLAC 1995). The government of the State of São Paulo, for example, through the Water Law of December 30, 1991, established an Integrated Water Management System with considerable public participation through consortiums of municipalities and user associations. A similar system has been established in the state of Ceara (ECLAC 1994).

In Mexico, the Water Law of 1992 encourages the development of river basin management through legally constituted Basin Councils. These councils are empowered to develop agreements between the CNA; federal, state, and municipal departments and agencies; and water user groups within the basin, region, or aquifer to formulate broad plans for water administration, development, and conservation. In addition to facilitating integrated water management, the establishment of Basin Councils will greatly facilitate the transferability of water. Once the CNA establishes a Basin Council and approves the overall plan and operating regulations, water is fully transferable among different users and uses within the basin, region, or aquifer, without further CNA review. The only formality for effecting transfers would be registration in the Public Registry of Water Rights. A Basin Council has been constituted for the Lerma-Chapala River Basin, an area with multiple uses and increasing competition for water between agricultural, household, and industrial areas.

Moreover, in Colombia, several river basins are managed by integrated administrative systems. Chile has decided to develop the management of river basins as a means to identify, account for, and manage the externalities involved in water use. In Peru, a key element of the new water management strategy is the establishment of Autonomous River Basin Authorities. These Authorities are responsible for irrigation in the lower reaches of their catchment areas and for soil and water conservation projects and forestry programs in their catchment headwaters. The functions of the river basin authorities include all activities related to soil and water management within the watershed, including monitoring of government regulations, plans for reforestation, coastal defenses, and resolution of user conflicts. The Ministry of Agriculture is also responsible for the National Program of River Basin Management and Soil Conservation—directed at small irrigation works and reforestation programs in the upper catchment areas of river basins (ECLAC 1994). Only three Autonomous River Basin Authorities had been formed by 1996 (Díaz-Albertini 1996). Finally, Bolivia currently considers incorporating river basin authorities into its water legislation (ECLAC 1999a).

The progress in these countries and others in LAC toward implementation of river basin management should be expanded. A series of workshops for managers of river basin authorities in LAC, sponsored by the Economic Commission for Latin America and the Caribbean, affirms the interest of this management structure in the region (ECLAC 1999a; 1999b).

The main roles of the public sector in water management are

- to define and implement a strategy for managing water resources;
- to provide an appropriate legal, regulatory, and administrative framework;
- to guide intersectoral allocations; and
- to develop water resources in the public domain.

It is at the river-basin level that water allocation decisions must be made across the major competing demands of agricultural, municipal, and industrial users. Investments and allocation decisions in one part of the basin affect activities in other parts of the basin. As a result, policy instruments designed to make more rational economic use of water resources need to be applied at this level. Improved water management at the river-basin level will require considerable strengthening of relevant public institutions and improved tools for planning and monitoring purposes.

IRRIGATION MANAGEMENT TRANSFER AND USER-MANAGED IRRIGATION

In many countries, poor performance of centralized administrative management, together with fiscal pressures from mounting O&M and other costs, has provided a major stimulus for transferring management responsibility for both irrigation and domestic water-supply systems from agencies to user groups. As a result, there has been a strong trend towards decentralization of irrigation management in LAC during the last decade. The level of devolution of systems range from participation of farmers in irrigation management to irrigation management transfer (IMT). The former concept refers to increasing farmer responsibility and authority in irrigation management, and the latter typically involves a shift of management responsibility from a centralized government irrigation agency to a financially-autonomous local-level non-profit organization, which is either controlled by the water users of the irrigation system or in which water users have a substantial voice (Svendsen, Trava, and Johnson 1997).

Irrigation management transfer can have positive effects for farmers, including improved irrigation service and maintenance, a sense of ownership of resources that provides incentives to improve operational performance, increased (financial) accountability and transparency and greater accessibility to irrigation system personnel, and reduced conflicts among users. A major advantage of the user allocation strategy is its potential flexibility to adapt water delivery patterns to meet local needs. Having more information on local conditions than agency staff, those directly involved in a sector's water use do not have to rely on rigid allocation formulas. For example, based on the soil's water retention capacity, certain fields may be given more water than others. The result can be improvements in either output per unit of water or in equity or both. Negative effects for farmers can include higher costs to manage the system, less disaster assistance, and less rehabilitation assistance.

Positive effects for irrigation agencies can include reduced financial burden, reduced conflicts and opportunities for rent seeking, and new responsibilities. Disadvantages for irrigation agencies can include reduced bureaucratic and political influence, uncertainty over role, and reduced control over water resources. Positive effects for the government include reduced costs and civil service staffing and greater farmer satisfaction; negative effects include less control over agricultural production and policies, and resistance in public staff reduction (Svendsen, Trava, and Johnson 1997; Kloezen, Garcés-Restrepo, and Johnson 1998).

The actual outcomes of management transfer have been mixed, but on the whole positive. Given the relatively recent implementation of IMT, the longer-term impacts of transfer on agricultural productivity and water use efficiency must still be evaluated. Svendsen, Trava, and Johnson (1997) examine cases of irrigation management transfer in Argentina, Colombia, and Mexico, among others. They find that national budgetary crisis, top-level political will to place irrigated agriculture on a sound economic footing, and the progressive deterioration of irrigation infrastructure due to deferred maintenance are key conditions that can trigger a transfer process. Only in Colombia did the farmers themselves initiate the process.

In Mexico, comprehensive water management was recognized as a priority by the Government in 1989. This led to the creation of the CNA and the take-off of the privatization process. CNA was granted the responsibility to define the country's water policies and to allocate water to users through licenses and permits. Another component of the reform process was the creation of autonomous and self-financing water utilities to

Box 2 Privatization of urban water services

An analogue to irrigation water transfers is the privatization of urban water services. Appropriately designed and regulated privatization can provide substantial benefits. Privatization initiated in 1993 in Buenos Aires has yielded quick results. Under the public water and sewage provider, Obras Sanitarias de la Nación (OSN), water losses averaged approximately 40 percent. Under the new private service provider, losses have dropped to 25 percent (Crampes and Estache 1996). In Chile, privatization and granting of secure water rights held by the urban water companies, together with an active water market, have encouraged the construction and operation of improved treatment plants that sell water for urban use. Efficiency in urban water and sewage services has been greatly increased with no significant impact on prices. The efficiency of urban water companies has been fostered because they can no longer get free water from the state, through expropriation from farmers. When incremental water could be obtained for free, there was no need to improve either physical efficiency (for example with the help of pipes or metering), or economic efficiency (collection). The coverage of potable water has risen to 99 percent in urban areas and 94 percent in rural areas from 63 percent and 27 percent respectively, prior to reforms provide water services in cities and irrigation districts. The IMT was carried out in parallel with reductions in subsidies for agricultural credit and inputs, the elimination of guaranteed support prices for major agricultural crops, and increases in energy and fuel prices. Farmers had mixed feelings about the transfer; in particular, the *ejido* leaders of communally held land were against the devolution process. However, the IMT program took off quickly as all systems were performing satisfactorily at the onset, although the systems were suffering from deferred maintenance. Colombia, on the other hand, realized the first transfer of two irrigation districts in 1976, following specific requests by water users. The process was stalled, however, chiefly for budgetary reasons in the 1980s. The transfer program was reinstated in 1991, when the National Planning Department submitted an ambitious Land Reclamation Program for 1991-2000. Here, the decentralization can be considered part of the larger effort towards minimizing state subsidies and regulation. However, the state continues to play a significant role in land reclamation and rehabilitation and expansion of irrigation systems.

Argentina is a federal country divided into 23 provinces, which are autonomous in all aspects related to water (rights, taxation, etc.). The IMT program was launched in 1990, following a general trend to increase efficiency and decentralize government services. As such, the IMT of water management to provinces was also one component of a larger decentralization effort that was kicked off in 1990 with the privatization of large electricity utilities. Here, the farmers were generally favorable towards the transfer program.

As a consequence of the transfer of O&M responsibility to irrigation districts, farmers in Mexico pay the real cost of irrigation water. Although the increase in fees has been dramatic, irrigation service costs have remained in the range of 5-8 percent of total production costs. Fee collection rates are at or above 70 percent in all three countries. In Mexico, for example, the irrigation fee collection rate was around 100 percent before the transfer, but this amount covered only 25 percent of O&M costs. After the transfer, the collection rate is still close to 100 percent but fees now cover close to 90 percent of O&M costs. Colombia has also shifted the financial burden of O&M to the users, while irrigation schemes in Argentina are under joint management with fee collection by both the Government and the irrigation associations.

Another consequence of IMT has been a sharp reduction in subsidies provided by the national governments - thus the important goal of reduction in government expenditures for irrigation management has been met. However, at least in a transition period, subsidies in the form of machinery and equipment (Colombia and Mexico), technical assistance and capacity training (Mexico), and assistance for rehabilitation and modernization as well as for emergency situations are often provided.

A detailed analysis of the Rio Lerma Irrigation District indicates that the IMT program in Mexico has also resulted in benefits to farmers through improved services and maintenance of irrigation systems. Other improvements due to IMT include purchase of modern machinery by the water user associations, an increase in the proportion of the total O&M budget spent on maintenance, and a dramatic improvement in financial self-sufficiency from about 50 percent before transfer to 120 percent after transfer (Kloezen, Garcés-Restrepo, and Johnson 1998). In Colombia, IMT has also increased the degree of financial self-sufficiency, and improved the efficiency and contained the cost of management of irrigation schemes (Vermillion and Garcés-Restrepo 1998).

However, the partial nature of the irrigation management transfer policies pursued thus far can discourage farmers from investing in the long-term sustainability of their irrigation schemes, thereby limiting the benefits of IMT (Vermillion and Garcés-Restrepo 1998). In Mexico, the irrigation associations have a limited concession to use the irrigation infrastructure and the associated water supply, but do not have a clearly specified right to a volumetric supply. As domestic water use has priority, farmers are vulnerable to changing urban water demands. Moreover, irrigation districts have been assigned concessions over a fixed time frame of 20-30 years, and it is unclear, if districts will be able to hold on to their concessions thereafter. In Colombia, irrigators depend to a large degree on the national irrigation agency, as the country has not established a legal water rights system. This and the relatively fast transfer process have led to some second-generation problems with uncertainty regarding ownership and changes in management practices.

Probably the most important limitation that needs to be addressed is the continued insecurity of water rights. This inhibits investment in irrigation, encourages short-term behavior, results in heavy legal expenditures to defend poorly defined rights and can, ultimately, lead to a reduction in water supply and a collapse of irrigation associations. The cohesive force of property is important in many aspects of water management, but is especially critical for allocation. User groups cannot make decisions regarding water if they have no *de jure* or *de facto* rights over the resource. Property rights, which can be ownership of the actual irrigation facilities and/or water rights, form the basis for relationships among irrigators, which become the social basis for collective action by irrigators in performing various irrigation tasks. In Mexico, for example, urban water uses have priority over irrigation water, and irrigation associations are not compensated when water is reallocated. To effectively manage water resources in both agriculture and other sectors, these rights need to be better defined and, in the case of reallocation of irrigation water, farmers need to be adequately compensated. A second problem identified in transferred irrigation systems is the shortfall of financial means. Moreover, rehabilitation and modernization efforts are usually beyond the technical and financial means of irrigation associations. Assistance in the areas of credit, assessment of facilities, and design and construction might be needed from the public sector in the future. Finally, lack of financial and administrative management expertise is preventing several associations to effectively manage their systems (Svendsen, Trava, and Johnson 1997).

Particularly crucial to the success of IMT and user management is a supportive policy and legal environment that includes establishment and adjudication of secure water rights, monitoring and regulating externalities and third-party effects of irrigation, and providing technical and organizational training and support. A strong start toward effective user-based management has been made in several LAC countries. In order to expand the benefits of IMT, local management should be given full authority over O&M plans and budgets, financial management, disposition of staff, and enforcement of sanctions (Vermillion and Garcés-Restrepo 1998). Most fundamentally, the user groups, or individual users, must be provided with secure water rights.

WATER RIGHTS, PRICING AND MARKETS

As described above, water allocation in LAC has predominately followed administrative allocation of water—publicly managed allocation through quantity distributions or administered water-pricing schemes. Quantity-based administrative water allocation in most of LAC has provided irrigation water at essentially no cost, and urban water at highly subsidized rates. There is a standing tradition in LAC of heavily subsidizing irrigation water. Water users therefore have little incentive to economize on its use. The primary alternative to quantity-based allocation of water is incentive-based allocation, either through volumetric water prices or through markets in transferable water rights. Incentive-based water allocation could be used as a policy instrument: to give incentives to farmers, to promote certain crops, to collect revenue, to absorb differential rents, to avoid externalities or the over-exploitation of a commonly held water resource, and for environmental management. Surveys of empirical evidence showed that farmers are price responsive in their use of irrigation water. The four main types of responses to higher water prices are use of less water on a given crop, adoption of water-conserving irrigation technology, shifting of water applications to more water-efficient crops, and change in crop mix to higher valued crops (Rosegrant, Gazmuri Schleyer, and Yadav 1995; Gardner 1983). Experience has shown that farmers in LAC adapt well to modern technologies when the incentives are right. In many Andean valleys, the use of simple sprinklers has been particularly successful as well as drip irrigation. In Brazil and Mexico, the use of pivot irrigation by large farmers or farmer cooperatives is also proving successful (FAO 1988b).

In principle, markets in tradable water rights may have considerable efficiency and other advantages over other allocation mechanisms. These include:

- empowerment of water users by requiring their consent to any water reallocation and compensation for any water transferred;
- security of water rights tenure to users, which can encourage investment in water-saving technology;

- provision of incentives for users to consider the full opportunity cost of water when making allocation decisions, including its value in alternative uses; and
- provision of incentives for water users to account for external costs imposed by their use, reducing the pressure to degrade resources.

The choice between administered prices and markets should be largely a function of which system has the lowest administrative and transaction costs. In urban areas, where consumers are concentrated and water usually accounts for a small share of expenditures, volumetric pricing can be implemented with relatively low administrative and transaction costs. Effective pricing combined with removal of subsidies in urban water use can dramatically reduce water use. A considerable body of analysis for developed countries shows a central range of price elasticities of demand for household water of -0.3 to -0.7 (Frederick 1993). There have been few studies of household demand elasticities in developing countries because water tariffs have generally been low, price changes have not been significant, and metering has been absent. However, the limited available evidence is consistent with the estimated values for developed countries. In urban Brazil and Mexico, estimated price elasticities for urban water demand are -0.60 and -0.38, respectively, showing substantial potential for water-conservation through removal of subsidies in urban areas (Gomez 1987).

Generalized water subsidies often harm, rather than help the poor. In most LAC countries, water subsidies go disproportionately to the better off: urban water users connected to the public system and irrigated farmers. The equity impacts are worsened because subsidies are often financed from regressive taxes. In Mexico and Peru, for example, unrealistically low water tariffs have encouraged farmers to grow cereals, roots and livestock on irrigated lands in direct competition with small rainfed producers, crowding them out of the most dynamic markets or limiting their access to them (FAO 1988b). The negative effects on equity are also shown in urban areas by the ratio between the prices charged for water by informal vendors to the price charged by urban water systems. In Cali, Colombia, the price of water from vendors is 10 times the price of the subsidized public water, in Lima, Peru, 17 times, in Guayaquil, Ecuador, 20 times, and in Tegucigalpa, Honduras, between 16 and 34 times (Bhatia and Falkenmark 1993). The results show that the urban poor, who must rely on water vendors, pay many times more for water than the generally better-off residents who receive subsidized water from the public systems. The removal of broad based water subsidies can improve equity by financing expansion of piped water and by allowing the government to increase the level of subsidies targeted directly to the rates paid for urban water by low-income sectors of the population. In Chile, for example, subsidies are now targeted through provision of a specified monthly free quantity of water (up to 20 cubic meter per month) in predetermined sectors of the cities accounting for the poorest 20 percent of the population.

In agriculture, markets in tradable water rights are in most cases preferable to efficiency pricing. In irrigation systems, the value of prevailing usufructuary water rights (formal or informal) has already been capitalized into the value of irrigated land. Rights holders see the imposition of administered pricing as expropriation of those rights, which creates capital losses in established irrigation farms. Attempts to establish administered efficiency prices are thus met with strong opposition from established irrigators, which makes it difficult to institute and maintain an efficiency-oriented system of administered prices. The establishment of transferable property rights would formalize existing rights to water, rather than being seen as an expropriation of these rights, and is therefore politically more feasible (Rosegrant and Binswanger 1994).

Despite the potential benefits of tradable water rights enumerated above, the unique physical, technological and economic characteristics of water resources pose special problems for establishing transferable water rights and developing markets for such rights. The fundamental importance of water to farm production and income raises serious equity concerns when major shifts in water allocation are considered. Multiple re-use of water creates the likelihood of significant externalities imposed on third parties, that is, spillover effects on other people's welfare from water trades, creating further difficulties in enforcing and regulating water trade.

Because of these complex interactions, establishment of markets in transferable water rights requires careful specification of rights and protections, with institutions in place to protect against third-party effects and possible negative environmental effects that are not eliminated by the change in incentives. To form the basis for allocation of water through tradable property rights, the law should be simple and comprehensive, should clearly define the characteristics of water rights and the conditions and regulations governing the trade of water rights; establish and implement water rights registers; delineate the roles of the government, institutions, and individuals involved in water allocation and the ways of solving conflicts between them; and provide cost-effective protection against negative third party and environmental effects which can arise from water trades.

The Chilean water law creating a system of tradable water rights has been successful in dealing with most of these issues. Chile adopted a comprehensive, market-oriented water policy nearly twenty years ago and has had important achievements in improving water use efficiency. Tradable water rights in Chile have fostered efficient agricultural water use, which has in turn increased agricultural productivity, generating more production per unit of water. The market valuation of water at its scarcity value has induced farmer investment in on-farm irrigation technology which has saved water to irrigate more area or to sell to other uses; has induced a shift to high-valued crops, which use less water per unit value of output; and has given farmers greater flexibility to shift cropping patterns according to market demand through the purchase, rent and lease of water. Because of the topography in Chile, reuse of drainage water is minimal in most river basins, so gains in water use efficiency in agricultural have represented real water savings (Gazmuri Schleyer and Rosegrant 1996).

Market-type incentives in water allocation can be strengthened through innovative approaches that would combine the benefits of water markets and user management. Although appropriate institutions would need to be designed for specific countries and regions, the wholesaling of relatively large blocks of water to user groups or privately run irrigation sub-units could establish appropriate incentives for water allocation. The user group would then be responsible for internal allocation of the water, and could re-sell water that was saved through efficient use. The price charged for water under this allocation method would have to be high enough to improve cost recovery for irrigation and to encourage conservation of water. Water prices can also include pollution or effluent charges in order to reduce the incentive to pollute.

GROUNDWATER MANAGEMENT

Because of the importance of groundwater in LAC, particularly for municipal and industrial uses, sustainable development of groundwater resources is also essential to meet growing water demands. Principles for groundwater management reform are similar to those for surface water and include the introduction of economic incentives and user involvement in the allocation process. Successful approaches in the western United States, particularly California, appear appropriate for conditions in much of LAC. Pragmatic, diverse, decentralized, and to a large extent successful approaches to groundwater management have evolved over time as water users and local governments have responded to depletion of groundwater resources and degradation of the environment. Groundwater management programs have eliminated overdrafts, impounded surface and imported water for aquifer replenishment, and stopped saltwater intrusion (Blomquist 1995).

A variety of instruments has been employed to influence water demand, including pumping quotas (usually based on historical use), pumping charges, and transferable rights to groundwater. The governance structure in the water basin (shared aquifer) establishes water rights, monitoring processes, means for sanctioning violations, representative associations of water users, financing mechanisms for administration and management, and procedures for adapting to changing conditions. Key elements for the success of this governance structure are that it is agreed upon and managed by the water users; that it is responsive to local conditions; that it operates with available information and databases, rather than requiring theoretically better but unavailable information; and that it adapts to the evolving environment.

The proper role for government is also suggested by a characteristic that is both a strength and a weakness of groundwater management procedures in California. Changes in groundwater management are not imposed, or even considered, unless a management problem exists, thus preventing interventions that can derail efficient utilization of groundwater. The negative side is that the move toward solutions often does not begin until significant damage to the groundwater resource has been done, in large part because of the difficulty in obtaining information about the state of the aquifer. Government can therefore play an important role in monitoring the groundwater resource to identify emerging problems; and in facilitating an institutional environment that is conducive to decentralized solutions.

11. CONCLUSIONS

Growing water scarcity problems and competition between uses of water pose a serious challenge to policymakers in LAC. Relatively high aggregate water availability per capita in the LAC region masks serious regional and seasonal freshwater shortages and water quality problems for agricultural, domestic and other uses. Some of the increasing demand for water must be met from carefully selected, economically efficient development of new water, both through impoundment of surface water and sustainable exploitation of groundwater resources, and through expansion in the development of non-traditional sources of water. However, in a context of accelerating demand and declining investments in water resource development, new water development is not the primary solution to water resource challenges in LAC. Much greater attention is needed on water policy and management reform to improve the efficiency and equity of irrigation and water supply systems. This is important not only for maintaining productivity and economic growth in the region, but also for arresting the degradation of soil and water resources. Finally, the income and well-being of a large number of small-scale agricultural producers in the region hinges on efficient, equitable, and sustainable water management, not only in agriculture, but across all water-using sectors.

The main constraint on the performance of and future prospects for irrigation development is imposed by the market and price prospects of the crops that may be grown with irrigation, and the high capital costs of irrigation. In order to pay for future investments, irrigated agriculture needs to produce high-value crops for both local consumption and exports into competitive world markets.

Historically, the dominant role of the state in managing water resources in LAC has been rationalized based on the public good characteristic of the resource. However, mounting costs of developing new sources of water, and problems with quality of service in agency-managed systems has led to a search for alternatives to increase the efficiency of water management. With fiscal pressures to reduce state subsidies for recurrent O&M costs, policies to officially transfer management responsibilities from agencies to farmers—and to privatize urban water supply and sanitation—are increasingly important. In addition to reducing costs, effectively managed irrigation management transfer can also improve irrigation service and maintenance, boost operational performance, and increase financial accountability and transparency. However, these benefits are unlikely to be attainable unless the user groups are provided control over water allocation. That is, members must have decision-making authority for both water allocation and distribution, and secure rights to water.

Secure water rights are also essential for incentive-based allocation of water. Market allocation has strong advantages in providing users incentives to seek the highest-value applications for scarce water resources. To operate effective water markets, well-defined, quantifiable and transferable water rights must exist. Market development and the establishment of clear and firm water rights are compatible with continued state involvement and expanded user group participation in water management. The establishment of tradable water rights and development of water markets require the government's strong and active role in identifying water rights; regulating harmful third-party effects; and providing the appropriate legal and institutional support system.

The outcome of market allocation depends on the economic value of water in different uses. This raises legitimate concerns over the equity implications for smallholders and others who may be unable to compete in the market, and therefore lose rights to water. But one of the major advantages of market allocation is that it provides compensation to those who give up water. As industrial, municipal and environmental demands grow, farmers are likely to lose water to other sectors also under public and user-based allocation and it is not clear that they will be compensated. Moving toward tradable property rights in water may ease the process of intersectoral reallocation by compensating the losers, and creating incentives for efficient water use in all sectors.

Developing appropriate institutions for intersectoral water allocation remains an important challenge. Under the fragmented management structure for water in most of LAC, the majority of institutions for water management deal only with one set of uses and users. As a result, strategic planning and decisions on how water should be used in different sectors are often poorly developed. This is a serious problem as long as there are unused sources of water to tap for increasing supplies to any sector. But water for different uses does not flow in neatly separate channels in most contexts: it is drawn from common sources, and wastes from each use mingle with the source for other purposes. As the demands for agricultural, domestic, industrial and even environmental uses increase and the scope for additional water supplies are limited, there is a need for greater attention to allocation between these competing uses, and to the disposal of their wastes. Water transfers out of low-value agricultural production are likely, but appropriate compensation mechanisms need to be set in place. Regulation of wastes from any use is also required to control externalities.

These complex tradeoffs across sectors and across uses can best be managed through integrated water management at the river basin level. The river basin framework provides the appropriate locus for carrying out the main roles of the public sector in water management, including defining and implementing a strategy for managing water resources; providing an appropriate legal, regulatory, and administrative framework; regulating intersectoral allocations; and developing water resources in the public domain. The innovative institutional and policy reforms required to meet the challenges of water scarcity and quality in LAC require a blending of public sector, market, and water user roles. The challenges for water policymakers in LAC are great, but a strategy that focuses on river basin management, irrigation management transfer and privatization, and market-based water allocation can effectively address these challenges.

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