Turkey

GEOGRAPHY, CLIMATE AND POPULATION

Geography

Turkey occupies a total area of about 783 560 km² of which approximately 10 400 km² are inland lakes. It forms the bridge between Europe and Asia, with about 3 percent of its land in Europe (Thrace) and the rest in Asia (Anatolia). It is bordered by Georgia, Armenia, Azerbaijan and the Islamic Republic of Iran in the east, by the Islamic Republic of Iran, Iraq and the Syrian Arab Republic in the southeast, by the Mediterranean and Aegean Sea in the south and west, by Bulgaria and Greece in the northwest, and finally by the Black Sea in the north. The total coastline is over 10 000 km, compared to a total land border with other countries of about 2 950 km in length.

The cultivated area of 26.6 million ha covers one-third of the total area of the country, of which about 10 percent is occupied by permanent crops, mainly vineyards, fruit trees and olives (Table 1).

Climate

Turkey has four seasons, but the climate varies widely across the country. Turkey experiences both maritime and continental weather patterns which, combined with its highly varied topography, cause extreme geoclimatic diversity. The Black Sea region in the north receives rain throughout the year and has both mild summers and mild winters. The southern coastal Mediterranean region is regarded as subtropical, characterized by hot, dry summers and mild, rainy winters. The Aegean region (Western Anatolia) has mountains which run roughly east to west (i.e. perpendicular to the coast) and which are interspersed with grassy floodplains. This region also has a Mediterranean type of climate with hot, dry summers and mild winters. Central Anatolia is a vast high plateau with an average altitude of 1 132 meters above sea level and a semi-arid continental climate with hot and dry summers and cold winters.

The average annual temperature is 18–20 °C on the south coast, falling to 14–15 °C on the west coast, and fluctuates between 4 and 19 °C in the interior regions, depending on the distance from the sea and the altitude.

The average annual rainfall in Turkey is about 643 mm, with significant spatial and temporal fluctuations. Rainfall is scarce during the growing season in normal years in most parts of Turkey. Overall, the western and southern coastal regions receive 800–1 000 mm of rainfall per year. The northern coastal zone (the Black Sea region) receives the highest annual rainfall (1 260–2 500 mm). Central Anatolia receives the lowest rainfall (200–600 mm) which, combined with high temperatures and high evaporation rates, causes drought during the summer months. Evaporation and/or evapotranspiration rates are high particularly in the southeast region, which receives almost no rainfall during the summer, and can reach more than 2 000 mm/year. The

TURKEY

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TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2005	78 356 000	ha
Cultivated area (arable land and area under permanent crops)	2005	26 606 000	ha
• as % of the total area of the country	2005	34	%
• arable land (annual crops + temp fallow + temp. meadows)	2005	23 830 000	ha
• area under permanent crops	2005	2 776 000	ha
Population			
Total population	2005	73 193 000	inhabitants
• of which rural	2005	32.7	%
Population density	2005	93.4	inhabitants/km^2
Economically active population	2005	35 190 000	inhabitants
• as % of total population	2005	48.1	%
• female	2005	39.0	%
• male	2005	61.0	%
Population economically active in agriculture	2005	14 994 000	inhabitants
• as % of total economically active population	2005	42.6	%
• female	2005	64.9	%
• male	2005	35.1	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2007	657 090	million US$/yr
• value added in agriculture (% of GDP)	2007	9	%
• GDP per capita	2005	4 966	US$/yr
Human Development Index (highest = 1)	2005	0.775	
Access to improved drinking water sources			
Total population	2006	97	%
Urban population	2006	98	%
Rural population	2006	95	%

southeast region records very low humidity levels, while the coastal regions have quite high levels, in line with precipitation rates.

Snow can be seen almost everywhere in Turkey, but the number of snowy days and the period covered by snow differ from region to region. There is one or less snowy day in the Mediterranean and Aegean regions, whereas in parts of eastern Anatolia there can be up to 120 days of snow. On the high mountains, snow cover can be seen throughout the year, which melts slowly.

Population

The population of Turkey is 73.2 million (2005) with an average annual population growth rate of 1.4 percent whereas it was almost 2 percent per year in the previous decade. Population density is 93.4 inhabitants/km^2 (Table 1). The rural population declined from 41 percent in 1990 to 33 percent in 2005. In 2006, about 98 and 96 percent of the urban and 95 and 72 percent of the rural population have access to safe drinking water and improved sanitation respectively.

ECONOMY, AGRICULTURE AND FOOD SECURITY

In 2006 the Gross Domestic Product (GDP) was US$402.7 billion, and agriculture contributed almost 10 percent of GDP (Table 1). The economically active population is about 35.2 million (2005) of which 61 percent is male and 39 percent female. In agriculture, 15 million inhabitants are economically active of which 35 percent is male and 65 percent female. The unemployment rate in 2005 was around 9 percent. In 2002 an estimated 1 515 adults in Turkey were infected by HIV, but data on its impact on the labour force are not available.

Turkey is a major agricultural producer. Wheat is the staple food crop with a share of 67 percent in total grain production. The principal agricultural exports are field crops, industrial crops, fruit, vegetables, and small livestock. The share of crop production in total agricultural production is 73.5 percent.

WATER RESOURCES AND USE

Water resources

Turkey is divided into 26 hydrological basins with large differences in specific discharge (Table 2) (GDRS, 2003). Most rivers originate in Turkey and there are more than 120 natural lakes and 579 artificial lakes. Total internal renewable water resources are estimated at 227 km^3/year (Table 3). About 186 km^3 is surface water and 69 km^3 groundwater, while 28 km^3 is considered to be the overlap between surface water and groundwater. Average surface runoff entering the country from Bulgaria and the Syrian Arab Republic is 1.8 km^3/year, of which 0.6 km^3 from the Tunca River coming from Bulgaria and 1.2 km^3 from the Asi-Orontes coming from the Syrian Arab Republic. The Meriç River, originating in Bulgaria, forms the border between Greece and Turkey with a flow of 5.8 km^3/year and therefore the part accounted for by Turkey is considered to be half of the total flow or 2.9 km^3/year. This gives a total inflow of 4.7 km^3/year. Adding the incoming flow to the internal renewable water resources brings the total natural renewable water resources to 231.7 km^3/year. Of the total flow

TABLE 2

Major hydrological basins in Turkey (GDRS, 2003)

Basin No	Name of basin	Area of basin in Turkey	Area equipped for irrigation by DSI	Specific discharge	Total annual flow	Draining to
		(km^2)	(ha)	(l/s per km^2)	(km^3/year)	
1	Euphrates[1]	127 304	377 680	8.3	31.61	Syria/Iraq/Iran (Persian Gulf)
2	Tigris[2]	57 614	31 875	13.1	21.33	Iraq/Iran (Persian Gulf)
3	South Mediterranean	22 048	39 685	15.6	11.07	Mediterranean Sea
4	Antalya	19 577	96 773	24.2	11.06	Mediterranean Sea
5	Western Mediterranean	20 953	47 139	12.4	8.93	Mediterranean Sea
6	Seyhan	20 450	134 675	12.3	8.01	Mediterranean Sea
7	Ceyhan	21 982	162 713	10.7	7.18	Mediterranean Sea
8	Asi (Orontes)	7 796	34 947	3.4	1.17	Mediterranean Sea
9	B.Menderes	24 976	176 732	3.9	3.03	Aegean Sea
10	Northern Aegean	10 003	27 496	7.4	2.09	Aegean Sea
11	Gediz	18 000	118 551	3.6	1.95	Aegean Sea
12	Meriç Ergene	14 560	80 480	2.9	1.33	Aegean Sea
13	K.Menderes	6 907	16 076	5.3	1.19	Aegean Sea
14	Marmara	24 100	42 479	11.0	8.33	Sea of Marmara
15	Susurluk	22 399	105 241	7.2	5.43	Sea of Marmara
16	Eastern Black Sea	24 077	4 848	19.5	14.90	Black Sea
17	Western Black Sea	29 598	36 334	10.6	9.93	Black Sea
18	Kızılırmak	78 180	114 716	2.6	6.48	Black Sea
19	Sakarya	58 160	120 802	3.6	6.40	Black Sea
20	Yeşil Irmak	36 114	114 461	5.1	5.80	Black Sea
21	Çoruh	19 872	13 498	10.1	6.30	To Georgia and then Black Sea
22	Aras	27 548	81 900	5.3	4.63	Armenia/Azerbaijan/ Iran (Caspian Sea)
23	Konya inland basin	53 850	385 173	2.5	4.52	Interior
24	Van inland basin	19 405	47 320	5.0	2.39	Interior
25	Burdur Lakes Area	6 374	47 465	1.8	0.50	Interior
26	Akarçay	7 605	60 706	1.9	0.49	Interior
	Total	**779 452**	**2 519 765**	**209.3**	**186.05**	

[1] The average flow of Euphrates varies between 26.3 and 31.6 km^3 per year and the latter figure is used in this table.
[2] The average flow of Tigris varies between 18.0 and 21.3 km^3 per year and the latter figure is used in this table.

TABLE 3
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	643	mm/yr
	-	503.83	10^9 m^3/yr
Internal renewable water resources (long-term average)	-	227.00	10^9 m^3/yr
Total actual renewable water resources	-	213.56	10^9 m^3/yr
Dependency ratio	-	1.01	%
Total actual renewable water resources per inhabitant	2005	2 918	m^3/yr
Total dam capacity	2006	651 000	10^6 m^3
Water withdrawal			
Total water withdrawal	2003	40 100	10^6 m^3/yr
- irrigation + livestock	2003	29 600	10^6 m^3/yr
- municipalities	2003	6 200	10^6 m^3/yr
- industry	2003	4 300	10^6 m^3/yr
• per inhabitant	2003	563	m^3/yr
Surface water and groundwater withdrawal	2003	39 100	10^6 m^3/yr
• as % of total actual renewable water resources	2003	18.3	%
Non-conventional sources of water			
Produced wastewater	2006	2 770	10^6 m^3/yr
Treated wastewater	2005	1 680	10^6 m^3/yr
Reused treated wastewater	2006	1 000	10^6 m^3/yr
Desalinated water produced	1990	0.5	10^6 m^3/yr
Reused agricultural drainage water		-	10^6 m^3/yr

of 53.74 km^3/year leaving the country, 28.1 km^3 flows to the Syrian Arab Republic (of which 26.29 km^3 is the natural outflow of the Euphrates), 21.33 km^3 to Iraq (Tigris and affluent), and 4.31 km^3 to Georgia. Groundwater flows to other countries are estimated at 11 km3/year, of which 1.2 km3/year to the Khabour Springs feeding the Khabour River, situated in the Syrian Arab Republic, with a runoff of 1.2 km^3/year, have their origin in groundwater coming from Turkey. Taking into consideration the outflow and the flows reserved between countries (see international water issues below), the total actual renewable water resources are equal to 213.56 km^3/year.

Turkey contributes about 90 percent of the total annual flow of the Euphrates, while the remaining part originates in the Syrian Arab Republic and nothing is added further downstream in Iraq. Turkey contributes 38 percent directly to the main Tigris River and another 11 percent to its tributaries joining the main river further downstream in Iraq. In general, the streams and rivers vary greatly in their flow from season to season and from year to year. For example, the Euphrates' annual flow at the border with the Syrian Arab Republic ranged from 15.3 km^3 in 1961 to 42.7 km^3 in 1963.

A trend analysis of annual minimum, maximum and mean stream-flow variables in Turkey showed that there was a significant decreasing trend seen mostly in the basins in western Turkey, whereas some basins draining to the Black Sea exhibited significant increasing trends. Almost no evidence of any significant change was experienced in the rest of the country (Topaloglu, 2006).

A significant part of the water in mountainous coastal areas finds its way to the sea without forming any large groundwater reservoir. Hydrogeological surveys carried out in 342 plains in order to assess groundwater potential, estimated the 'reliable groundwater reserves' or 'exploitable groundwater' at 14 km^3/year (Kırmızıtaş, 2006). The legislation on groundwater reserves taking effect in 1960 mandated the DSI (General Directorate of State Hydraulic Works) to carry out work for the exploration, utilization, maintenance and registration of groundwater reserves in Turkey. Under this mandate, it conducts surveys on groundwater reserves and makes the necessary arrangements for the utilization of identified reserves. So far the DSI has allocated an annual 11.44 km^3 of this reliable reserve, of which 5.20 km^3 for municipal and industrial purposes, 3.90 km^3 for state administered irrigation and 2.34 km^3 for private irrigation schemes (DSI, 2006).

Turkey is a country rich in wetlands, ranking first in this respect among the Middle Eastern and European countries. There are more than 250 wetlands in the country with a total area of approximately one million hectares. Almost 75 wetlands are larger than 100 hectares (TÇV, 1995). Of all Turkish wetlands, 60 percent has freshwater, 20 percent brackish water and 20 percent salt water. Turkey's wetlands are important because they are concentrated in Anatolia, which is crossed by two major bird migration routes. There are four major wetlands: Göksu Delta, Kizilirmak Delta, Sultan Marshes and Kus Cenneti. Five wetlands are identified as "Ramsar" sites: Göksu Delta, Manyas Bird Sanctuary, Sultan Marsh, Lake Burdur and Lake Seyfe. Based on international criteria, 18 wetlands have been classified as first class areas (Class A) that can offer refuge and food to over 25 000 birds at a time. An additional 45 wetlands have been identified as Class B, accommodating 10 000–25 000 birds.

The most serious negative development encountered in the preservation of wetlands is intentional draining. Swamps and marshes have been drained and reclaimed for agriculture and for malaria control (Harmancıoglu *et al*, 2001). A second important threat to the wetlands is pollution, both directly and indirectly by the rivers that feed them. In particular, sediments in contaminated rivers accumulate in wetlands. The heavy metals and pesticides cause mass deaths of fish, frogs and waterfowl. Another threat to wetlands is the collection of bird eggs and frogs, cutting and burning of grasses, grazing cattle, especially water buffalo, in the shallow areas.

By 2006, 208 large dams, mostly rock-fill or earth-fill, had been constructed. In total 579 dams have been completed and put into service for water supply, irrigation, hydropower and flood control (DSI, 2006). Almost 210 dams are under construction. The 208 large dams were constructed in large irrigation schemes (>1 000 ha, with 70 percent >10 000 ha), the rest are in the small irrigation schemes (<1 000 ha). The large dams have a total reservoir capacity of almost 157 km^3, whereas the total capacity of all dams is 651 km^3.

The Ataturk dam on the Euphrates River in the south-eastern part of the country, with a total storage capacity of 48.7 km^3, is one of the 10 largest dams in the world. In the beginning of 1990, the filling of the reservoir behind the dam started and was completed in 1992. The surface area of the reservoir is about 817 km^2. The water obtained from the Ataturk dam is carried to the Harran Plain by the Sanliurfa tunnel system, which is the largest tunnel system in the world in view of its length and flow rate. The water passes through banners which are 26.4 km in length and 7.62 m in diameter with an estimated flow of about 328 m^3/s, which is one-third of the total flow of the Euphrates.

There are 3 215 municipalities in Turkey, 1 327 of which have their own sewage system. About 60 percent of the population is connected to a wastewater treatment plant. Today, almost 1.68 km^3 of municipal wastewater per year is treated using extended aeration, biological nutrient removal (BNR) and trickling filters system (TÜIK, 2003). In 1994 treatment of municipal wastewater was estimated at 0.1 km^3/year. In the year 2000, the GDRS (General Directorate of Rural Services) of the Ministry of Agriculture, Forestry and Village Affairs ordered every village to have a wastewater treatment plant which uses special absorbent crops, such as reed and grass, for treating municipal wastewater. Whereas this project is successful in some regions, no reliable statistically data are available as the GDRS were discontinued following a government reorganization.

Water use

In 2003, the total water withdrawal was estimated at 40.1 km^3/year, of which 74 percent for irrigation, 15 percent for municipal purposes and 11 percent for industrial purposes

(Table 3, Figure 1 and Figure 2). In 2000, the total water withdrawal was 42 km³. Of this total 10.5 km³ was groundwater withdrawal of which 39 percent for irrigation, 37 percent for municipal purposes and 24 percent for industrial purposes. Demand for groundwater is rapidly increasing, especially in areas where there is a lack or an extreme shortage of surface water. Apart from private initiatives for various purposes, by the end of 1998 the DSI and the GDRS had established irrigation facilities using groundwater to irrigate 505 783 ha of land (net irrigated area 434 120 ha).

FIGURE 1
Water withdrawal by sector
Total: 40.1 km³ in 2003

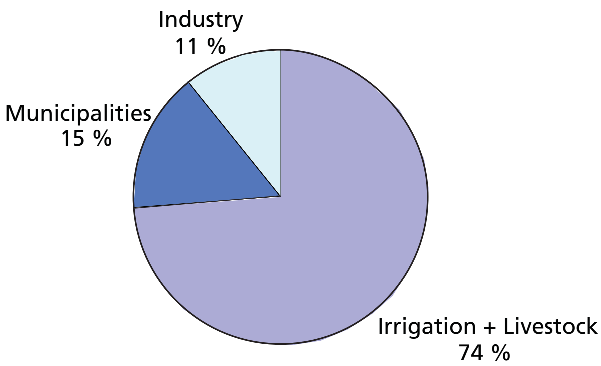
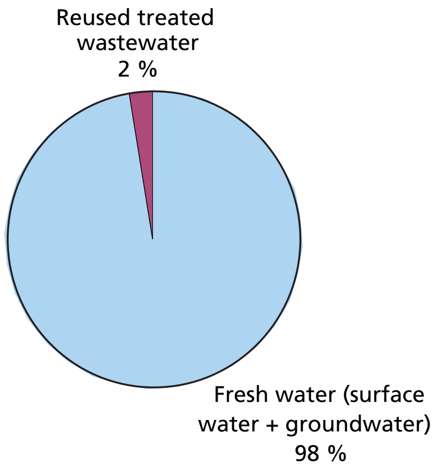


FIGURE 2
Water withdrawal by source
Total: 40.1 km³ in 2003



Since 1975, non-conventional sources of water such as urban wastewater and drainage water have been used as water sources for irrigation. Urban wastewater discharged to the sewage systems was about 2.77 km³ in 2006 (Öztürk, 2006) (Table 3). The treated wastewater of about 1.68 km³ is used in different ways. Its use for irrigation is limited to some dry provinces such as the central and southeastern regions of Turkey, where almost 200 000 ha are irrigated by wastewater (Gökçay, 2004) (Table 4). In some irrigation areas, such as Seyhan and Harran, drainage water is used for irrigation during dry years at the lower part of the scheme where the water delivered is insufficient for irrigation. At present, no data for the amount of drainage water used for irrigation are available.

International water issues

About 615 km, or one-fifth of the total border length of 2 950 km between Turkey and other countries, is formed by rivers: 238 km with Bulgaria and Greece, 243 km with Armenia and Georgia, 76 km with the Syrian Arab Republic, 58 km with Iraq and the Islamic Republic of Iran. In 1927, Turkey and the USSR signed a "Treaty on the beneficial uses of boundary waters", in which they agreed to share the water on an equal share basis. A joint Boundary Water Commission was established (without legal identity) to control the use of the frontier water. In 1973, the two governments signed an additional "Treaty on the joint construction of the Arpaçay or Ahurhyan storage dam". After the Treaty of Lausanne (1923), Turkey and Greece signed several protocols regarding the control and management of the Meriç River which flows along the border between Greece and Turkey.

Concerning the Euphrates and the Tigris rivers a similar protocol was established in 1946 when Turkey and Iraq agreed that the control and management of the rivers

TABLE 4
Reuse of treated wastewater in the central, eastern, southeastern, western, Black sea and Mediterranean regions in Turkey (Gökçay, 2004)

Province	Place	Name of Plant	1 000 m^3/yr	Receiving Environment	Irrigation Status
Aksaray (Primary treatment)	Merkez	Aksaray Municipality WWTP	9 125	Karasu Stream	Indirect[1]
Ankara	Merkez	ASKI, Ankara Municipality WWTP	192 696	Ankara Creek	Indirect
Eskşehir[2, 3]	Merkez	ESKİ, Municipality WWTP	24 820	Porsuk River	Indirect
Gaziantep[2, 3]	Merkez	GASKİ, Municipality WWTP	73 000	S. Creek	Direct
Iğdır	Merkez	Iğdır Municipality WWTP	552	Aras River	Direct
Kayseri [3]	Merkez	Kayseri Municipality WWTP	32 850	Karasu River	Indirect
Adana	Kozan	Kozan Municipality WWTP	2 780	Kozan Creek	Indirect
Adana	Yumurtalık	Yumurtalık Municipality WWTP	48	Ayas Creek	Indirect
Konya	Ilgın	Ilgın Municipality WWTP	2 838	Bulasan River	Indirect
Nevşehir	Ürgüp	Ürgüp Municipality WWTP	-	Damsa Creek	Indirect
İzmir	Merkez	IZSU Municipality WWTP	182 500	İzmir Bay	Direct/Gediz Plain
		Total	**521 209**		

WWTP = Wastewater treatment plant
[1] Indirect means that treated wastewater is discharged into a river from which water is withdrawn for irrigation.
[2] ESKI WWTP serves to irrigate 50 000 ha of land and GASKI WWTP 80 000 ha of land.
[3] Irrigation projects are being constructed by SHW.

The treated wastewater from the smaller plants, Konya-Kadınhanı and Niğde-Bor, is being used directly for irrigation (total of 50 000 ha).

depended to a large extent on flow regulation in the Turkish source areas. In addition, Turkey agreed to begin monitoring the two rivers and to share related data with Iraq. In 1980, Turkey and Iraq further specified the nature of the earlier protocol by establishing a joint Technical Committee on Regional Waters. After a bilateral agreement in 1982, the Syrian Arab Republic joined the committee. Turkey unilaterally guaranteed that it will allow 500 m^3/s water flow (15.75 km^3/year) across the border to the Syrian Arab Republic, but no formal agreement has been obtained so far on sharing of the Euphrates water. Problems regarding sharing water might arise between Turkey, the Syrian Arab Republic and Iraq because, according to the different scenarios established, full irrigation development by the countries in the Euphrates-Tigris river basins would lead to water shortages and solutions will have to be found at basin level through regional cooperation.

The construction of the Ataturk Dam, one of the GAP projects completed in 1992, has been widely portrayed in the Arab media as a belligerent act, since Turkey began the process of filling the Ataturk dam by shutting off the river flow for a month (Akanda *et al*, 2007). Both the Syrian Arab Republic and Iraq accused Turkey of not informing them about the cut-off, thereby causing considerable harm. Iraq even threatened to bomb the Euphrates dams. Turkey countered that its co-riparians had been informed in good time that river flow would be interrupted for a period of one month for reasons of "technical necessity" (Kaya, 1998). Turkey returned to previous flow-sharing agreements after the dam became operational, but the conflicts were never fully resolved as downstream demands had increased in the meantime (Akanda *et al*, 2007).

As shown, a number of crises have occurred in the Euphrates-Tigris basin, amongst other things as a result of lack of communication, conflicting approaches, unilateral development, and inefficient water management practices. The Arab countries have long accused Turkey of violating international water laws with regard to the Euphrates and the Tigris rivers. Iraq and the Syrian Arab Republic consider these rivers as international, and thus claim a share of their waters. Turkey, in contrast, refuses to concede the international character of the two rivers and only speaks of the rational utilization of transboundary waters. According to Turkey, the Euphrates becomes an international river only after it joins the Tigris in lower Iraq to form the Shatt al-Arab, which then serves as the border between Iraq and the Islamic Republic of Iran until it reaches the Persian Gulf only 193 km further downstream. Furthermore, Turkey is the only country in the Euphrates basin to have voted against the United Nations Convention on the Law of Non-navigational Uses of International Watercourses. According to Turkey, if signed, the law would give the lower riparians a right of veto over Turkey's development plans. Consequently, Turkey maintains that the Convention does not apply to them and is thus not legally binding (Akanda *et al*, 2007).

In 2001, a Joint Communiqué was signed between the General Organization for Land Development (GOLD) of the government of the Syrian Arab Republic and the GAP Regional Development Administration (GAP-RDA), which works under the Turkish Prime Minister's Office. This agreement envisions supporting training, technology exchange, study missions, and joint projects (Akanda *et al*, 2007).

In April 2008, Turkey, the Syrian Arab Republic and Iraq decided to cooperate on water issues by establishing a water institute consisting of 18 water experts from each country to work toward the resolution of water-related problems between the three countries. This institute will conduct its studies at the facilities of the Ataturk Dam, the biggest dam in Turkey, and plans to develop projects for the fair and effective use of transboundary water resources (Yavuz, 2008).

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

Out of the cultivable area of 28 million ha, almost 26 million ha are classified as suitable for irrigation according to the USDA-Reclamation Bureau Method. Considering the availability of water resources, this area is reduced to 12.5 million ha. Moreover, when economic considerations are included, Turkey's official estimated irrigation potential is 8.5 million ha, of which 93 percent from surface water resources and 7 percent from groundwater.

Irrigation development in Turkey is carried out by the public sector, represented by the DSI (General Directorate of State Hydraulic Works) and the GDRS (General Directorate of Rural Services), or by farmers and groups of farmers. Irrigation development by the public sector is called improved irrigation, while irrigation development by farmers themselves without a project is called public (or also primitive) irrigation. In 1965, less than 0.5 million ha had been developed by the government and about 1.1 million ha by farmers. In January 1994, of the total of about 4.2 million ha under irrigation more than 3.1 million ha had been developed by the DSI and the GDRS. In 2006, of the total of 4.97 million ha almost 3.97 million ha had been developed by the public sector, of which 2.8 million ha by the DSI and 1.1 million ha by the GDRS. Table 5 shows the irrigation area by organization type around 2000.

Of the total area equipped for irrigation, which was 4 860 800 hectares in 2005, about 78 percent used surface water resources, 19 percent groundwater and 3 percent non-conventional sources of water, see Table 6 and Figure 3 (DSI, 2006). Table 7 shows the source of the water used by public irrigation schemes in

TABLE 5
Distribution of irrigated areas (ha) according to organization type (Ozlu *et al*, 2002)

Type of organization	Area (ha)
1. SHW (DSI), of which	1 908 954
Directly managed by DSI	245 224
Transferred to farmers, of which:	1 663 730
- Village authority	33 643
- Municipality	56 619
- Water Users Associations (WUA)	1 518 118
- Cooperative operation	54 318
- Other	1 032
2. GDRS	981 000
3. Cooperative (groundwater irrigation developed by DSI and GDRS)	371 000
4. Farmers	1 080 000
5. Other	17 046
Total	**4 358 000**

TABLE 6
Irrigation and drainage

Irrigation potential		**-**	**8 500 000**	**ha**
Irrigation				
1. Full or partial control irrigation: equipped area		2006	4 970 000	ha
- surface irrigation		2006	4 572 400	ha
- sprinkler irrigation		2006	298 200	ha
- localized irrigation		2006	99 400	ha
• % of area irrigated from surface water		2005	78.4	%
• % of area irrigated from groundwater		2005	18.5	%
• % of area irrigated from mixed surface water and groundwater		2005	0	%
• % of area irrigated from non-conventional sources of water		2005	3.1	%
• area equipped for full or partial control irrigation actually irrigated		2006	4 320 000	ha
- as % of full/partial control area equipped		2006	87	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)		2001	13 000	ha
3. Spate irrigation		2006	0	ha
Total area equipped for irrigation (1+2+3)		**2006**	**4 983 000**	**ha**
• as % of cultivated area		2006	19	%
• % of total area equipped for irrigation actually irrigated		2006	87	%
• average increase per year over the last 12 years		1994-2006	1.3	%
• power irrigated area as % of total area equipped		1994	5.4	%
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**	**4 983 000**	**ha**
- as % of cultivated area		2006	19	%
Full or partial control irrigation schemes	**Criteria**			
Small-scale schemes	< 1 000 ha	1994	2 265 360	ha
Medium-scale schemes		1994	0	ha
Large-scale schemes	> 1 000 ha	1994	1 805 390	ha
Total number of households in irrigation			-	
Irrigated crops in full or partial control irrigation schemes				
Total irrigated grain production (wheat and barley)		2004	1 160 000	metric tons
- as % of total grain production		2004	3.8	%
Harvested crops				
Total harvested irrigated cropped area		2004	4 206 000	ha
• Annual crops: total		2004	3 392 000	ha
- Wheat		2004	172 000	ha
- Rice		2004	71 000	ha
- Barley		2004	86 000	ha
- Maize		2004	545 000	ha
- Potatoes		2004	179 000	ha
- Sugar beet		2004	315 000	ha
- Pulses		2004	260 000	ha
- Vegetables		2004	483 000	ha
- Cotton		2004	640 000	ha
- Flowers		2004	17 000	ha
- Groundnut		2004	24 000	ha
- Sunflower		2004	550 000	ha
- Other annual crops		2004	50 000	ha
• Permanent crops: total		2004	814 000	ha
- Fodder		2004	475 000	ha
- Citrus		2004	110 000	ha
- Other perennial crops (bananas, olives, grapes, strawberries)		2004	229 000	ha
Irrigated cropping intensity (on full/partial control area actually irrigated)		2004	100	%
Drainage – Environment				
Total drained area		2006	454 518	ha
- part of the area equipped for irrigation drained		2006	340 890	ha
- other drained area (non-irrigated)		2006	113 628	ha
- drained area as % of cultivated area		2006	1.7	%
Flood-protected areas		2006	397 302	ha
Area salinized by irrigation		2004	1 519 000	ha
Population affected by water-related diseases			-	inhabitants

the different regions in 2003 (SIS, 2003).

In the irrigation schemes constructed by the DSI and the GDRS, irrigation water is conveyed by different types of canals: trapezoidal canals (classic type) are used in 45 percent of all schemes, while 48 percent use canalettes (half ellipsoidal open canals constructed above the surface of the ground) and 7 percent use pipes. About 71 percent of the area equipped for irrigation uses a gravity distribution system. In 2006, of the total area equipped for irrigation, 92 percent used surface irrigation methods, 6 percent sprinkler irrigation (mostly hand-move) and 2 percent localized irrigation (Figure 4). In the regions of Marmara (Bursa), Thrace (Edirne) and Middle-East (Kayseri), sprinkler irrigation systems accounted for a larger share with 62, 14 and 11 percent respectively. In the Mediterranean region (around Adana) 47 percent used drip irrigation methods. In the remaining regions, only surface irrigation methods were used. In schemes transferred to farmers, on average 92 percent used surface irrigation, 7 percent sprinkler irrigation and 1 percent drip irrigation methods (Wasamed, 2003).

In 2002, 604 231 ha, of which 118 914 ha of DSI-operated schemes and 485 317 ha of irrigation schemes transferred to farmers to manage, could not be irrigated for various

FIGURE 3
Source of irrigation water
Total: 4 860 800 ha in 2005

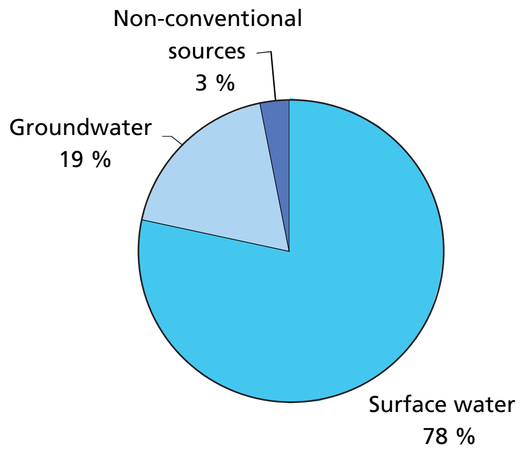


FIGURE 4
Irrigation techniques
Total 4 970 000 ha in 2006

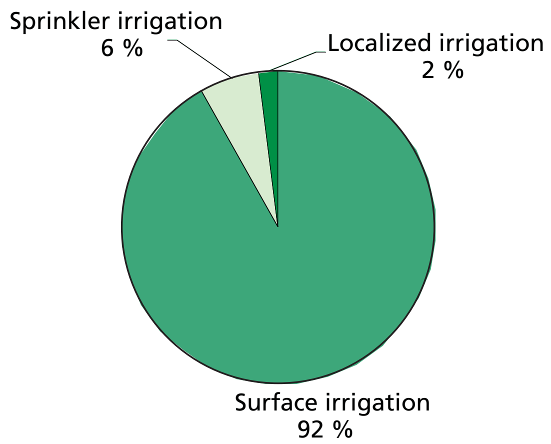


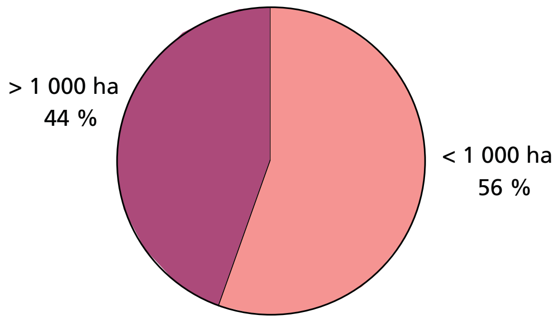
TABLE 7
Sources of irrigation water used in public irrigation schemes in Turkey (SIS, 2003)

Agricultural Regions	Irrigation area by source of irrigation water (1 000 ha)							Total
	Well	Spring	Stream	Lake	Pond	Dam	Other	
Middle North	93.47	14.09	80.37	1.18	7.62	17.16	10.87	224.76
Aegean	249.65	65.39	151.46	22.3	21.72	152.69	22.12	685.33
Thrace	37.22	9.99	62.69	14.28	6.84	12.45	12.28	155.75
Mediterranean	199.16	62.85	198.99	12.46	9.58	170.87	12.96	666.87
Northeast	20.95	40.85	174.21	0.25	14.31	12.49	5.36	268.42
Southeast	264.29	63.26	120.92	1.68	10.8	128.61	7.26	596.82
Black Sea	36.95	11.67	51.27	1.23	7.31	4.23	6.57	119.23
Middle East	34.58	62.42	128.03	8.35	18.56	20.50	3.70	276.14
Middle South	380.02	21.80	35.91	5.93	2.98	37.34	27.88	511.86
Total	**1 316.29**	**352.32**	**1 003.85**	**67.66**	**99.72**	**556.34**	**109.00**	**3 505.18**

TABLE 8
Major reasons for non-irrigation in 2002 in the DSI irrigation schemes and the irrigation schemes where the management was transferred to farmers (DSI, 2002 and 2003)

Reasons for non-irrigation	Areas of DSI		Areas transferred to farmers		Total	
	ha	%	ha	%	ha	%
Inadequate water resources	1 987	1.7	32 693	6.7	34 680	5.7
Insufficient irrigation infrastructure	1 519	1.3	33 690	6.9	35 209	5.8
Inadequate maintenance	7 556	6.4	7 165	1.5	14 721	2.4
Topographic conditions	4 285	3.6	18 545	3.8	22 830	3.8
Used for rainfed cropping	46 364	39.0	144 043	29.7	190 407	31.5
Fallow	20 280	17.1	16 604	3.4	36 884	6.1
Economic and social problems	26 196	22.0	115 504	23.8	141 700	23.5
Drainage related problems:						
Groundwater	2 440	2.1	9 275	1.9	11 715	1.9
Salinity	750	0.6	17 169	3.5	17 919	3.0
Other reasons	7 537	6.3	90 629	18.7	98 166	16.2
Total	**118 914**	**100.0**	**485 317**	**100.0**	**604 231**	**100.0**

FIGURE 5
Type of irrigation schemes
Total: 4 070 746 ha in 1994



reasons, as explained in Table 8. Three years later, in 2005, 678 448 ha could not be irrigated, of which 42 443 ha of DSI-operated schemes and and 636 005 ha of irrigation schemes transferred to farmers to manage. In 2006, the area equipped for irrigation but not irrigated was estimated at 650 000 ha. In 1994, 44 percent of the schemes were larger than 1 000 ha (Figure 5).

Today, in all cities, landscape and public gardens are irrigated, however, data for urban and peri-urban irrigation are not available for the whole of Turkey.

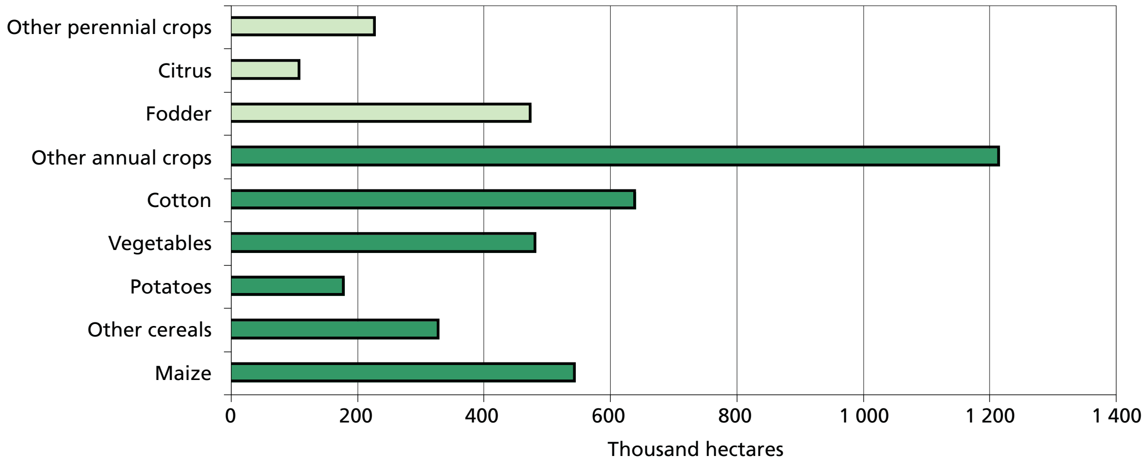
There is no waterharvesting in Turkey. In the past, in the Manisa province of the Aegean region, a water spreading system was used in small vineyards (Akyürek, 1978). However, this has now been replaced by a new irrigation system.

Role of irrigation in agricultural production, economy and society

Diverse geoclimatic characteristics have led to the development of a wide range of farming systems throughout the country under both rainfed and irrigated conditions. The average yield of irrigated land can be five times that of dry farming land and the average value-added per irrigated hectare is 2.6 times that of one rainfed hectare. While the area equipped for irrigation accounts for less than 20 percent of the cultivated area, it contributes 34 percent to the agricultural GDP derived from crops (Nostrum-DSS, 2006).

In 2006, just over 4.2 million ha, or 86 percent of the equipped area, was actually irrigated (Table 6). In general, the percentage of equipped area actually irrigated varies between 38 and 88 percent, with large regional and annual fluctuations. The long-term average value for DSI irrigation areas is about 65 percent. In 2004, the harvested irrigated crop area was about 4.2 million ha. More than 1.7 million ha or over 40 percent of this area was occupied by cotton, maize and sunflower. Other important irrigated crops are vegetables, fodder, sugar beet, potatoes and wheat, occupying another 1.6 million

FIGURE 6
Irrigated crops
Total harvested area: 4 206 000 ha in 2004 (cropping intensity on equipped area actually irrigated: 100%)



ha (Table 6 and Figure 6). The average yield for irrigated cereals (wheat and barley) was 4.5 tonnes/ha as against 2.3 tonnes/ha for rainfed cereals. For irrigated pulses (pea, dry beans, cow vetches, and grass pea) the average weighed yield was 4.5 tonnes/ha, for cotton 3.8 tonnes/ha, for sunflower 1.6 tonnes/ha, for maize 5.5 tonnes/ha, for sugar beet 43 tonnes/ha, and for potatoes 26.8 tonnes/ha (TÜIK, 2006). Rainfed crops include field crops (wheat, barley, etc), nut trees (olive, pistachio, walnut, almond, hazelnut and chestnut), and winter vegetables. Of the total rainfed crop production, 42.5 percent comes from rainfed wheat and barley alone (TÜIK, 2006).

The cost of irrigation development varies between US$7 000/ha for small schemes and US$15 000/ha for large schemes (including pump). The costs of operation and maintenance (O&M) vary from US$100/ha for schemes smaller than 1 000 ha (56 percent of the total area, see Table 5), to US$60/ha for schemes larger than 1 000 ha (including dams). After the economic crisis in 2001, prices in Turkey increased five to tenfold and the cost of irrigation development rose sharply, but water prices did not change as much as those of irrigation development for political reasons. Ten years ago, the average cost of irrigation development was estimated at US$1 750/ha for small schemes and US$3 000/ha for large schemes. Water charges are based on cropped area, with different rates for each crop. During 2001–2005, the average water charges for large schemes were estimated as US$83/ha.

In 2004, the Turkish economy earned US$20.9 billion in production value from irrigated areas. This was equivalent to US$19.1 billion in terms of marketable production. In the same year, total O&M costs were estimated at US$416 million. Data for the rehabilitation and modernization of irrigation schemes are not available for the whole of Turkey, however, during planning 10 percent of net return is assigned for the rehabilitation and modernization of irrigation systems. In addition, it was estimated that collectible water fees on the irrigated areas would amount to US$406.7 million. This brings the total net return from irrigation to about US$19 billion.

While agriculture is one of the most important factors in providing employment, the urban population is increasing and the part of the economically active population working in agriculture is declining steadily, from 64 percent in the 1970s to just over 40 percent at present (Table 1). Of the women working in the agricultural sector, 81 percent are unpaid family workers, 16 percent are self-employed or employers themselves, and 3 percent are regular or casual employees. In rural areas, irrigation is the most important source of employment and an important factor in preventing migration to urban areas. For example, it is estimated that when the irrigated areas reach 6.5 million ha, this will provide work for 2 million unemployed people in rural areas (DSI, 2006). Irrigation also increases the gross domestic agricultural product (GDAP): in 2004 the average GDAP was US$400/ha without irrigation and US$2 000/ha with irrigation. Women represent 64 percent of the agricultural labour force, but more men than women are employed in agricultural water management (for example in irrigation, drainage, and erosion control).

Both the distribution efficiency E_d (the combination of the conveyance efficiency E_c and the field canal efficiency E_b, $E_d = E_c \times E_b$) and the field application efficiency E_a vary depending on regional conditions and the irrigation methods employed. Average field application efficiencies for the country are 84 percent for drip, 80 percent for sprinkler and 55 percent for surface irrigation. Turkey's distribution efficiency shows fluctuations by region and is calculated to be 87–97 percent (Wasamed, 2004). The average total project efficiency E_p ($E_p = E_d \times E_a$) depends on the institutions which operate and manage the irrigation systems. In 2001, it was calculated that the total irrigation efficiency was 38 percent in the DSI-operated irrigation schemes and 48 percent in irrigation schemes where the management was transferred to the farmers (DSI, 2006).

Status and evolution of drainage systems

The DSI and the GDRS construct the drainage infrastructure in the irrigation schemes. The main, secondary and tertiary drainage canals are constructed by the DSI, while the GDRS builds the on-farm drainage systems. In total, 20 716 km of drainage canals have been constructed by the DSI, of which 5 133 km main canals, 6 499 km secondary canals and 9 083 km tertiary drainage canals. For the operation, maintenance and repair of drainage canals, 38 278 km of service-road have been built by the DSI (DSI, 2006). The total area drained in irrigation schemes is 340 890 ha. In addition, 113 628 ha of wetlands had been drained by DSI by 2006. During recent decades, the GDRS has carried out many small on-farm water development works, for example on-farm drainage systems and saline and alkaline soils reclamation.

The area protected from flooding amounts to almost 397 302 ha (GDRS, 2006). It was estimated in 1992, that of the total area operated by the DSI, about 41 000 ha was salinized by irrigation. In 2004, the total area salinized by irrigation in Turkey was estimated at 1.5 million ha. An area of 2.8 million ha are affected by waterlogging and drainage problems (Sönmez, 2004).

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

Institutions

Two institutions are or were responsible for irrigation and drainage development activities, namely the previously mentioned DSI (General Directorate of State Hydraulic Works) and the GDRS (General Directorate of Rural Services).

The DSI was established in 1954 by an exclusive Act No. 6200 (Ozlu *et al*, 2002b). It is the main agency responsible for the planning, development and management of water and soil resources as well as the operation and maintenance of irrigation and drainage systems, including construction of dams for flood control, irrigation, power generation, pumping stations, water supply and groundwater development. In projects it manages directly, the DSI uses its own labour resources and mechanical equipment (Tekinel and Erdem, 1995). Based in Ankara, the DSI operates through its regional directorates situated in the 26 river basins. In these regions, 56 sub-directorates and 14 project directorates carry out operation and maintenance activities in irrigation through their field units (MSDC, 1999; Akusum and Kodal, 2000; Ozlu *et al*, 2002a).

The GDRS was established in 1985 as part of the reorganization of the General Directorate of Soil and Water, the General Directorate of Roads, Water and Electricity and the General Directorate of Soil and Resettlement. The GDRS was mainly responsible for irrigation development and small irrigation works up to 500 l/sec (MSDC, 1999; FNCI, 2001). However, the GDRS was abolished under Law No. 5286 of 13 January 2005 on Village Services and most of its duties and competencies were transferred to special provincial administrations in 79 provinces and to the greater municipalities in the provinces of Istanbul and Kocaeli. Many problems have occurred due to the lack of an inventory and standardization units. In 2005, Law No. 5403 gave powers to the Ministry of Agriculture and Rural Affairs for soil protection and land use.

Water management

Irrigation projects have been implemented by the DSI and the GDRS. As is the case in many other countries, the irrigation schemes developed by the state are operated and managed in two ways: by the government and by local authorities, cooperatives and irrigation farmers unions in the irrigation districts (Uskay, 2001). The DSI can be responsible for the operation, maintenance and management of irrigation facilities it has constructed or it can transfer such responsibility to several organizations according to current legislation. In the case of a transfer, however, it is only the management that is transferred, not the ownership of these facilities. The DSI has transferred the largest area to Water User Associations (WUAs), which cover about 1.52 million ha of land (Table 5). The responsibilities of the former GDRS were reassigned to the Special Provincial Administrations by Law No. 5286 after 2005.

Finances

Historically, Turkey had a poor record as regards collecting water fees before the management of irrigation schemes was transferred from the DSI to the WUAs. For example, the collection rate of water fees was 38 percent in 1989–1994. After management was transferred to the farmers, performance improved and cost recovery was 93 percent in 1997, 76 percent in 2003, and 87 percent in 2006. The two main inputs in the preparation of the water tariffs for irrigation management by the DSI are: cost of operation and maintenance and estimated areas that can be irrigated (Unver and Gupta, 2003). In schemes managed by the WUAs, the water tariffs are set annually when the budget of the association is prepared for the approval of the DSI and the local governorship. Water fees are collected by an official acting under Law No. 6183 on the Collection of Public Receivables. Depending on the decision of the WUAs, payments can be made in two or three instalments. There are economic incentives for early payment and substantial penalties for late payment (Halcrow-Dosar Joint Venture, 2000; Ozlu *et al*, 2003). Nevertheless, the present form of irrigation charges, based on the type of crop and the area irrigated, provides little incentive to irrigators to conserve water.

Policies and legislation

Although the DSI has had a policy of transferring irrigation systems management to users since the 1950s, the average area transferred only amounted to about 2 000 ha/year until 1993 (Doker *et al*, 2001). Since 1993, DSI policy has been to transfer only small and isolated schemes, which are difficult and uneconomical for them to manage. However, with persuasion from the World Bank, since 1993, the DSI also started to apply an Accelerated Transfer Program (ATP). The main purpose of the ATP has been to alleviate the unsustainable operation and maintenance financial burden on both DSI and government resources (Svendsen and Murray-Rust, 2001). The ATP in Turkey was founded on a downward-reaching link between the DSI and local administrations rather than through the bottom-up organization of village-level associations of irrigators (Svendsen and Nott, 1999). The ATP continues to be successfully implemented today (Yıldırım and Çakmak, 2004).

ENVIRONMENT AND HEALTH

The water quality of most rivers can be considered to be suitable for irrigating many soils and crops. Kizilirmak River has the water with the highest salinity - 2.25 dS/m.

Salinity-alkalinity and waterlogging problems are caused by irrigation and insufficient drainage systems. These problems increase gradually because of insufficient on-farm water development project works, insufficient land levelling, lack of maintenance and restoration of drainage systems, inadequate training and education of farmers, and ineffective agricultural extension services to avoid, for example, excessive use of water by farmers.

In areas where agrochemicals are extensively used, the hazardous effects of pesticides and fertilizers threaten the use of groundwater sources for drinking water. In the agricultural plains of Bornova (Izmir) the excessive use of agrochemicals resulted in significant groundwater pollution, with nitrate concentrations in the groundwater reaching the limit value of 45 mg/l (Harmancıoglu *et al*, 2001). Again, in the Nevşehir-Niğde provinces in Middle Anatolia, where 25 percent of the total potato growing area and 44 percent of total produce are located, groundwater resources and soils are seriously polluted with nitrate concentration. Various proportions of pesticide residues (Lindane, Heptachlor, Aldrin, and Endosulfan) are encountered in drains, irrigation canals, small bays, some lakes and in well water. Pesticide use in Turkey is the highest in the Mediterranean region, particularly in the Çukurova region south of Adana. But the Black Sea is also becoming polluted with agricultural pesticides, although the residues are not yet at a level to constitute a hazard for human health. Some rivers and creeks such as the Ankara stream in Ankara province, the Ergene River and its branches in the Thrace region, Karasu creeks, a branch of Sakarya River in Eskişehir, and the Simav stream in the Aegean region are all polluted by industrial, municipal and agricultural wastewater (Doğan *et al*, 1996; Gidişoğlu *et al*, 1996; Öğretir, 1992; Börekçi, 1986).

In several areas, problems emerge as urban activities encroach onto agricultural lands. There is an increasing interest in using the land as a vehicle for the treatment and disposal of the wastewater from agribusiness and urban activities. In particular there is currently concern about the use of polluted water resources to irrigate agricultural lands, especially in western Turkey, which has been experiencing water shortages on a regular basis in recent years.

The two major water-related diseases related to irrigation and water resources development are schistosomiasis (bilharzia) and malaria. Schistosomiasis occurs sporadically, but the implementation of large-scale projects under the Southeastern Anatolia Project (GAP) may eventually lead to epidemics (Harmancıoglu, 2001). Malaria has long been a significant health problem in the country and is still common in areas of irrigation and water resources development.

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

The Southeastern Anatolia Project (GAP) was planned for the lower Euphrates and the Tigris river basins within Turkey's boundaries and is the biggest investment in the history of the country. The GAP is an integrated development project involving irrigated agriculture, agro-industry and supporting services including communications, healthcare and education. It includes 13 major projects of which 7 are in the Euphrates river basin and 6 in the Tigris river basin. After full development it will include 22 dams and 19 hydroelectric power plants and the irrigation of almost 1.82 million ha. By 2005, 75 percent of the investment in energy and 12 percent of the investment in irrigation had been made with 213 000 ha under irrigation. At present, 103 000 ha in the Euphrates river basin and 57 000 ha in the Tigris river basin are under construction. In 1998, the Turkish Government decided to complete all irrigation investment in the GAP at the end of 2010 and, as a result, investment in irrigation is the top priority to cover plans for the remaining 910 000 ha in the Euphrates river basin and 540 000 ha in the Tigris river basin.

In most of the new development areas, sprinkler and localized irrigation will be used, especially drip irrigation. Surface irrigation is permitted only on the flat areas near the southern boundaries of Turkey. These irrigation projects have been financed locally and by international agencies.

Overall, however, the performance of the irrigation schemes have not yet reached acceptable levels (Wasamed, 2003). Irrigation efficiencies in almost all systems are low and, for various reasons, it is not yet possible to irrigate the total area. In all irrigation schemes, there are considerable variations in the size of the irrigated area and cropping pattern from year to year.

Water consumption projections by sector for 2030 have been made considering the needs of a growing population as well as those of the rapidly developing sectors of industry and tourism. These projections are based on the assumption that the DSI and the other agencies involved, including private sector companies, will develop their projects so that by 2030, 110 km^3 of water will be available – the figure now considered to be the total exploitable renewable water resources. The projection presupposes that the 8.5 million ha of land that is economically irrigable will be brought under irrigation by the year 2030 and that total irrigation water withdrawal will reach 71.5 km^3 by the same year. The target is to reduce the share of irrigation water in total water consumption to 65 percent by introducing and promoting more water-saving irrigation techniques (Wasamed, 2003). It is assumed that the present rate of population growth will begin to slow down and that the total population of the country will be around 90 million in 2030. Projections regarding water withdrawal for municipal purposes indicate a need for 25.3 km^3 in 2030, of which 5 km^3 for tourism. Assuming that the industry sector has an average annual growth rate of 4 percent, its projected water need in 2030 will be 13.2 km^3.

As mentioned in the previous paragraph, the exploitable renewable water resources are enough to irrigate only 8–9 million ha. In order to irrigate a larger area, new sources of water need to be developed, such as non-conventional sources of water. Water treatment units are to be constructed in all residential and production areas. In addition, it is planned to equip 4 065 village units to treat wastewater biologically, as required by the Ministry of Agriculture at the end of 2006. Up to now, it is reported that very few village units treat wastewater because of organizational and bureaucratic problems and untreated wastewater is used directly for irrigation. The Government is working to solve these problems and extend the wastewater treatment project to all village units in Turkey.

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United Arab Emirates

GEOGRAPHY, CLIMATE AND POPULATION

Geography

The United Arab Emirates (UAE) is a federation of seven emirates: Abu Dhabi, Dubai, Shariqah, Ras Al Khaymah, Fujayrah, Umm Al Qaywayn and Ajman. By far the largest emirate is Abu Dhabi and Abu Dhabi City is the capital of both the emirate and the whole country. The UAE is situated in the eastern corner of the Arabian Peninsula and is bordered in the north by the Persian Gulf, in the east by the Gulf of Oman and Oman and in the south and west by Saudi Arabia. Six of the seven emirates lie on the coast of the Persian Gulf, while the seventh, Fujayrah, is situated on the eastern coast of the peninsula and has direct access to the Gulf of Oman.

The total area of the UAE is about 83 600 km² (Table 1), of which 77 700 km² is the mainland surface area, where the population lives. The Abu Dhabi Emirate represents almost 87 percent of the mainland area (Table 2). The coast stretches over a shallow marine area, with many islands and coral reefs. The total area of the many - and generally uninhabited - islands is about 5 900 km². The UAE can be divided into three ecological areas: the northeastern mountain areas, sandy/desert areas and marine coastal areas; 80 percent of the area of the UAE is desert, especially the western area (MOEW, 2006).

From 1994 to 2003, the agricultural area more than tripled to reach 260 732 ha (Table 2). In 2003 the cultivated area was around 254 918 ha, of which 75, 16 and 9 percent consisted in permanent crops, annual crops and shifting areas respectively (Table 3).

Climate

The climate is arid with very high summer temperatures. The coastal area, where the bulk of the population lives, has a hot and humid climate in the summer with temperatures and relative humidity reaching 46° C and 100 percent respectively. Winters are generally mild with temperatures between 14 °C and 23 °C. The interior desert region has hot summers with temperatures rising to about 50 °C and cool winters during which the lowest temperature can fall to around 4 °C.

Mean annual rainfall is about 78 mm, ranging from less than 40 mm around Liwa in the southern desert to 160 mm in the northeastern mountains. Precipitations cover a period of between 9 and 19 days over the whole year. Over 80 percent of the annual rainfall occurs during the winter (December to March). In spring (April–May) rainfall is infrequent and is usually associated with isolated thunderstorms. In summer (June–September), rain is rare and occurs as a result of the afternoon thunderstorm over the eastern highlands or isolated thunderstorms accompanying the rarely occurring sea breeze fronts. On a very few occasions, the Inter-Tropical Convergence Zone (ITCZ)

UNITED ARAB EMIRATES **FAO - AQUASTAT, 2008**

TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2005	8 360 000	ha
Cultivated area (arable land and area under permanent crops)	2003	254 918	ha
• as % of the total area of the country	2003	3	%
• arable land (annual crops + temp. fallow + temp. meadows)	2003	64 530	ha
• area under permanent crops	2003	190 388	ha
Population			
Total population	2005	4 496 000	inhabitants
• of which rural	2005	14.5	%
Population density	2005	53.8	inhabitants/km²
Economically active population	2005	2 666 000	inhabitants
• as % of total population	2005	59.3	%
• female	2005	14.4	%
• male	2005	85.6	%
Population economically active in agriculture	2005	103 000	inhabitants
• as % of total economically active population	2005	3.9	%
• female	2005	0	%
• male	2005	100	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2005	129 700	million US$/yr
• value added in agriculture (% of GDP)	2005	2	%
• GDP per capita	2005	28 848	US$/yr
Human Development Index (highest = 1)	2005	0.868	
Access to improved drinking water sources			
Total population	2006	100	%
Urban population	2006	100	%
Rural population	2006	100	%

may move northwards and give some rainfall over the area. The most settled weather conditions with very little rain prevail in the autumn (October–November), especially in October (MOEW, 2006).

TABLE 2
Mainland area and farms by emirates

Emirate	Mainland area, excl. islands		Farms in 2003	
	Area (km²)	%	Number	Area (ha)
Abu Dhabi	67 340	86.7	22 985	218 590
Dubai	3 885	5.0	1 326	6 176
Sharjah	2 590	3.3	4 392	13 275
Ras Al Khaimah	1 683.5	2.2	4 465	13 571
Fujairah	1 165.5	1.5	4 346	5 324
Umm Al Qaiwain	777	1.0	343	1 693
Ajman	259	0.3	691	2 104
Total	**77 700**	**100.0**	**38 548**	**260 732**

Population

Total population is almost 4.5 million (2005), of which 14.5 percent is rural (Table 1). The average annual demographic growth rate was estimated at 6.7 percent during the period 2000–2005. The average population density is about 54 inhabitants/km².

Abu Dhabi has the largest population numerically, but it also has the lowest population density among the emirates. Dubai, which has the highest population density, is considered the business capital and the most important port in the country. Over two-thirds of the total population is concentrated in these two emirates. The male population accounted for over 68 percent of the total population in 2005, mainly because of the male immigrant labour force.

In 2006, 97 percent of the population had access to improved sanitation (98 and 95 percent in urban and rural areas respectively) and the whole population had access to improved water sources.

TABLE 3
Cultivated area by emirate in 2003 (Ministry of Environment and Water)

Emirate	Abu Dhabi	Dubai	Sharjah	Ajman	Umm Al Quwain	Ras Al Khaimah	Fujairah	Total
Palm tree	172 080	1 519	4 824	502	385	3 762	2 258	**185 330**
Other permanent crops	340	584	1 551	357	182	1 066	978	5 058
Crop and Fodder	24 719	804	1 599	248	289	2 419	359	**30 437**
Vegetables	3 826	750	1 667	184	176	2 446	721	**9 769**
Greenhouses	144	3	23	2	2	55	19	**247**
Shifting area	13 202	2 257	3 244	682	334	3 498	860	**24 077**
Cultivated area	**214 311**	**5 917**	**12 909**	**1 975**	**1 367**	**13 246**	**5 193**	**254 918**

ECONOMY, AGRICULTURE AND FOOD SECURITY

In 2005, the national Gross Domestic Product (GDP) of the United Arab Emirates was US$129.7 billion (Table 1). The main source of income is the revenue from oil exports. The total economically active population was 2.7 million (59 percent of the total population), of which 86 percent was male and 14 percent female. Agriculture employed an estimated 4 percent of the labour force and accounted for 2 percent of the country's GDP. The entire labour force working in agriculture is male.

For management purposes, the former Ministry of Agriculture and Fisheries (MAF) (current Ministry of Environment and Water (MOEW)) has divided the area it covers (i.e. all the Emirates except Abu Dhabi) into three zones or districts as follows: Eastern (Fujayrah and Shariqah), Central (Dubai, Part of Shariqah, Umm Al Qaywayn, Ajman and part of Ras Al Khaymah), and Northern (most of Ras Al Khaymah). This division is not related to the borders of the Emirates or any other administrative partitioning. The total number of farms in the UAE is 38 548 (2003), of which 60 percent in Abu Dhabi, 16 percent in the Central and Eastern zones and the remainder in the Northern zone. Farms produce primarily date palms, fodder and vegetable crops. The government purchases date production from farmers at a maximum of 70 kg per tree and at a price depending on quality. Fodder production is also purchased by the government but only in the Abu Dhabi Emirate. In the other emirates, fodder is sold in the local market for local consumption or for export to neighbouring countries. The same applies to vegetable crops throughout the country.

In each of the three zones it covers, the MAF has a centre staffed with engineers and technicians to support farmers. The services to farmers focus on the provision of subsidies, for example for cultivation (free of charge), crop protection (50 percent free with the exception of general campaigns which are totally free), veterinary services and fertilizers (50 percent free). This system of subsidies does not concern private companies specialized in the intensive production of vegetable crops. Some extension advisory services are also provided, but they deal mainly with agricultural practices; advisory services for irrigation are actually lacking for several reasons including the fact that the extension staff are not qualified in this area. The number of extension agents is 46, 8, 13 and 13, respectively in Abu Dhabi, the Eastern, the Central and the Northern zones (FAO, 2004).

In the UAE, traditional knowledge and traditions are very important. While creating a modern country, the government aims to conserve the heritage of the past. Today's UAE residents come from different Arabian groups, some of which had a traditional nomadic lifestyle, breeding camels and goats; most of them were settled in the Liwa Oasis to work in simple agriculture and palm plantations. In the coastal area, groups used to work in fishing and pearl hunting. In the Al Ain Oasis, other groups work in agriculture, especially in date plantations using underground water and aflaj irrigation. In the northern emirates where, relatively, there is more rainfall, people can work in agriculture all year round. In the Hajjar Mountains of Al Fujayrah, terrace farming is practised, while in Dubai, Shariqah & Galfar (Ras Al Khaymah) people are trading with boats and modern ships (MOEW, 2006).

WATER RESOURCES AND USE

Water resources

The total annual renewable water resources are about 150 million m³, but there are no perennial streams (Table 4). Groundwater resources occur in the upper clastic and lower carbonate formations located in the Bajada region in the eastern part of the country. The aquifers consist of alluvial fan deposits along the base of the Oman and Ras Al Khaymah mountains extending over a large area. The upper aquifer is composed of gravel sand and silt, the lower aquifer of limestone, dolomite and marl. Both aquifers range in thickness from 200 to 800 metres. In addition, the Dammam and Umm er Radhuma formations extend into the western desert areas, with thicknesses ranging from 500 to 1 000 metres. Groundwater quality in the two aquifer systems, particularly in the Bajada region, ranges from 600 to 2 000 ppm. The Dammam and Umm er Radhuma aquifers contain highly saline water (ESCWA, 2001). Average annual groundwater recharge may be estimated at about 120 million m³, most of which comes from infiltration from the river beds.

To increase the groundwater recharge, a number of dams have been built at various locations in the country. In 2003, there were 114 dams and embankments of various dimensions with a total storage capacity of 118 million m³, which is an increase of almost 48 percent compared to 1995, but total water stored was only 12.3 million m³. While most of these dams are basically built for recharging purposes, they also provide protection against damage caused by flash floods.

The first desalination plant was installed in Abu Dhabi in 1976 with a total capacity of 250 m³/day. Because of a rapid increase in municipal and industrial water demand more plants were installed, particularly in Abu Dhabi and Dubai. In 2002, the total installed gross desalination capacity (design capacity) in the United Arab Emirates was 4 725 346 m³/day or 1 725 million m³/year (Wangnick Consulting, 2002). In 2005, total

TABLE 4
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	78	mm/yr
	-	6.521	10⁹ m³/yr
Internal renewable water resources (long-term average)	-	0.15	10⁹ m³/yr
Total actual renewable water resources	-	0.15	10⁹ m³/yr
Dependency ratio	-	0	%
Total actual renewable water resources per inhabitant	2005	48.29	m³/yr
Total dam capacity	2006	118	10⁶ m³
Water withdrawal			
Total water withdrawal	2005	3 998	10⁶ m³/yr
- irrigation + livestock	2005	3 312	10⁶ m³/yr
- municipalities	2005	617	10⁶ m³/yr
- industry	2005	69	10⁶ m³/yr
• per inhabitant	2005	889.2	m³/yr
Surface water and groundwater withdrawal	2005	2 800	10⁶ m³/yr
• as % of total actual renewable water resources	2005	1 867	%
Non-conventional sources of water			
Produced wastewater	1995	500	10⁶ m³/yr
Treated wastewater	2006	289	10⁶ m³/yr
Reused treated wastewater	2005	248	10⁶ m³/yr
Desalinated water produced	2005	950	10⁶ m³/yr
Reused agricultural drainage water	-	-	10⁶ m³/yr

desalinated water produced was 950 million m³, compared to 385 million m³ in 1995, meaning an increase of almost 150 percent in ten years. Desalination provides most of the municipal supply.

In 1995 the total wastewater produced was about 500 million m³. About 289 million m³ of this water was treated in 2006 of which around 86 percent was reused. The amount of sewage water increases according to the size of the town and its population. The UAE have been pioneers in this field as regards the Gulf Area. Sewage water is subjected to tertiary treatment and then used in landscaping work in and around the towns. Due to the increase in the amount of such treated water, studies and research are being done as to whether this kind of water can be used to irrigate vegetables and fruit trees or can even be injected into the groundwater (MOEW, 2006).

Water use

Total water withdrawal was estimated at 3 998 million m³ in 2005. Distribution by sector is not available at national level but in the Abu Dhabi Emirate, where total water used was 3 382 million m³ in 2003, 83 percent was used for irrigation (agriculture, forestry and amenities), 15 percent for municipal purposes and less than 2 percent for industrial purposes (Figure 1). Over 70 percent of the total water withdrawal was groundwater (including fossil water), 24 percent was desalinated water and around 6 percent was reused treated wastewater (Table 4 and Figure 2). Historically, all the Abu Dhabi Emirate's water requirements were met solely from groundwater obtained from shallow hand dug wells and the traditional falaj system, comprising human-made channels used to collect groundwater, spring water and surface water and transport it, by using gravity, to a demand area. Since the entire Emirate's aflaj irrigation tunnels are now dry, a system of borehole support has been developed over the last 5–10 years (Brook *et al.*, 2006). In 2003 the former Ministry of Electricity and Water (current Ministry of Environment and Water) reported that 76 556 wells were in use throughout the UAE.

Groundwater depletion is hard to estimate because there is no information on the possible annual recharge of groundwater entering from neighbouring countries (for example from the Eastern Arabia Aquifer). In any case, the overextraction of groundwater resources is real and has led to a lowering of the groundwater table, while sea water intrusion is increasing in the coastal areas.

FIGURE 1
Water withdrawal by sector
Total: 3 998 km³ in 2005

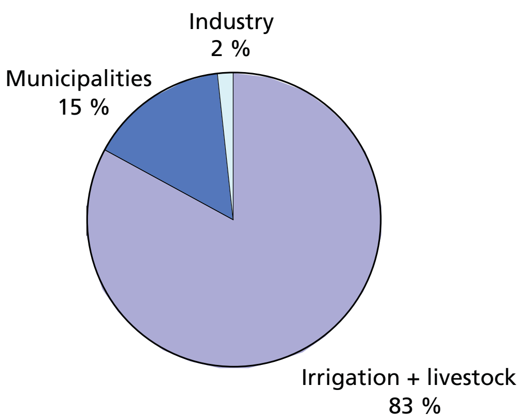
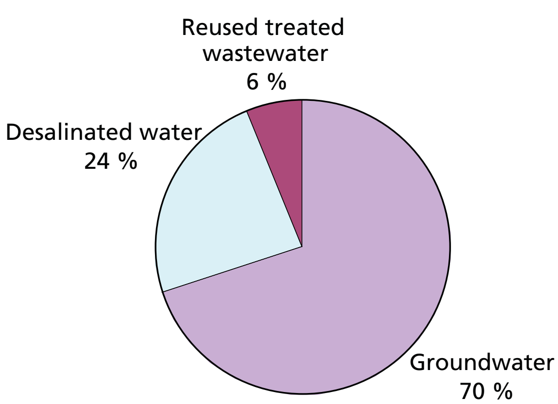


FIGURE 2
Water withdrawal by source
Total: 3 998 km³ in 2005



IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

The UAE has limited potential for agricultural development since over 80 percent of the land is desert, there are no perennial surface water resources and rainfall is very low and erratic. However, in spite of the harsh weather conditions and soil and water constraints, remarkable progress has been made in the agricultural sector, particularly during the last decade. The total water managed area increased from 66 682 ha in 1994 to 226 600 ha in 2003 (Table 5). The main agricultural areas are located in the northeast (Ras Al

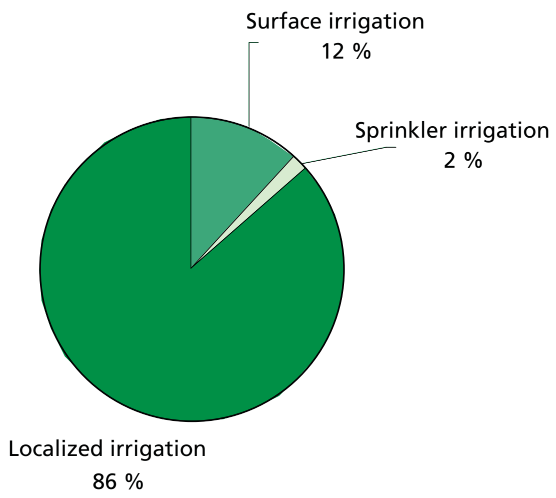
TABLE 5
Irrigation and drainage

Irrigation potential		-	ha
Irrigation			
1. Full or partial control irrigation: equipped area	2003	226 600	ha
- surface irrigation	2003	27 100	ha
- sprinkler irrigation	2003	4 000	ha
- localized irrigation	2003	195 500	ha
• % of area irrigated from surface water	2003	0	%
• % of area irrigated from groundwater	2003	100	%
• % of area irrigated from mixed surface water and groundwater		0	%
• % 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	226 600	ha
• as % of cultivated area	2003	88.9	%
• % of total area equipped for irrigation actually irrigated		-	%
• average increase per year over the last 10 years	1993-2003	13	%
• power irrigated area as % of total area equipped		-	%
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	226 600	ha
• as % of cultivated area	2003	88.9	%
Full or partial control irrigation schemes — **Criteria**			
Small-scale schemes — < ha		-	ha
Medium-scale schemes		-	ha
large-scale schemes — > ha		-	ha
Total number of households in irrigation	2003	38 548	
Irrigated crops in full or partial control irrigation schemes			
Total irrigated grain production (wheat and barley)	2003	15	metric tons
• as % of total grain production	2003	100	%
Harvested crops			
Total harvested irrigated cropped area	2003	228 521	ha
• Annual crops: total	2003	38 307	ha
- Wheat	2003	6	ha
- Vegetables (including potatoes, beans...)	2003	8 083	ha
- Other annual crops (mainly green fodder)	2003	30 218	ha
• Permanent crops: total	2003	190 214	ha
- Palm tree	2003	185 330	ha
- Alfalfa	2003	2 801	
- Other perennial crops (citrus, mango)	2003	2 083	ha
Irrigated cropping intensity (on full/partial control irrigation equipped area)	2003	101	%
Drainage – Environment			
Total drained area		-	ha
- part of the area equipped for irrigation drained		-	ha
- other drained area (non-irrigated)		-	ha
• drained area as % of cultivated area		-	%
Flood-protected areas		-	ha
Area salinized by irrigation		-	ha
Population affected by water-related diseases		-	inhabitants

TABLE 6
Number and area of farms practicing sprinkler and localized irrigation in 2003 (Ministry of Environment and Water)

Region/Zone	N° of farms	Area				
		Drip	Bubbler	Sprinkler	Other	Total
Abu Dhabi	20 227	145 335	19 939	18 046	3 499	186 818
Central	2 015	1 444	2 231	1 424	821	5 919
Northern	842	1 651	1 110	1 724	1 061	5 546
Eastern	337	197	774	160	0	1 131
Total	**23 421**	**148 627**	**24 053**	**21 354**	**5 380**	**199 414**

FIGURE 3
Irrigation techniques
Total: 226 600 ha in 2003



Khaymah), in the east along the coast from Kalba to Dibba (Fujayrah), in the southeast (Al Ain/Abu Dhabi) and in the central region (Dhaid/Abu Dhabi).

Prior to the introduction of modern irrigation systems (sprinkler and localized irrigation), all agricultural land was irrigated by traditional flood and furrow methods. Extensive research was carried out during the period 1976–81 to select suitable irrigation systems, a pilot farm was established in 1983 to introduce sprinkler and localized irrigation systems and a subsidy was given to the farmers. These irrigation systems are believed to have saved about 60 percent of the irrigation water. In 2003, the total equipped area for full or partial control irrigation was 226 600 ha, of which 195 500 ha used localized irrigation, 27 100 ha surface irrigation and only 4 000 ha sprinklers (Figure 3). All irrigation water is groundwater.

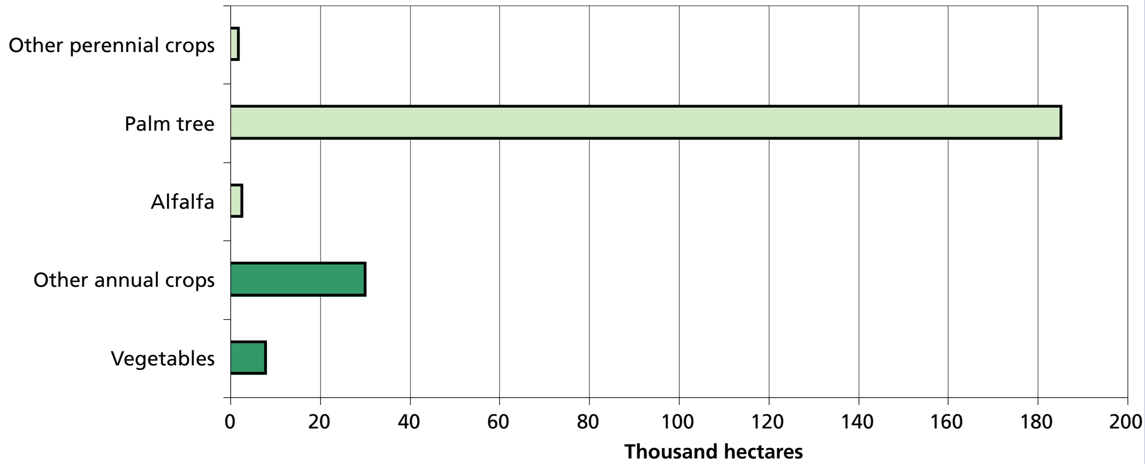
Apart from the government's experimental farms, nurseries, afforestation schemes and public gardens, all the agricultural land is owned and developed by private owners. In 2003, 61 percent of the farm holdings (23 421 units) owned modern irrigation systems (Table 6). More than 86 percent of the farms with modern irrigation systems are in the Abu Dhabi Emirate, and 9, 4 and 1 percent in the Central, Northern and Eastern zones respectively (Environmental and Agricultural Information Centre, 2007).

Role of irrigation in agricultural production, economy and society

All crops in the UAE are irrigated. In 2003, the harvested irrigated cropped area was 228 590 ha (EAIC, 2007) consisting mostly of palm trees (81 percent), green fodder (13 percent) and vegetables (3.5 percent) (Table 5 and Figure 4). Palm trees produced 757 601 tonnes, which is 97 percent of the total production from fruit trees. Green fodder covered 91 percent of field crops area and alfalfa 8 percent. The main vegetables were tomatoes (22 percent of vegetable areas) and onions (8.5 percent) producing 76 and 23 tonnes/ha respectively.

In 2003, almost 90 percent of the harvested irrigated cropped area was in the Abu Dhabi Emirate (EAIC, 2007). In this Emirate, agriculture is generally dominated by two perennial crops, dates and Rhodes grass, with some seasonal plantings of short

FIGURE 4
Irrigated crops
Total harvested area: 228 590 ha in 2003 (cropping intensity on equipped area: 101%)



season annual vegetable crops. A limited amount of cereals and fruits is also grown. Most agriculture is on small private farms that have been established in relatively recent times, but there are also small areas of traditional date palm gardens, and larger government forage production units. Traditional date palm gardens in Al Ain Oasis consume about 10 million m³/year of groundwater for around 375 000 date palm trees and occupy an area of 350 ha. There is also a limited area of protected horticulture where greenhouses and cloches are used (Brook *et al.*, 2006).

In 2006 the average cost of irrigation development was estimated at US$3 800/ha and the average cost of operation and maintenance at US$700/ha/year in public schemes. There are no irrigation water charges levied by the government, but the farmers pay for the drilling of boreholes on their farms and the pumping of groundwater. With increasing water scarcity, more farmers are adopting modern irrigation systems. The latter cost around US$8 500/ha for bubbler and US$10 000–13 000/ha for drip irrigation, excluding head stations. Sprinkler systems tend not to be used because of water salinity problems.

Exact figures regarding water application by farmers for each crop and the related irrigation efficiency and productivity are lacking as there is no monitoring system for water use, either at the farm level or at that of aquifers or regions. Figures of excessive water use in the region of 25–30 percent have been given and this concerns essentially traditional irrigation systems. Farmers irrigate frequently and apply large amounts of water. All soils are of light texture (gravel, loamy sand and sandy loam) with high infiltration rates and hence prone to high percolation losses.

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

Institutions

There are four main institutions involved in water resources management:

- The Ministry of Environment and Water (MOEW) is responsible of protecting and developing ecosystems and developing and sustaining water resources, livestock and agriculture.
- Abu Dhabi is covered by the Abu Dhabi Administration of Municipalities and Agriculture (ADAMA), which is directly under the Governor of Abu Dhabi.

TABLE 7
Current responsibilities in the water sector in Abu Dhabi Emirate (Brook *et al.,* 2006)

Government Agency	Responsibility
Abu Dhabi Water and Electricity Authority (ADWEA)	Supply and distribution of drinking water
Environment Agency Abu Dhabi (EAD)	Management, monitoring, assessment and regulation of groundwater and protection against pollution
Municipalities & Agriculture	Development of agriculture irrigation
Municipalities & Agriculture (Abu Dhabi)	Development of forestry irrigation
Diwan of Eastern Region	Development of forestry irrigation
Municipalities & Agriculture (Al Ain)	Management of sewerage and waste water treatment Eastern Region
Municipalities & Agriculture (Abu Dhabi) Sewage Projects Committee	Management of sewerage and waste water treatment Western Region
Regulation and Supervision Bureau	Regulation of drinking water and sewerage / Waste water treatment
Ministry of Communications	Meteorological monitoring and assessment
Ministry of Presidential Affairs Dept of Atmospheric Studies (formerly DWRS)	Meteorological monitoring and assessment
Abu Dhabi National Oil Company (ADNOC)/National Drilling Company (NDC)/USGS	Specialist groundwater research (Eastern Region)

The Directorate of Irrigation and Soils of the former Ministry of Agriculture and Fisheries (MAF) was in charge of promoting irrigated agriculture and for the planning, investigation and management of groundwater resources, the investigation of quality and salinization of soil due to irrigation, the construction of dams for flood control and groundwater recharge, the operation and maintenance of the hydro-meteorological network, the operation of laboratories and designing of the irrigation networks.

- Local government water departments and authorities especially in the emirates of Abu Dhabi, Dubai and Shariqah are independently responsible for the supply of drinking water and all water affairs in their respective emirates.
- The Federal Environmental Agency has the power to control and regulate water pollution.

Table 7 shows the agencies and their responsibilities in the water sector in the Abu Dhabi Emirate.

Water management

The Directorate of Irrigation and Soils, both through its headquarters in the former Ministry of Agriculture and Fisheries (MAF) and its decentralized centres in the three zones, supported farmers free of charge for the survey and design of modern irrigation systems. Fifty percent of the costs of these systems, which include bubbler, drip and sprinkler irrigation, are subsidized by the government. At present, these systems cover 55, 21 and 75 percent of the total irrigated areas in the Central, Eastern and Northern zones respectively. In the Abu Dhabi emirate however, the percentage is over 90 percent (2003).

The Emirate of Al Sharja has recently decreed the mandatory conversion of its entire irrigated area to modern irrigation. The Directorate of Irrigation and Soils also organized training sessions for its technicians and volunteer farmers on pilot farms (FAO, 2004).

Finances

Water used for agriculture is free of charge while water for municipal use, which is mostly desalinated water, is subsidized by the state.

ENVIRONMENT AND HEALTH

The main source of water for agricultural production is groundwater, in addition to surface water runoff stored in dams that is only occasionally available. Irrigation expansion coupled with precipitation decline - and hence natural recharge decline - over the past 2–3 decades, has led to a rapid decline in the groundwater level. For instance, encroachment of seawater had already been reported in 1982, when it apparently penetrated as far as 20 km inland in the northern emirates. In the Central zone, the groundwater level has dropped over the last twenty years from an average depth of 45 m to over 400 m. The consequences of this over-utilization are numerous and include: the dropping out of small farmers who could not compete and of those located in areas where groundwater has either been completely depleted or reached high salinity levels; frequent deepening of wells by those farmers who remain in business; increased salinity level in many aquifers; and the adoption of procedures to desalinate brackish water to fulfil irrigation requirements. Comprehensive and accurate statistics of groundwater decline and its consequences are currently lacking, but the situation is alarming everywhere although at different levels from district to district. The Eastern zone is the least affected at present. Most of the existing groundwater is saline with varying levels from region to region. Groundwater drawdown is also causing salinity levels to increase. At present, water salinity in the country ranges from less than 1 000 ppm to 1 500 ppm, but in some areas it reaches 4 000 ppm and more - up to 14 000 ppm in the Eastern zone (FAO, 2004).

In the Abu Dhabi Emirate, there are about 23 000 citizen's farms and a small number of large, government-owned fodder farms (2003). Citizen's farms are typically 2–3 ha in size and each has two drilled wells at opposite corners of the plot. Through subsidies, agricultural expansion up to about 3 000 new farms each year is promoted, although expansion is currently restricted due to exhaustion of groundwater supplies. The major limitations on agricultural development are the lack of groundwater resources and the high salinity of the groundwater used in irrigation. Close proximity of wells results in well interference effects and unrestricted irrigation causes extreme cones of depression resulting in increased salinity in water which is usually low-brackish to high-brackish to begin with. For example, in citizen's farms in the Al Ain region, irrigation water salinity exceeds 4 000 mg/l on 65 percent of farms. In the forestry sector, groundwater used for irrigation ranges in quality from 4 200 to 40 000 mg/l (Brook *et al.*, 2006).

The National Environmental Action Plan for Water Resources is supposed to implement the National Environmental Strategy for Water Resources, initially through programmes for strengthening those institutions responsible for water resources and associated regulatory controls and by comprehensive monitoring and data acquisition programs. The plan would address the key priority of enhancing the planning and management of water resources by making the existing High Committee for Water Management fully functional. Effective water resources management, to be based on an optimal blend of supply and demand management, was addressed in the plan by the MOEW in 2006:

- Creation of specific departments within all water supply authorities with responsibility for demand management to enact policies and programmes for distribution system loss control and legislative and economic instruments to promote water conservation;
- Investigation, and implementation where feasible, to augment resources through enhanced aquifer recharge and potential use of alternative water resources such as expansion of the scope for reusing treated municipal wastewater;
- Assessment of the long-term sustainability of desalination as the principal supply source for municipal water demands, including studies of the impact of

desalination on the coastal environment and the possible use of solar power for the desalination of brackish groundwater for rural areas.

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

At present the total water demand for all uses is met almost entirely by overabstraction from the strategic groundwater aquifer resource. The following sets out the main issues and defines the elements of a sustainable water resource strategy (MOEW, 2006):

Provision of suitable baseline data;

- Quantification of the sustainable yields of natural water resources;
- Identification of desalinated water production and distribution;
- Quantification of existing demands on the system;
- Prediction of likely future demands on the system;
- Assessment of additional water resource requirements and economic feasibility;
- Development and implementation of a demand management policy;
- Specification of water resources objectives and targets.

The first step in advancing the water resources strategy is to understand the present and probable future water resources and demand situation. This requires a baseline data set incorporating information on all of the factors influencing the resource-demand balance. The sustainable yield of the various natural water resources must be determined. The groundwater aquifers are key to this process. Careful consideration of the recharge capacity for all climate scenarios and any artificial recharge options will be required and average and critical period demand provisions will be evaluated.

Having established the water resources situation, including natural resources and the potential use of wastewater and desalinated water, a more detailed analysis of the existing demands is required. A prediction of future demands should then include scenarios for progressive municipal, agricultural and industrial development.

Within the national strategy for water management, priority is given to sustainable and economically viable agricultural products and to research on the growth of salt tolerant crops. Utilizing all the possible options, the ultimate aim is to maintain the present level of growth if further development is obstructed because of water scarcity.

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Yemen

GEOGRAPHY, CLIMATE AND POPULATION

Geography

Yemen, with a total area of 527 970 km², is located on the south-western edge of the Arabian Peninsula. Apart from the mainland it includes many islands, the largest of which are Socotra in the Arabian Sea and Kamaran in the Red Sea. The country is bordered by Saudi Arabia to the north, Oman to the east, the Arabian Sea and the Gulf of Aden to the south, and the Red Sea to the west. The present Republic of Yemen was created in 1990 as a result of the unification of the former Yemen Arab Republic (YAR) and the People's Democratic Republic of Yemen (PDRY). The country is divided into 21 administrative governorates, including the three newly created governorates Amran and Al-Daleh, created in 2000, and Raimah, created in 2004.

The cultivable land is estimated at about 3.62 million ha, which is 7 percent of the total area. In 2004 the total cultivated area was 1.19 million ha, compared with 1.05 million ha in 1994, of which 81 percent consisted of temporary crops and 19 percent of permanent crops (Table 1). The main crops were cereals, covering about 686 000 ha (58 percent of the total cultivated area), and qat, covering 122 844 ha (10 percent). Farm size, including both rainfed and irrigated agriculture, is generally very small: 62 percent of farms have less than 2 ha, while only 4 percent cover more than 10 ha.

Geographically, the country can be divided into three physiographic regions: the western, the eastern and the southern escarpment. Cultivated areas are mostly silty, with a high degree of heterogeneity, both laterally and vertically. Lower wadi reaches are extensively affected by blown sand, which tends to form dunes. The wadi soils are alluvial deposits, mostly consisting of fine sands and silts, which may reach several metres in depth. Agricultural soils have a high pH of about 7.8 to 8.0, very little organic matter and are nearly always deficient in nitrogen and phosphorus. Most of the land areas in the highlands are steep, rugged and badly eroded as a consequence of overgrazing and removal of woody vegetation. Agriculture is restricted to hillside terraces and riparian farms on the sides of the wadis, which range in size from a few metres to more than 100 metres, depending on the geologic and geomorphic features of the wadis. Soils captured by terraces show profiles of varying depths and morphology.

Climate

The climate is semi-arid to arid. Rainy seasons occur during the spring and the summer. Rainfall depends on two main mechanisms: the Red Sea Convergence Zone (RSCZ) and the monsoonal Inter-Tropical Convergence Zone (ITCZ). The RSCZ is active from March to May. Its influence is most noticeable at the higher altitudes in the western parts of the country. The ITCZ reaches Yemen in July-September, moving north and

YEMEN

FAO - AQUASTAT, 2008

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TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2005	52 797 000	ha
Cultivated area (arable land and area under permanent crops)	2004	1 188 888	ha
• as % of the total area of the country	2004	2.3	%
• arable land (annual crops + temp. fallow + temp. meadows)	2004	956 855	ha
• area under permanent crops	2004	232 033	ha
Population			
Total population	2005	20 975 000	inhabitants
• of which rural	2005	73.7	%
Population density	2005	39.7	inhabitants/km^2
Economically active population	2005	6 820 000	inhabitants
• as % of total population	2005	32.5	%
• female	2005	28.5	%
• male	2005	71.5	%
Population economically active in agriculture	2005	3 091 000	inhabitants
• as % of total economically active population	2005	45.3	%
• female	2005	44.2	%
• male	2005	55.8	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2007	22 520	million US$/yr
• value added in agriculture (% of GDP)	2000	10	%
• GDP per capita	2005	796	US$/yr
Human Development Index (highest = 1)	2005	0.508	
Access to improved drinking water sources			
Total population	2006	66	%
Urban population	2006	68	%
Rural population	2006	65	%

then south again so that its influence lasts longer in the south. Rainstorms observed during the winter months of December and January are attributed to the influence of the Mediterranean Sea.

- The country can be divided into fourteen agro-climatic zones, which can be grouped into five regions:
- The Coastal Plains: the plains are located in the west and southwest and are flat to slightly sloping, with maximum elevations of only a few hundred meters above sea level. Temperatures vary from 27 °C to 42 °C and rainfall is low to very low (< 200 mm/year). Nevertheless, the plains contain important agricultural zones due to the numerous wadis that drain the adjoining mountainous and hilly hinterland.
- The Yemen Mountain Massif: this massif constitutes a high zone of very irregular and dissected topography, with elevations ranging from a few hundred meters to 3 760 m above sea level. The climate varies from hot at lower elevations to cool at the highest altitudes. The western and southern slopes are the steepest and enjoy moderate to rather high rainfall, on average 300–500 mm/year, but in some places even more than 1 000 mm/year. The eastern slopes show a comparatively smoother topography and average rainfall decreases rapidly from west to east.
- The Eastern Plateau: this region covers the eastern half of the country. Elevations decrease from 1 800 to 1 200 m at the major watershed lines to 900 m on the northern desert border and to sea level on the coast. The climate in general is hot and dry, with average annual rainfall below 100 mm, except in the higher parts. Nevertheless, floods following rare rainfall may be devastating.
- The Desert: between the Yemen Mountain Massif and the Eastern Plateau lies the Ramlat as Sabatayn, a sand desert. Rainfall and vegetation are nearly absent, except along its margins where rivers bring water from adjacent mountain and

upland zones. The Rub Al Khali Desert in the north extends far into Saudi Arabia and is approximately 500 000 km² in area.

- The Islands: the most important island is Socotra, where more exuberant flora and fauna can be found than in any other region in Yemen.

Population

Total population is almost 21 million (2005), of which 74 percent is rural (Table 1). The average annual demographic growth rate is estimated at 3.2 percent during the period 2000-2005. The average population density is about 40 inhabitants/km², but the population density is quite different from one governorate to another. About 43 percent of the population lives in four governorates: Ta'iiz with 2.4 million, Hodiedah with 2.2 million, Ibb with 2.1 million and the capital city Sana'a with 1.8 million inhabitants. This is closely related to the physical environment. By far the largest part of the population lives in the Yemen Mountain area in the western part of the country, where rainfall is still significant, although not high in many locations. The hostile environment of the desert and eastern upland areas is reflected in low population density.

In 2006, 46 percent of the population had access to improved sanitation (88 and 30 percent in urban and rural areas respectively) and 66 percent had access to improved water sources (68 and 65 percent in urban and rural areas respectively).

ECONOMY, AGRICULTURE AND FOOD SECURITY

In 2007, the national Gross Domestic Product (GDP) of Yemen was US$22.5 billion (Table 1). The total economically active population was 6.8 million (32.5 percent of the total population), of which 71.5 percent male and 28.5 percent female.

The agriculture sector plays an important role in the economy of the country. Although its contribution to GDP is only about 10 percent (2000), the sector employs more than 45 percent of the total economically active population (50.4 percent in 2000) and provides livelihood to more than two-thirds of the population. The discrepancy between the contribution of agriculture to GDP and the percentage of those employed in this sector reflects seasonal employment, underemployment and the low productivity of workers and factors of production, thus resulting in low incomes and poor standards of living for workers in agriculture. Women are involved in nearly all agricultural activities, providing 44 percent of the population economically active in this sector, but cultural traditions keep them at a lower status and prevent them from gaining control over important household resources.

According to the Agriculture Census, the total cereal area showed a negative trend between 1998 and 2004, with total cereal production decreasing by 0.6 percent per year. The average domestic cereal production in 2000–2004 covered only 21 percent of the domestic demand, estimated at 2.73 million tons. The cost of imported cereal has increased from US$195.2 million in 2000 to US$315 million in 2004. When aggregating main food imports, cereals (2.3 million tons), sugar (468 000 tons), vegetables and fruit (77 000 tons), livestock and milk products (164 000 tons), the food import bill reaches US$744 million. Food exports total around US$236 million and are dominated by fish products with 76 percent of food export value (US$181 million), coffee (US$14.4 million), banana (US$8 million), onion (US$7.6 million) and other fruits (US$4.3 million).

WATER RESOURCES AND USE

Water resources

Annual rain volume all over the country varies between 67 and 93 km³. Precipitation falls more on the western highlands, southwest highlands and the upper plateaus. It then gradually becomes lower towards the east. The ratio between the rainfall and potential evaporation reaches around 0.03–0.25 in the Rub Al Khali Desert.

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	167	mm/yr
	-	88.17	10^9 m^3/yr
Internal renewable water resources (long-term average)	-	2.1	10^9 m^3/yr
Total actual renewable water resources	-	2.1	10^9 m^3/yr
Dependency ratio	-	0	%
Total actual renewable water resources per inhabitant	2005	100	m^3/yr
Total dam capacity	2006	462.5	10^6 m^3
Water withdrawal			
Total water withdrawal	2000	3 400	10^6 m^3/yr
- irrigation + livestock	2000	3 060	10^6 m^3/yr
- municipalities	2000	272	10^6 m^3/yr
- industry	2000	68	10^6 m^3/yr
• per inhabitant	2000	187	m^3/yr
Surface water and groundwater withdrawal	2000	3 384	10^6 m^3/yr
• as % of total actual renewable water resources	2000	161.1	%
Non-conventional sources of water			
Produced wastewater	2000	74	10^6 m^3/yr
Treated wastewater	1999	46	10^6 m^3/yr
Reused treated wastewater	2000	6	10^6 m^3/yr
Desalinated water produced	2006	25.1	10^6 m^3/yr
Reused agricultural drainage water		-	10^6 m^3/yr

The country can be subdivided into four major drainage basins, grouping numerous smaller wadis:

- the Red Sea Basin
- the Gulf of Aden Basin
- the Arabian Sea Basin
- the Rub Al Khali Interior Basin

The floods of the wadis are generally characterized by abruptly rising peaks that rapidly recede. Between the irregular floods the wadis are either dry or carry only minor base flows. Surface water resources have been estimated at 2 km^3/year, but this quantity corresponds to the runoff from major rivers and does not include the runoff produced within the smaller catchments. Renewable groundwater resources have been estimated at l.5 km^3/year of which a large part, estimated at 1.4 km^3/year, probably comes from infiltration in the river beds. Total internal renewable water resources are thus estimated at around 2.1 km^3/year (Table 2).

Surface runoff to the sea measured in some major wadis is estimated at 270 million m^3/year and groundwater outflow to the sea at 280 million m^3/year. There might be some groundwater flowing into Saudi Arabia but no data are available. The existence of surface drainage crossing into Saudi Arabia suggests that some sharing of surface flows could be possible, but details are not known.

The volume of groundwater reaches around 10 km^3, of which 1 km^3 in the Al-Masila Basin, 2.5 km^3 in the Tihama Basin and the remaining distributed over the other regions.

Yemen has a long history of dam construction and the ancient civilization was founded upon the great dam of Ma'areb, the destruction of which marked the end of its existence. After the revolution, the government carried out the reconstruction of the Ma'areb Dam financed by the United Arab Emirates. The new dam has a capacity of 400 million m^3. The remaining dams have a total capacity of 62.5 million m^3, giving a total dam capacity of 462.5 million m^3.

There are over a thousand hydraulic structures falling into three different categories:

1. Dams: 347 storage dams have been constructed in the upper lands to store rainfall water for irrigation and for domestic use, and to recharge sub-aquifers. There are three types: large dams with a capacity above 500 000 m^3, medium dams with a variable capacity from 200 000 to 500 000 m^3 (71 dams of this type have been constructed) and small dams with a capacity of less than 200 000 m^3.
2. Spate water diversion structures: 33 of these structures have been constructed in the main wadis for spate water regulation and diversion.
3. Small water harvesting structures: this category includes cisterns, pits and reservoirs with a storage capacity ranging from 500 m^3 to 50 000 m^3.

Thirteen wastewater treatment plants (WWTP) are in operation. They are concentrated in the capitals of the governorates and in some secondary cities. However, while the cities are growing fast, the capacity of the plants has not increased. For example, in Sana'a the WWTP was designed to treat 25 000 m^3/day of wastewater, but now it receives more than 50 000 m^3/day. Similarly, in Ibb city the WWTP was designed to receive 5 000 m^3/day, but now it receives more than 10 000 m^3/day. These examples reflect the insufficient treatment leading to the production of bad quality water that is not suitable for irrigation. The Ministry of Agriculture and Irrigation considers this water to be harmful and it should be appropriately treated in a way that prevents environmental pollution. In 2000, the total volume of produced wastewater was 74 million m^3 and the treated wastewater was 46 million m^3 in 1999, while the amount of treated wastewater used in agriculture was only 6 million m^3/year in 2000.

In 2002, the total installed gross desalination capacity (design capacity) was 76 596 m^3/day or 28 million m^3/year (Wangnick Consulting, 2002). The production of desalinated water reached 25.1 million m^3 in 2006, an increase of 151 percent compared with 1989, contributing to the water supply of Aden city.

FIGURE 1
Water withdrawal by sector
Total: 3.400 km^3 in 2000

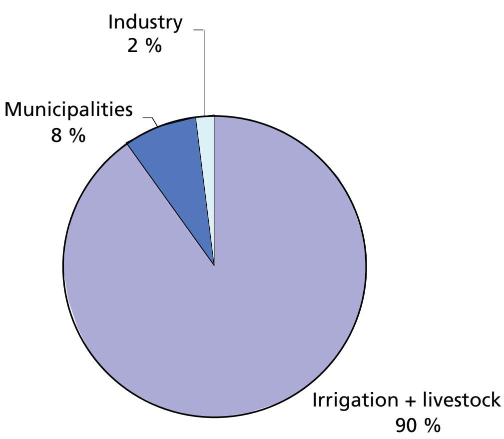
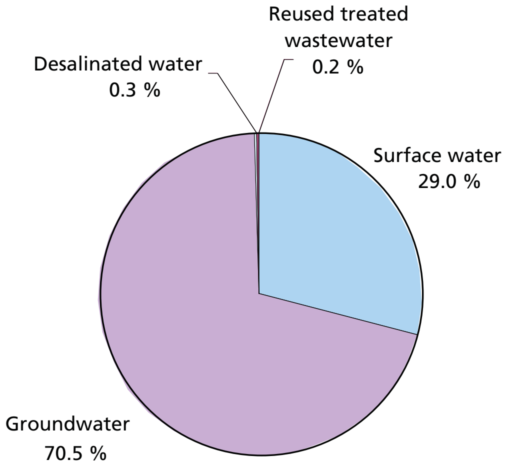


FIGURE 2
Water withdrawal by source
Total: 3.400 km^3 in 2000



Water use

Between 1990 and 2000 total water withdrawal increased from 2.9 km^3/year to 3.4 km^3/year. In 2000, 90 percent of water withdrawal was used for agricultural purposes, 8 percent for municipal use and 2 percent for industrial use (Table 2 and Figure 1). Most of the water withdrawn was groundwater (from wells and springs) (Figure 2), resulting in groundwater depletion as withdrawal exceeded the annual groundwater recharge. The rate of decline of the groundwater levels is alarmingly high in many zones, especially in the highlands, where a decline of 2 to 6 m/year is commonly observed. In coastal zones overexploitation of groundwater leads to salt water intrusion. The decline in groundwater tables has also significantly reduced spring-fed irrigation.

Many farmers are pumping groundwater from wells using diesel or electric pumps. The yield of wells is between 5 and 50 l/sec. It is estimated that there are 52 000 to 55 000 active wells in Yemen. The volume of the water that is pumped every year from these wells is about 1.5 km^3. About 800 water well drilling rigs are in use that are owned by individuals or companies which generally do not have any permits despite government legislation limiting the drilling of wells. Recently, the National Water Resources Authority started a programme of registrations & licensing for the water well drilling companies; the records show that in May 2005 only 70 rigs were licensed and only 1 000 wells were registered and licensed (Al-Asbahi, 2005).

Two types of treated wastewater reuse in agriculture exist (Al-Asbahi, 2001):

- controlled irrigation, which is practiced in government projects by the Ministry of Agriculture and Irrigation to build the green belts, mainly in the coastal plain cities (Aden, Al Hudaydah), and for sand dune fixation or desertification control in the affected areas of coastal plains;
- non-controlled irrigation (commonly in the highlands and wadis), which is practiced by the farmers themselves to grow corn, fodder in some areas (Ta'iiz), and to grow restricted and non-restricted crops, such as vegetables (tomato, carrot) and fruits (in Sana'a area).

An undefined quantity of brackish water is used in the rock cutting industry, mainly in the highlands, as well as for irrigating some salt-tolerant crops, mainly in the coastal plains (Al-Asbahi, 2005).

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

A global figure for irrigation potential is not available. In 2004, the total water management area was estimated at 679 650 ha, an increase of around 41 percent compared with 1994 (Table 3). Three main types of water management exist:

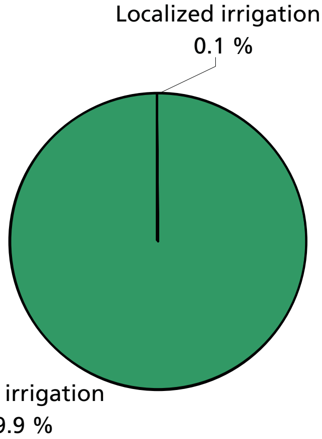
- Full/partial control irrigation: this concerns an area of 454 310 ha (2004), all irrigated from groundwater, of which 420 386 ha from tube wells and 33 924 ha from spring water. In general, the area irrigated from wells has decreased as many wells have gone out of production due to declining water tables.
- Spate irrigation: the area actually irrigated by spate water varies considerably from year to year, depending on the availability of spate water. It is estimated that the area equipped for spate irrigation (command area) may be as large as 217 541 ha, which was the area also actually irrigated in 2001 (Al-Asbahi, 2001), while in 2002 only 124 683 ha were actually irrigated and in 2004 only 89 363 ha. The government constructed many spate water diversion and canal control structures in some of the main wadis, such as wadi Zabid, Tuban, Abyan, Mowr, Seham and Bayhan. Moreover, spate irrigation structures have been maintained and improved for enhancing spate water management and distribution along these wadis. The Irrigation Improvement Project (IIP) has been established recently to introduce the participatory spate irrigation management approach on two pilot wadis (Zabid and Tuban). This project created 'water user associations' (WUAs) to manage the spate structures on the wadis and to take over the operation and maintenance of the spate structures. The project also created the Water Council (WC) from the members of those associations and the local authorities.
- Small-scale irrigation: 347 dams were recently constructed in the different governorates especially in the uplands to capture rainwater for complementary

TABLE 3
Irrigation and drainage

Irrigation potential		**-**	**ha**
Irrigation			
1. Full or partial control irrigation: equipped area	2004	454 310	ha
- surface irrigation	2004	453 825	ha
- sprinkler irrigation		-	ha
- localized irrigation	2004	485	ha
• % of area irrigated from surface water	2004	0	%
• % of area irrigated from groundwater	2004	100	%
• % of area irrigated from mixed surface water and groundwater	2004	0	%
• % of area irrigated from non-conventional sources of water	2004	0	%
• area equipped for full or partial control irrigation actually irrigated	2004	454 310	ha
- as % of full/partial control area equipped	2004	100	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)	2004	7 799	ha
3. Spate irrigation	2004	217 541	ha
Total area equipped for irrigation (1+2+3)	**2004**	**679 650**	**ha**
• as % of cultivated area	2004	57.2	%
• % of total area equipped for irrigation actually irrigated	2004	81.1	%
• average increase per year over the last 10 years	1994-2004	3.5	%
• power irrigated area as % of total area equipped	2004	66.8	%
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)	**2004**	**679 650**	**ha**
• as % of cultivated area	2004	57.2	%
Full or partial control irrigation schemes — **Criteria**			
Small-scale schemes — < ha		-	ha
Medium-scale schemes		-	ha
large-scale schemes — > ha		-	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	527 038	ha
• Annual crops: total	2004	332 784	ha
- Wheat	2004	41 903	ha
- Barley	2004	11 223	ha
- Maize	2004	19 234	ha
- Millet	2004	7 947	ha
- Sorghum	2004	42 888	ha
- Potatoes	2004	16 870	ha
- Pulses	2004	26 832	ha
- Vegetables	2004	55 494	ha
- Tobacco	2004	7 935	ha
- Cotton	2004	17 246	ha
- Sesame	2004	14 440	ha
- Fodder	2004	70 772	ha
Permanent crops: total	2004	194 254	ha
- Coffee	2004	18 753	ha
- Citrus	2004	11 252	ha
- Bananas	2004	8 837	ha
- Other perennial crops	2004	155 412	ha
Irrigated cropping intensity (on full/partial control area equipped)	2004	116	%
Drainage - Environment			
Total drained area		-	ha
- part of the area equipped for irrigation drained		-	ha
- other drained area (non-irrigated)		-	ha
• drained area as % of cultivated area		-	%
Flood-protected areas		-	ha
Area salinized by irrigation		-	ha
Population affected by water-related diseases		-	inhabitants

irrigation purposes in inland valleys. Moreover, 519 small reservoirs and water cisterns have been constructed in different upland villages. The main purpose of these water harvesting or small-scale irrigation schemes is to use the water for complementary irrigation. The total area irrigated by these systems was about 7 799 ha in 2004, including 4 215 ha from dams. It increased to 8 526 ha in 2005 thanks to the construction of new dams.

FIGURE 3
Irrigation techniques
Total: 454 310 ha in 2004



Irrigation efficiency is low, between 35 and 45 percent depending on field levelling and the water conveyance system used. Localized irrigation systems (drip and bubbler) are introduced through several projects on limited demonstration areas and 485 ha have been realized up to now. Because of the high cost of sprinkler irrigation systems, they have been installed in very limited areas only, such as the governmental farms and the big investment farms mostly used for fodder crop production. To enhance water conveyance and distribution efficiency, the government introduced PVC buried pipes and GI pipes to the farmers to replace the earthen distribution canals and offered subsidies reaching 50 percent of the equipment costs. It is estimated that irrigation efficiency could be increased to 60 percent by installing the conveyance pipe system and to over 80 percent by adopting localized irrigation systems. Average yields of crops growing under the improved conveyance pipe system and localized irrigation systems are assumed to increase by 5 percent and 10 percent respectively. In 2004, 99.9 percent was surface irrigation and 0.1 percent was localized irrigation (Figure 3).

Role of irrigation in agricultural production, economy and society

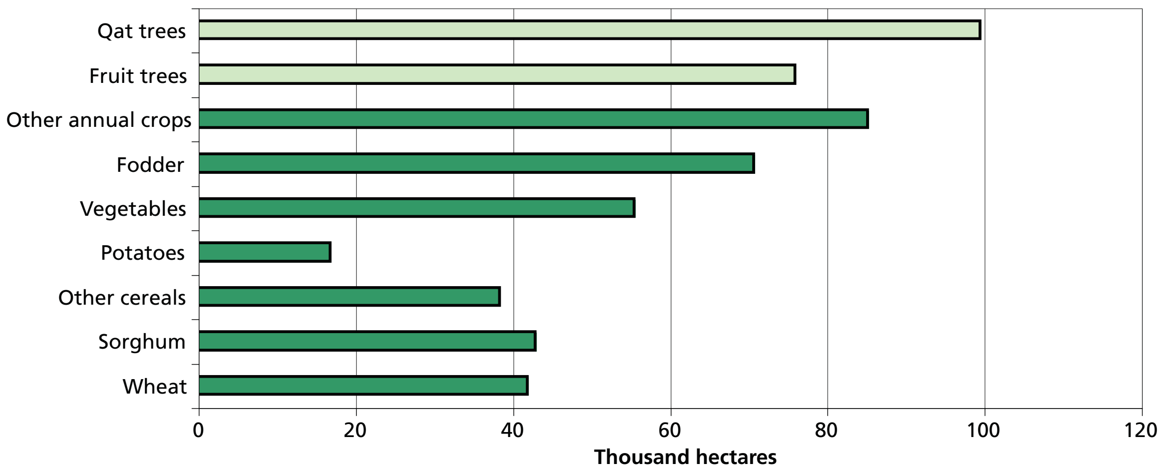
The price of irrigation equipment has increased considerably in recent years. The average cost of a surface irrigation system with a piped conveyance and distribution system is about US$800/ha. The cost of a localized irrigation system depends on the type: the estimated cost of a drip irrigation system for fruit trees is about US$2 600/ha and for vegetables about US$3 600/ha, while a bubbler irrigation system costs about US$3 000/ha. A central pivot sprinkler system is estimated to cost about US$6 000–8 000/ha. The cost of the operation and maintenance is approximately US$120/ha for the piped surface irrigation system and US$300/ha for a localized irrigation system. The farmers are responsible for operation and maintenance costs.

Government action focuses on the construction of water harvesting schemes and spate irrigation structures with the participation of the beneficiaries, as well as on the rehabilitation of those structures. The beneficiaries are responsible for operation and maintenance. The cost of small and medium spate diversion works and water harvesting structures is between US$1 500 and 2 000/ha.

The crops grown under full/partial control irrigation can be aggregated into six types: cereals, fruits, vegetables, cash crops, pulses and fodders. In 2004, the total harvested irrigated cropped area was 527 038 ha distributed as follows (Table 3 and Figure 4):

- cash crops: 157 878 ha or 30 percent, including 99 504 ha of qat; other cash crops are cotton, coffee, tobacco and sesame;

FIGURE 4
Irrigated crops
Total harvested area: 527 038 ha in 2004 (cropping intensity on equipped area actually irrigated: 116%)



- cereals: 123 195 ha or 23 percent, mainly sorghum and wheat and to a lesser extent maize, barley and millet;
- fruit trees: 75 997 ha or 15 percent, of which 11 percent is banana and 15 percent citrus; other crops under this category are grapes, palm dates, papaya, apricots, peach, quince, figs, apples and guava;
- vegetables: 72 364 ha or 14 percent, including 16 870 ha of potatoes cultivated particularly in the Dhamar and Amran governorates;
- fodder: 70 772 ha or 13 percent;
- pulses: 26 832 ha or 5 percent; most pulses are rainfed.

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

Institutions

The Ministry of Agriculture and Irrigation (MAI) is responsible for formulating policies on irrigation, crops, livestock and forestry production and for coordinating public investment and services in the agricultural sector. The General Directorate of Irrigation (GDI) is located within the Ministry and carries out all the duties related to irrigation, particularly the construction of dams and water harvesting and spate structures. Most field services are provided to farmers through decentralized Regional Agriculture and Irrigation Offices (RAIO) in the different governorates of the country. Several projects are working under the supervision of the MAI to provide different services, particularly the introduction of water saving techniques and the construction of water harvesting and spate structures. Other areas of action include wadi bank protection and the rehabilitation of abused terraces, as well as the rehabilitation and maintenance of existing irrigation structures. To support agricultural development at the regional level, three Regional Development Authorities (RDA) have been established in the northern governorates: (i) Tihama Development Authority (TDA), (ii) Sana'a, Sa'dah, Hajjah and Amran Rural Development Authority (SSHARDA) and (iii) Eastern Region Agricultural Development Authority (ERADA). Although RDAs have not been established in the southern governorates, agricultural production in wadis such as Wadi Hadramout, Wadi Tuban, Wadi Beihan has been supported by donor agencies through the Directorates of Agriculture in the respective governorates.

In addition to the above authorities, the Agriculture Research and Extension Authority (AREA) is working under the umbrella of the Ministry. The Agricultural Cooperative Union (ACU) was established in August 1991 with 213 societies. Its main objective is to consolidate integration and coordination with the government effort in setting up several common projects, of which the most important ones are infrastructure projects such as water storage, regulation dams and weirs, and agricultural marketing. It also supplies agricultural inputs and means for livestock development. At present the ACU has four general societies with 400 primary societies and 20 branches in all the provinces of the country.

The Ministry of Water and Environment (MWE) was established in May 2003. It is responsible for water resource planning and monitoring, legislation and public awareness. MWE has many sub-sectors and authorities such as the National Water Resources Authority (NWRA), Environment Protection Authority (EPA), General Rural Water Authority (GRWA), Urban Water Supply and Sanitation Corporation, and Rural Water Supply and Sanitation Corporation.

The Ministry of Public Works and Urban Planning (MPWUP) is responsible for observing and monitoring the drinking water purification stations. The Ministry of Local Administration (MLA) is responsible for water supply and sanitation in rural areas.

Water management

According to the Constitution, surface water and groundwater resources are defined as ‘res communis’. However, a landowner has ‘precedence’ for water taken from a well on his land. In spring-irrigated areas water can be attached to land in the form of ‘turns’, which give rights to divert the canal into the field for a fixed period of time. The ‘turn’ can, however, be detached from the land and sold or rented separately. This landowner’s ‘precedence’ has permitted the private development of deep tubewell extraction, which is in some ways in conflict with Islamic principles. Islamic and customary law has no precedent for dealing with a new technology that allows landowners to extract (and sell) unlimited quantities of water from deep aquifers, and modern law has not yet regulated it either.

Following the Water Law, water user associations (WUAs), water user groups (WUGs) and water councils (WCs) were established to transfer operation and maintenance (O&M) functions of the spate irrigation and groundwater irrigation schemes from the MAI to the user organizations. Up to now, 65 WUAs, 1 287 WUGs and 2 WCs (in Wadi Zabid and Wadi Tuban) have been established. They have received training on issues such as technical, financial and administrative management, provided by different projects.

Between 2005 and 2006 the International Programme for Technology and Research in Irrigation and Drainage (IPTRID), carried out the Project Design and Management Training Programme (PDM) for Professionals in the Water Sector in some countries of the Near East such as Yemen. The objective of the programme is to strengthen participants’ capacities in developing more effective and efficient projects to address pressing water issues in the region (FAO, 2008).

Policies and legislation

The government recognizes the critical water situation in the country and is undertaking different actions to deal with it. Several water sector strategies, legislations and policies have been prepared and implementation of some of them has begun. The Water Law was enacted on 31 August 2002, and amended by Parliament in December 2006. Implementation of this law will give a major thrust to the issue of water conservation. On 19 November 2002, the Cabinet passed a decree proclaiming Sa’dah, Sana’a and Ta’iiz protected areas, as stipulated in Article 49 of the Water Law. The National Water Resources Authority (NWRA) will monitor closely these critical areas.

The following policies and the strategies have been developed after assessment of the water sector and irrigation sub-sector:

- water resources policy and strategy (1999-2000)
- irrigation water policy (2001)
- watershed policy (2000)
- agricultural sector reform policy (2000)
- urban water supply and sanitation sector reform policy (1997)
- wastewater reuse strategy (under development).

ENVIRONMENT AND HEALTH

The successful and sustainable exploitation of water resources is threatened by the rapid depletion of groundwater resources. Almost all the important groundwater systems are being over-exploited at an alarming rate. The socioeconomic consequences of groundwater depletion are dramatic because it will become too expensive for use in agriculture and, as a result, regional agricultural economies based on groundwater irrigation are doomed to collapse if the water resources are not adequately controlled. Groundwater availability may be further reduced by groundwater salinization in coastal areas and groundwater pollution in urban areas and areas of intensive agriculture. A study conducted by the Tehama Development Authority (2004) reported that the EC increased from 225 to 3 480 μs/cm (at 25 °C) in the Al-Jar area as a result of sea water intrusion. The Al-Jar region is located in the northwest of the Yemeni coastal area, 8 km away from the Red Sea. During the last ten years there has been a huge investment in this area, leading to the cultivation of more than 3 500 ha of mango trees and the drilling of about 2 000 wells. In the whole country, the area cultivated with high water consuming crops increased, such as the area under qat, which has more than tripled in 25 years.

The quality of treated wastewater varies from one area to another. While the quality is very good in Hajah, it is very bad in Ta'iiz, depending on the method of treatment as well as the capacity of the station and the operational circumstances. The quality affects the farmers' willingness to use such water for their crops (Al-Asbahi, 2005). Moreover, the outflow of the WWTP stations in the coastal areas becomes a source of groundwater pollution.

Environmental degradation occurs in areas where springs have dried up or where treatment plants are not able to treat oil residues and discharge the raw wastewater directly to the wadis (such as from the Sana'a station). Water scarcity leads to ever-increasing competition which, if uncontrolled, might lead to socioeconomic problems.

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

Reducing the gap between water abstraction and available renewable resources and improving the efficiency of water management is a priority. Specific objectives of the second Five-Year Plan are: optimal exploitation of available water resources; improving the means and techniques for water resources recovery and for feeding aquifers; and protecting water resources from pollution.

To achieve these objectives, the government plans to make investments in groundwater recharge, water harvesting, encouragement of traditional and modern water management techniques, and application of modern irrigation techniques. Furthermore, it plans to invest in improving water use efficiency, capacity building, public and social awareness, as well as to pursue policies for equitable distribution of available water resources in rural and urban areas.

Strategies dealing more specifically with the various challenges of irrigated agriculture are set out in the National Water Strategy, adopted by the Council of Ministers in 1999, and in the National Irrigation Strategy, adopted by the Council of Ministers in 2001, which highlight the following aspects:

1. ensuring the sustainability of groundwater irrigation: to reduce the rapid overdraft of aquifers, the government strategy will apply macro-economic measures (diesel price increase, increasing import duty on drilling rigs...);
2. ensuring the sustainability of spate irrigation schemes: most of the spate irrigation infrastructure is deteriorating due to poor maintenance caused by budgetary constraints in the public sector. The government strategy is to improve the cost effectiveness of their management and to involve users in the management and paying for O&M;
3. increasing the productivity of irrigated agriculture: by regional standards, returns to water in irrigation in Yemen are low. The government policy is to promote improved irrigation technologies and research on agricultural water use efficiency and conservation;
4. changing the role of the government: the government strategy is to reduce its role to the essential minimum and to involve users more and more in irrigation investment and management.

Concerning O&M of large spate works, decrees have already been issued for Lahej and Abyan governorates to charge an irrigation fee from the farmers on the basis of areas actually irrigated; this will be used for O&M of the head works and the main canals to be implemented by the Government. Farmers themselves are responsible for O&M of the tertiary canals.

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