Section III

Country profiles

Country profiles

EXPLANATORY NOTES

In this section country profiles for Armenia, Azerbaijan, Bahrain, Georgia, Iran (Islamic Republic of), Iraq, Israel, Jordan, Kuwait, Lebanon, Occupied Palestinian Territory, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Turkey, United Arab Emirates and Yemen have been designated as an extra to the publication with their exclusive assigned numbers to figures and tables, and including a detailed map for each country.

The main reason for this is that these profiles have also been included on the AQUASTAT country web page (http://www.fao.org/nr/water/aquastat/countries/index.stm), where each country profile can be downloaded as a stand-alone profile in PDF format.

Armenia

GEOGRAPHY, CLIMATE AND POPULATION

Geography

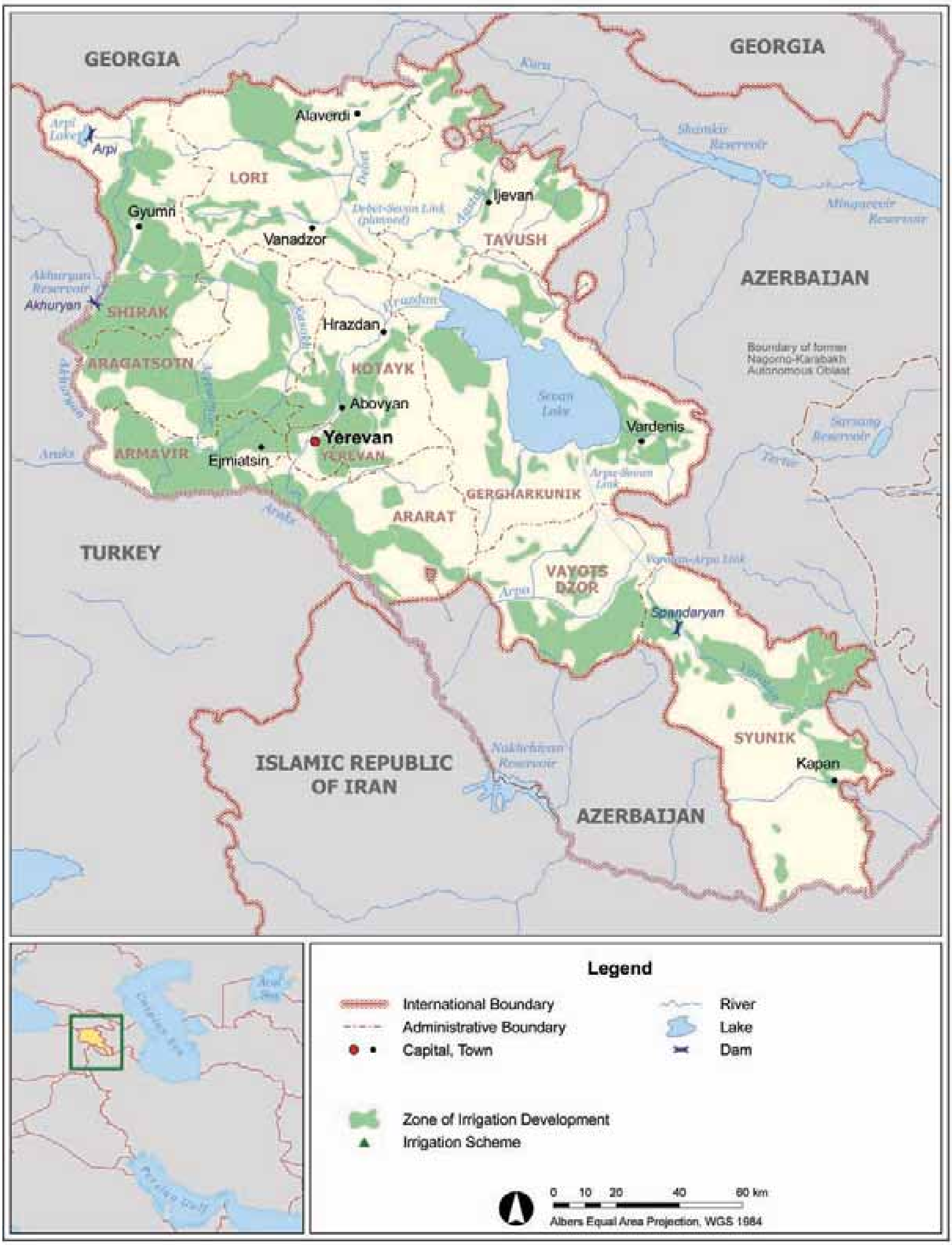
Armenia, with a total area of 29 800 km², is a landlocked country in the Caucasus region bordered in the north by Georgia, in the east by Azerbaijan, in the southeast by the Islamic Republic of Iran, and in the southwest and west by Turkey. Until 1995, the country was divided into 37 districts. It is now divided into ten marzes (provinces) plus Yerevan, the capital city.

Armenia is a mountainous country, with 77 percent of its territory located at 1 000 to 2 500 m above sea level and with an average altitude of 1 850 m. The highest point is 4 095 m (Mount Aragats) and 42 percent of the area is unusable for habitation (MNR, 2005). The country has a complex combination of uplands, plateaus, river valleys, depressions, and limited land, water and forest resources, with unfavourable engineering-geological conditions in most of the area (high seismicity, abundance of geodynamic processes). The landform in the centre and north of the country consists of rocky high mountain ranges separating narrow fertile valleys. Towards the south are the broad, flat and fertile Ararat valleys along the left bank of the Araks River forming the border with Turkey. To the west and north of Mount Aragat and around Lake Sevan in the east, the landform is generally rolling with rocky outcrops. In the southeast, a few small irregular-shaped valleys are surrounded by high mountain ranges. Pastures dominate at higher altitudes. The country is divided into two major river basins, the Araks Basin in the southwest and the Kura Basin in the northeast, which converge farther downstream in Azerbaijan. The low-lying areas, such as the Ararat plains, have rich, deep soils, but at higher elevations and on steep slopes, soils tend to be shallow.

Agriculture is greatly influenced by the topography, most of the cultivated land lying within an altitude range of 600–2 500 m. The predominant agricultural soils are generally fertile and deep. The cultivable area is estimated at almost 1.4 million ha, which is 47 percent of the total area of the country. In 2005, the cultivated area was estimated at 555 000 ha, of which 495 000 ha were under annual crops and 60 000 ha under permanent crops (Table 1).

Climate

Armenia has a highland continental climate: hot summers and cold winters. The geographical location of the country and its complex mountainous relief have conditioned the diversity of natural conditions across the country. There are six climate zones ranging from dry subtropical to rigorous high mountainous. The average annual temperature is 5.5 °C. Summer in Armenia is moderate, with an average temperature in July of around 16-17 °C, but ranging from 24 to 26 °C in the Ararat Valley. Winters are quite cold; the average winter temperature in Armenia is almost –7 °C. Total annual



ARMENIA **FAO - AQUASTAT, 2008**

TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2005	2 980 000	ha
Cultivated area (arable land and area under permanent crops)	2005	555 000	ha
• as % of the total area of the country	2005	18.6	%
• arable land (annual crops + temp. fallow + temp. meadows)	2005	495 000	ha
• area under permanent crops	2005	60 000	ha
Population			
Total population	2005	3 016 000	inhabitants
• of which rural	2005	35.9	%
Population density	2005	101.2	inhabitants/km^2
Economically active population	2005	1 522 000	inhabitants
• as % of total population	2005	50.5	%
• female	2005	51.9	%
• male	2005	48.1	%
Population economically active in agriculture	2005	162 000	inhabitants
• as % of total economically active population	2005	10.6	%
• female	2005	21	%
• male	2005	79	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2007	9 180	million US$/yr
• value added in agriculture (% of GDP)	2007	18	%
• GDP per capita	2005	1 626	US$/yr
Human Development Index (highest = 1)	2005	0.775	
Access to improved drinking water sources			
Total population	2006	98	%
Urban population	2006	99	%
Rural population	2006	96	%

precipitation is 592 mm. The driest regions are the Ararat Valley and the Meghri region, where the annual precipitation is 200–250 mm. The maximum precipitation is observed in high mountainous areas with more than 1 000 mm annually. The multiyear average for annual evaporation in Armenia is 10–11 million m^3, equal to about 350 mm over the entire country (UNDP, 2006).

Population

The total population is slightly more than 3 million (2005), of which about 36 percent is rural (Table 1). The population density is 101 inhabitants/km^2. The annual demographic growth rate was estimated at –2.1 percent for the period 2000–2005. In 2006, 91 percent of the population had access to improved sanitation (96 and 81 percent in urban and rural areas, respectively). Access to improved drinking-water sources reached 96 percent (99 and 96 percent for urban and rural population respectively). It is estimated that about half of the population in Armenia lives below the poverty line. The rural population is less vulnerable because of its capacity to provide for basic foodstuffs on a more or less stable basis. The poorest communities in Armenia reside in the mountainous regions and the very poor are principally concentrated in the earthquake zone, in border regions or in regions with a low level of economic activity (FAO and MOA, 2002) More than 90 percent of households have access to an improved/not shared toilet facility (NSS and MOH, 2006).

ECONOMY, AGRICULTURE AND FOOD SECURITY

During the Soviet era, Armenia experienced robust industrial and agricultural development despite its limited natural resources. It became one of the most industrialized republics, providing machinery, chemicals, electronics and software to Russia and other Soviet Republics. In return, Armenia received raw materials and energy.

In December 1988, a devastating earthquake struck Armenia, killing more than 25 000 people and destroying large areas of the industrial heartland. This was followed by the break-up of the Soviet Union in 1991 and the consequent loss of markets and largely subsidized energy. This further led to a rapid decline in industrial output and to high unemployment. By 1993 the Gross Domestic Product (GDP) had fallen by almost two-thirds. Since 1994, however, Armenia has been among the most reform-minded countries of the former Soviet Union. Factors that have contributed to economic growth include: reforms in the electricity sector; growth in exports in specific sectors, such as cut diamonds, metals, electricity, and processed food; housing construction, and a major programme of international assistance. However, the high levels of economic growth have not yet compensated for jobs lost because of downsizing or the closure of Soviet era enterprises (USAID, 2006).

In 2007, Armenia's GDP was US$9.2 billion and agriculture accounted for 18 percent (Table 1), down from a share of 41 percent in 1994. Industry on the contrary increased its contribution to GDP between 2000 and 2007 from 35 to 44 percent. Just over 50 percent of the population, 1.5 million people – of whom 21 percent is female - is economically active (2005): 162 000 people, or 11 percent of the labour force, are employed in agriculture whereas in 1994 agriculture employed 15 percent of all workers.

In 2003, crops accounted for 55.8 percent and stock breeding 44.2 percent of agriculture compared with 49.4 and 50.6 percent respectively in 1990. Since the beginning of the transition period the grain sowing areas have expanded by more than 20 percent and areas under cultivated potato by about 40 percent. However, the areas under forage plants have decreased by more than 3 times. In 2004, the main agricultural products were cereals, potatoes, vegetables, forage plants and fruit, especially grapes, given the long tradition of viticulture and wine-making. Agriculture has played a very important role in the economy of the country although it depends heavily on irrigation - half the total cultivated area is currently irrigated.

At present, in the agricultural food products sector, there is a free economy system regulated by the market which includes more than 338 000 farms. More than 98 percent of gross agricultural production comes from the private sector. The contribution of the agriculture and food sectors to the Armenia's international trade has changed considerably since the start of the transition: exports have shrunk while imports have surged. In recent years, there has been a visible and steady trend to sectoral development, but agriculture continues to be vulnerable, mainly because of the relative shortage of suitable land, the lack of sufficient water resources, the small size and detachment of farms formed as a result of land privatizations, the underdeveloped industrial market and social infrastructure, as well as because agriculture does not at present meet the requirements of a market economy.

An important objective of agricultural development is to ensure appropriate levels of food security for the urban and rural population. It is estimated that expenditure on food accounts for between 60 and 70 percent of households' total consumption. It can be as high as 85 percent for the poorest quintile, while it is 57 percent for the richest quintile. In view of the high share of food expenditure in total consumption, an adequate level of food security for the population requires that food is provided at affordable and stable prices. Given that farmgate prices of agricultural products are low and unfavourable to farmers' incomes, increasing food security for the population implies improving significantly the efficiency of the processing and marketing chains for agricultural products. This kind of improvement will be attained primarily through better organization of the markets, increased competition in processing and trade and increased safety of marketed products. Investments in market infrastructure need to be carefully assessed in order to avoid unnecessary costs that would increase retail food prices (FAO and MOA, 2002).

WATER RESOURCES AND USE

Water resources

The internal renewable surface water resources are estimated at 3.948 km³/year and the internal renewable groundwater resources at 4.311 km³/year. The overlap between surface water and groundwater is estimated at 1.400 km³/year. This gives a total of 6.859 km³ of annual internal renewable water resources (IRWR) (Table 2).

The rivers in Armenia are tributaries of the main rivers of the southern Caucasus, namely the Araks and the Kura. About 76 percent of the total territory is part of the Araks basin and 24 percent of the Kura basin (UNDP/GEF, 2006). Total outflow is equal to the IRWR. The outflow to Georgia through the Debet River is estimated at about 0.89 km³/year and the outflow to Azerbaijan through the Agstay River at about 0.35 km³/year; both these rivers are located in the Kura basin. The total outflow to Azerbaijan through the Araks and its tributaries (Arpa, Vorotan, Vokhchi) is estimated at about 5.62 km³/year. The Araks River forms the border between Turkey and Armenia and further downstream, between the Islamic Republic of Iran and Armenia, it flows into Azerbaijan, joining the Kura River about 150 km before its mouth at the Caspian Sea. The border flow of the Akhuryan (with Turkey) is estimated at 1.03 km³/year and the Araks at 0.79 km³/year. Half of the border flow is accounted for in Armenia's water balance, bringing the total actual renewable water resources to 7.769 km³/year.

The 14 sub-basins of the two main river basins (Kura and Araks) have been grouped into five basin management areas: Akhuryan, Northern, Sevan-Hrazdan, Ararat and Southern basins (USAID, 2006). About 9 500 rivers and streams with the total length of 23 000 km flow in Armenia. Out of that number 379 rivers are around 10–100 km long, and seven, namely the Akhuryan, Debet, Vorotan, Hrazdan, Aghstev, Arpa and Metsamor-Kasakh, are longer than 100 km. The annual distribution of river flow generated in the country by the 14 river basins and their characteristic features are presented in Table 3 (UNDP, 2006). Armenian rivers are typically of a mountainous nature with sharp seasonal variations, spring freshets and low water flow in summer.

Armenia has more than 100 small lakes, some of which regularly dry out in the dry season. The Sevan and Arpi lakes are the most important in terms of size and economic

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	592	mm/yr
	-	17.642	10⁹ m³/yr
Internal renewable water resources (long-term average)	-	6.859	10⁹ m³/yr
Total actual renewable water resources	-	7.769	10⁹ m ³/yr
Dependency ratio	-	11.71	%
Total actual renewable water resources per inhabitant	2005	2 576	m³/yr
Total dam capacity	2004	1 399	10⁶ m³
Water withdrawal			
Total water withdrawal	2006	2 827	10⁶ m³/yr
- irrigation + livestock	2006	1 859	10⁶ m³/yr
- municipalities	2006	843	10⁶ m³/yr
- industry	2006	125	10⁶ m³/yr
• per inhabitant	2005	776.5	m³/yr
Surface water and groundwater withdrawal	2006	2 827	10⁶ m³/yr
• as % of total actual renewable water resources	2006	36.4	%
Non-conventional sources of water			
Produced wastewater	2006	363	10⁶ m³/yr
Treated wastewater	2006	89	10⁶ m³/yr
Reused treated wastewater	1994	0.1	10⁶ m³/yr
Desalinated water produced		-	10⁶ m³/yr
Reused agricultural drainage water		-	10⁶ m³/yr

TABLE 3
Characteristics of the main river basins in Armenia

N	River Basin	Area	Precipitation	Evaporation	Flow	Flow volume module	Reservoirs (2004)
		km²	million³ per year	million m³ per year	million m³ per year	million m³ per km²	In operation
I	Debet - within Armenia	3 895	2 726	1 457	1 203	0.309	1
II	Aghstay - within Armenia	2 480	1 569	979	445	0.205	5
III	Small tributaries of Kura - within Armenia	810	510	354	199	0.106	4
IV	Akhuryan - within Armenia	2 784	1 653	972	392	0.140	8
V	Kasakh	1 480	979	486	329	0.222	6
VI	Metsamor, without Kasakh	2 240	not available	not available	711	0.317	25
VII	Hrazdan	2 565	1 572	876	733	0.286	7
VIII	Lake Sevan Basin	4 750	not available	not available	265	0.056	4
IX	Azat	952	607	306	232	0.244	2
X	Vedi	998	573	340	110	0.111	1
XI	Arpa - within Armenia	2 306	1 643	768	764	0.331	11
XII	Vorotan – within Armenia	2 476	1 828	811	725	0.293	7
XIII	Voghji - within Armenia	1 341	1 097	448	502	0.374	2
XIV	Meghri	664	470	241	166	0.250	-

importance. The Hrazdan and Akhuryan rivers originate from these two lakes, the largest of which is Lake Sevan, located in the centre of the country. It lies at 1 900 m above sea level, which makes it a strategic source of energy and irrigation water. The level of the lake, originally with a surface area of about 1 414 km² and 58 km³ of stored water, has fallen since the 1930s due to the lake's increasing use for irrigation and domestic water supply. By 1972, its level had fallen by almost 19 m and its surface area had been reduced to 1 250 km². At present, it covers an area of about 1 200 km², has a volume of approximately 34 km³, and plays a central and important hydrological role in the country. It serves the densely populated Hrazdan river basin and the Ararat Valley where Yerevan, the capital, is situated. Through its regulated surface outflow into the Hrazdan River, the lake's water provides a substantial amount of hydropower and irrigation to croplands in the Ararat Valley. The lake is also an important recreational, natural habitat and cultural resource for the Armenian population (MNP, 2005). Since 1960, two inter-basin transfer schemes were implemented to restore the ecology of the lake and its storage capacity as a strategic water reserve for multipurpose use. A 48 km tunnel was built from 1963 to 1982 to divert some 250 million m³ of water annually from the Arpa River to Lake Sevan. A similar project, to divert 165 million m³ of water annually from the upper Vorotan River to the Arpa River through a 22 km tunnel, was completed in 2004. In the last few years, the lake's level has risen by about 2.7 m as a result of favourable meteorological conditions and improved management. Electricity generation at the Sevan-Hrazdan Cascade is currently tied to irrigation releases. During the last few years, irrigation releases have ranged from 120 to 150 million m³. The second most important lake is Lake Arpi. It is located in the western part of the Ashotsk depression at an altitude of 2 020 m above sea level. With the construction of a dam to solve irrigation problems, the lake became a reservoir.

Most of the reservoirs were constructed during the Soviet period. In 2004, some 83 reservoirs were operating in Armenia and total capacity was estimated at 1 399 million m^3, of which approximately 1 350 million m^3 was stored in reservoirs with a capacity of over 5 million m^3 each. Most of the water is used for irrigation. Some reservoirs are used for hydropower, recreation, fisheries and environmental protection. In 1995, about 145 million m^3 was used for municipal and industrial purposes. The largest reservoir is on the Akhuryan River, which forms the border with Turkey. It has a storage capacity of 525 million m^3, is shared with Turkey, and provides water for the irrigation of about 30 000 ha in Armenia. In contrast, many small off-channel reservoirs in the southwest of Aragats (Talish, Talin, Kakavadzor, Bazmaberd, Katnakhpyur), which accumulate spring tide waters, have a capacity of only 10 000–50 000 m^3 (UNDP, 2006).

Water use

Since the mid-1980s, there has been a decrease in the total water withdrawal, mainly due to a decrease in agricultural and industrial water withdrawal. In fact, the reduction in water use has been accompanied by a remarkable improvement in surface water quality. In 2006, the total water withdrawal for agricultural, municipal and industrial purposes was 2 827 million m^3, of which about 66 percent for agricultural purposes, 30 percent for municipal use and 4 percent for industrial purposes (Table 2 and Figure 1). Agricultural water withdrawal mainly refers to irrigation of crops. Works for the watering of pastures began in 1956, including providing water for cattle in the pasturing period. Sources of pasture watering are springs, mountain melted snow, and non-discharge water bodies (UNDP 2005). Surface water withdrawals represent 78 percent of the total water withdrawals (Figure 2).

In most of Armenia's territory, it is possible to use groundwater for drinking needs without any additional treatment. Indeed, about 95 percent of the water used for drinking purposes comes from groundwater sources (MNP, 2003). Both surface water and underground springs are used for industrial water supply. Industrial water supply is provided by independently operating water supply systems as well as from the city drinking water supply network. For the past 10–15 years, the water requirements of industrial enterprises have significantly decreased due to the reduction of the activity of many enterprises. It should be mentioned

FIGURE 1
Water withdrawal
Total: 2.827 km^3 in 2006

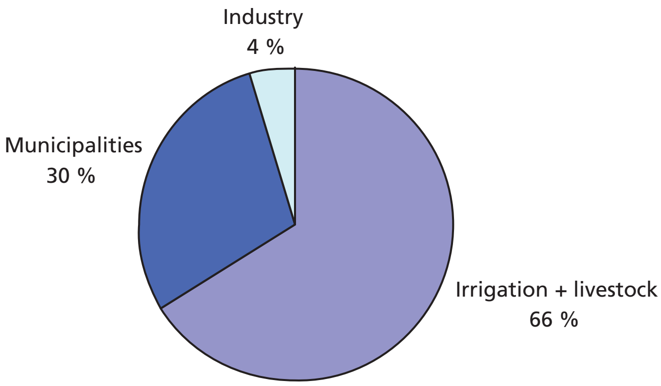
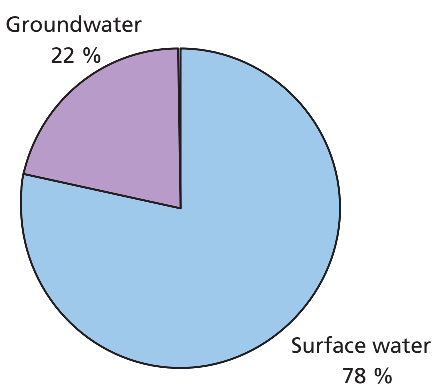


FIGURE 2
Water withdrawal by source
Total: 2.827 km^3 in 2006



that 40 percent of the industrial enterprises using water are located in Yerevan. The largest water-using industrial enterprise is the Armenian Nuclear Power Plant which uses about 35 million m^3/year (UNDP, 2005). There are 35 high and middle capacity hydropower plants in Armenia, nine of which are the plants at the Vorotan and Hrazdan hydropower cascades. As a result of insufficient regulation of volumes, hydropower production is also subject to seasonal variations (MNP, 2005).

While the industrial sector is not considered a major water user, an important problem for this sector is the implementation of industrial wastewater removal and treatment. Most industrial facilities were never equipped individually because they had been connected to the public sewer network during the Soviet Era, and thus were able to access municipal wastewater treatment. Attention should therefore be paid to those industries that have resumed production and from which the wastewater generated is channelled to the municipal wastewater treatment system, where only the mechanical treatment step is currently being operated. Also, the industries that are not connected to a municipal sewerage system discharge their mostly untreated wastewater directly into a stream or river. In general, old industries that resume production are the most polluting.

The total quantity of wastewater produced in 2006 amounted to 363 million m^3, of which 89 million m^3 was treated.

International water issues

Most river basins are transboundary and through a number of bilateral agreements Armenia assumes obligations related to the development and use of international waters. Armenia has an agreement with Turkey concerning the use of the Araks and Akhuryan rivers, according to which the water of these two transboundary rivers is divided equally between the two countries. Another agreement with Turkey concerns the joint use of the dam and the reservoir of the Akhuryan River. According to an agreement between the Islamic Republic of Iran and Armenia, the water of the Araks River is divided equally between them. Though these agreements were signed by the USSR, Armenia is considered a successor country, and consequently is required to fulfil any related obligations. There have been decrees issued and agreements signed between Armenia and Georgia concerning the Debet River. Corresponding decrees were passed between Armenia and Azerbaijan concerning the use of the water of the Arpa, Vorotan, Aghstay and Tavush rivers.

In 1998, Armenia ratified the agreement with Georgia on environmental protection according to which the governments pledged their cooperation in creating specifically protected areas within the transboundary ecosystems. The Ministry of Nature Protection (MNP) develops and implements international environmental projects, some of which are related to water issues. Part of the Caucasus Initiative, launched by the German Ministry of Cooperation and Development, involves the implementation of the "Ecoregional Nature Protection Programme for the Southern Caucasus". The programme, covering the three Caucasus countries, is going to be implemented in the very near future and will facilitate the protection and sustainable use of water resources in the region.

In 2002, the Republic of Armenia Commission on Transboundary Water Resources was established, which is chaired by the Head of Water Resources Management Agency. This commission, together with corresponding commissions in neighbouring countries, dealt with issues related to transboundary water resources use and protection.

From 2000 to 2002, USAID, in collaboration with Development Alternatives, Inc. (DAI), implemented the South Caucasus Water Management project which has the aim of strengthening the cooperation among water-related agencies at the local, national and regional levels, to provide integrated water resources management. In parallel, between 2000 and 2006, the EU and the Technical Assistance Commonwealth of Independent States (TACIS) developed the Joint River Management Program on Monitoring and Assessment of Water Quality on Transboundary Rivers, aimed at the prevention, control and reduction of transboundary pollution. The program covers four basins, including the Kura River basin. In addition, regional organisations such as REC and the Eurasia Foundation, as well as numerous local foundations, promote national and regional activities in the field of water resources management and protection (UNDP, 2002). USAID also funded the national project for Sustainable Water Resources Management in Armenia.

From 2002 to 2007, NATO-OSCE developed the South Caucasus River Monitoring Project whose general objectives were "to establish the social and technical infrastructure for an international, cooperative, Transboundary River water quality and quantity monitoring, data sharing and watershed management system among the Republics of Armenia, Azerbaijan and Georgia." (OSU, 2008).

The project Reducing Transboundary Degradation in the Kura-Araks River Basin, implemented by the UNDP Bratislava Regional Centre in collaboration with the GEF, has involved four of the basin countries - Armenia, Azerbaijan, Georgia and the Islamic Republic of Iran. The project preparation phase lasted 18 months and began in July 2005. It is co-funded by Sweden. The project aims to ensure that the quality and quantity of the water throughout the Kura-Araks river system meets the short and long-term needs of the ecosystem and the communities that rely upon this ecosystem. The project will achieve its objectives by fostering regional cooperation, increasing capacity to address water quality and quantity problems, demonstrating water quality/quantity improvements, initiating the required policy and legal reforms, identifying and preparing priority investments and developing sustainable management and financial arrangements.

There are currently no water treaties between the three South Caucasian countries, a condition directly related to the political situation in the region. Nagorno-Karabakh is one of the main obstacles, making it difficult for Azerbaijan and Armenia to sign a treaty even one relating only to water resource management (Berrin and Campana, 2008).

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

Irrigation in Armenia started about 3 000 years ago. Clay pipes were used to transport water to orchards and fields and some are still intact. In the fourth century, the total irrigated area was estimated at about 100 000 ha, in 1920 it had dropped to 60 000 ha, and in 1990 it was 320 000 ha (UNDP, 2006). The actually irrigated area declined from more than 300 000 ha in 1985 to 176 000 ha at present. Major factors that have contributed to this decline are the widespread deterioration of the irrigation conveyance systems, high pumping costs, the disintegration of the former collective farms into many small private farms (with a size of 1 to 2 ha), and drainage problems, particularly in the Ararat Valley, where groundwater tables are shallow.

At present, the area equipped for full or partial control irrigation is estimated at almost 274 000 ha (Table 4). The reason for the decrease in recent years has been, on the one hand, the earthquake of 1988 that destroyed part of the area, and on the other, the difficult economic situation due to the transition period, that has made it difficult to keep or maintain the irrigation infrastructure. The major irrigation schemes are located on the left bank of the Araks River.

The irrigation systems of Armenia were mainly established during the Soviet period. The irrigation infrastructure includes 80 reservoirs (77 of which are used only for irrigation and 3 used for both irrigation and drinking water), together with more than 3 000 km of main and secondary canals, about 15 000 km of tertiary canals, over 400 small and large pumps, 1 276 tubewells, and 945 artesian wells. Eight major conveyance systems distribute irrigation water to some 150 000 ha, and minor systems cover the rest of the areas. The conveyance systems are served by main, branch and secondary canals/pipes. Three-quarters of the canals are lined with concrete or are pipes. The

TABLE 4
Irrigation and drainage

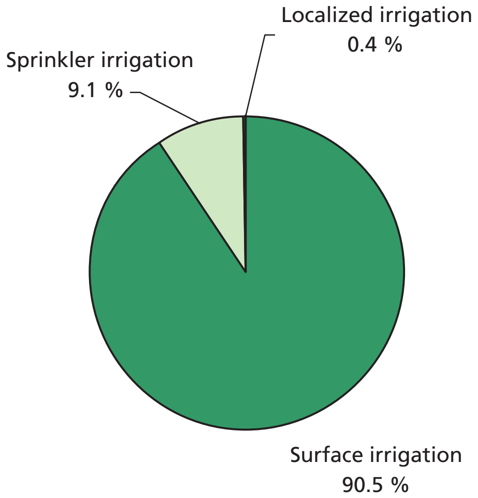
Irrigation potential	-	660 000	ha
Irrigation			
1. Full or partial control irrigation: equipped area	2006	273 530	ha
- surface irrigation	2006	247 530	ha
- sprinkler irrigation	2006	25 000	ha
- localized irrigation	2006	1 000	ha
• % of area irrigated from surface water	2006	81.4	%
• % of area irrigated from groundwater	2006	18.6	%
• % of area irrigated from mixed surface water and groundwater	2006	0	%
• % of area irrigated from non-conventional sources of water	2006	0	%
• area equipped for full or partial control irrigation actually irrigated	2006	176 000	ha
- as % of full/partial control area equipped	2006	64.3	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)		-	ha
3. Spate irrigation		-	ha
Total area equipped for irrigation (1+2+3)	**2006**	**273 530**	**ha**
• as % of cultivated area	2006	49.3	%
• % of total area equipped for irrigation actually irrigated	2006	64.3	%
• average increase per year over the last 11 years	1995-2006	-0.40	%
• power irrigated area as % of total area equipped	2002	42.6	%
4. Non-equipped cultivated wetlands and inland valley bottoms		-	ha
5. Non-equipped flood recession cropping area		-	ha
Total water-managed area (1+2+3+4+5)	**2006**	**273 530**	**ha**
• as % of cultivated area	2006	49.3	%
Full or partial control irrigation schemesCriteria			
Small-scale schemes < 200 ha	2006	55 697	ha
Medium-scale schemes			ha
Large-scale schemes > 200 ha	2006	217 833	ha
Total number of households in irrigation		-	
Irrigated crops in full or partial control irrigation schemes			
Total irrigated grain production (wheat and barley)		-	metric tons
• as % of total grain production		-	%
Harvested crops:			
Total harvested irrigated cropped area	2006	176 000	ha
• Annual crops: total	2006	125 100	ha
- Wheat	2006	35 000	ha
- Barley	2006	5 900	ha
- Maize	2006	3 100	ha
- Potatoes	2006	24 000	ha
- Sugar beet	2006	200	ha
- Pulses	2006	2 000	ha
- Vegetables	2006	23 200	ha
- Tobacco	2006	200	ha
- Fodder	2006	26 000	ha
- Sunflower	2006	200	ha
- Other annual crops	2006	5 300	ha
• Permanent crops: total	2006	50 900	ha
- Other perennial crops	2006	50 900	ha
Irrigated cropping intensity (on full/partial control area actually irrigated)	2006	100	%
Drainage – Environment			
Total drained area	2006	34 457	ha
- part of the area equipped for irrigation drained	2006	34 457	ha
- other drained area (non-irrigated)		-	ha
• drained area as % of cultivated area	2006	6.2	%
Flood-protected areas		-	ha
Area salinized by irrigation	2006	20 415	ha
Population affected by water-related diseases	2001	1 644	inhabitants

main water structures, together with the main and secondary canals, are under state ownership whereas the tertiary level irrigation system (the intra-community irrigation network) was transferred to community ownership with the establishment of the Local Self-Governments in 1997. Around 80 percent of the total irrigated land is irrigated through the main network operated by the "Vorogum-Jrar" Closed Joint Stock Company (CJSC), while the remaining 20 percent is irrigated through the community-owned networks (WB-IBRD, 2004).

Surface irrigation is practised on over 90 percent of the area equipped for irrigation and can be divided into four categories of irrigation: furrow, borderstrip, flooding or basin, and that using hydrants and flexible hose systems (Figure 3). Flooding is used where soil depth does not permit the grading of either furrows or borderstrips. The water is let out over the land by cutting an irrigation head canal at intervals. In the case of irrigation using hydrants, the hydrants are generally spaced in a 50 x 50 m grid and discharge water directly onto the ground, from where it is distributed by any of the surface irrigation methods. Conveyance of water to the hydrant is by buried steel pipes, but may be by open canals further upstream. Sprinkler irrigation and localized irrigation are practised on the remaining area equipped for full or partial control irrigation.

Groundwater is used for irrigation on 19 percent of the equipped area (Figure 4). The remaining part is irrigated from surface water through reservoirs, river diversion or pumping in rivers.

FIGURE 3
Irrigation techniques
Total 273 530 ha in 2006



Role of irrigation in gricultural production, economy and society

The irrigation potential has been estimated at about 660 000 ha and 41 percent of this had been equipped for irrigation in 2006. Almost 71 percent of the irrigated area was occupied by annual crops. Cereals, mainly wheat, covered 20 percent, fodder 15 percent, potatoes 14 percent and vegetables 13 percent (Table 4 and Figure 5). More than 80 percent of total crop production is produced under irrigation. The difference in productivity between irrigated and rainfed agriculture is estimated at about US$900 per hectare. Table 5 gives an illustration of estimated returns for irrigation water at the farmgate by main crop and agro-economic zone.

An analysis based on standardized farm models indicates that even

FIGURE 4
Source of irrigation water
Total: 273 530 ha in 2006

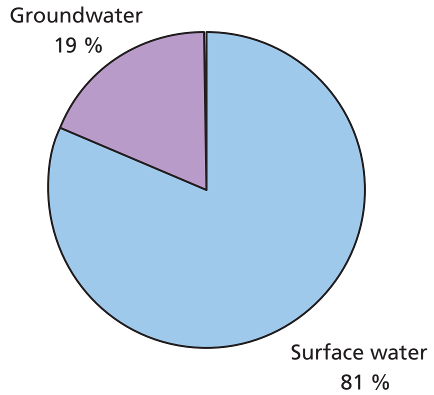
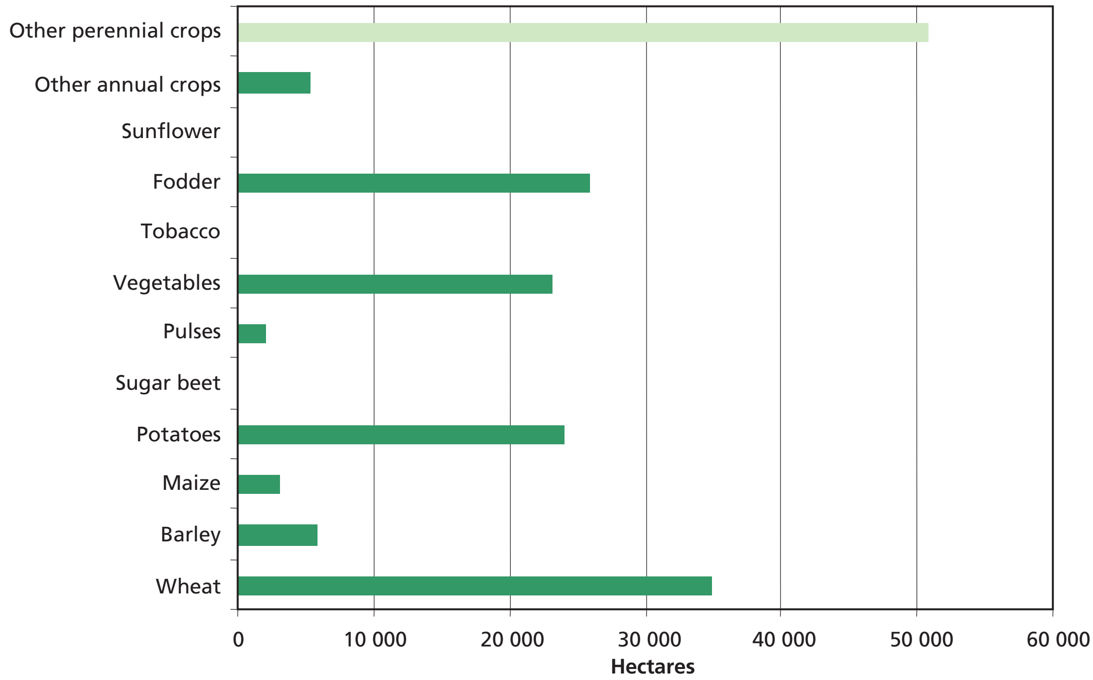


FIGURE 5
Irrigated crops
Total harvested area 176 000 ha in 2006 (cropping intensity on actually irrigated: 100%)



without taking into account changing cropping patterns in response to the increased reliability of irrigation, a 30 percent increase in irrigated land for an average farm will generate sufficient incremental net income to lift a family out of poverty, providing that other sources of income remained unchanged. However, an analysis based on information collected from 54 Water Users' Associations (WUAs) revealed that although irrigation in 2005 clearly improved in terms of reliability of supply, only 125 000 ha was actually irrigated out of the 228 000 ha equipped for the service. Three main problems explain this situation. First, the high cost of water supply in areas with predominantly pumping irrigation makes irrigation economically non-viable due to very inefficient pumping schemes. Second, water losses in secondary and tertiary canals are reported to be in the order of 40–50 percent, which effectively reduces the total irrigated area, since additional water supplies are unavailable in most cases for technical or/and economic reasons. Third, most of the pumping stations have very high levels of electricity consumption compared with their design parameters and high maintenance costs due to frequent service disruptions beyond what was designed.

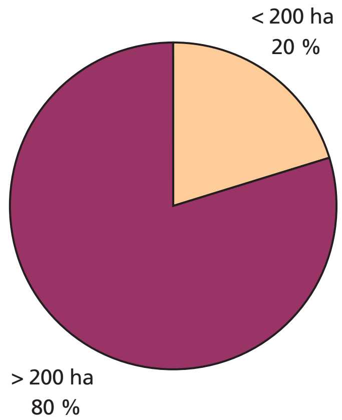
TABLE 5
Net return to irrigation water at the farm gate (US$ cents per m³)

Crop	Ararat Plain Area	Hilly Area	Mountainous Area	Subtropical Area
Wheat	12	6	5	11
Vegetables	26	2	20	33
Potatoes	54	11	42	29
Alfalfa	1	0	1	0
Fruit	23	72	25	61
Grapes	51	22	-	11

TABLE 6
Assessment of water demand for irrigation for WUAs (2005)

Marz	Actually irrigated area	Water withdrawal	Water used in the field	Average losses	Water volume for 1 ha of irrigated lands (m^3)	
	(ha)	(million m^3)	(million m^3)	(%)	gross	net
Ararat	27 584	285	169	41	10 332	6 127
Armavir	42 597	525	314	40	12 325	7 371
Kotayk	8 102	85	49	42	10 491	6 048
Aragatsotn	18 899	192	113	41	10 159	5 979
Gegharkunik	4 366	19	12	37	4 352	2 749
Shirak	10 157	31	16	48	3 052	1 575
Vayots Dzor	3 165	17	10	41	5 372	3 160
Syunik	4 703	22	14	36	4 678	2 977
Tavush	2 816	14	9	36	4 972	3 196
Lory	2 875	8	5	38	2 783	1 739
TOTAL	**125 264**	**1 198**	**711**	**41**	**9 564**	**5 676**

FIGURE 6
Type of irrigation schemes
Total 273 530 ha in 2006



Annual irrigation water demand begins to increase in late April, peaks in early July, and drops off in October. Nearly 40 percent of the irrigation area depends on high-lift pumping, with pumping lifts of more than 100 m. For the larger irrigation systems, losses may amount to 50 percent of the water intake. Information about actually irrigated lands is presented in Table 6, containing data provided by WUAs in 2005 on the demand for water for irrigation purposes.

There are pronounced differences between the communities with respect to share of irrigated land. In 2003, 24 percent of rural communities did not have access to irrigation, 5 percent had less than 20 percent of their total arable land under irrigation, 24 percent had between 20 and 80 percent under irrigation, while 47 percent had over 80 percent of their total arable land under irrigation (WB-IBRD, 2004). In 2006, small schemes (< 200 ha) covered 20 percent of total equipped area for irrigation, while large schemes (> 200 ha) covered 80 percent (Figure 6).

Crop budgets were prepared based on the monitoring and evaluation of WUAs in 2004 and prices were obtained through farm surveys. The country was divided into four agro-economic zones (valley, upland, high mountainous and subtropical), in three of which rainfed farming is possible. Composition of crops, yields, incomes per hectare by crop and by zone are presented in Table 7 and Table 8.

Status and evolution of drainage systems

In 2006 drainage was practised on 34 457 ha, of which 7 729 ha of horizontal closed drainage, 26 408 ha of horizontal open drainage and 320 ha of vertical drainage. The part of the irrigated land that is waterlogged is 18 722 ha.

TABLE 7
Crop budgets by agro-economic zones (2004)

Crop / Budget	Valley		Hilly		Mountainous		Subtropical	
	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated
Wheat	-	42%	50%	24%	65%	54%	60%	16%
Vegetables	-	20%	-	10%	-	6%	-	9%
Potatoes	-	5%	-	1%	-	27%	-	2%
Alfalfa	-	8%	50%	31%	35%	11%	40%	-
Fruit	-	17%	-	26%	-	2%	-	44%
Grape	-	8%	-	8%	-	-	-	29%
Total	-	100%	100%	100%	100%	100%	100%	100%

TABLE 8
Crop yield and net income by agro-economic zones (2004)

Zone	Yield (kg per ha)		Net Income (US$ per ha)	
	Non-irrigated	Irrigated	Non-irrigated	Irrigated
Valley				
Wheat		3 350		470
Vegetables		37 810		2 098
Potatoes		30 750		4 196
Alfalfa		11 920		75
Fruit		5 600		1 631
Grapes		12 410		3 596
Weighted average				1 385
Hilly				
Wheat	1 200	2 760	57	303
Vegetables	-	16 200	-	141
Potatoes	-	13 000	-	540
Alfalfa	3 000	7 000	13	14
Fruit	-	11 850	-	4 297
Grapes	-	5 860	-	1 291
Weighted average				1 316
Mountainous				
Wheat	1 400	2 570	116	286
Vegetables	-	22 500	-	992
Potatoes	-	21 070	-	2 110
Alfalfa	2 500	6 200	12	57
Fruit	-	6 100	-	1 265
Weighted average				820
Subtropical				
Wheat	2 300	6 000	366	1 137
Vegetables	-	28 700	-	2 615
Potatoes	-	19 700	-	1 436
Alfalfa	3 000	-	35	-
Fruit	-	10 000	-	4 243
Weighted average				2 328

WATER MANAGEMENT, POLICIES AND LEGISLATION RELATED TO WATER USE IN AGRICULTURE

Institutions

The most important institutions involved in water resources development and management are:

- The National Water Council (NWC): the highest advisory body in the water sector, chaired by the Prime Minister. It advises on water management issues, and makes recommendations on policies, legal documents, and the National Water Program.

- The Ministry of Nature Protection, with:
  - the Underground Resources Protection Department;
  - the Environmental Protection Department;
  - the Water Resources Management Agency, which controls the use of water resources through water use permits;
  - the Climate Change Information Center;
  - the State Environmental Inspectorate.
- The Ministry of Agriculture: responsible for the development of agriculture policy and strategies, including irrigation and drainage policies, with:
  - the Planning of Agricultural and Social Development of Rural Areas Department;
  - the Crop Production, Forestry and Plant Protection Department.
- The Vorogum-Jrar Closed Joint Stock Company (CJSC): brings together State organizations with responsibilities for the provision of irrigation and drainage services. This company pumps or diverts the water from the river, operates and maintains the primary canals, and sells the water to WUAs under seasonal water supply contracts.
- The Public Services Regulatory Commission (PSRC): responsible for the economic regulation of natural monopolies in the irrigation and municipal water sectors. The main responsibilities are water infrastructure use permits, the monitoring of the quality of service provisions, and setting of tariffs.
- The Ministry of Territorial Administration, with:
  - the State Committee on Water Systems (SCWS), which is responsible for the management and operation of state-owned municipal and irrigation water supply, sewerage and wastewater treatment systems; it includes the "Melioration" CJSC, which is responsible for operation and maintenance of drainage systems;
- The Armenian State Hydrometeorological and Monitoring Service (Armstatehydromet) and Environmental Impact Monitoring Center (EIMC): provide surface water monitoring data;
- The Hydrogeological Monitoring Center: responsible for monitoring all groundwater bodies.

Water management

Reforms in the water sector have been initiated since the implementation of the World Bank-supported "Integrated Water Resources Management Project" in 1999–2000. The idea of river basin management was also proposed through the introduction of annual and perspective planning mechanisms for water resources. One of the most important steps towards reform in the water sector was the adoption of a new Water Code on 4 June 2002 and, in order to ensure its enforcement, 80 regulations have been adopted by the Government since 2002, which relate, among others, to the procedures for water use permit provisions, transparency and public participation in the decision-making processes, accessibility of information, establishment of the state water cadaster, formation of water resources monitoring, management of transboundary water resources. The Code also contains the idea of integrated river basin management, for which a methodology of developing integrated water basin management plans has been developed, making it possible to use economic tools for water resources management and cost recovery. In order to promote more efficient, targeted and decentralized management of water resources, five territorial divisions (Basin Management Organizations) have been established under the umbrella of the Water Resources Management Agency: Northern, Akhuryan, Araratian, Sevan-

Hrazdan and Southern. The Law on “Fundamental Provisions of the National Water Policy” was adopted in 2005; this represents a forward-looking development concept for water resources and water systems’ strategic use and protection. Since 2005 the water basin management principle is being applied in the sector of water resources management. In addition to this, a law concerning the “National Water Programme” has been developed. This law is the main document for the prospective development of water resources and water systems management and protection. As a result of the above-mentioned legal and institutional reforms, Armenia is currently one of the leaders in the region in the sector of water resource management.

By law, local mayors are responsible for providing the water service within a municipality unless the water sources and facilities serve more than one municipality, in which case one of the five State-owned water companies provides the water service. In 2006, about 80 percent of the population was served by the State water companies. The remainder of the population is served by small municipal systems and numerous community-based organizations. The “Yrevan Djur” CJSC is the largest of the five State companies and provides water and sewer services to the city of Yerevan and 28 neighbouring villages, covering around 50 percent of the total population. It operates under a recently signed lease contract with a French water company. The next largest State water company is the Armenian Water and Sewerage Company (AWSC) which operates under the terms of a management contract with another French water company. AWSC provides service to roughly 22 percent of the population. The other three State water companies, Lori, Shirak and Nor Akunk are managed with significant input from foreign consultants under the terms of a financing agreement between the State and a German lending agency. At the beginning of 2006, the average monthly water bill for most residential customers in Armenia was less than US$2. The collection rate has been improving but is still less than desirable.

Hydropower accounts for 20 percent of electricity generation. The total installed hydropower generating capacity of Armenia is about 1 100 MW, of which 1 050 MW is operational. Almost 95 percent of this capacity is installed along two important hydropower cascades: the Sevan-Hrazdan Cascade and the Vorotan Cascade. Electricity generation at the Sevan-Hrazdan Cascade is tied to irrigation releases from Lake Sevan on the basis of an annual water allocation plan (USAID, 2006).

USAID designed the Programme for Institutional and Regulatory Strengthening of Water Management in Armenia (2004-2008) to provide technical assistance, training and equipment to improve water resource management and the regulation of the increasingly decentralized irrigation and municipal water sectors. The programme will lay the foundation for effective water resource management and planned investment in the Armenian drinking water, sewerage, and irrigation sectors and assist the Government and leading water sector agencies to enhance their effectiveness through initiatives based on international best practices adapted for the Armenian context.

Finances

Currently, the State funds about 50 percent of the annually assessed Operation and Maintenance (O&M) requirements of the water services for irrigation. For 2005, the O&M requirements were estimated to be US$16 million, with a contribution from the State budget of US$8 million, which essentially covers the electricity costs for operating the pumping stations. The irrigation tariffs that WUAs or other users pay to the Vorogum-Jrar differ by region and mode of water delivery (pumped or gravity) and are capped at approximately US$20/1 000 m^3 or US$150/ha. Maintenance is still inadequate to sustain the irrigation systems due to an underestimation of the annual O&M requirements and lower than expected tariff collection rates. The real O&M costs may vary from US$5/1 000 m^3 or US$40/ha for gravity schemes to more than

US$50/1 000 m^3 or US$400/ha for some high-lift pumped schemes. The latter costs are higher than the incremental income earned by many subsistence farmers as a result of irrigation and may range from US$200/ha to US$400/ha per year (USAID, 2006).

Investments, such as the recently approved grant of US$236 million from the US Millennium Challenge Corporation may go a long way toward stabilizing the irrigation subsector. The grant will support a five-year programme of strategic investments in irrigation and rural roads, aimed at increasing agricultural production. The grant will also fund the improvement of drainage facilities, the rehabilitation of irrigation infrastructure, the strengthening of the Vorogum-Jrar and WUAs, and a water-to-market project that will provide training and access to credit for farmers who want to make the transition to more profitable, market-oriented agricultural production (USAID, 2006).

Policies and legislation

As mentioned in the "Water management" section above, the legal and institutional structure of the water sector is based on the National Water Code adopted in 2002. The Water Code defines three major functions in the water sector: management of water resources, management of water systems, and regulation of water supply and wastewater services.

ENVIRONMENT AND HEALTH

Most of the drinking water is provided by groundwater, which has high organoleptic properties and is very pure. Due to the poor state of the water supply networks, however, the risk of water contamination is high. Due to the lack of liquid and lime chlorine, and the electric power deficit, in most cases, water is supplied without chlorination. In many places sewage and drinking water supply networks are put together and at present the sewage system is in an emergency situation: 63 percent of the network is more than 20 years old and 22 percent requires immediate renewal. According to the data provided by the Ministry of Health, during 1984–1991, no infection outbreak episodes related to drinking water quality were recorded in Armenia. However, since 1992 such episodes have been periodically registered. During the 1999–2002 period, 18 outbreak episodes related to water pollution were recorded with the total number of 5 690 diseased persons (UNDP, 2005). In 2003, 21 839 incidents were recorded, 5 839 of which (26.7 percent) occurred in Yerevan.

Solonetzic soils, which are characterized by a tough, impermeable hardpan that may vary from 5 to 30 cm or more below the surface soils, are widespread. These soils are most of all exposed to the risk of irrigation-related salinization, mainly as a result of rising groundwater in the plains, where the majority of irrigated lands are located. In the Ararat plain, solonetzic soils cover about 10 percent of the area. In 2006, the part of the irrigated land that is salinized was 20 415 ha, of which 15 137 ha weakly salinized, 2 385 ha medium salinized, and 2 893 ha strongly salinized (MTA, 2007).

The malaria situation was stable in Armenia until 1994. In subsequent years, a downgrading of malaria prevention services and a weakening of the malaria surveillance system resulted in a steady increase in the number of malaria cases, reaching 1 156 by 1998. Over 98 percent of these cases were detected in the Masis district of the Ararat Valley, an area bordering Turkey. In recent years, owing to epidemic control interventions, the number of autochthonous malaria cases has continued to decrease, dropping to 8 in 2003. However, although numbers have been on the decline, the situation must be monitored closely, because of the existence of favourable conditions for malaria transmission. In 2003, Armenia redefined and adjusted the present malaria control strategy, objectives and approaches, bearing in mind the results achieved to date, the extent of the problem, and potential threats in the country (MTA, 2007).

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

To reduce the burden of high expenditure in the State budget for government bodies engaged in water resource management, steps have been taken to involve the private sector.

Within the framework of the Agricultural Sustainable Development Strategy, the main priorities in the development of crop production are an increase in crop yield and a reduction in expenses per production unit through the application of advanced agro-technologies.

Main and secondary canals with high water losses, the collector-drainage system in the Ararat valley, and the tertiary irrigation systems need rehabilitation. About half of the total amount of the Agreement (US$113 million), signed between US Government Millennium Challenge Corporation and Armenia, will be directed to solve the main problems in the irrigation sector.

The main directions in the development of the irrigation sector are as follows:

a. Improvement of the managerial structure and technical conditions of the irrigation system;
b. Substitution of pumped irrigation with gravity irrigation conveyance systems and introduction of clear mechanisms for the management, supply and stock-taking of irrigation water;
c. Support to the establishment of water users' unions, as well as to the development of water users' associations;
d. Support to the rehabilitation of inter-farm irrigation networks;
e. Implementation of the "Cleaning and maintenance of the collector-drainage network programme" to regulate the level and mineral content of subsoil water located in the irrigated areas under the drainage systems, to prevent secondary salinization, floods and infectious diseases, to reclaim land and to provide a sustainable yield from agricultural crops;
f. Decrease in water tariffs; provision of sustainable water supply; decrease in water losses and water utilization prices through improvement of the water systems; increase in efficiency of farming activities due to the additional water supply; creation of favourable conditions for the utilization of the irrigation systems and denationalization of maintenance procedures; improvement of efficient management of the network through implementation of structural reforms, provision of transparency for water tariffs and switching to self-financing of the network by the end of the programme;
g. Implementation of the first and second dam safety programmes. The first programme aims at the provision of dam safety for a population of 360 000 and at increased efficiency in the supply of the irrigation system. The programme includes rehabilitation of the 20 most dangerous 20 dams and some other activities besides. The second programme includes the rehabilitation of 47 dams;
h. Implementation of the subprogramme on "Irrigated agriculture" under the Millennium Goal programme. According to the programme, US$113 million will be spent on solving the existing problems in the irrigation system (over 5 years). The programme includes irrigation schemes for 21 districts and the construction of 18 gravity-fed systems, 5 new water reservoirs and rehabilitation of 2 non-finished water reservoirs, rehabilitation of 6 big water pipes for a total length of 200 km, rehabilitation and re-equipping of 68 pump stations, rehabilitation of inter-farm irrigation networks on a total area of 75 000 ha with the assistance of water users; and rehabilitation of the Ararat valley irrigation-drainage network and, as a result, ensuring soil quality improvement over an area of 25 000 ha. The implementation of the programme will enable a decrease in electricity use of 30 percent, and a rehabilitated irrigation network covering 30 000 ha, thus a decrease in total expenses of 20 percent;

i. Implementation of the programme on the watering of natural pastures. Annually, over US$530 000 (160 million AMD at 2008 rate) will be spent on these activities, with the aim of increasing the crop yield of the pastures and net income, which will promote poverty reduction;
j. Implementation of the programme on improvement of soil quality of the secondary salinized irrigated land of the Ararat valley. As a result, the subsoil water level will be regulated over about 8 000 ha, secondary salinization and flooding of the settlements will be prevented, and sustainable crop yield will be ensured thus promoting poverty reduction;
k. Implementation of the programme on the definition of irrigation norms and regimes for agricultural crops. The programme aims to develop new norms and regimes to replace those in place for the last thirty years. The new norms will meet the actual requirements, supplying crops with sufficient water for growth. Moreover, there will be a saving of water resources in the order of 10–15 per cent. (FAO and MOA, 2002)

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Azerbaijan

GEOGRAPHY, CLIMATE AND POPULATION

Geography

Azerbaijan, with a total area of 86 600 km², is located on the southeastern slopes of the Caucasus Mountains. It is bordered to the east by the Caspian Sea, to the south by the Islamic Republic of Iran, to the southwest by Turkey, to the west by Armenia, to the northwest by Georgia and to the north by the Russian Federation. The Nakhchivan Autonomous Republic of Azerbaijan in the southwest is separated from the rest of the country by Armenia.

About 43 percent of the area of Azerbaijan is situated more than 1 000 m above sea level. The country can be divided into five main physiographic regions:

- the Greater Caucasus mountain range in the north, extending from the Black Sea in the west to the Caspian Sea in the east, over the northern part of Georgia and Azerbaijan and the southern part of the Russian Federation;
- the Lesser Caucasus mountain range, south of the Greater Caucasus and covering the south of Georgia and Azerbaijan and the north of Armenia;
- the lowlands around the Kura and Araks Rivers;
- the Talish Mountains with the adjoining Lankaran lowland in the southeast, along the border with the Islamic Republic of Iran;
- the Nakhchivan Autonomous Republic in the southwest.

The cultivable area is estimated to be about 4.32 million ha, which is 50 percent of the total area of the country. In 2005, the cultivated area was 2.06 million ha, or 48 percent of the cultivable area, of which 1.84 million ha were annual crops and 0.22 million ha permanent crops (Table 1). Between 1993 and 2005 the cultivated area increased by 15 percent.

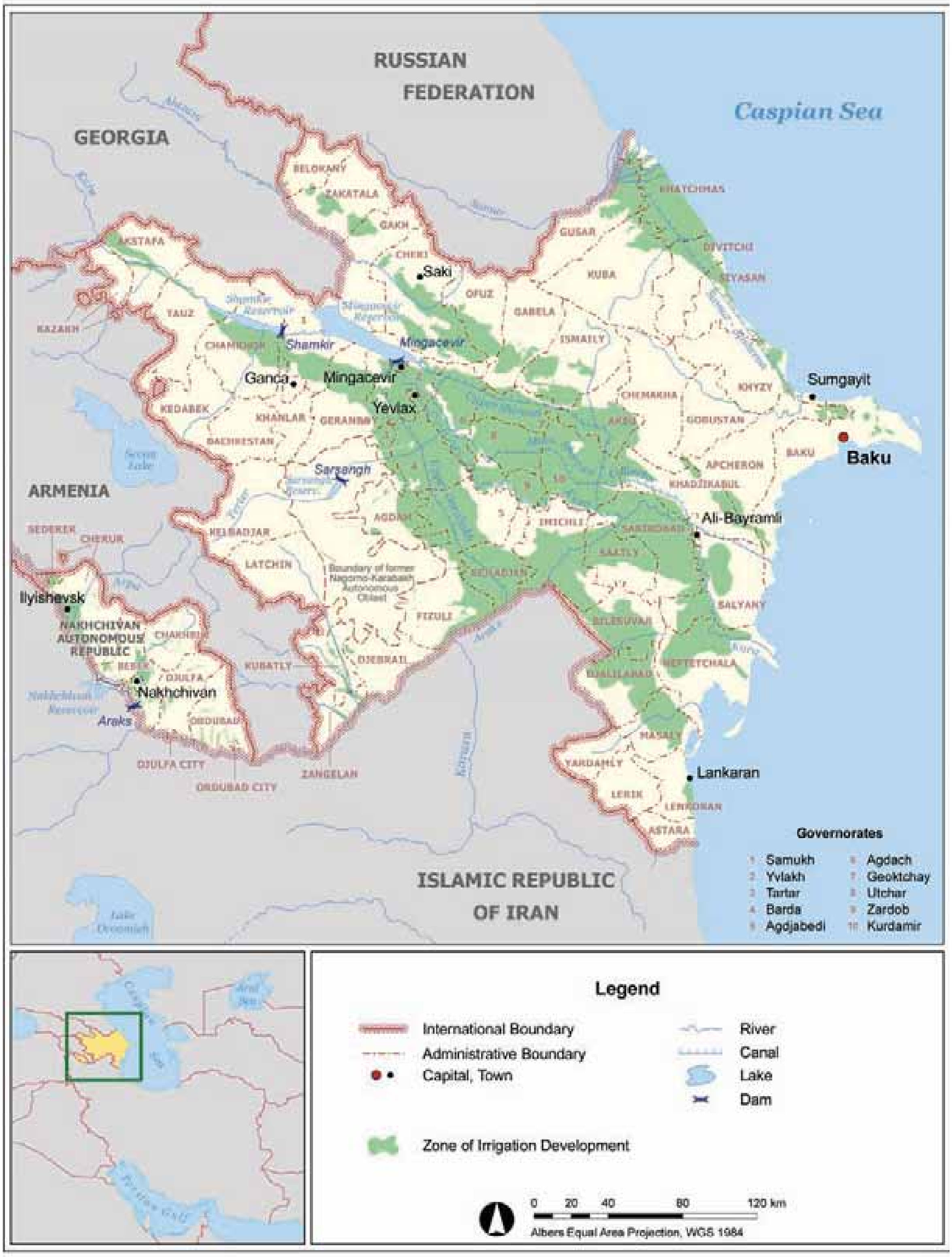
Climate

Azerbaijan is situated on the northern edge of the subtropical zone. Its climatic diversity is the result of its particular geographical location and landscape, the proximity of the Caspian Sea, the effect of sun's radiation and air masses of different origin.

The climate in Azerbaijan is continental. The weather in the lowlands is arid, with average summer temperatures of over 22 °C. In the mountain regions, temperatures can fall below 0 °C in winter and in Nakhchivan severe frost may occur. Humid tropical weather prevails in the coastal zone near the Caspian Sea, mainly in the Lankaran lowlands in the southeast. The estimated average precipitation is 447 mm/year.

Population

The total population is 8.4 million (2005), around 50 percent of which is rural. The average population density is 97 inhabitants/km².



AZERBAIJAN **FAO - AQUASTAT, 2008**

TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2005	8 660 000	ha
Cultivated area (arable land and area under permanent crops)	2005	2 064 700	ha
• as % of the total area of the country	2005	23.8	%
• arable land (annual crops + temp fallow + temp. meadows)	2005	1 843 200	ha
• area under permanent crops	2005	221 500	ha
Population			
Total population	2005	8 411 000	inhabitants
• of which rural	2005	50.1	%
Population density	2005	97.1	inhabitants/km^2
Economically active population	2005	3 980 000	inhabitants
• as % of total population	2005	47.3	%
• female	2005	46.2	%
• male	2005	53.8	%
Population economically active in agriculture	2005	982 000	inhabitants
• as % of total economically active population	2005	24.7	%
• female	2005	52.4	%
• male	2005	47.6	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2007	31 250	million US$/yr
• value added in agriculture (% of GDP)	2007	6	%
• GDP per capita	2005	1 569	US$/yr
Human Development Index (highest = 1)	2005	0.746	
Access to improved drinking water sources			
Total population	2006	78	%
Urban population	2006	95	%
Rural population	2006	59	%

In 2006, 80 percent of the population had access to improved sanitation (90 and 70 percent in urban and rural areas respectively) and 78 percent had access to improved water sources (95 and 59 percent in urban and rural areas) (Table 1).

ECONOMY, AGRICULTURE AND FOOD SECURITY

Agriculture plays an important role in the Azerbaijan's development and in guaranteeing the supply of staples and constitutes one of the main sectors of the economy.

In 2007, the Gross Domestic Product (GDP) was US$31.3 billion (Table 1). The share of agriculture dropped from 39 percent in 1990 to 6 percent in 2007, due to extensive industrial development from 1995 to 2004. Production sharing agreements with large foreign companies regarding oil and gas fields have led to the rapid development of these industries.

In 2005, the total economically active population was 3.98 million, or just over 47 percent of the total population, with some 25 percent employed in the agricultural sector. Women make up about 52 percent of the rural labour force.

Plant cultivation is one of the key sectors of agriculture in Azerbaijan. Its fertile lands, good climate and topography provide opportunities for the production of agricultural products year-round (Heydar Aliyev Foundation, 2008). The most important crops are wheat, cotton, potatoes, vegetables, tobacco, melon, sugar beet, sunflowers and fruit trees.

WATER RESOURCES AND USE

Water resources

It is estimated that internal renewable water resources amount to about 8.12 km^3/year (Table 2). Annual surface runoff is estimated at 5.96 km^3 and groundwater recharge

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	447	mm/yr
	-	38.7	10^9 m^3/yr
Internal renewable water resources (long-term average)	-	8.115	10^9 m^3/yr
Total actual renewable water resources	-	34.675	10^9 m^3/yr
Dependency ratio	-	76.6	%
Total actual renewable water resources per inhabitant	2005	4 123	m^3/yr
Total dam capacity	2003	21 542	10^6 m^3
Water withdrawal			
Total water withdrawal	2005	12 211	10^6 m^3/yr
- irrigation + livestock	2005	9 330	10^6 m^3/yr
- municipalities	2005	521	10^6 m^3/yr
- industry	2005	2 360	10^6 m^3/yr
• per inhabitant	2005	1 452	m^3/yr
Surface water and groundwater withdrawal	2005	12 050	10^6 m^3/yr
• as % of total actual renewable water resources	2005	34.8	%
Non-conventional sources of water			
Produced wastewater	2005	659	10^6 m^3/yr
Treated wastewater	2005	161	10^6 m^3/yr
Reused treated wastewater	2005	161	10^6 m^3/yr
Desalinated water produced		-	10^6 m^3/yr
Reused agricultural drainage water		-	10^6 m^3/yr

at 6.51 km^3, of which 4.35 km^3 constitutes the base flow of the rivers. The estimated incoming surface flow is 25.38 km^3/year, of which 11.91 km^3 from Georgia, 7.50 km^3 from the Islamic Republic of Iran and 5.97 km^3 from Armenia. The Sumar River, with a total flow of 2.36 km^3/year, forms the border between Azerbaijan and the Russian Federation. The total renewable surface water resources (RSWR), including incoming and bordering flows, are therefore estimated at 32.52 km^3/year. In the case of the Kura and Araks Rivers, which flow through Turkey, Georgia, Armenia, the Islamic Republic of Iran and Azerbaijan, discussions are under way on a water sharing agreement.

The groundwater resources are famous for their quality as mineral drinking water and are also used for medical purposes. The Nakhchivan Autonomous Republic is especially rich in mineral groundwater.

Azerbaijan has four major river basins, two of which are international:

- The basin of the Kura and Araks Rivers. This is by far the largest basin in the country (excluding the occupied zone and the zone declared neutral in May 1994). The Kura River rises in the Kars upland in northeast Turkey. It then flows into Georgia and crosses the border to Azerbaijan in the northwest. The total length of the Kura River system is 1 515 km, of which 900 km is located within Azerbaijan. The total annual inflow from Georgia is estimated at 11.91 km^3. The Araks River also rises in the northeast of Turkey. It forms the border between Turkey and Armenia, Turkey and Azerbaijan, the Islamic Republic of Iran and Azerbaijan, the Islamic Republic of Iran and Armenia, and the Islamic Republic of Iran and Azerbaijan again, before flowing into the eastern part of Azerbaijan. About 100 km downstream of the border it joins the Kura River, which continues to flow southeast towards the Caspian Sea. The total inflow of the main branch of the Araks River and its tributaries from Armenia and Iran is estimated at 13.47 km^3/year, bringing the total inflow into Azerbaijan to an estimated 25.38 km^3/year.
- The Samur River Basin, located in the northeast of the country. The Samur River rises in the Russian Federation and then forms its border with Azerbaijan. Its estimated annual discharge is 2.36 km^3, half of which is considered to be available

for Azerbaijan. The river divides into several branches before flowing into the Caspian Sea.
- The Caspian Sea coastal river basins in the northeast, between the Samur and Kura River Basins.
- The Caspian Sea coastal river basins in the Lankaran region in the southeast, south of the Kura River Basin.

The total reservoir capacity of Azerbaijan's dams is around 21.54 km³. Most of this capacity, 21.04 km³, comes from large dams, of more than 100 million m³ each. The four largest reservoirs are the Mingacevir and Shamkir on the Kura River, the Araks dam on the Araks River, and the Sarsang on the Terter River, in Armenia.

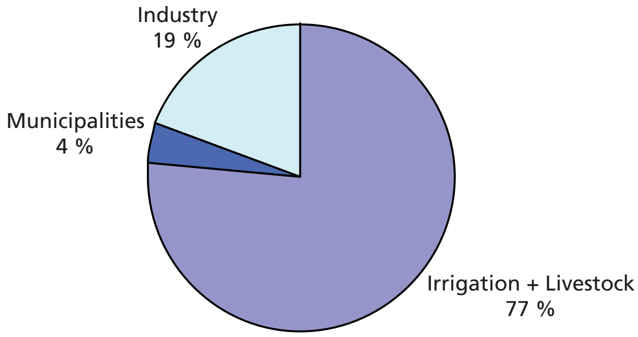
In 2005, wastewater production totalled some 659 million m³. Most wastewater is produced by the cotton cleaning, cotton oil production, fish-curing and grape processing industries. In 2005, 161 million m³ of wastewater was treated for reuse (Table 2). Although wastewater treatment plants exist in 16 towns and cities, the majority are partly or completely out of operation.

Water use

In 2005 water withdrawal was estimated at 12.21 km³, of which 76.4 percent for agricultural purposes, 4.2 percent for municipal uses and 19.3 percent for industrial processes (Table 2 and Figure 1).

In 2004, total freshwater withdrawal amounted to 11.44 km³, of which 10.73 km³ surface water and 0.71 km³ groundwater. In 2005, freshwater withdrawal totalled 12.05 km³ (Figure 2).

FIGURE 1
Water withdrawal by sector
Total: 12.211 km³ in 2005

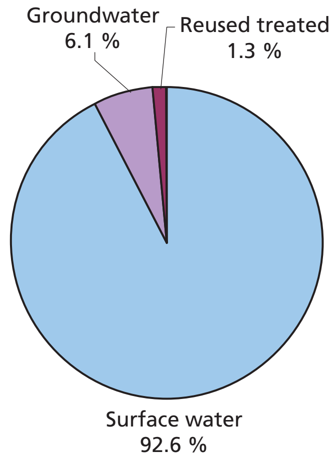


International water issues

Azerbaijan is party to three agreements with its neighbours on transboundary rivers: with the Islamic Republic of Iran on the Araks River, with Georgia on Gandar Lake and with the Russian Federation on the Samur River. No agreement exists regarding the Kura River, the most important transboundary river in the region (UNECE, 2004). Issues of critical importance are the sharing and joint management of the Kura and Araks Rivers and of the Caspian Sea to prevent further pollution and ensure sustainable development of their resources.

In 1997 the Government of Georgia ratified an agreement with Azerbaijan concerning environmental protection, providing for cooperation in the creation of specifically protected areas within transboundary ecosystems.

FIGURE 2
Water withdrawal by source
Total: 12.211 km³ in 2005



The Caucasus Initiative, launched by the German Ministry of Cooperation and Development, envisages, among other things, the implementation of the “Ecoregional Nature Protection Programme for Southern Caucasus” covering the three Caucasus countries: Georgia, Azerbaijan and Armenia. It will be implemented in the nearest future and will facilitate to protect and sustainable use of water resources in the region (Tsiklauri, 2004).

A number of international organizations have cooperated on initiatives in Azerbaijan in the field of ecology through the UN mission and the UNDP. Negotiations have been held with representatives of the UN, UNEP, UNESCO, World Bank and environmental protection organizations of the USA, UK, Germany, Turkey, the Islamic Republic of Iran and CIS countries. One of the results has been the adoption of the “Agreement on cooperation in the field of ecology and environmental protection between Azerbaijan and Turkey” (UNEP/GRID-Arendal, 2005).

From 2000 to 2002, USAID, in collaboration with Development Alternatives Inc. (DAI), implemented the South Caucasus Water Management project. Its aim was to strengthen co-operation among water agencies at local, national and regional levels and demonstrate integrated water resources management. In parallel, between 2000 and 2006, the EU and the Technical Assistance Commonwealth of Independent States (TACIS) carried out the Joint River Management Programme on Monitoring and Assessment of Water Quality on Transboundary Rivers for the prevention, control and reduction of the impact of trans-boundary pollution. The programme covered four basins, including the Kura River Basin. In addition, regional organisations such as REC, Eurasia Foundation, and numerous local foundations have promoted national and regional activities concerning water resources management and protection (UNEP, 2002).

Between 2002 and 2007, NATO-OSCE realized the South Caucasus River Monitoring Project. Its general objectives were to establish the social and technical infrastructure for a joint international Transboundary River water quality and quantity monitoring, data sharing and watershed management system among the Republics of Armenia, Azerbaijan and Georgia (OSU, 2008).

The project Reducing Transboundary Degradation in the Kura-Araks River Basin, implemented by the UNDP Bratislava Regional Centre in collaboration with the Global Environmental Facility (GEF), has involved four of the basin countries: Armenia, Azerbaijan, Georgia and the Islamic Republic of Iran. Efforts are being made to involve Turkey in the project as well. The preparation phase, which is co-funded by Sweden, began in July 2005 and will last 18 months. The objective of the project is to ensure that the quality and quantity of the water throughout the Kura-Araks River system meets the short and long-term needs of the ecosystem and the communities that rely upon it. It will be achieved by fostering regional cooperation, increasing the capacity to address water quality and quantity problems, demonstrating water quality/quantity improvements, initiating required policy and legal reforms, identifying and preparing priority investments, and developing sustainable management and financial arrangements.

Currently there are no water treaties between the three south Caucasian countries owing to the political situation in the region. Nagorno-Karabakh is one of the main obstacles, making it difficult for Azerbaijan and Armenia to sign a treaty even one only relating to water resources management (Berrin and Campana, 2008).

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

The irrigation potential is estimated at 3.2 million ha. In the last century, irrigation was concentrated alongside the rivers and it was only at the beginning of this century that the construction of large irrigation canals started. In 1913, 582 000 ha were irrigated. The most intensive development took place after the Second World War and in 1975 the area equipped for irrigation was 1.17 million ha. By 1995 this had become 1.45 million ha, which is 45 percent of the irrigation potential.

In 1995, the total length of all irrigation canals was 65 900 km, of which only 2 400 km, or 3.6 percent, were concrete canals. National irrigation efficiency was estimated at 55 percent. The largest canals are the Upper Garabakh, the Upper Shirvan and the Samur-Apsheron, all earthen. The Upper Gabarakh canal runs southeast from the Mingacevir reservoir to the Araks River. It is about 174 km long and has a capacity of 113.5 m^3/s. About 85 000 ha were irrigated by this canal in 1995. The Upper Shirvan canal also starts from the Mingacevir reservoir and runs east to the Akhsu River. It is about 126 km in length and has a capacity of 78 m^3/s and in 1995 irrigated about 91 100 ha.

In 1995, almost 90 percent of the irrigation was surface irrigation, mainly furrow and border strip irrigation. Sprinkler irrigation and localized irrigation were used mainly on perennial plantations and vineyards (Table 3 and Figure 3). Surface water was used on 93 percent of the area, mainly from reservoirs and through direct pumping in rivers and canals (Figure 4). About 96 700 ha were irrigated by groundwater through more than 5 000 wells. Private farmers exploit this source intensively as the major irrigation installations are seriously degraded.

In 1995, small schemes (<10 000 ha) covered 5.3 percent of the total area equipped for irrigation, medium size schemes (10 000–20 000 ha) 13.3 percent and large schemes (>20 000 ha) 81.5 percent (Figure 5). Most schemes were state-owned. Farmer-owned irrigation started to appear in 1992 and in 1996 represented 1 percent of the area.

In 2003, the total area equipped for irrigation was about 1 426 000 ha and the power-irrigated area was estimated at 479 249 ha.

FIGURE 3
Type of irrigation
Total: 1 453 618 ha in 1995

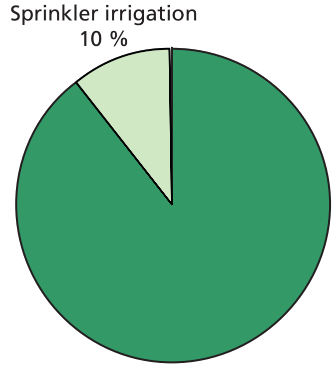


FIGURE 4
Source of irrigation water
Total: 1 453 700 ha in 1995

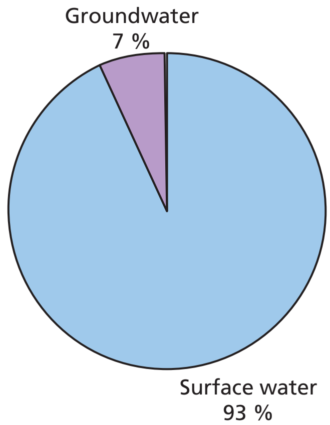


FIGURE 5
Type of irrigation schemes
Total: 1 453 020 ha in 1995

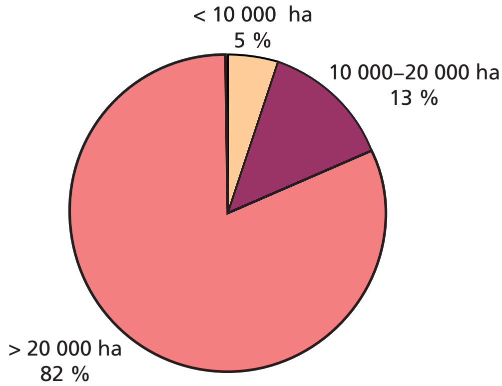
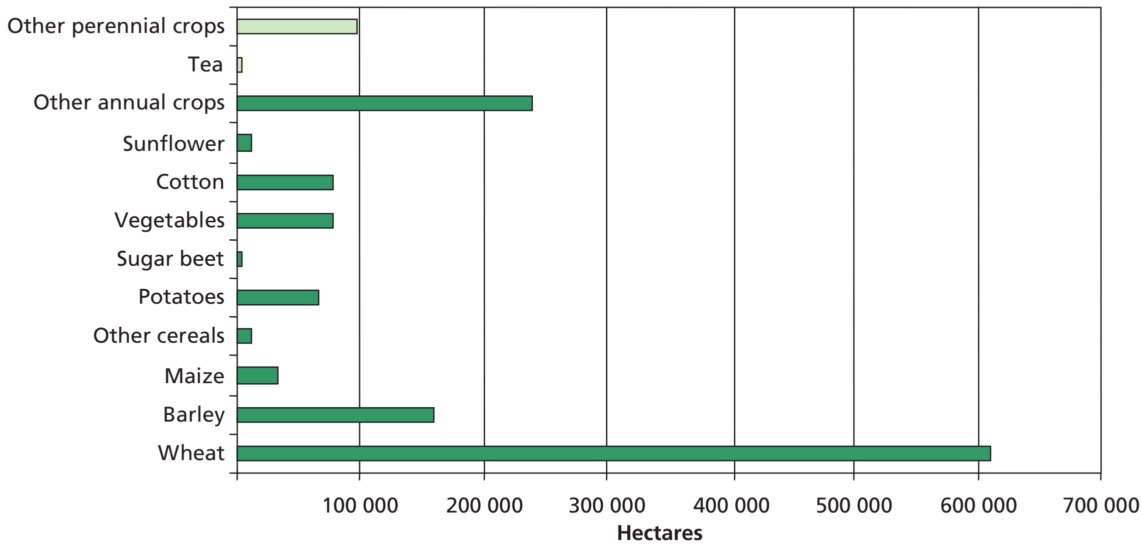


TABLE 3
Irrigation and drainage

Irrigation potential		-	3 200 000	ha
Water management				
1. Full or partial control irrigation: equipped area		2003	1 426 000	ha
- surface irrigation		1995	1 302 000	ha
- sprinkler irrigation		1995	149 000	ha
- localized irrigation		1995	2 618	ha
• % of area irrigated from surface water		1995	93	%
• % of area irrigated from groundwater		1995	7	%
• % of area irrigated from mixed surface water and groundwater		1995	0	%
• % of area irrigated from non-conventional sources of water		1995	0	%
• area equipped for full or partial control irrigation actually irrigated			-	ha
- as % of full/partial control area equipped			-	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)			-	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)		**2003**	**1 426 000**	**ha**
• as % of cultivated area		2003	69	%
• % of total area equipped for irrigation actually irrigated			-	%
• average increase per year over the last 8 years		1995-2003	- 0.23	%
• power irrigated area as % of total area equipped		2003	33.6	%
4. Non-equipped cultivated wetlands and inland valley bottoms			-	ha
5. Non-equipped flood recession cropping area			-	ha
Total water-managed area (1+2+3+4+5)		**2003**	**1 426 000**	**ha**
• as % of cultivated area		2003	69	%
Full or partial control irrigation schemes	**Criteria:**			
Small-scale schemes	< 10 000 ha	1995	77 420	ha
Medium-scale schemes		1995	192 600	ha
large-scale schemes	> 20 000 ha	1995	1 183 000	ha
Total number of households in irrigation			-	
Irrigated crops in full or partial control irrigation schemes				
Total irrigated grain production (wheat and barley)			-	metric tons
• as % of total grain production			-	%
Harvested crops				
Total harvested irrigated cropped area		2004	1 391 521	ha
• Annual crops: total		2004	1 290 114	ha
- Wheat		2004	610 919	ha
- Rice		2004	2 573	ha
- Barley		2004	158 909	ha
- Maize		2004	33 194	ha
- Other cereals		2004	9 302	ha
- Potatoes		2004	65 796	ha
- Sugar beet		2004	3 202	ha
- Vegetables		2004	77 248	ha
- Cotton		2004	78 161	ha
- Tobacco		2004	2 649	ha
- Sunflower		2004	11 381	ha
- Other annual crops		2004	236 780	ha
• Permanent crops: total		2004	101 407	ha
- Tea		2004	3 658	ha
- Other perennial crops (bananas, olives, grapes, strawberries)		2004	97 749	ha
Irrigated cropping intensity (on full/partial control irrigation equipped area)		2004	97.6	%
Drainage - Environment				
Total drained area		2003	608 336	ha
- part of the area equipped for irrigation drained		2003	608 336	ha
- other drained area (non-irrigated)			-	ha
• drained area as % of cultivated area			-	%
Flood-protected areas			-	ha
Area salinized by irrigation		2003	635 800	ha
Population affected by water-related diseases			-	inhabitants

FIGURE 6
Irrigated crops
Total harvested area: 1 391 521 ha in 2004 (cropping intensity on equipped area: 97.6%)



Role of irrigation in agricultural production, the economy and society

In 2004, the harvested irrigated area was 1 391 521 ha. Annual crops represent 93 percent of this area and permanent crops 7 percent. The main irrigated crops are wheat (44 percent), barley (11 percent), cotton (5.6 percent) and vegetables (5.6 percent), while the most important permanent crops are tea, bananas, olives, grapes and strawberries (Table 3 and Figure 6).

Status and evolution of drainage systems

The total drainage network covers 608 336 ha, all in the areas equipped for irrigation. In more than half the drained area the installations need to be renovated. In 2003 the area salinized by irrigation was estimated at 635 800 ha (Table 3).

WATER MANAGEMENT, POLICIES AND LEGISLATION RELATED TO WATER USE IN AGRICULTURE

Institutions

The main institutions involved in water management are all state institutions. They are:

- the Ministry of Ecology and Natural Resources, which has overall responsibility for the conservation of water resources and the prevention of pollution. It issues wastewater discharge permits, which are valid for 3–5 years. Its regional offices control and enforce discharge permits;
- the Committee on Ecology and Nature Use, which is in charge of monitoring salinization and water pollution;
- the State Committee on Amelioration and Water Management, which is responsible for monitoring water use and for issuing permits for surface water. It also levies charges for water use. The committee's activities concern mainly irrigation, for which it sets rules on water use and handles public relations. It is also in charge of land improvement on irrigated land and the operation and maintenance of the irrigation infrastructure;

- the Ministry of Health, whose Centre for Epidemiology and Hygiene is responsible for monitoring drinking water quality.

Water management

The rehabilitation of irrigation and drainage systems to ensure the sustainability of the subsector remains a priority. Major policy changes in land ownership and irrigation management play an important role in improving irrigation performance.

Control of erosion is another major issue as, according to the Ecological Committee's data, this problem affects almost 43 percent of the country. Effective measures to combat water erosion are the creation of a wood belt to protect fields, as well as wood belts along the banks of large rivers, canals and reservoirs.

There are several problems affecting the irrigation infrastructure (UNECE, 2004). They include:

- deterioration of infrastructure and pumping equipment due to insufficient maintenance;
- heavy reliance on pumped irrigation, which in many instances would make agriculture uneconomic if the energy were valued at its real cost;
- negligible contribution from users to operation and maintenance expenses;
- inefficient water distribution and application.

As a result of recent efforts to improve the situation, institutional mechanisms have been established for the collection and use of water charges and the transfer of responsibility to water users. It is estimated that 40–45 percent of the irrigation infrastructure is in need of renovation. The inefficient use of water and the heavy water losses in irrigation represent major problems for water resources and soils.

Finances

Since 1997 water used for agricultural purposes is chargeable. Rates were changed in June 2003. The fee is charged for technical-operational costs and not for the use of water as a natural resource.

Charges on wastewater discharge were also introduced in 1992. The rates are very low, as is the collection rate, making the charge system less effective (UNECE, 2004).

The Presidential Decree of 23 October 2004 authorized the establishment of a public corporation "Agroleasing" and a series of measures to develop leasing in the agricultural sector. It was decided to provide AZM100 billion and 150 billion from the state budget in 2005 and 2006 for Agroleasing's activities (Heydar Aliyev Foundation. 2008).

Policies and legislation

The water sector is regulated by the following legislation:

- The Water Code (1997)
- The Law on Water Supply and Wastewater (1999)
- The Law on Amelioration and Irrigation (1996)
- The Law on Environmental Protection (1999)

The Water Code is the basis for water management in Azerbaijan and sets out the following main principles for use and protection:

- economic development and environmental protection;
- provision of the population with quality water;
- water management to be based on river basins;
- water protection functions to be separate from water use and water industry functions.

The Law on Water Supply and Wastewater sets the legal framework for this sector.

The Law on Amelioration and Irrigation regulates the planning, design, construction and operation of amelioration and irrigation systems. Accordingly, design and construction activities require special permits (licences) and systems have to be certified with technical passports.

The Law on Environmental Protection identifies the legal, economic and social bases of environmental protection. It governs the use of natural resources, amongst which water, and protection against domestic and industrial pollution. The Law also sets the basis for economic mechanisms, such as payment for the use of natural resources and for the disposal of domestic and industrial waste and economic incentives for environmental protection.

In July 1996, a land reform law was adopted by the National Assembly (Milli Majlis), establishing private property rights to land. The land is to be transferred to all rural inhabitants free of charge. It can then be sold freely, exchanged, transferred by right of succession, leased or used as mortgage security.

In November 2003, the presidential decree "On intensification of the socio-economic development in the Republic of Azerbaijan" envisioned the start of the second stage of the agrarian reforms and the accomplishment of appropriate activities. It has been followed up by the state programme for socio-economic development of the regions of the Republic of Azerbaijan (2004-2008), adopted on 11 February 2004. The implementation of the programme will create the opportunities for radical changes and wider business development in agriculture. Among other activities, the state programme will restore agricultural processing enterprises, establish new production enterprises, increase the efficiency of local resources, build or modernize the infrastructure for regional development, step up the second stage of agrarian reforms, establish technical service centres in the region, and extend seed depots and other important activities (Heydar Aliyev Foundation. 2008).

ENVIRONMENT AND HEALTH

Water losses in the irrigation distribution systems, estimated at 50 percent, cause waterlogging and salinization. Moreover, only 600 000 ha of irrigated land, the most naturally saline areas, have drainage. The increased water level of the Caspian Sea has also made land on the coast more saline. Salinization is particularly widespread on the Kura-Araks lowland (UNECE, 2004).

The rapid development of all spheres of economics and human activity has had an increasingly negative impact on the environment, partly due to the inefficient use of natural resources. Like many other countries, Azerbaijan is interested in finding solutions to the problems of environmental protection and rational utilization of natural resources. In support of the country's environmental protection goals, a number of important laws, legal documents and state programmes, all conforming to European law requirements, have been approved.

Almost 30 percent of the Caspian Sea coastal area is exposed to contamination. More than half of the rivers more than 100 km long are considered to be contaminated. All the lakes of the low-lying parts of the country are exposed to the changes in the thermal, biological and chemical regimes. The lakes of the Apsheron Peninsula and the Kura Araks Lowland, covering a total area of more than 200 km^2, are in a critical state. The main sources of contamination of water resources are industry, agriculture, the municipal domestic sector, energy, heating and recreation (UNEP/GRID-Arendal, 2005).

Irrational use of water resources and pollution of water bodies can be put down to the fact that cities, regional centres and other human settlements are poorly equipped with sewerage systems and wastewater treatment facilities, as well as to the obsoleteness of the existing technical facilities. Untreated wastewater released from Baku, Ganja, Sumgayit, Mingacevir, Ali-Bayramli, Nakhchivan and other urban centres significantly contributes to the pollution of the water bodies.

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

Major positive factors in Azerbaijan's environmental outlook include the enactment of new legislation and the signing of international conventions. Although economic development is not advanced, the country is moving slowly in the right direction for water resources management.

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Bahrain

GEOGRAPHY, CLIMATE AND POPULATION

Geography

The Kingdom of Bahrain is a group of islands located off the central southern shores of the Persian Gulf. The archipelago comprises 40 islands, with a total land area of about 710 km² (Table 1). The largest of these is Bahrain Island where the capital city, Manama, is situated. Bahrain Island accounts for nearly 85 percent of the total area of the country. Next largest is the southern archipelago called Hawar (50 km²), not far from the coast of Qatar, followed by the desert island of Umm Nasan (19 km²), the populous Muharraq Island (18 km²) connected by causeways to Bahrain, and finally Sitra (10 km2), a mainly industrial island also connected to Bahrain by causeways. The remaining small islands, islets and coral reefs make up the rest of the land mass (around 1.5 percent).

Bahrain is low lying. Limestone bedrock slopes rise gently towards the roughly central peak of Jebel Dukhan, with its highest point at 137 meters above sea level. Land use varies greatly, from extensive urban development and diligently cultivated areas in the north, to sandy wastes spreading south, east and west from Jebel Dukhan. Here there are true desert conditions with only sparse tough desert plants growing among the barren limestone rimrock and sands of varying depth.

Climate

Bahrain has an arid to extremely arid environment. According to the aridity criteria used, Bahrain has been regarded as arid or hyperarid as a result of the very great variations in climatic conditions (Elagib and Abdu, 1996). The country is characterized by high temperatures, erratic and often scanty rainfall, high evapotranspiration rates (with peaks of over 10 mm/day in July) and high humidity levels due to the surrounding Gulf waters.

Temperature averages from 17 °C in winter (December–March) to 35 °C in summer (June–September). The rainy season runs from November to April, with an annual average of 83 mm, sufficient only to support the most drought resistant desert vegetation. Mean annual relative humidity is over 67 percent. The annual average potential evaporation is 2 099 mm (Al-Noaimi, 2005).

Population

Total population is 727 000 (2005), of which around 10 percent is rural (Table 1). With a population density of 1 024 inhabitants/km², Bahrain is one of the world's most densely populated countries. It has experienced high rates of population growth and urbanization since the early 1960s following the sudden increase in the country's oil revenues, leading to a fast increase in its economic base and an improvement in the standard of living. The average annual demographic growth rate was 4 percent during

BAHRAIN **FAO - AQUASTAT, 2008**

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TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2005	71 000	ha
Cultivated area (arable land and area under permanent crops)	2000	4 235	ha
• as % of the total area of the country	2000	6	%
• arable land (annual crops + temp. fallow + temp. meadows)	2000	1 015	ha
• area under permanent crops	2000	3 220	ha
Population			
Total population	2005	727 000	inhabitants
• of which rural	2005	9.8	%
Population density	2005	1 024	inhabitants/km^2
Economically active population	2005	353 000	inhabitants
• as % of total population	2005	48.6	%
• female	2005	23.2	%
• male	2005	76.8	%
Population economically active in agriculture	2005	3 000	inhabitants
• as % of total economically active population	2004	0.85	%
• female	2005	0	%
• male	2005	100	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2005	16 040	million US$/yr
• value added in agriculture (% of GDP)	2002	0.85	%
• GDP per capita	2005	17763	US$/yr
Human Development Index (highest = 1)	2005	0.866	
Access to improved drinking water sources			
Total population		-	%
Urban population	2006	100	%
Rural population		-	%

the period 1980–1991 but this has dropped to 2.5 percent during the last 10 years. The water supply and sanitation coverage are 100 percent in urban areas. The total economically active population is 353 000 (2005), of which 77 percent are men and 23 percent women. Only 3 000 people work in agriculture.

Urban development at the expense of agricultural land has caused a significant loss of traditionally agricultural areas. Furthermore, soil salinization resulting from deterioration in the quality of the groundwater used in irrigation has led to a general reduction of cultivated land. In 2005, the total cultivated area was estimated at 6 000 ha, or 8 percent of the total area of the country, of which around 95 percent was equipped for irrigation. This area is mainly used for growing date palms, alfalfa and vegetables (FAO, 2002).

ECONOMY, AGRICULTURE AND FOOD SECURITY

The Gross Domestic Product (GDP) is around US$16 billion (current US$), with an annual growth of 7.8 percent (2005). Agriculture is one of the traditional activities in Bahrain but its contribution to national GDP is less than 1 percent (Table 1). Agriculture provided many job opportunities for Bahraini nationals, who accounted for 75 percent of agricultural labour during the 1970s. In 2004, the total economically active population in agriculture was only 3 000, all of whom were men. Agriculture in Bahrain is generally in an unhealthy state with tenancy problems, small farm holdings, labour shortages and lack of financial incentives, all of which restrict investment.

Bahrain is heavily dependent on imports to satisfy its need for animals and animal products, at the cost of home-based production. In an open-market economy, local animal products, especially dairy and eggs, face tough competition from imports. Part of this competition comes from some Gulf States which have the advantage of relatively well-established multifaceted livestock enterprises that started much earlier with more favourable cost structures. Sheep imports in Bahrain are subsidized. Rehabilitation of the national livestock industry would require improvement of the cost structure of locally produced animals and animal products (FAO, 2004).

There are some animal production activities based on local agricultural products, such as milk production or on imported feed, such as poultry and egg production. Nevertheless, livestock productivity is low because of poor management, which is reflected in poor growth rates, high mortality, late sexual maturity, long parturition intervals, inbreeding and poor-quality meat. The availability of feed for the livestock industry is uncertain and most feed ingredients are imported (FAO, 2003).

WATER RESOURCES AND USE

Water resources

Total annual surface runoff is only about 4 million m^3 and there are no rivers, perennial streams or lakes (Table 2). There are also no dams. Bahrain receives groundwater by lateral under-flow from the Damman aquifer, which forms only a part of the extensive regional aquifer system (the Eastern Arabian Aquifer). This aquifer extends from central Saudi Arabia, where its main recharge area is located at about 300 meters above sea level, to eastern Saudi Arabia and Bahrain, which are considered the discharge areas. The rate of groundwater inflow has been estimated at about 112 million m^3/year under steady-state conditions (before 1965) and this figure is considered to be the safe groundwater yield in Bahrain. But groundwater reserves suffer from severe degradation, in terms of both quality and quantity, as a result of over-extraction and seawater intrusion.

Over-utilization of the Dammam aquifer, the principal aquifer in Bahrain, by the agricultural and domestic sectors has led to its salinization through water coming from adjacent brackish and saline water bodies (particularly from the underlying saline aquifer of Umm er Radhuma). A hydrochemical study identified the locations of the sources of aquifer salinization and delineated their areas of influence. The investigation indicates that the quality of aquifer water quality has been significantly modified as groundwater flows from the northwestern parts of Bahrain, where the aquifer receives its water by lateral underflow from eastern Saudi Arabia, to the southern and southeastern parts. Four types of salinization of the aquifer have been identified:

- Brackish water up-flow from the underlying brackish water zones in north-central, western, and eastern regions;
- Seawater intrusion in the eastern region;
- Intrusion of sabkha water (saline water from saline areas) in the southwestern region;
- Irrigation return flow in a local area in the western region.

Four alternatives for the management of groundwater quality are under discussion by the water authorities in Bahrain. Priority areas have been proposed based on the type and extent of each salinization source, in addition to groundwater use in that area. Simulation modelling could be used to evaluate the effectiveness of the proposed management options in controlling the degradation of water quality in the Dammam aquifer (Zubari, 1999).

Since it has become the policy to curb the abstraction of groundwater resources in the Damman aquifer and to improve its quality, further development of water sources will undoubtedly involve desalination, either by a thermal process or reverse osmosis. The choice will depend on site-specific conditions and economy or cost. The first multi-stage flash (MSF) seawater desalination plant was introduced in Bahrain in 1976. The use of reverse-osmosis (RO) desalination for saline groundwater on Bahrain Island began in 1984–1986. One of the world's largest RO plants for the treatment of saline groundwater, located 25 km south of the capital of Bahrain at Ras Abu-Jarjur, was commissioned in 1984. The plant has an installed capacity of 45 500 m^3/day and its source of raw water is the highly saline brackish groundwater in the Umm er Radhuma formation. The RO plant was designed to meet the domestic water demand of Manama city, taking into account its advantages over an MSF plant, such as short construction time, lower energy cost, ease of operation and maintenance (UNU, 1995). In 2002, the total installed gross desalination capacity (design capacity) in Bahrain was 500 259 m^3/day (Wangnick Consulting, 2002).

The reuse of treated wastewater for agriculture and landscape irrigation started in 1985. The main wastewater treatment plant in Bahrain is the Tubli Water Pollution Control Centre (Tubli WPCC) which is currently (2005) producing about 160 000 m^3/day of secondary treated effluent and around 60 674 m^3/day receives tertiary treatment. There are also eleven minor wastewater treatment plants with a total designed capacity of about 9 720 m^3/day. Treated sewage effluent is expected to reach 200 000 m^3/day or 73 million m^3 per year by 2010 (Al-Noaimi, 2005). The additional amount treated, if properly used for irrigation, could significantly reduce water extraction, reserving the limited freshwater resources for potable supply and other priority uses. In Bahrain the cost of tertiary treated effluent is about US\$0.317/m^3, while the cost of desalinated water is about US\$0.794/m^3 (FAO/WHO, 2001).

Water use

Historically, Bahrain has utilized groundwater for both agricultural and municipal requirements. Natural freshwater springs used to flow freely in the northern part of Bahrain and before 1925 the water supply depended on these springs and some hand-dug wells, the total discharge of which was estimated at 93 million m^3/year. With increased water demand after the exploration of offshore reservoirs of crude oil and gas in 1946, spring flow decreased and water started being pumped from boreholes. During the 1980s, most of the springs ceased flowing, and increased demand for water caused deterioration in water quality, including the intrusion of seawater into the aquifer system (UNU, 1995). In 1988, groundwater use in Bahrain was estimated to be 153 million m^3/year, including 138 million m^3 of tube-well abstraction, 8.1 million m^3 of water from land springs, and 6.6 million m^3 of water from marine springs.

In 2003, total water withdrawal in Bahrain was 357.4 million m^3 (Table 2 and Figure 1). The part used for irrigation and livestock watering purposes dropped to 45 percent whereas it was 56 percent in 1991. Total annual water demand was met by three sources: groundwater (238.7 million m^3), desalinated water (102.4 million m^3) and treated sewage effluent (16.3 million m^3) (Table 3 and Figure 2). This means that non-conventional water sources accounted for 34 percent of total water withdrawal in 2003. About 90 percent of the water used in agriculture, including livestock, was groundwater and 10 percent treated wastewater. For municipal and industrial purposes about 48 percent of the water used was groundwater and the remaining part was desalinated water.

The total surface water and groundwater withdrawal represented 206 percent of the total renewable water resources in 2003, meaning that abstraction of fossil water and groundwater mining was taking place.

FIGURE 1
Water withdrawal by sector
Total: 0.357 km^3 in 2003

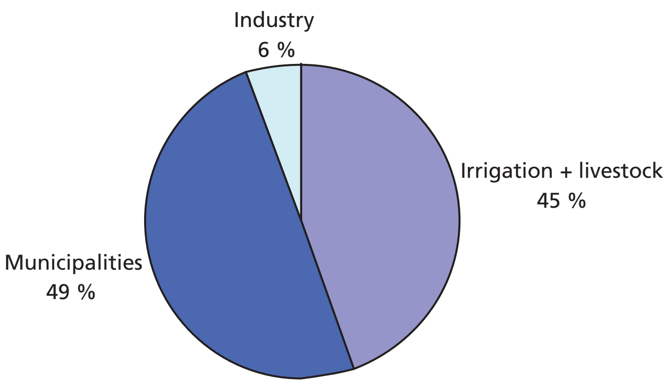


TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	83	mm/yr
	-	0.059	10^9 m^3/yr
Internal renewable water resources (long-term average)	-	0.004	10^9 m^3/yr
Total actual renewable water resources	-	0.116	10^9 m^3/yr
Dependency ratio	-	97	%
Total actual renewable water resources per inhabitant	2005	160	m^3/yr
Total dam capacity	1995	0	10^6 m^3
Water withdrawal			
Total water withdrawal	2003	357.4	10^6 m^3/yr
- irrigation + livestock	2003	159.2	10^6 m^3/yr
- municipalities	2003	177.9	10^6 m^3/yr
- industry	2003	20.3	10^6 m^3/yr
• per inhabitant	2003	506	m^3/yr
Surface water and groundwater withdrawal	2003	238.7	10^6 m^3/yr
• as % of total actual renewable water resources	2003	205.8	%
Non-conventional sources of water			
Produced wastewater	1991	44.9	10^6 m^3/yr
Treated wastewater	2005	61.9	10^6 m^3/yr
Reused treated wastewater	2005	16.3	10^6 m^3/yr
Desalinated water produced	2003	102.4	10^6 m^3/yr
Reused agricultural drainage water	2001	3	10^6 m^3/yr

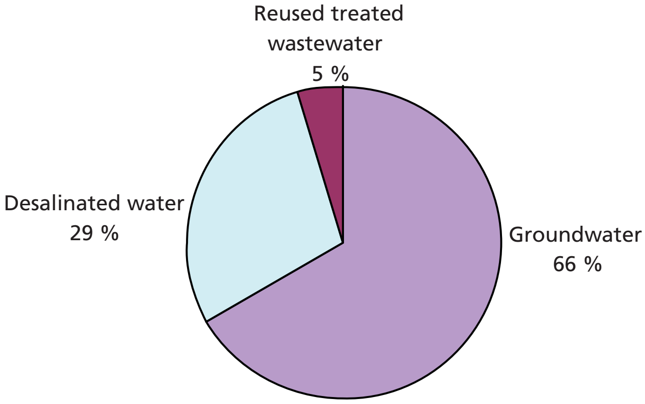
TABLE 3
Water uses in Bahrain by sources and categories of use for the year 2003 (million m^3)

Source	Municipal	Agriculture	Industrial	Total uses
Groundwater	83.3	143.2	12.2	238.7
Desalinated water	94.3	-	8.1	102.4
Treated sewage effluent	-	16.3*	-	16.3*
Total	**177.6**	**159.5**	**20.3**	**357.4**

*Year 2005

The excessive pumping of groundwater caused a sharp decrease in groundwater storage and a reduction in potentiometric levels of about 4 meters between 1965 and 1992. As a result, more than half the original groundwater reservoir has been completely degraded due to seawater intrusion and saline water up-flow from the deeper zones. Table 4 shows that annual extraction is almost twice the annual recharge, leading to an ever-increasing groundwater deficit. While the average annual groundwater depletion over the period 1965-1992 was approximately 40 million m^3, in 1991/92 it was over 96 million m^3.

FIGURE 2
Water withdrawal by source
Total: 0.357 km^3 in 2003



In 2003, the total quantity of desalinated water used was 102.4 million m^3 against 44.1 million m^3 in 1991. In 2005 treated wastewater amounted to about 62 million m^3/year of wastewater (secondary treatment) against about 45 million m^3 in 1991. Despite an increase of 100 percent compared with 1991, only 16.3 million m^3/year received tertiary treatment and part was used for irrigation purposes in

TABLE 4
Groundwater depletion in Bahrain, 1991/92

Component	Average annual rate (million m³)
Inflow:	
Recharge by under-flow (aquifer safe yield)	112.00
Recharge by rainfall on outcrop and irrigation return flows	0.28
Total inflow	112.28
Outflow:	
Wells abstraction for irrigation, livestock, domestic, industrial and other purposes	190.20
Sabkha natural discharge	12.72
Natural springs discharge	5.40
Total outflow	208.32
Total inflow - Total outflow	**- 96.04**

government farms and some private farms, while the rest was discharged to the sea. The chemical and hygienic properties of the tertiary treated water are within international limits and are considered good for agricultural purposes. Although the government has plans for the full utilization of Treated Sewage Effluent (TSE) water through major agricultural projects, delays and lack of funds for these projects have limited the use of these waters.

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

The limited availability of good quality soil and water has resulted in the concentration of agricultural development in a relatively narrow strip of land along the northwestern coast of Bahrain Island with isolated pockets in the north central areas and along the east coast. Most soils have a sandy texture, traces of organic matter (0.05–1.5 percent), a deficiency in major nutrients, low water-holding capacity (available moisture 2–6 percent), and high infiltration rates (> 120 mm/hr). In areas along the coastal strip, calcareous impermeable layers are found at depths of 1–3 metres, causing waterlogging and impeding leaching. Electrical conductivity (EC) in irrigated soils lies within a range of 4–12 mmhos/cm, while in the areas of recently abandoned agriculture (1 065 ha) it could reach 60 mmhos/cm.

In the period from 1956 to 1977, agricultural land decreased from about 6 460 ha (with 3 230 ha cultivated) to about 4 100 ha (with 1 750 ha cultivated). This decrease was attributed mainly to urban expansion, waterlogging and soil salinization due to the deterioration of the quality of the groundwater used in irrigation. In an attempt to reverse the situation, the government initiated a major agricultural development programme in the early 1980s consisting of:

- Replacement of surface irrigation with more water efficient localized irrigation by subsidizing more than 50 percent of the implementation cost;
- Construction of major drainage systems to reduce waterlogging and salt accumulation;
- Provision of agricultural extension services in terms of training and advising farmers on types of crops suitable for agriculture under prevailing conditions;
- Introduction of TSE water in irrigation;
- Reclamation of new agricultural lands.

This resulted in a gradual increase and restoration of agricultural lands to about 4 230 ha, with 4 015 ha cultivated and irrigated at present, all power irrigated. Between 1994 and 2000, there was a 4 percent average increase per year of the area equipped for irrigation. It is difficult to estimate the quantity of groundwater available in the future for agriculture since groundwater quality, and hence its availability for irrigation, changes with time. In 2003, groundwater accounted for 90 percent of the total irrigation water (Table 5 and Figure 3).

In 1991, the utilization of 8 million m³/year of tertiary TSE water in reclaimed government lands (280 ha) and on some private farms (150 ha), using sprinkler and localized irrigation techniques, had a palpable effect on the increase of agricultural lands and their productivity. Government subsidy for installation of modern irrigation systems stopped in the 1990s because of lack of funds. Despite efforts to introduce modern irrigation techniques, most farms still use traditional surface irrigation, which

TABLE 5
Irrigation and drainage

Irrigation potential		**-**	**4 230**	**ha**
Irrigation:				
1. Full or partial control irrigation: equipped area		2000	4 015	ha
- surface irrigation		2000	3 390	ha
- sprinkler irrigation		2000	160	ha
- localized irrigation		2000	465	ha
• % of area irrigated from surface water		2003	0	%
• % of area irrigated from groundwater		2003	90.3	%
• % of area irrigated from mixed surface water and groundwater		2003	0	%
• % of area irrigated from non-conventional sources of water		2003	9.7	%
• area equipped for full or partial control irrigation actually irrigated			-	ha
- as % of full/partial control area equipped		1994	100	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)		2000	0	ha
3. Spate irrigation		2000	0	ha
Total area equipped for irrigation (1+2+3)		**2000**	**4 015**	**ha**
• as % of cultivated area		2000	94.8	%
• % of total area equipped for irrigation actually irrigated			-	%
• average increase per year over the last 6 years		1994-2000	4	%
• power irrigated area as % of total area equipped		1994	100	%
4. Non-equipped cultivated wetlands and inland valley bottoms		2000	0	ha
5. Non-equipped flood recession cropping area		2000	0	ha
Total water-managed area (1+2+3+4+5)		**2000**	**4 015**	**ha**
• as % of cultivated area		2000	94.8	%
Full or partial control irrigation schemes:	**Criteria:**			
Small-scale schemes	< 50 ha	1994	2 885	ha
Medium-scale schemes		1994	0	ha
large-scale schemes	> 50 ha	1994	280	ha
Total number of households in irrigation		1994	-	
Irrigated crops in full or partial control irrigation schemes:				
Total irrigated grain production		2000	0	metric tons
• as % of total grain production			-	%
Harvested crops:				
Total harvested irrigated cropped area		2000	4 015	ha
• Annual crops: total		2000	1 015	ha
- Vegetables (mainly tomatoes)		2000	1 015	ha
• Permanent crops: total		2000	3 000	ha
- Fodder (mainly alfalfa)		2000	790	ha
- Other perennial crops (dates, fruits)		2000	2 210	ha
Irrigated cropping intensity (on full/partial control area actually irrigated)		2000	100	%
Drainage - Environment:				
Total drained area		1994	1 300	ha
- part of the area equipped for irrigation drained			-	ha
- other drained area (non-irrigated)			-	ha
• drained area as % of cultivated area		1994	41	%
Flood-protected areas		1995	1 300	ha
Area salinized by irrigation		1994	1 065	ha
Population affected by water-related diseases			-	inhabitants

causes higher water losses, estimated at between 24 and 40 percent. Sprinkler irrigation is used only in government projects, while localized irrigation is used in government projects and on a limited number of private farms (Figure 4). Most of the land is cultivated either directly by the owner, often with hired labour, or by tenant farmers under a lease agreement lasting one or two years. Such short and insecure periods do not encourage tenants to invest in the installation of modern irrigation systems, which cost 40 percent and even up to 100 percent more than surface irrigation systems since government subsidies for the installation of modern irrigation systems are no longer available. The small size of agricultural landholdings, ranging between 0.5 and 10 ha, with an average of 2.5 ha, and in particular the fragmentation of the agricultural land of farm holdings, further restrict investment in the more expensive modern irrigation techniques.

FIGURE 3
Source of irrigation water
In 2003

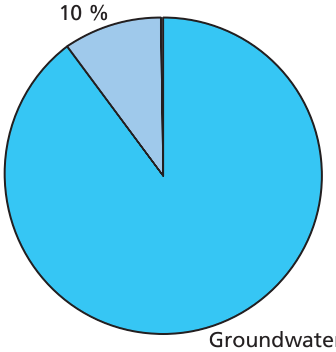
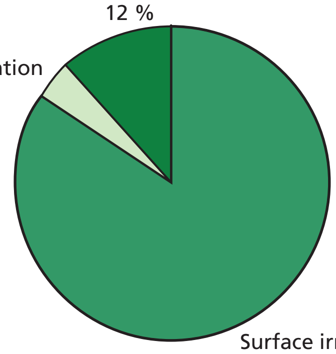


FIGURE 4
Irrigation techniques
Total: 4 015 ha in 2000



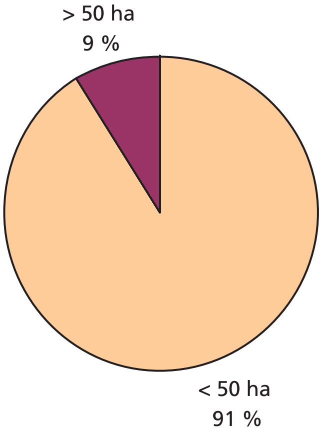
About half of the cultivated area is covered with high water-consuming perennial date palms under traditional surface irrigation practices. Some basic installations with modern irrigation systems (drip irrigation for vegetables and bubbler irrigation for dates) have been established too, but they are rather poorly operated with no irrigation schedules. Unfortunately, many drip and sprinkler systems have been designed on the basis of incorrect criteria, using the outdated irrigation equipment of the 1970s which is poorly installed and inadequately maintained (FAO, 2002). The overall irrigation efficiency is very low, also demonstrated by the huge amount of water used (almost 160 million m^3) on a total irrigated area of just over 4 000 ha.

Role of irrigation in agricultural production, economy and society

In 1991, of the total equipped area of 3 165 ha, 2 885 ha consisted of small schemes (< 50 ha). Most farms in these small-scale schemes were run under the tenancy system and there were about 250 households on these schemes. The remaining 280 ha of large schemes (> 50 ha) were owned and completely run by the government and irrigated by treated wastewater, with a total of 80 government workers of whom 11 were involved in irrigation (Figure 5).

In 1991, the average cost of irrigation development on small schemes varied between US$6 600/ha for surface irrigation, US$9 300/ha for localized irrigation and US$13 200/ha for sprinkler irrigation. For large schemes the cost was US$16 200/ha for

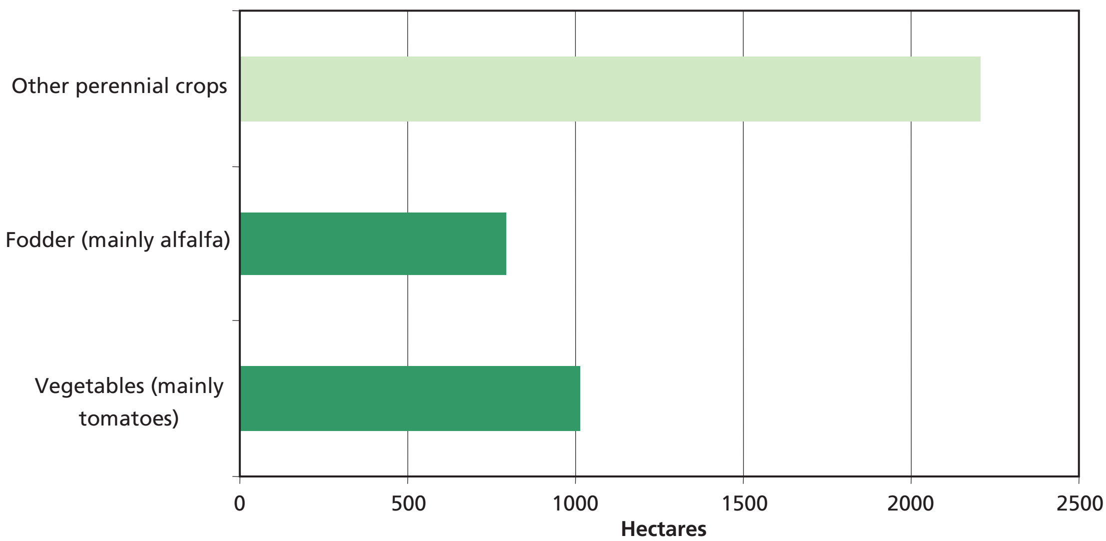
FIGURE 5
Type of irrigation schemes
Total: 3 165 ha in 1994



surface irrigation, US$13 600/ha for localized irrigation and US$19 800/ha for sprinkler (central pivot) irrigation. The high costs for large scheme development were attributed to the fact that the major projects were carried out by the government on reclaimed lands. Operation and maintenance costs varied between 10 and 15 percent of the irrigation development costs on small schemes and between 5 and 15 percent on large schemes.

The major crops grown are: dates and fruit trees with a yield of 7.5 tons/ha; vegetables, mainly tomatoes, with a yield of 11.7 tons/ha; and fodder crops, mainly alfalfa, with a relatively high yield of 74.5 tons/ha. There is no cereal production. In the 1980s, there had been an increasing trend in the cultivation of alfalfa for fodder production rather than the cultivation of the traditional date and vegetable crops. Alfalfa tolerates high salinity and is a cash crop grown all year round with high local demand. However, because of the very high irrigation water requirements of alfalfa, it is expected that this trend will have negative implications for the country's groundwater resources. Horticulture and agriculture flourish in the north, using water from some artesian wells or desalination plants. Gardens grow dates, almonds, pomegranates, figs, citrus fruit, and a wide range of vegetables. In 2000, permanent crops (mainly alfalfa and date palms) covered 75 percent of the irrigated area while vegetables represented the remaining 25 percent (Table 5 and Figure 6). In 2004, Bahrain produced 14 000 tons of fruits and dates and 7 700 tons of vegetables.

FIGURE 6
Irrigated crops
Total harvested area: 4 015 ha in 2000 (cropping intensity on equipped area actually irrigated:100%)



Status and evolution of drainage systems

Drainage works have been carried out on 1 850 ha of the irrigated area. The remaining areas still suffer from shallow water tables resulting in waterlogging in the crop root zones and an increasing salinization of the top soil. Drainage requirements are exacerbated by the inefficient surface irrigation systems used. In 1994, drainage works had been completed on about 1 300 ha (Table 5). The existing drainage network consists of open drains, which are very inefficient and difficult to maintain. The average cost of drainage development was estimated at US$6 600/ha.

The only flood protection works carried out in Bahrain are those against rainfall floods and are developed in one residential, modern town located in the west, over an area of 1 300 ha, where there are no agricultural activities.

WATER MANAGEMENT, POLICIES AND LEGISLATION RELATED TO WATER USE IN AGRICULTURE

Institutions

The Ministry of Municipalities, Affairs and Agriculture is responsible for the country's groundwater resources development, management and utilization. This ministry also manages the utilization of TSE in agriculture. The current organizational structure and staff shortages in the Directorates of the Ministry and the services dealing with water development and use, i.e. the Agricultural Engineering Service and the Water Resources Service, are a major constraint to the efficient performance of these services, both of which lack human resources and updated know-how. One of the constraints in developing optimum irrigation facilities is the lack of engineers and technicians as well as of farmers trained in modern irrigation techniques.

The Ministry of Electricity and Water is responsible for providing adequate electricity and water supplies in a safe and cost effective manner to the different segments of consumers in Bahrain.

Water-related research is carried out by the Arabian Gulf University and the University of Bahrain.

Water management

Given the limited land and water resources, recent development plans for improved agricultural production (FAO, 2003) have the goals of:

- Conservation and rational utilization of the limited water resources through the adoption of modern irrigation and drainage techniques, the promotion of the use of treated wastewater and the implementation of legislation related to water use and management;
- Conservation and rehabilitation of land resources and the implementation of legislation to regulate agricultural and non-agricultural land uses;
- Conservation and rational utilization of marine resources;
- Increased agricultural productivity and profitability through the intensification and utilization of treated wastewater;
- Creation of an enabling environment to promote private sector participation in agricultural investment and enhance the productivity and competitiveness of Bahrain's agricultural products in domestic and regional markets;
- Reduction of natural resource degradation through the promotion of agricultural activities that generate sufficient income and employment to sustain the livelihoods of rural communities.

The authorities intend to take a comprehensive approach to water resources planning, recognizing the close inter-relationship between the country's available water resources and the growing demand for additional quantities from the various sectors of economy, i.e. agriculture, landscape development, industry and domestic supplies. Pressure is also increasing to reallocate water in agriculture from high water consuming to lower water consuming crops, and to higher value uses, such as the expanding the domestic, tourist and services sector.

Policies and legislation

The privately-owned water use rights are the only water rights that exist in Bahrain. The general principle governing these rights is that groundwater is the property of the landowners and, therefore, they have an exclusive right to extract and use as much water as they wish and for any purpose they want without being liable for any damage caused to their neighbours or to the groundwater in general. At present, the agricultural sector's utilization of water is not subjected to any licensing system nor is it controlled by a pricing system. However, from the mid-1980s on, agricultural wells have been metered by the government and the government is in the process of passing a law that would make it compulsory for all well owners to install meters on their wells. The total number of wells metered in 1995 was about 1 670 (86 percent of total). The final objective of this programme is to observe irrigation water requirements, and subsequently to set up a licensing system for groundwater withdrawal and design an appropriate pricing system for excess water utilization.

There is no well-defined national water master plan for sustainable water resources development and management. However, a number of rather fragmented water policies and water conservation measures have been initiated over the last three decades to resolve the escalating water shortage problems in the country (Al-Noaimi, 2005). These include, but are not limited to, the following:

- Increased supply as a result of a major desalination and wastewater treatment programme;
- Demand management measures;
- Water pricing;
- Institutional and legal reforms;
- Enhanced monitoring and information systems.

ENVIRONMENT AND HEALTH

The toxicity level of the groundwater of the semi-arid tract of Bahrain was examined for the fluoride concentration and other chemical constituents such as the sodium absorption ratio (SAR), chloride, sulfate, bicarbonate, and boron. The fluoride concentration varied from 0.50 to 1.46 mg/litre and 38 percent of the water contained concentrations of fluoride deemed harmful for drinking. However, the fluoride concentration in the water is not harmful for most crops. Spring and well water have rather high salinity but could be used for agricultural purposes, particularly for crops that can tolerate high salinity levels (Akther, 1998).

While the standard of living and quality of life of the people has improved in the last 20 years, these improvements have produced negative effects on the terrestrial, coastal and marine environments due to overexploitation of these ecosystems and to unsustainable development practices. Also as a consequence of two Gulf wars and unstructured economic diversification, the country has been subjected to serious environmental and health hazards. However, under its constitution, Bahrain is committed to managing its natural and human resources and has since 1996 implemented a programme to reorganize the country's environmental planning. The government has recognized that sustainable development can only be assured if the full range of potential impacts of development projects is assessed in a timely fashion and that action can only proceed from that assessment. Unfortunately, due to the limitations on the institutional capacity of government authorities and other relevant institutions in this field, there have been no comprehensive environmental health impact assessments.

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

A FAO study entitled '*Comparative advantage, competitiveness and policy options for sustainable agricultural development in Bahrain*' was conducted in 2003. The results of the study indicated that most plant production and livestock activities showed a good level of comparative advantage, as measured by the Domestic Resource Cost (DRC) indicator. The activities that appeared to have the best comparative advantage were the production of high-quality date palm varieties, Khalas and Khinezi in particular, and greenhouse production of cucumbers and tomatoes. Most open-field vegetables under drip irrigation also seemed to have a clear comparative advantage, although leafy vegetables generally showed much higher values than other vegetables. However, the production of vegetables under traditional irrigation systems did not show any clear comparative advantage with the possible exception of green onions (FAO, 2003).

Since the 1980s, the government has been taking several steps and courses of action to provide solutions to the water crisis in the country and to stem deterioration in the agricultural sector. These include: water conservation campaigns in all sectors, water pricing in the domestic sector and more reliance on non-conventional water sources (TSE in agriculture and desalinated water for domestic purposes).

Government policy with regard to water use is to reduce groundwater dependency for the domestic water supply, the second main water user, by constructing additional desalination plants. It is planned that groundwater will be exclusively used for irrigation. Additional requirements for future agricultural development should be supplemented by TSE water, which is expected to reach 73 million m^3 by 2010, especially through the expansion and upgrading of the plant production facilities at Tubli under TSE Phase-2 and the construction of transmission and distribution networks. On completion of 150 000 metres of closed pipes distribution network, it will irrigate 588 farms over an area of 2 200 ha. In addition, a drainage network to dispose of highly saline subsoil water will be constructed. However, these plans are still awaiting major government funds for the construction of a TSE conveyance system and farmers' acceptance. Although the intentions exist, an agricultural licensing system and water pricing have still to be put in place.

Although government policy indicates the will to develop a modern farming sector on larger production units using mechanization and up-to-date techniques, these aims have not yet been reflected clearly in the government's capital investment and subsidy programs.

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Georgia

GEOGRAPHY, CLIMATE AND POPULATION

Geography

Georgia has a total area of 69 700 km². It is located in the Caucasus region and is bordered by the Russian Federation to the north and northeast, Azerbaijan to the southeast, Armenia and Turkey to the south, and the Black Sea to the west for a distance of 309 km. For administrative purposes, the country is divided into 11 regions (comprising some 67 districts) plus the capital city Tbilisi. It declared independence from the Soviet Union in April 1991.

The country can be divided into three physiographic regions: mountains covering about 54 percent of the total area, highlands about 33 percent, and valleys some 13 percent. The Caucasus Mountains form Georgia's northern boundary, their highest peak standing some 5 000 m above sea level. About 70 percent of the country lies below 1 700 m above sea level. Cropping is possible throughout the country up to 2 000 m. At higher altitudes, there are only pastures.

The total cultivable area, which according to Georgian statistics is equal to the agricultural area, was estimated in 1996 at some 3 million ha, or 43 percent of the country. About 2.2 million ha are forest, which, under the 1978 Forest Code, cannot be transformed into agricultural cropped areas. A process of land privatization has been under way since the end of the Soviet period. Agricultural production is generally small-scale, but commercial farming is progressively gaining importance. Of the total 3 million ha of agricultural land, some 0.7 million ha are owned and cultivated by private farmers; 0.3 million ha have been leased to farmers for short-term (3–5 years), medium-term (25 years) or long-term (49 years) periods; and 2 million ha are still owned by the state. Most of the state agricultural land is not cultivated. Only about 30 percent is rented, mainly due to the complicated orography, poor soil, distance from habited areas, and damaged irrigation and drainage systems.

In 2005, the total cultivated area was estimated at 1.07 million ha, of which 802 000 ha consisted of annual crops and 264 000 ha of permanent crops (Table 1). Water and wind erosion, environmentally degrading agricultural practices and other anthropogenic and natural processes have led to an almost 35 percent degradation of farmland (Government of Georgia, 2002).

Climate

Georgia, with an average rainfall of 1 026 mm/year, can be divided into two climatic regions:

- West Georgia, which has a subtropical humid climate, with mild winters and not very hot summers. The average precipitation is estimated at between 1 100 and 1 700 mm/year. Drainage of excess water is one of the main problems for

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agriculture in this part of the country. Average temperatures vary between 5 °C in January and 22 °C in July.

- East Georgia, which has a subtropical dry climate, with fairly cold winters and arid, hot summers. The average precipitation varies between 500 and 1 100 mm/year. About 80 percent of the rainfall occurs from March to October, while the longest dry period is about 50–60 days. Drought years are common. Hail occurs in spring and autumn. There is a need for irrigation in the areas where precipitation is less than 800 mm/year. Average temperatures vary between -1 °C in January and 22 °C in July.

Population

The total population is estimated at 4.47 million (2005), of which 48.5 percent is rural. The average population density is 64 inhabitants/km² (Table 1). Before independence, the population growth rate was about 1 percent per year, but since 1991 the growth has been negative. During the period 1992–2000 it was -1.5 percent and during the period 2000–2005 -1.1 percent.

In 2006, 93 percent of the population had access to improved sanitation (94 and 92 percent in urban and rural areas respectively) and 99 percent to improved water sources (100 and 97 percent in urban and rural areas, respectively).

ECONOMY, AGRICULTURE AND FOOD SECURITY

In 2007, the national Gross Domestic Product (GDP) of Georgia was US$10.2 billion of which agriculture accounted for 11 percent (Table 1). The total economically active population was 2 287 000 or just over 51 percent of the total population (2005), of which 52 percent male and 48 percent female. The economically active population in agriculture is estimated at 395 000, 40 percent of which is female.

TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2005	6 970 000	ha
Cultivated area (arable land and area under permanent crops)	2005	1 066 000	ha
• as % of the total area of the country	2005	15.3	%
• arable land (annual crops + temp. fallow + temp. meadows)	2005	802 000	ha
• area under permanent crops	2005	264 000	ha
Population			
Total population	2005	4 474 000	inhabitants
• of which rural	2005	48.5	%
Population density	2005	64.2	inhabitants/km²
Economically active population	2005	2 287 000	inhabitants
• as % of total population	2005	51.1	%
• female	2005	48.1	%
• male	2005	51.9	%
Population economically active in agriculture	2005	395 000	inhabitants
• as % of total economically active population	2005	17.3	%
• female	2005	39.5	%
• male	2005	60.5	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2007	10 180	million US$/yr
• value added in agriculture (% of GDP)	2007	11	%
• GDP per capita	2005	1 430	US$/yr
Human Development Index (highest = 1)	2005	0.754	
Access to improved drinking water sources			
Total population	2006	99	%
Urban population	2006	100	%
Rural population	2006	97	%

WATER RESOURCES AND USE

Water resources

The country can be divided into two main river basin groups:

- The Black Sea Basin, in the west of the country. The internal renewable surface water resources (IRSWR) generated in this basin are estimated at 42.5 km³/year. The main rivers are, from north to south, the Inguri, the Rioni and the Chorokhi. The main stream of the Chorokhi rises in Turkey (the Corub River) and the estimated inflow from Turkey is 6.3 km³/year.
- The Caspian Sea Basin, in the east of the country. The IRSWR generated in this basin are estimated at 14.4 km³/year. The main rivers are, from north to south: the Terek and the Andiyskoye, which rise in the north of the country and flow northeast to the Russian Federation before entering the Caspian Sea; the Alazani, the Iori and the Kura, which rise in Georgia and flow into Azerbaijan in Lake Adzhinour, before flowing southeast in Azerbaijan and then entering the Caspian Sea. Two tributaries of the Kura River rise in Turkey: the Mtkvari, with an estimated inflow from Turkey of 0.91 km³/year, and the Potskhovi, with an estimated inflow from Turkey of 0.25 km³/year. The inflow of the Debet River, a southern tributary of the Kura River, is estimated at 0.89 km³/year from Armenia.

The renewable groundwater resources are estimated at 17.23 km³/year, of which 16 km³/year are drained by the surface water network (overlap). This gives a total of 58.13 km³/year for internal renewable water resources (IRWR). The total actual renewable water resources (ARWR) are 63.33 km³/year (Table 2).

In 1990, the total water abstraction was estimated at 3 km³/year from some 1 700 tube-wells. According to a recent assessment a further 7 km³/year could be abstracted in the future. Groundwater use was not greatly developed during the Soviet period, due to the emphasis on large-scale state-run surface irrigation schemes.

Georgia has 25 075 rivers exist with a total length 54 768 km; 99.4 percent of them are small rivers with a total length of less than 25 km. Hydrological studies are made of 555 rivers of the Black Sea Basin and 528 rivers of the Caspian Sea Basin. More than 17 000 rivers (total length 32 574 km) belong to the Black Sea Basin. There are about

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	1 065	mm/yr
	-	74.23	10^9 m³/yr
Internal renewable water resources (long-term average)	-	58.13	10^9 m³/yr
Total actual renewable water resources	-	63.33	10^9 m³/yr
Dependency ratio	-	8.21	%
Total actual renewable water resources per inhabitant	2005	14 155	m³/yr
Total dam capacity	2004	3 414	10^6 m³
Water withdrawal			
Total water withdrawal	2005	1 621	10^6 m³/yr
- irrigation + livestock	2005	1 055	10^6 m³/yr
- municipalities	2005	358	10^6 m³/yr
- industry	2005	208	10^6 m³/yr
• per inhabitant	2005	362	m³/yr
Surface water and groundwater withdrawal	2005	1 621	10^6 m³/yr
• as % of total actual renewable water resources	2005	2.6	%
Non-conventional sources of water			
Produced wastewater		-	10^6 m³/yr
Treated wastewater	2005	9	10^6 m³/yr
Reused treated wastewater		-	10^6 m³/yr
Desalinated water produced		-	10^6 m³/yr
Reused agricultural drainage water		-	10^6 m³/yr

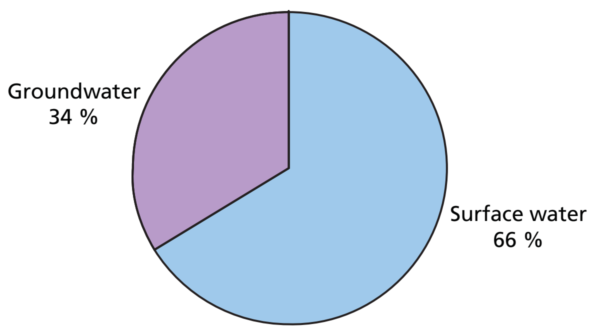
43 dams in Georgia, 35 of which are in the east and 8 in the west; their total reservoir capacity is estimated at about 3.4 km³. The water is primarily used for irrigation and hydropower generation and less for water supply. The largest dam, for hydropower is the Inguri dam, with a reservoir capacity of 1.092 km³. In 1995, hydropower supplied 89 percent of electricity. Some 31 dams have been built for irrigation purposes; they have a total reservoir capacity of 1 km³, of which 782 million m³ are active. The three largest irrigation reservoirs are: the Sioni reservoir (325 million m³) on the Iori River, the Tbilisi reservoir (308 million m³) on the Kura River and the Dalimta reservoir (180 million m³) on the Iori River.

In 2005, the total treated wastewater was estimated at 9 million m³. There is no tradition of treated wastewater reuse in Georgia.

Some wetlands have a primary environmental importance such as:

- central Kolkheti (33 710 ha), on both sides of the Rioni River mouth along the central part of the eastern Black Sea coast, in the regions Guria and Samegrelo near the city of Poti. The site contains many relicts and endemic species of flora and fauna. The area is a coastal alluvial plain, composed of quaternary deposits. The average water flow rate (over a long period) of the River Rioni (the largest river in the site) is 399 m³/second. Kolkheti State Reserve (500 ha) was established in 1947.
- Ispani (513 ha) in the autonomous Republic of Adjara, one kilometre from the Black Sea coast near the city of Kobuleti. The area supports rare mammal species and migratory waterbirds of international importance. The area is a coastal alluvial plain, composed of quaternary, lake-riverine and additional lake deposits, which have developed to a depth of 9–14 m.

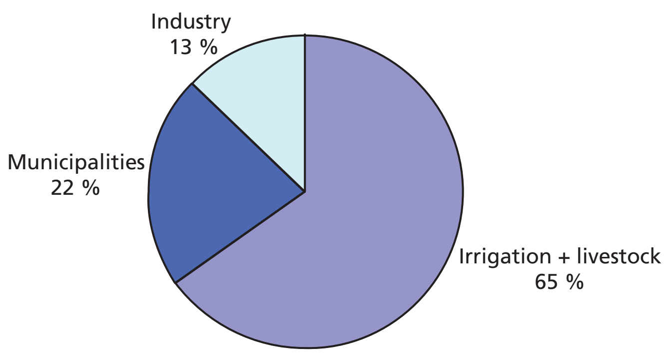
FIGURE 1
Water withdrawal by source
Total: 1.6 km³ in 2005



Water use

Between 1985 and 1990, the total water withdrawal decreased from 4 600 to 3 500 million m³ because of the industrial decline since the end of the Soviet Union. During 2005 the total water withdrawal was 1 621 million m³, 66 percent of which came from surface water and 34 percent from groundwater (Table 2 and Figure 1). Agricultural water withdrawal accounted for 1 055 million m³ and water withdrawal for municipal purposes for 358 million m³. Industrial water withdrawal was estimated at 208 million m³ (Figure 2).

FIGURE 2
Water withdrawal by sector
Total: 1.6 km³ in 2005



International water issues

In 1925, an agreement with Turkey was reached on the use of water from the Chorokhi River, allocating half of the average surface water flow to each country. This agreement dealt only with water flow and did not consider the sediment flow, estimated at 5 million m^3/year. About 46 percent of these sediments form the sand beach and are an important resource, as tourism is of prime importance to Georgia's earnings. Turkey plans to construct a cascade of 11 dams on the Chorokhi River, which will affect the sediment flow and thus the beaches on the Georgian shore. Georgia is pressing for a reconsideration of the agreement, which should not only deal with the allocation of water but also address the issue of sediment flow.

In 1997, Georgia ratified the agreement between the Governments of Georgia and Azerbaijan on environmental protection. In 1998, Georgia ratified a similar agreement with Armenia. According to both agreements, the governments will cooperate in creating specifically protected areas within the transboundary ecosystems.

The implementation of the "Ecoregional Nature Protection Programme for Southern Caucasus" is part of the Caucasus Initiative, launched by the German Ministry of Cooperation and Development. The programme covers the three Caucasus countries, Georgia, Azerbaijan and Armenia, and will facilitate the protection and sustainable use of water resources in the region.

Measures are already being taken in support of the development of protected areas in Georgia. Within the Black Sea Integrated Management Programme, supported by the Global Environment Facility (GEF) and the World Bank, implementation of the system of protected wetland areas in the coastal zone of Georgia is in progress (Tsiklauri, 2004).

From 2000 to 2002, USAID, in collaboration with Development Alternatives Inc. (DAI), implemented the South Caucasus Water Management Project, designed to strengthen co-operation between water-related agencies at all local, national and regional levels, and demonstrate integrated water resources management. In parallel, between 2000 and 2006, the EU and the Technical Assistance Commonwealth of Independent States (TACIS) have developed the Joint River Management Programme on Monitoring and Assessment of Water Quality on Transboundary Rivers; its aim is the prevention, control and reduction of trans-boundary pollution impact. The programme covers four basins, including the Kura River Basin. In addition, regional organisations such as REC, Eurasia Foundation and numerous local foundations are promoting national and regional activities in the field of water resources management and protection (UNEP, 2002).

The main objective of the USAID/Caucasus-Georgia Strategic Plan (2004–2008) is to ensure continued support for the South Caucasus Regional Water Management Programme as a principal component of its regional conflict-prevention and confidence-building objectives. It hopes to maintain the dialogue between the three countries that has already contributed to confidence-building measures (USAID, 2006).

From 2002 to 2007, the NATO-OECD has developed the South Caucasus River Monitoring Project. Its general objectives are to establish the social and technical infrastructure for an international, cooperative, transboundary river water quality and quantity monitoring, data sharing and watershed management system among the Republics of Armenia, Azerbaijan and Georgia (OSU, 2008).

The project Reducing Transboundary Degradation in the Kura-Araks River Basin, currently being implemented by the UNDP Bratislava Regional Centre in collaboration with the Global Environmental Facility (GEF), has involved four of the basin countries: Armenia, Azerbaijan, Georgia and the Islamic Republic of Iran. Efforts are being made to involve Turkey in the project. The project preparation phase is 18 months and began in July 2005. It is co-funded by Sweden. The project aims to ensure that the quality and quantity of water throughout the Kura-Araks River system meets the short and long-term needs of the ecosystem and the communities relying upon it.

The project will achieve its objectives by fostering regional cooperation, increasing capacity to address water quality and quantity problems, demonstrating water quality/quantity improvements, initiating required policy and legal reforms, identifying and preparing priority investments, and developing sustainable management and financial arrangements.

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

The irrigation potential in Georgia is estimated at 725 000 ha. The country has a tradition of land improvement through irrigation and drainage. At the beginning of the twentieth century, the total irrigated area in Georgia was about 112 000 ha. Major investments were made in the irrigation sector during the Soviet period, resulting in a total area of about 500 000 ha equipped for irrigation at the beginning of the 1980s, mainly located in the more arid eastern part of the country.

During the 1990s, civil strife, war, vandalism and theft, as well as problems associated with land reform, the transition to a market economy, and the loss of markets with traditional trading partners, contributed to a significant reduction of the irrigated area. It has been reported that during the severe drought of 2000 only about 160 000 ha were irrigated. Almost all pumping schemes (about 143 000 ha) were out of order. As a consequence, Georgia's State Department of Melioration and Water Resources started a rehabilitation programme to renew the infrastructure of existing irrigation and drainage schemes and to establish Amelioration Service Cooperatives. About 255 000 ha are covered by these programmes.

In 2007, irrigation covered 432 790 ha, of which 31 500 ha equipped wetland and inland valley bottoms and 401 290 ha full or partial control irrigation. River diversion is the main source of water for irrigation and groundwater is not used for irrigation in Georgia. The main irrigation technology is surface irrigation (372 980 ha). Localized irrigation is practiced on 28 300 ha (Table 3 and Figure 3).

Most of the schemes are large-scale (Figure 4). The largest one are: the upper Alazani (41 100 ha), the lower Alazani (29 200 ha), the upper Samgori (28 100 ha), and the lower Samgori (29 200 ha). There is no private irrigation in Georgia. All irrigation schemes are managed by the State through its Department of Melioration and Water Resources. Though irrigation remains the responsibility of the State, the land irrigated can be owned either by private farmers or by the State but leased to farmers, cooperatives or agro-firms.

FIGURE 3
Irrigation techniques
Total: 401 290 ha in 2007

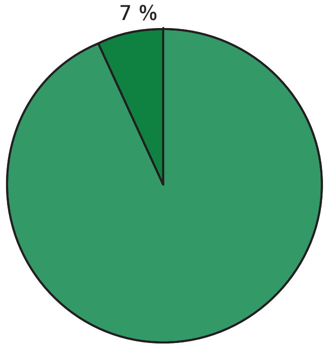


FIGURE 4
Type of irrigation schemes
Total: 401 290 ha in 2007

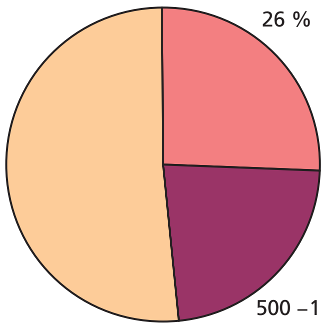


TABLE 3
Irrigation and drainage

Irrigation potential		-	725 000	ha
Irrigation				
1. Full or partial control irrigation: equipped area		2007	401 290	ha
- surface irrigation		2007	372 980	ha
- sprinkler irrigation		2007	0	ha
- localized irrigation		2007	28 310	ha
• % of area irrigated from surface water		2007	100	%
• % of area irrigated from groundwater		2007	0	%
• % of area irrigated from mixed surface water and groundwater		2007	0	%
• % of area irrigated from non-conventional sources of water		2007	0	%
• area equipped for full or partial control irrigation actually irrigated			-	ha
- as % of full/partial control area equipped			-	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)		1996	31 500	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)		**2007**	**432 790**	**ha**
• as % of cultivated area		2007	40.6	%
• % of total area equipped for irrigation actually irrigated			-	%
• average increase per year over the last 11 years		1996-2007	-0.72	%
• power irrigated area as % of total area equipped		2007	21.9	%
4. Non-equipped cultivated wetlands and inland valley bottoms			-	ha
5. Non-equipped flood recession cropping area			-	ha
Total water-managed area (1+2+3+4+5)		**2007**	**432 790**	**ha**
• as % of cultivated area		2007	40.6	%
Full or partial control irrigation schemes	**Criteria**			
Small-scale schemes	< 500 ha	2007	103 770	ha
Medium-scale schemes		2007	90 350	ha
Large-scale schemes	> 1000 ha	2007	207 170	ha
Total number of households in irrigation				
Irrigated crops in full or partial control irrigation schemes				
Total irrigated grain production (wheat and barley)			-	metric tons
• as % of total grain production			-	%
Harvested crops				
Total harvested irrigated cropped area		2006	126 060	ha
• Annual crops: total			-	ha
- Wheat			-	ha
- Rice			-	ha
- Barley			-	ha
- Maize			-	ha
- Potatoes			-	ha
- Other annual crops			-	ha
• Permanent crops: total			-	ha
- Fodder			-	ha
- Citrus			-	ha
- Other perennial crops (bananas, olives, grapes, strawberries)			-	ha
Irrigated cropping intensity (on full/partial control irrigation: equipped area)		2006	31.4	%
Drainage - Environment				
Total drained area		1996	164 700	ha
- part of the area equipped for irrigation drained		1996	31 800	ha
- other drained area (non-irrigated)		1996	132 900	ha
• drained area as % of cultivated area			-	%
Flood-protected areas			-	ha
Area salinized by irrigation		2002	113 560	ha
Population affected by water-related diseases			-	inhabitants

The unfavourable location of plots, low soil fertility, the failure of old irrigation and drainage systems, desertification, secondary bogging, salinization and erosion processes contribute to the non-lease and non-transfer of land to private owners. In addition, the slow pace of registering land ownership is due to the fact that the existing system deals with owner registration only, which is an insufficient basis for the full exercise of land ownership rights and the conclusion of subsequent transactions. Moreover, land registration and the process of proving land ownership are time consuming as old Soviet data have to be checked thoroughly (Government of Georgia, 2002).

Role of irrigation in agricultural production, economy and society

At the beginning of 1997, irrigation water charges were introduced in Georgia, at a rate of US$3 per 1 000 m^3. This figure was the same for all schemes in Georgia. The water charges covered about 12 percent of total O&M costs, the government budget covered 15 percent of the total, while the remaining 73 percent was not covered, resulting in the degradation of irrigation systems. In 1996, over 300 000 ha were estimated to be in need of rehabilitation. The current policy is for the government to pay for the O&M of the dams and headworks which have been constructed, while the O&M costs of the distribution and on-farm network are to be paid by irrigation users through a higher water charge.

No recent data for irrigation costs are available. In 1996 the average cost of irrigation development varied between US$3 500 and US$4 500/ha for surface irrigation, and between US$6 500 and 7 200/ha for sprinkler irrigation. Average O&M costs vary between US$55 and US$70/ha per year respectively.

In 2006, the total irrigated crop area was estimated at 126 060 ha, but no details for the different crops are available. In 1986, the major crops cultivated under full or partial control irrigation were fruit trees and grapes, pasture and fodder crops, vegetables, potatoes, wheat, maize and sunflower. Irrigated crop yields compared relatively favourably with rainfed crop yields, although the average difference is very small due to the good climatic conditions in the areas where rainfed agriculture is practiced. In 1986, in the full or partial control irrigation schemes, the average irrigated crop yields were 3.0 tonnes/ha for winter wheat, 2.9 tonnes/ha for maize, 4.8 tonnes/ha for grapes, 5.0 tonnes/ha for fruits and 12 tonnes/ha for potatoes.

Status and evolution of drainage systems

In 1996, the total drained area was estimated at 164 740 ha, consisting mainly of surface drainage. However, the infrastructure deteriorated drastically during the 1990s, reducing the drainage area to 65 000 ha.

Drainage has been developed mainly in the high rainfall region of western Georgia (Kolkhety lowland), on 132 940 ha out of a total of 164 740 ha for the whole country. The total area of the Kolkhety lowland where drainage infrastructure could be developed in the future is about 800 000 ha.

About 31 800 ha of full or partial control irrigation equipped areas are also equipped with a network of surface and subsurface drains (Table 3). About 31 100 ha of the equipped wetland and inland valley bottoms are also power drained. They are located in the coastal regions of west Georgia, in polder systems where electric pumps drain seawater and excess floodwater.

WATER MANAGEMENT, POLICIES AND LEGISLATION RELATED TO WATER USE IN AGRICULTURE

Institutions

The main institutions involved in water resources management are:

- The Ministry of Food and Agriculture with: (i) the Department of Melioration and Water Resources, responsible for planning, monitoring, and promoting irrigated agriculture. This department defines the water requirements for irrigation and supervises the management of the irrigation schemes; (ii) the Hydraulic Design Institute (Saktskalproject), responsible for irrigation, drainage, flood control, land reclamation, hydroelectric and water supply schemes design; (iii) the Georgian Scientific Research Institute of Water Management and Engineering Ecology, responsible for research into all issues related to water.

- The Ministry of Environment Protection and Natural Resources with the Centre for Monitoring and Prognostication, responsible for the assessment of surface water quantity, including the Black Sea, as well as groundwater. The Centre unites several departments for monitoring quantity and quality of surface water and groundwater, namely: (i) the Department of Hydrometeorology, responsible for surface water quantity observations (except of the rivers of the Ajara Autonomous Republic and the Black Sea); (ii) the Department of Monitoring of Environmental Pollution, responsible for surface water quality (except of the rivers of the Ajara Autonomous Republic and the Black Sea); (iii) the Black Sea Branch (located in Batumi), responsible for surface water quantity and quality monitoring of the Black Sea and rivers from the Ajara Autonomous Republic.

Water management

During the Soviet period, many administrative units were involved in the management of the same irrigation scheme. With the institutional changes, every scheme is directly managed by one of the 48 administrative units of the Department of Melioration and Water Resources.

Developing an Integrated Water Resources Management Plan for Georgia is a complicated task at this moment, because first new water legislation, based on a basin approach, must be enacted.

Policies and legislation

The policy document “Concept of agrarian policy in Georgia” was adopted by presidential decree in 1997; it covers the following issues relating to irrigation:

- the main irrigation infrastructure will remain in the hands of the State, while the inter-farm distribution will be included in the privatization programme;
- there should be an increase in state investment in irrigation, soil protection, research, selection, breeding information and plant protection services, development of environmental protection for rural infrastructure.

While there is no separate policy document that directly spells out Georgian policy for protecting and managing water availability and quality, the Law on Water does outline a number of key principles that comprise a policy framework (UNECE, 2003). Some of these are:

- water protection is a major element of environmental protection for Georgian citizens, in view of both current and future needs;
- drinking water for the population is the highest priority of all uses;
- both groundwater and surface water are under state control;
- management of water varies according to hydrologic importance;
- a system of “user-polluter pays” is key;
- pollution is not allowed, although a definition of what constitutes pollution is lacking.

There are more than 10 major laws in Georgia that have significant influence on the protection and management of water resources and associated environmental concerns. The most comprehensive is the above Law on Water, which has been in force since October 1997 and was last amended in June 2000. The 96 separate articles of this Law cover a very wide and comprehensive set of issues, such as pollution control policies, protection of drinking water sources, licensing of water use and discharge, categorization and protection of resources, particular measures for the Black Sea, flood control, and many others. All surface water, groundwater and near-coastal water is deemed to be under the control of the national government. Many of the provisions of the Law are supplemented by legislative orders and decrees, as well as by regulations of the Ministry of Environment Protection and Natural Resources, which specify necessary actions in greater detail. The Ministry holds overarching responsibility for implementing the Law on Water, although other ministries are key players on specific topics. The Law is implemented by personnel at the regional or municipal level. The Law on Water does provide for the licensing of water use and the discharge of pollutants, an approach that has been in place since 1999.

The government has prepared the national programme of harmonization of Georgian legislation (including water legislation) to EU legislation (Tsiklauri, 2004).

ENVIRONMENT AND HEALTH

Regardless of the fact that Georgia is a country with abundant fresh water resources, the current situation of the water supply is extremely complicated. This is largely due to anthropogenic contamination, deficit of drinking water and low sanitary standards of the water supply system. About 60 percent of existing water pipelines are depreciated. Their sanitary and technical conditions are unsatisfactory, resulting in frequent accidents and this, in turn, leads to water contamination. Due to water network damages, large quantities of water are lost. According to data for 1999, such losses amounted to 40 percent of the overall quantity of water supplied to households.

Due to the degradation of the water supply and sewerage infrastructure, the quality of drinking water often does not comply with human health and safety standards. Some 38 percent of the water pipeline system of the cities and regions belongs in the high-risk water pipeline category, in which the microbiological contamination index is high. The poor quality of water has resulted in several outbreaks of infectious intestinal diseases and epidemics (Government of Georgia, 2002).

In eastern Georgia there is a salinization problem relating to irrigation. Currently, 59 220 ha are severely salinized and 54 340 ha are moderately salinized. The poor quality of management and infrastructure of the irrigation systems has added to these problems during the past decade (UNECE, 2003).

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

Small-scale irrigation is developing without any subsidies from the government. Groundwater irrigation is likely to increase in the future for small-scale irrigation schemes, but only in western Georgia where the shallow aquifers are located.

Future irrigation development is expected to be on a very limited scale, particularly for large-scale and medium-scale schemes, mainly because of the high opportunity cost and the shortage of funds. Flow regulation through dams would be needed for these schemes, but there is competition between hydropower and irrigation.

Drainage works might be carried out in the future, particularly in the Kolkhety lowland, with attention to ecological and environmental analysis. The eradication of malaria in this area would be one of the goals of these drainage works. However, opponents of this project propose halting land reclamation in the Kolkhety lowland and the creation of a national park.

Donors and international financial institutions have developed projects for the rehabilitation of irrigation and drainage. The “irrigation and drainage community development project”, which started in 2002, is funded by the World Bank.

Finally, legislative acts need to be passed to ensure biodiversity protection and conservation, as well as to envisage the rational use of land resources (forests, water, mineral deposits) during territorial-spatial development planning (Government of Georgia, 2002)

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Iran (Islamic Republic of)

GEOGRAPHY, CLIMATE AND POPULATION

Geography

The Islamic Republic of Iran covers a total area of about 1.75 million km². The country is bordered by Armenia, Azerbaijan, the Caspian Sea and Turkmenistan to the north, Afghanistan and Pakistan to the east, the Gulf of Oman, the Strait of Hormuz and the Persian Gulf to the south, and Iraq and Turkey to the west. About 52 percent of the country consists of mountains and deserts and some 16 percent of the country has an elevation of more than 2 000 m above sea level. The largest mountain massif is that of the Zagros, which runs from the northwest of the country southwards first to the shores of the Persian Gulf and then continues eastwards till the most south-eastern province. Other mountain ranges run from the northwest to the east along the southern edge of the Caspian Sea. Finally, there are several scattered mountain chains along the eastern frontier of the country. The Central or Interior Plateau is located in between these mountain chains and covers over 50 percent of the country. It is partly covered by a remarkable salt swamp (kavir) and partly by areas of loose sand or stones with stretches of better land near the foothills of the surrounding mountains.

The cultivable area is estimated at about 51 million ha, which is 29 percent of the total area. In 2005 18.1 million ha were cultivated. Of this area, 16.5 million ha consisted of annual crops and 1.6 million ha of permanent crops (Table 1). In 2003, 72.5 percent of the landholders cultivated less than 5 ha, 22.5 percent between 5 and 20 ha, and only 5 percent more than 20 ha.

Climate

The climate of the Islamic Republic of Iran is one of great extremes due to its geographic location and varied topography. The summer is extremely hot with temperatures in the interior rising possibly higher than anywhere else in the world; certainly over 55 °C has been recorded. In winter, however, the great altitude of much of the country and its continental situation result in far lower temperatures than one would expect to find in a country in such low latitudes. Minus Temperatures of –30 °C can be recorded in the northwest and –20 °C is common in many places.

Annual rainfall ranges from less than 50 mm in the deserts to 2 275 mm in Rasht near the Caspian Sea. The average annual rainfall is 228 mm and approximately 90 percent of the country is arid or semi-arid. About 23 percent of the rain falls in spring, 4 percent in summer, 23 percent in autumn and 50 percent in winter.

Population

Total population is about 69.5 million (2005), of which 32 percent are living in rural areas (Table 1). This means that the ratio between urban and rural population has been

ISLAMIC REPUBLIC OF IRAN **FAO - AQUASTAT, 2008**

TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2005	174 515 000	ha
Cultivated area (arable land and area under permanent crops)	2005	18 107 000	ha
• as % of the total area of the country	2005	10.4	%
• arable land (annual crops + temp. fallow + temp. meadows)	2005	16 533 000	ha
• area under permanent crops	2005	1 574 000	ha
Population			
Total population	2005	69 515 000	inhabitants
• of which rural	2005	31.9	%
Population density	2005	39.8	inhabitants/km^2
Economically active population	2005	27 594 000	inhabitants
• as % of total population	2005	39.0	%
• female	2005	30.3	%
• male	2005	69.7	%
Population economically active in agriculture	2005	6 689 000	inhabitants
• as % of total economically active population	2005	24.2	%
• female	2005	44.3	%
• male	2005	55.7	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2007	270 940	million US$/yr
• value added by agriculture (% of GDP)	2007	9	%
• GDP per capita	2005	3 207	US$/yr
Human Development Index (highest = 1)	2005	0.759	
Access to improved drinking water sources			
Total population	2000	94	%
Urban population	2006	99	%
Rural population	2000	84	%

reversed over the last 50 years, the urban population being around 31 percent in 1955 (Mahmoodian, 2001). Average population density is 40 inhabitants/km^2, but ranges from less than 10 in the eastern part of the country up to more than 150 in the Gilan province, located on the Caspian Plain in the north, which is by far the most densely populated region in the country after Tehran province where the capital is located and where the population density reaches 400 inhabitants/km^2. The annual demographic growth rate was estimated at 3.7 percent over the period 1980–1990 and decreased to 0.9 percent over the period 2000–2005.

In 2006, 99 percent of the urban population had access to safe drinking water. In 2000, 84 percent of the rural population had access to safe drinking water. In 2000, 86 and 78 percent of the urban and rural populations respectively had access to improved sanitation.

ECONOMY, AGRICULTURE AND FOOD SECURITY

In 2007 the Gross Domestic Product (GDP) was US$270.9 billion (Table 1). Agriculture accounted for around 9 percent of GDP, while in 1992 it accounted for 23 percent. The economically active population is about 27.6 million (2005) of which 70 percent is male and 30 percent female. In agriculture, 6.7 million inhabitants are economically active of which 56 percent male and 44 percent female.

Agriculture is mostly practiced on small farming units. From 1960 to 1993 the number of farming units increased from 1.8 to 2.8 million units, with the average area per unit decreasing from just over 6 ha to less than 5.5 ha. More than 80 percent of these farming units have a total size of less than 10 ha and even these 10 ha are on average scattered over five different locations. About 5 percent of the agricultural land is used by cooperative companies, consisting of both traditional and modern systems. Usually each cooperative has 8 members with an average size of 40 ha. Commercial companies cover around 14 percent of the agricultural land, mostly located in Khozestan province in the southwest of the country.

WATER RESOURCES AND USE

Water resources

Of the average rainfall volume of 376 km^3/year an estimated 66 percent evaporates before reaching the rivers. The total long-term total renewable water resources are estimated at 137.5 km^3 of which about 9 km^3/year are external water resources (Table 2). Internal renewable water resources are estimated at 128.5 km^3/year. Surface runoff represents a total of 97.3 km^3/year, of which 5.4 km^3/year come from drainage of the aquifers, and groundwater recharge is estimated at about 49.3 km^3/year, of which 12.7 km^3/year are obtained from infiltration in the river bed, giving an overlap of 18.1 km^3/year. The Islamic Republic of Iran receives 6.7 km^3/year of surface water from Afghanistan through the Helmand River. The flow of the Araks River, at the border with Azerbaijan, is estimated at 4.63 km^3/year. The surface runoff to the sea and to other countries is estimated at 55.9 km^3/year, of which 7.5 km^3/year to Azerbaijan (Araks) and 10 km^3/year from affluents of the Tigris to Iraq. About 24.7 km^3/year flows from the Karun into Iraq, but since this is just before it discharges into the sea, it does not count as inflow into Iraq.

The Islamic Republic of Iran is divided into 6 main and 31 secondary catchment areas. The 6 major basins are: the Central Plateau in the centre (Markazi), the Lake Oroomieh basin in the northwest, the Persian Gulf and the Gulf of Oman basin in the west and south, the Lake Hamoon basin in the east (Mashkil Hirmand), the Kara-Kum basin in the northeast (Sarakhs) and the Caspian Sea basin in the north (Khazar) (Figure 1). All these basins, except the Persian Gulf and the Gulf of Oman basin, are interior basins. Almost half of the country's renewable water resources are located in the Persian Gulf and the Gulf of Oman basin, which only covers one fourth of the country (Table 3). On the other hand the Markazi basin, covering over half of the country, has less than one third of the total renewable water resources. With an area

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	228	mm/yr
	-	397.9	10^9 m^3/yr
Internal renewable water resources (long-term average)	-	128.5	10^9 m^3/yr
Total actual renewable water resources	-	137.5	10^9 m^3/yr
Dependency ratio	-	6.6	%
Total actual renewable water resources per inhabitant	2005	1 978	m^3/yr
Total dam capacity	2006	31 610	10^6 m^3
Water withdrawal			
Total water withdrawal	2004	93 300	10^6 m^3/yr
- irrigation + livestock	2004	86 000	10^6 m^3/yr
- municipalities	2004	6 200	10^6 m^3/yr
- industry	2004	1 100	10^6 m^3/yr
per inhabitant	2004	1 356	m^3/yr
Surface water and groundwater withdrawal	2004	93 100	10^6 m^3/yr
• as % of total actual renewable water resources	2004	67.7	%
Non-conventional sources of water			
Produced wastewater	2001	3 075	10^6 m^3/yr
Treated wastewater	2001	130	10^6 m^3/yr
Reused treated wastewater		-	10^6 m^3/yr
Desalinated water produced	2004	200	10^6 m^3/yr
Reused agricultural drainage water		-	10^6 m^3/yr

of 424 240 km^2, the Caspian Sea is the largest landlocked water body in the world and its surface lies about 22 metres below sea level.

There are several large rivers, but the only navigable one is the Karun, the others being too steep and irregular. The Karun River, with a total length of 890 km, flows in the southwest of the country to the Shatt al Arab, which is formed by the Euphrates and the Tigris in Iraq after their confluence. The few streams that empty into the Central Plateau dissipate into the saline marshes. All streams are seasonable and variable. Spring floods do enormous damage, while there is little water flow in summer when most streams disappear. Water is however stored naturally underground, finding its outlet in subterranean water canals (qanats) and in springs. It can also be tapped by wells.

FIGURE 1
Major basins in Iran

TABLE 3
Water resources in major basins

Name of basin	Percentage of total area of the country	Percentage of renewable water resources
Khazar	10	15
Persian Gulf and Gulf of Oman	25	46
Lake Oroomieh	3	5
Markazi	52	29
Hamoon	7	2
Sarakhs	3	3
Total for country	**100**	**100**

Dams have always played an important role in harnessing precious Iranian water reserves and the long-term objective of the Islamic Republic of Iran's water resources development plan is based on the control and regulation of water resources through dams. In 2006, 94 large storage dams with a total capacity of 31.6 km^3 were operating and 85 large dams with a capacity of 10 km^3 were under construction. Aside from hydropower, dams also play an important role in flood control through the routing of floods. Several reservoirs behind the dams would seem to offer good sailing and water-skiing facilities, but have not been used for recreation so far.

In 2001, there were 39 wastewater treatment plants with a total capacity of 712 000 m^3/day, treating the wastewater produced by a population of 3.8 million. The wastewater actually treated was around 130 million m^3/year (Mahmoodian, 2001). Some 79 treatment plants with a total capacity of 1.917 million m^3/day were under construction and 112 treatment plants with a total capacity of 1.590 million m^3/day were being studied for completion by the year 2010.

In 2002, the total installed gross desalination capacity (design capacity) in the Islamic Republic of Iran was 590 521 m^3/day or almost 215.5 million m^3/year (Wangnick Consulting, 2002). The desalinated water produced was around 200 million m^3 in 2004.

Water use

In 2004, the total agricultural, municipal and industrial water withdrawal was estimated at about 93.3 km^3, of which 40.0 km^3 from surface water, 53.1 km^3 from groundwater (qanats and wells) and 0.2 km^3 desalinated water (Table 2, Table 4 and Figure 2). Groundwater depletion is estimated at 3.8 km^3/year. Most of the overexploitation happens in the central basins where less surface water is available. Total surface water and groundwater withdrawal represents almost 68 percent of the total actual renewable water

FIGURE 2
Water withdrawal by source
Total: 93.3 km³ in 2004

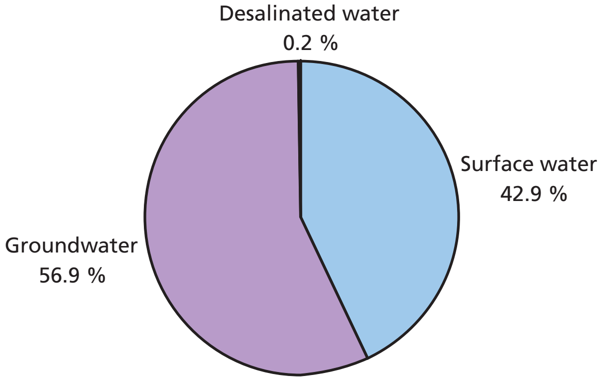
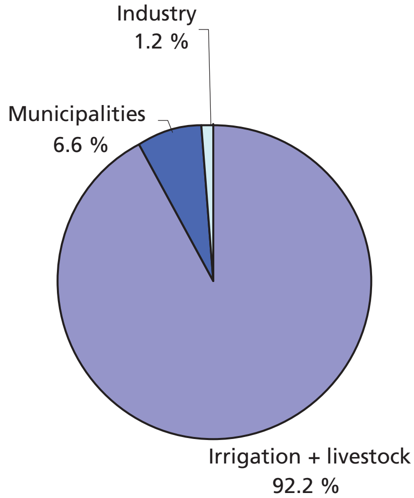


FIGURE 3
Water withdrawal by sector
Total: 93.3 km³ in 2004



resources. Use of non-conventional sources of water is minimal. The treated wastewater is said to be indirectly used in agriculture. In some towns, albeit in a limited form, raw wastewater is used directly for irrigation, resulting in some health-related problems (Mahmoodian, 2001). Agriculture is the main water withdrawal sector, with 86 km³ in 2004 (Figure 3). Its part of the total water withdrawn remains identical compared to 1993 (around 92 percent). Municipal and industrial water withdrawal amount to 6.2 and 1.1 km³ respectively. About 16 km³ of water was used for electrical power generation in 1999.

Groundwater discharge (through wells, qanats and springs) varied from less than 20 km³/year in the early 1970s to over 74 km³/year at the beginning of the present millennium (Table 4). The number of wells during that period increased fivefold, from just over 9 000 to almost 45 000.

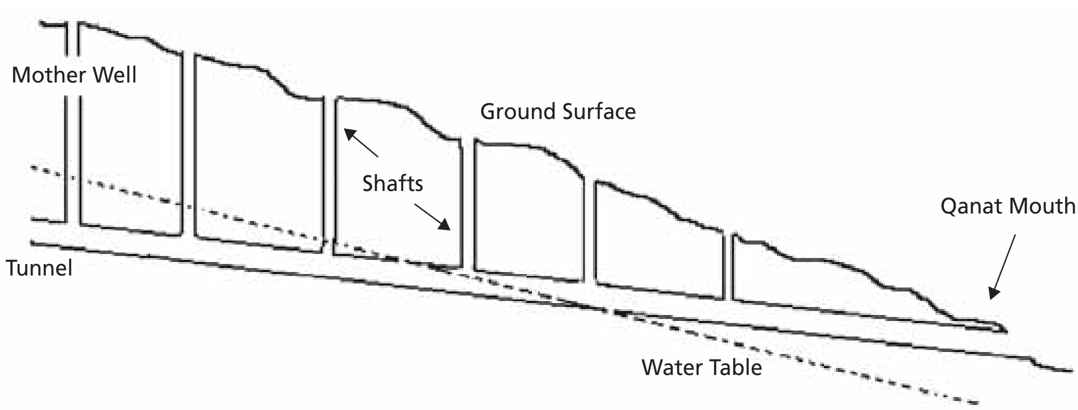
The qanat is a traditional system in the Islamic Republic of Iran for using groundwater. It is a subterranean water collection and conduction device for bringing water from one place to another. It consists of three parts (Figure 4):

i. the mother well dug at the beginning of the qanat where water is available;
ii. access shafts built along the tunnel to provide ventilation and for the removal of debris, at a distance of 20–50 meters and with the depth depending on the depth of the underground tunnel;

TABLE 4
Groundwater discharges in major sub-basins (2001)

name of basin	Wells		Qanats		Springs		Total Discharge (km³/year)
	Quantity	Discharge (km³/year)	Quantity	Discharge (km³/year)	Quantity	Discharge (km³/year)	
Khazar	130 267	4.39	2 611	0.45	25 404	3.00	7.83
Persian Gulf and Gulf of Oman	97 376	10.08	3 950	1.06	13 529	15.24	26.38
Lake Oroomieh	72 019	1.97	1 540	0.23	943	0.12	2.32
Markazi	155 415	25.93	22 017	5.79	13 681	2.47	34.18
Hamoon	3 873	0.80	2 606	0.40	1 140	0.06	1.26
Sarakhs	9 099	1.73	1 631	0.29	1 215	0.35	2.36
Total	**468 049**	**44.89**	**34 355**	**8.23**	**55 912**	**21.24**	**74.35**

FIGURE 4
The qanat system



iii. the tunnel per se dug from downstream to upstream with a slope gradient of 1/500 to 1/2 500 in order to prevent erosion and siltation, and with a length varying from about 100 metres to 120 km in a qanat in the Yazd region. Its diameter is just enough for a maintenance worker to crawl through.

International water issues

Prior to the Taliban regime in Afghanistan there was an agreed flow of 27 m^3/s (850 million m^3/year) of the Helmand River entering the Islamic Republic of Iran. However during the Taliban regime in Afghanistan (1995–2001), this agreement ceased completely and this caused an economic and environmental disaster in the provinces of Sistan and Baluchistan bordering Afghanistan and Pakistan (Bybordi, 2002). The Helmand River is the longest river in Afghanistan. It stretches 1 150 km from the Hindu Kush mountains about 80 km west of Kabul and crosses southwest through the desert to the Seistan marshes and the Hamun-i-Helmand lake region around Zabol on the Afghan-Iranian border.

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

Water supply has been a constant preoccupation since the beginning of the country's history, thousands of years ago. Its inhabitants learnt to design and implement efficient techniques for harnessing their limited water resources and for irrigation. Apart from the qanat, which was a major source of irrigation and domestic water supply for centuries, Iranians have in the past built dams of various types and weirs. Some of these head control structures, built as long as 1 000 years ago, are still in good condition.

Agricultural land availability is not a major constraint. The major constraint is the availability of water for the development of these lands. The irrigation potential, based on land and water resources, has been estimated at about 15 million ha, or 29 percent of the cultivable area (Table 5). However, this would require optimum storage and water use.

The total area equipped for irrigation is about 8.13 million ha in 2003, compared to 7.26 million ha in 1993. About 62 percent of that area is irrigated by groundwater (Figure 5). Surface irrigation is the main irrigation technology used in the Islamic Republic of Iran, covering 91.4 percent of the area equipped for irrigation (Figure 6). Localized and sprinkler irrigation cover 5.2 and 3.4 percent respectively, compared to only 0.6 percent each in 1993. Almost all pressurized irrigation systems are manufactured in

TABLE 5
Irrigation and drainage

Irrigation potential		**-**	**15 000 000**	**ha**
Irrigation				
1. Full or partial control irrigation: equipped area		2003	8 131 564	ha
- surface irrigation		2003	7 431 564	ha
- sprinkler irrigation		2003	280 000	ha
- localized irrigation		2003	420 000	ha
• % of area irrigated from surface water		2003	37.9	%
• % of area irrigated from groundwater		2003	62.1	%
• % of area irrigated from mixed surface water and groundwater			-	%
• % of area irrigated from non-conventional sources of water			-	%
• area equipped for full or partial control irrigation actually irrigated			-	ha
- as % of full/partial control area equipped			-	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)			-	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)		**2003**	**8 131 564**	**ha**
• as % of cultivated area		2003	46.0	%
• % of total area equipped for irrigation actually irrigated			-	%
• average increase per year over the last 10 years		1993-2003	1.13	%
• power irrigated area as % of total area equipped		1993	32.2	%
4. Non-equipped cultivated wetlands and inland valley bottoms		1993	0	ha
5. Non-equipped flood recession cropping area		1993	10 000	ha
Total water-managed area (1+2+3+4+5)		**2003**	**8 141 564**	**ha**
• as % of cultivated area		2003	46.1	%
Full or partial control irrigation schemes	**Criteria**			
Small-scale schemes	< 10 ha	2003	4 000 000	ha
Medium-scale schemes		2003	3 281 564	ha
large-scale schemes	> 50 ha	2003	850 000	ha
Total number of households in irrigation		2004	2 828 646	
Irrigated crops in full or partial control irrigation schemes				
Total irrigated grain production		1993	10 000 000	metric tons
• as % of total grain production		1993	61	%
Harvested crops				
Total harvested irrigated cropped area		2003	8 592 554	ha
• Annual crops: total		2003	7 258 899	ha
- Wheat		2003	2 634 106	ha
- Rice		2003	628 105	ha
- Barley		2003	607 485	ha
- Maize		2003	275 941	ha
- Other cereals		2003	65	ha
- Sweet potatoes		2003	186 671	ha
- Other roots and tubers		2003	48 758	ha
- Sugar beet		2003	152 875	ha
- Vegetables		2003	563 011	ha
- Pulses		2003	159 716	ha
- Tea		2003	2 934	ha
- Tobacco		2003	10 142	ha
- Cotton		2003	143 233	ha
- Soybeans		2003	56 586	ha
- Groundnuts		2003	647 852	ha
- Fodder		2003	878 181	ha
- Sunflowers		2003	77 781	ha
- Flowers		2003	61 860	ha
- Other annual crops		2003	123 597	ha
• Permanent crops: total		2003	1 333 655	ha
- Sugar cane		2003	63 385	ha
- Bananas		2003	2 889	ha
- Citrus fruit		2003	213 348	ha
- Other perennial crops		2003	1 054 033	ha
Irrigated cropping intensity (on equipped area)		2003	106	%

TABLE 5
Irrigation and drainage (continued)

Drainage - Environment			
Total drained area	2002	1 508 000	ha
- part of the area equipped for irrigation drained	2002	1 508 000	ha
- other drained area (non-irrigated)		-	ha
• drained area as % of cultivated area	2002	8.6	%
Flood-protected areas		-	ha
Area salinized by irrigation	1993	2 100 000	ha
Population affected by water-related diseases		-	inhabitants

the country. The water in the surface irrigation schemes arrives through a combination of gravity and water lifting systems. Most of the dams constructed in the Islamic Republic of Iran are for irrigation purposes with main and secondary canals built downstream, covering a total area of 1.56 million ha and which are called modern systems. The rest of the irrigated areas have traditional canals built by farmers that in many cases have to be rebuilt every year. Small schemes (< 10 ha) cover 50 percent of the total equipped area for irrigation, medium size schemes (10–50 ha) 40 percent and large schemes (>50 ha) 10 percent (Figure 7). Among the holdings practicing irrigation, the average irrigated area is 2.9 ha.

In 1993 non-equipped flood recession cropping was practiced in an area of about 10 000 ha in the southwest of the country.

FIGURE 5
Source of irrigation water
Total: 8 131 564 ha in 2003

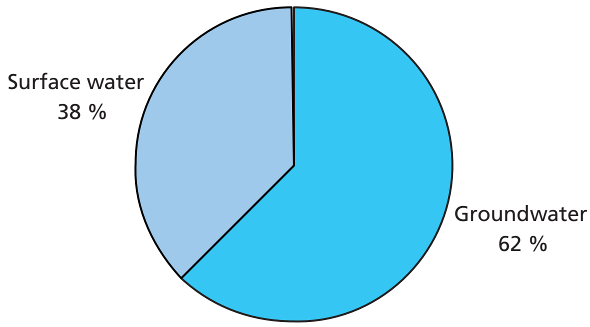
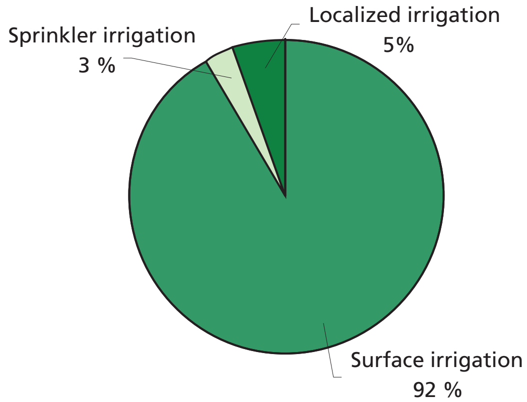


FIGURE 6
Irrigation techniques
Total: 8 131 564 ha in 2003

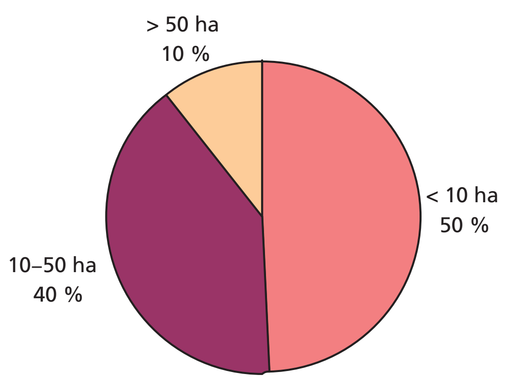


Role of irrigation in agricultural production, the economy and society

About 98.5 percent of the agricultural land in the Islamic Republic of Iran is under private ownership. Rainfed cultivation is possible in the higher rainfall areas in the northwest, the west and in the littoral zone along the Caspian Sea. About 89 percent of the total agricultural products in the last 5 years have come from the irrigated land.

The total harvested irrigated cropped area was 8 592 554 ha in 2003 (Table 5 and Figure 8). By far the most important harvested irrigated crop is wheat (almost 31 percent of the total harvested irrigated area), followed by fodder (10 percent), groundnuts (7.5 percent), rice (7 percent), barley (7 percent) and vegetables (6.5 percent). Wheat is also

FIGURE 7
Type of irrigation schemes
Total: 8 131 564 ha in 2003



by far the most important rainfed crop. In 2003, around 40 percent of the area under wheat was irrigated and 60 percent rainfed. In 1993 the yield for irrigated wheat was estimated at 2.78 tonnes/ha against 0.95 tonnes/ha for rainfed wheat

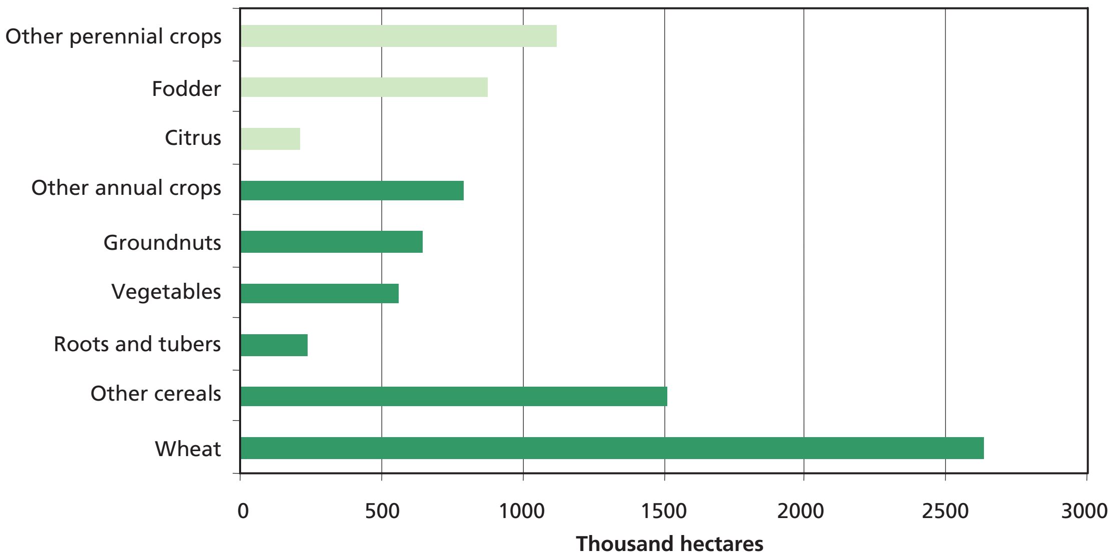
Crop yields on irrigated land, although generally 2–3 times higher than on rainfed land, are still on the low side by international standards. Water shortage and soil salinity are mentioned among the main causes of this yield gap (Smedema, 2003).

Irrigation efficiency is generally low, 33 percent on average at national level. This causes waterlogging and salinization in the irrigated areas, which are major problems in the Islamic Republic of Iran.

The average cost of surface irrigation development is about $US7 500/ha for public schemes. The cost of sprinkler and localized irrigation for on-farm installations is estimated at $US1 700/ha and US$2 500/ha respectively.

In 1995, the average price of water delivered to farmers by the government was $US0.2 to 0.8 per 1 000 m³, while the cost of groundwater withdrawal was $US5 to 9 per 1 000 m³ and the cost for regulating surface water in existing projects was $US 3 to 5 per 1 000 m³. This means that the government heavily subsidized delivered water, which is probably one of the main reasons for the low irrigation efficiency throughout the country.

FIGURE 8
Irrigated crops
Total harvested area: 8 592 554 ha in 2003 (cropping intensity on equipped area: 106%)



Status and evolution of drainage systems

Drainage is not as extensive as irrigation is. Almost all modern irrigation systems have surface drainage systems, which cover about 1.5 million ha (Table 5). Subsurface drainage systems have been constructed on a total of 170 000 – 180 000 ha, of which about half is in Khozestan Province in the southwest of the country.

WATER MANAGEMENT, POLICIES AND LEGISLATION RELATED TO WATER USE IN AGRICULTURE

Institutions

According to the water legislation, three ministries are directly in charge of water resources assessment and development:

- The Ministry of Energy (MOE) has two responsibilities: energy supplies and water resources. As far as irrigation is concerned, it is in charge of the construction of large hydraulic works, including dams and primary and secondary irrigation and drainage canals for the distribution of water. Within the MOE, the Water Affairs Department (WAD) is responsible for overseeing and coordinating the planning, development, management and conservation of water resources. The WAD consists of the following sections: Water Resources Management Company (WRMC), Provincial Water Authorities (PWA), Irrigation and Drainage Operation and Maintenance Companies (O&M). WRMC is the mother company that manages all water sectors within the MOE except drinking water distribution for rural and urban areas. PWAs are responsible for the water sector in each province including irrigation and drainage development and operation. Drinking water distribution is the responsibility of provincial water and wastewater companies. O&M companies are responsible for modern irrigation and drainage operation and maintenance. 49 percent of the shares of these companies belong to the MOE and 51 percent belong to private sectors. There are 19 O&M companies working under the supervision of the PWAs.
- The Ministry of Agriculture (MOA) is responsible for supervising rainfed and irrigated crop development. It is in charge of subsurface drains, tertiary and quaternary canals as well as farm development and irrigation techniques, planned and operated by the Provincial Agricultural Organizations and the Deputy Ministry for Infrastructure Affairs of the Ministry of Agriculture.
- The Ministry of Jihad-e-Sazandagi (MOJ) deals with watershed management and rural development.

The Islamic Republic of Iran's Department of the Environment (DOE) is responsible for the preparation of the environmental protection policy and the laws, directives and systems necessary for evaluating the impacts of social and economic development projects, particularly irrigation and hydropower projects, on the environment and following up their implementation.

The "Farmers' House" was established in order to protect the rights of the farmers. Its role is to streamline and coordinate the farmers' activities, including their commitments in the fields of farming, fruit growing, animal husbandry, hunting, poultry production, supportive industries and so on.

Water management

Traditionally, the provision of water has been the responsibility of the government. As far as groundwater is concerned, the private sector invests in well drilling after which it is operated and managed by farmers. In recent years there has been a large increase in private sector financing of water projects, especially irrigation and drainage systems. Between 1994 and 1999 the cumulative new private sector capital expenditures in water projects in the Islamic Republic of Iran came to US$84 million. The construction of a total of about 300 000 ha surface irrigation networks has been financed and/or by farmers and the operation of these systems has been or will be transferred to the water user associations (WUAs) upon completion. In addition, the operation of some parts of the old systems has been transferred to the WUAs as pilot projects. These projects are located in Qazvin, Fomanat, Zabol and Khozestan. Another role of the WUAs is to decrease the number of water delivery points and it is also their responsibility to further distribute the irrigation water and collect the fees.

Irrigation development has always featured quite prominently in the Five Year Plans (FYP). In the first FYP (1989–1994) and second FYP (1995–2000), the area under modern irrigation was expanded and additional water resources were mobilized. The third FYP (2000–2005) marked a shift in the country's irrigation development policy. Since further withdrawal of water will be increasingly costly and in future more water needs to be allocated to other water use sectors (drinking water, industry and environment), more attention must be given to water saving measures than to further expansion of the irrigated area: more demand management as opposed to the current supply management practiced, canal and watercourse lining, sprinkling and other types of pressurized field irrigation, land levelling and so on (Smedema, 2003).

Policies and legislation

According to national law all water bodies (rivers, lakes, seas, etc.) are public property and the government is responsible for their management. The first water law after the revolution in the Islamic Republic of Iran was approved in 1982. Based on this law, allocating and issuing permits to use the water for domestic, agricultural and industrial purposes is the responsibility of the MOE. The MOA is appointed to distribute water for agriculture among farmers and collect the water fees. Water and wastewater companies are responsible for the distribution of water for domestic use in urban and rural areas and for collecting fees.

In the traditional irrigation systems, farmers receive their share of water based on their water rights, usually in proportion to the land area. This right to water use is usually measured based on the water delivery time. The water rights are attached to the land and when selling the land the water rights are also transferred to the new owner. Water rights can be rented or traded. Groundwater is mainly private property and it is traded between farmers. Wells can be sold with or without the land. Qanats have shared ownerships. Those who have built the qanat or participate in its maintenance are entitled to use its water. The oldest water rights legislation in the country is about how to use and divide the qanats' water among farmers.

ENVIRONMENT AND HEALTH

Salinity is one of the biggest problems in the Islamic Republic of Iran. The total area affected by salinity and waterlogging is estimated to be about 15.5 million ha or 9.4 percent of the total country area. About 7.32 million ha have saline affected soils. Leaching, built into the irrigation network, has proved to be a successful way to treat these soils. Because of the existing high concentration of calcium in soils, it is possible to treat sodic soils with leaching without using any additive materials. No comprehensive study has been undertaken regarding the extent of irrigation-induced salinity, but it is estimated that over 2 million ha are salt-affected and/or waterlogged.

Although the extent is unknown, water-related diseases are prevalent in some irrigated areas where the water is also used for domestic purposes.

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

The Water Resources Management Policy emphasizes an integrated approach in water resources development to maximize positive impacts and avoid or minimize any negative effects of irrigation development. Based on the country's perspective on water resources, in order to control the overexploitation of groundwater resources, the surface water withdrawal percentage should change from 43 percent at the present to 55 percent. In addition, the country aims at decreasing the agricultural share from 92 percent to 87 percent by increasing water use efficiency. Water productivity is expected to increase from 0.7 kg/m^3 to 1.4 kg/m^3 over the next 20 years. The country plans to develop irrigation for another 1.76 million ha in the next 20 years.

The increasing water shortage in the country has forced many decision-making bodies to consider the reuse of effluent as an appealing option. Among the recent decisions taken by the Expediency Council were the adoption and implementation of general plans for recycling water nationwide. The proposed policies and strategies are as follows (Mahmoodian, 2001):

- Fully satisfy the drinking water demand potential from freshwater, prior to any other use.
- Guarantee future urban water demands by replacing the agricultural water rights to using freshwater (from brooks, rivers, springs well, etc.) with using treated effluents.
- Avoid the use of high quality urban water to create green spaces, and instead allot low quality water for this purpose.
- Cut off water supply to industries which have not taken practical measures for treating and reusing their wastewater.
- Expand research projects for the establishment of reasonable standards for the safe and reliable reuse of wastewater. Replacing freshwater with treated effluents in agriculture necessitates introducing farmers to the positive and economic advantages of using wastewater, and consequently convincing them to exchange freshwater with effluents. This in itself requires research and study on the sanitary, economic and environmental impacts of using wastewater for agriculture and the artificial recharging of groundwater resources.

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