Iraq

GEOGRAPHY, CLIMATE AND POPULATION

Geography

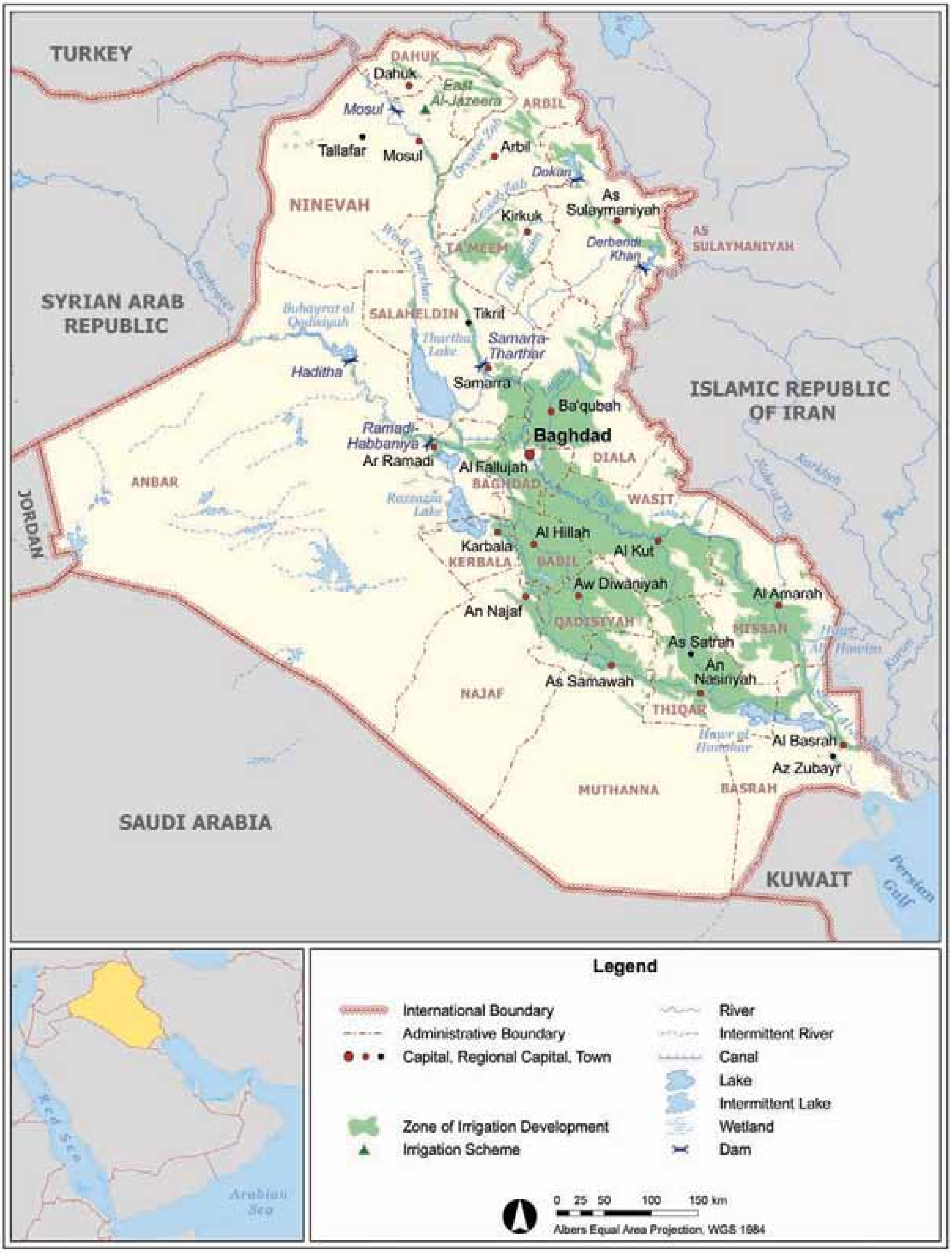
Iraq, with a total area of 438 320 km², is bordered by Turkey to the north, the Islamic Republic of Iran to the east, the Persian Gulf to the southeast, Saudi Arabia and Kuwait to the south, and Jordan and the Syrian Arab Republic to the west. Topographically, Iraq is shaped like a basin, consisting of the Great Mesopotamian alluvial plain of the Tigris and the Euphrates rivers (Mesopotamia means, literally, the land between two rivers). This plain is surrounded by mountains in the north and the east, which can reach altitudes of 3 550 m above sea level, and by desert areas in the south and west, which account for over 40 percent of the land area. For administrative purposes, the country is divided into eighteen governorates, of which three (Arbil, Dahuk, and As Sulaymaniyah) are gathered in an autonomous region in the north and the other fifteen governorates are in central and southern Iraq. This division corresponds roughly to the rainfed northern agricultural zone and the irrigated central and southern zone.

It is estimated that about 11.5 million ha, or 26 percent of the total area of the country, are cultivable. The remaining part is not viable for agricultural use under current conditions and only a small strip situated along the extreme northern border with Turkey and the Islamic Republic of Iran is under forest and woodlands. The total cultivated area is estimated at about 6 million ha, of which almost 50 percent in northern Iraq under rainfed conditions. Less than 5 percent is occupied by permanent crops (Table 1). Permanent pasture covers around 4 million ha. Livestock grazing occurs throughout all agricultural zones, but is more widespread in the north where hillside grazing prevails. Small ruminants (mainly sheep and goats) are the main livestock species. However, beef cattle have been the traditional source of dietary protein for most Iraqis. Poultry production occurs in close proximity to urban centres.

Climate

The climate in Iraq is mainly of the continental, subtropical semi-arid type, with the north and north-eastern mountainous regions having a Mediterranean climate. Rainfall is very seasonal and occurs in the winter from December to February, except in the north and northeast of the country, where the rainy season is from November to April. Average annual rainfall is estimated at 216 mm, but ranges from 1 200 mm in the northeast to less than 100 mm over 60 percent of the country in the south (Table 2). Winters are cool to cold, with a day temperature of about 16 °C dropping at night to 2 °C with a possibility of frost. Summers are dry and hot to extremely hot, with a shade temperature of over 43 °C during July and August, yet dropping at night to 26 °C.

Iraq can be divided into four agro-ecological zones (FAO, 2003):



IRAQ **FAO - AQUASTAT, 2008**

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TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2005	43 832 000	ha
Cultivated area (arable land and area under permanent crops)	2005	6 010 000	ha
• as % of the total area of the country	2005	13.7	%
• arable land (annual crops + temp fallow + temp meadows)	2005	5 750 000	ha
• area under permanent crops	2005	260 000	ha
Population			
Total population	2005	28 807 000	inhabitants
• of which rural	2005	33.2	%
Population density	2005	65.7	inhabitants/km^2
Economically active population	2005	8 189 000	inhabitants
• as % of total population	2005	28.4	%
• female	2005	21.6	%
• male	2005	78.4	%
Population economically active in agriculture	2005	651 000	inhabitants
• as % of total economically active population	2005	7.9	%
• female	2005	55.1	%
• male	2005	44.9	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2000	25 860	million US$/yr
• value added in agriculture (% of GDP)	2000	5	%
• GDP per capita	2000	1 031	US$/yr
Human Development Index (highest = 1)		-	
Access to improved drinking water sources			
Total population	2006	77	%
Urban population	2006	88	%
Rural population	2006	56	%

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	216	mm/yr
	-	94.68	10^9 m^3/yr
Internal renewable water resources (long-term average)	-	35.2	10^9 m^3/yr
Total actual renewable water resources	-	75.61	10^9 m^3/yr
Dependency ratio	-	53.45	%
Total actual renewable water resources per inhabitant	2005	2 625	m^3/yr
Total dam capacity	2000	139 700	10^6 m^3
Water withdrawal			
Total water withdrawal	2000	66 000	10^6 m^3/yr
- irrigation + livestock	2000	52 000	10^6 m^3/yr
- municipalities	2000	4 300	10^6 m^3/yr
- industry	2000	9 700	10^6 m^3/yr
• per inhabitant	2000	2 632	m^3/yr
Surface water and groundwater withdrawal	2000	64 493	10^6 m^3/yr
• as % of total actual renewable water resources	2000	85.3	%
Non-conventional sources of water			
Produced wastewater		-	10^6 m^3/yr
Treated wastewater		-	10^6 m^3/yr
Reused treated wastewater		-	10^6 m^3/yr
Desalinated water produced	1997	7.4	10^6 m^3/yr
Reused agricultural drainage water	1997	1500	10^6 m^3/yr

➢ Arid and semi-arid zones with a Mediterranean climate. A growing season of about nine months, over 400 mm of annual winter rainfall, and mild/warm summers prevail. This zone covers mainly the northern governorates of Iraq. Major crops include wheat, barley, rice and chickpea. Other field crops are also produced in smaller quantities. There is some irrigation, mainly from springs, streams and bores.

- Steppes with winter rainfall of 200–400 mm annually. Summers are extremely hot and winters cold. This zone is located between the Mediterranean zone and the desert zone. It includes the feed barley production areas, limited wheat production, and it has limited irrigation.
- The desert zone with extreme summer temperatures and less than 200 mm of rainfall annually. It extends from just north of Baghdad to the Saudi Arabian and Jordanian borders. It is sparsely populated and cultivated with just a few crops in some irrigated spots.
- The irrigated area which extends between the Tigris and Euphrates rivers from the north of Baghdad to Basra in the south. Serious hazards for this area are poor drainage and salinity. The majority of the country's vegetables, sunflower and rice are produced in this zone.

Population

Total population is about 28.8 million (2005), of which 33 percent is rural (Table 1). Average population density is estimated at 66 inhabitants/km^2, but varies greatly from the almost uninhabited Anwar province in the desert in the western part of the country to the most inhabited Babylon province in the centre of the country. Average population growth was estimated at 3.6 percent during 1980–90, but emigration of foreign workers, severe economic hardships and war have since reduced this growth rate.

In 1991 safe water supplies reached 100 percent in urban areas but only 54 percent in rural areas. The water supply and sanitation situation has deteriorated as a result of the wars, among other things owing to shortages of chlorine imports for water treatment. In 2006 access to improved drinking water sources reached 77 percent of the population (88 and 56 percent of urban and rural population respectively). The sanitation coverage was 76 percent (80 and 69 percent respectively).

ECONOMY, AGRICULTURE AND FOOD SECURITY

In 2000 the Gross Domestic Product (GDP) was US$25.9 billion, with an annul rate growth of -4.3 percent. In 1989 the agriculture sector contributed only 5 percent to GDP, which was dominated by oil (61 percent); in 2000 the agriculture sector accounted for 5 percent of GDP (Table 1).

The economically active population is about 8.2 million (2005) of which 78 percent is male and 22 percent female. In agriculture, 0.7 million inhabitants are economically active, of which 45 percent male and 55 percent female. While the agricultural labour force represented 31 percent of the economically active population in 1975, it decreased to about 8 percent in 2004, partly due to the introduction of agricultural mechanization, the development of education and health services in the urban areas and increased job opportunities encouraging rural–urban migration. However, after public service and the trade sector, agriculture still is the main provider of employment in Iraq (FAO, 2003). A large portion of Iraq's population lives in poverty, with many people engaged in subsistence agriculture.

The nation-wide rationing system set up by the Government of Iraq in 1991 prevented famine but with the decline in the energy content of the ration and the reduction in food available outside the rationing system, malnutrition and mortality of young children increased dramatically. In April 1995 the Oil-for-Food Programme was established under Security Council Resolution 986 (SRC 986), according to which the distribution of humanitarian supplies to the population is undertaken by the government in the centre and south and by the UN Inter-Agency Humanitarian

Programme on behalf of the government in the three northern governorates. This arrested further decline in nutrition (FAO, 2000).

However, despite substantial increases in the food ration since SCR 986, the following has occurred:

- child malnutrition rates in the centre and south of the country do not appear to have improved significantly and nutritional problems remain serious and widespread
- existing food rations do not provide a nutritionally adequate and varied diet
- the monthly food basket lasts up to three weeks, depending on the type of ration
- despite shortfalls in the ration, some segments of the population can supplement their diet with market purchases, albeit at considerable cost.

WATER RESOURCES AND USE

Water resources

Both the Tigris and the Euphrates are transboundary rivers, originating in Turkey. Before their confluence, the Euphrates flows for about 1 000 km and the Tigris for about 1 300 km within the territory of Iraq.

The area of the Tigris River Basin in Iraq is 253 000 km², which is 54 percent of the total river basin area. The average annual runoff is estimated at 21.33 km³ as it enters Iraq. All the Tigris tributaries are on the left bank. From upstream to downstream:

- the Greater Zab, which originates in Turkey. It generates 13.18 km³ at its confluence with the Tigris; 62 percent of the total area of this river basin of 25 810 km² is in Iraq;
- the Lesser Zab, which originates in the Islamic Republic of Iran and which is equipped with the Dokan Dam (6.8 km³). The river basin of 21 475 km² (of which 74 percent is in Iraqi territory) generates about 7.17 km³, of which 5.07 km³ of annual safe yield after construction of the Dokan Dam;
- the Al-Adhaim (or Nahr Al Uzaym), which drains about 13 000 km² entirely in Iraq. It generates about 0.79 km³ at its confluence with the Tigris. It is an intermittent stream subject to flash floods;
- the Diyala, which originates in the Islamic Republic of Iran and drains about 31 896 km², 75 percent of which in Iraqi territory. It is equipped with the Derbendi Khan Dam and generates about 5.74 km³ at its confluence with the Tigris;
- the Nahr at Tib, Dewarege (Doveyrich) and Shehabi rivers, draining together more than 8 000 km². They originate in Iranian territory and bring together about 1 km³ of highly saline waters in the Tigris;
- the Karkheh, the main course of which is in the Islamic Republic of Iran and which, from a drainage area of 46 000 km², brings around 6.3 km³ yearly into Iraq, namely into the Hawr Al Hawiza during the flood season and into the Tigris River during the dry season.

The average annual flow of the Euphrates as it enters Iraq is estimated at 30 km³, with a fluctuating annual value of between 10 and 40 km³. Unlike the Tigris, the Euphrates receives no tributaries during its passage in Iraq. About 10 km³ per year are drained into the Hawr al Harnmar (a marsh in the south of the country). The Shatt Al-Arab is the river formed by the confluence downstream of the Euphrates and the Tigris; it flows into the Gulf after a course of only 190 km. The Karun River, originating in Iranian territory, has a mean annual flow of 24.7 km³ and flows into the Shatt Al-Arab, to which it brings a large amount of fresh water just before reaching the sea.

It is difficult to determine the average annual discharge of the Euphrates and Tigris rivers together due to the large yearly fluctuation. According to the records for 1938–1980, there have been years in the mid-1960s when 68 km³ were recorded in the two rivers and years in the mid-1970s when the amount reached over 84 km³. On the other hand, there was the critical drought year with less than 30 km^3 at the beginning of the 1960s. Such variations in annual discharge make it difficult to develop an adequate water allocation plan for competing water demand from each sector as well as to ensure fair sharing of water among neighbouring countries (UNDG, 2005).

This yearly fluctuation in the annual discharge has also caused large and possibly disastrous floods as well as periodic severe droughts. The level of water in the Tigris can rise at a rate of over 30 cm/hour. In the southern part of the country, immense areas are regularly inundated, levees often collapse, and villages and roads must be built on high embankments. The Tharthar Reservoir was planned in the 1950s among other to protect Baghdad from the ravages of the periodic flooding of the Tigris by storing extra water upstream of the Samarra Barrage.

The major part of the river flow occurs during the spring flood period, which is from February through June on the Tigris River and from March through July on the Euphrates River. On the Tigris the natural flow during this period makes up 60–80 percent of the total annual flow and on the Euphrates 45–80 percent. During the low water period (July through September) the natural flow does not exceed 10 percent of the annual amount under normal conditions.

In order to increase water transport efficiency, minimize losses and waterlogging, and improve water quality, a number of new watercourses were constructed, especially in the southern part of the country. The Third River (also called Saddam River), which was completed in 1992, functions as a main outfall drain collecting drainage waters from more than 1.5 million ha of agricultural land from the north of Baghdad to the Gulf between the Euphrates and the Tigris. The length of the watercourse, completed in December 1992, is 565 km, with a total discharge of 210 m^3/s. In 1995 an estimated 17 million tons of salt was said to have been transported to the Gulf through the Third River. Other watercourses were also constructed to reclaim new lands or to reduce waterlogging.

Groundwater aquifers in Iraq consist of extensive alluvial deposits of the Tigris and Euphrates rivers, and are composed of Mesopotamian-clastic and carbonate formations. The alluvial aquifers have limited potential because of poor water quality. The Mesopotamian-clastic aquifers in the northwestern foothills consist of Fars, Bakhtiari and alluvial sediments. The Fars formation is made up of anhydrite and gypsum inter-bedded with limestone and covers a large area of Iraq. The Bakhtiari and alluvial formations consist of a variety of material, including silt, sand, gravel, conglomerate and boulders, with a thickness of up to 6 000 metres. Water quality ranges from 300 to 1 000 ppm. Another major aquifer system is contained in the carbonate layers of the Zagros Mountains. Two main aquifers are found in the limestone and dolomite layers, as well as in the Quaternary alluvium deposits. The limestone aquifer contributes large volumes of water through a number of springs. The alluvial aquifers contain large volume reservoirs and annual recharge is estimated at 620 million m^3 from direct infiltration of rainfall and surface water runoff. Water quality is good, ranging from 150 to 1 400 ppm (ESCWA, 2001).

Good quality subterranean water has been found in the foothills of the mountains in the northeast of the country and in the area on the right bank of the Euphrates. The aquifer in the northeast of Iraq has an estimated safe yield of between 10 and 40 m^3/sec at depths of 5–50 metres. Its salinity increases towards the southeast of the area until it reaches between 0.5 and 1 mg/l. The aquifers on the right bank of the Euphrates River, trapped between gypsum and dolomite at depths increasing towards the west where water is found at 300 m (at Abu-Aljeer), have an estimated safe yield of 13 m^3/sec. In the western part of that area the salinity of the water is only 0.3 mg/l compared with 0.5–1 mg/l in the eastern section. In other areas of the country good quality water is fairly limited because of high levels of salinity (Ministry of Irrigation, 1986). An estimated 0.08 km^3/year of water from the Umm er Radhuma aquifer enters Iraq from Saudi Arabia. Internal renewable water resources are estimated at 35.2 km^3/year (Table 2).

Total gross dam capacity of the major dams in the Tigris Basin is estimated at 102.2 km³, of which on-river dam capacity is 29.4 km³ (7 dams). The off-river storage Samarra-Tharthar Dam, constructed in 1954, has a capacity of 72.8 km³. It is filled with Wadi Tharthar waters and, since 1985, also with Euphrates water.

Total gross capacity of the major dams in the Euphrates Basin is estimated at 37.5 km³, of which on-river dam capacity is 34.2 km³. The off-river Ramadi-Habbaniya Dam, constructed in 1951, has a capacity of 3.3 km³; it can be filled with upstream Euphrates waters and drains into the Euphrates downstream (UNEP, 2001a).

There are eleven major wastewater treatment plants in Iraq, three of which are in Baghdad. All the treatment plants are located near rivers (three near the Euphrates, two near the Tigris, two near the Diala, and one each near the Kahla, the Aw Diwaniyah, the Husseinya and the Shatt Basrah). The total treatment capacity of these plants is 650 000 m³/day. The technologies used are: primary sedimentation, aeration and secondary sedimentation (chlorination) at five plants; primary sedimentation, trickling filtering and chlorination at three plants; primary sedimentation, extended aeration and chlorination at two plants; aeration lagoons and secondary sedimentation at one plant (UNEP, 2001b). Until now, the majority of wastewater after treatment has been discharged into rivers and drainage canals by gravity and there is no definite canal network for wastewater collection.

The two largest wastewater treatment plants were built in Baghdad County (Salih, 2001). The first, Al-Rustumia, was designed to handle an average flow of 204 million m³/year and the second, Al-Karkh, handles an average flow of 150 million m³/year. Baghdad city is generally supplied by less saline drinking water (0.8–1.2 dS/m) and this salinity increases 2–3 times in the wastewater. It can therefore be used without creating any salinity and alkalinity problems except for very sensitive crops. The sodium concentration is rather low, resulting in a sodium adsorption ratio (SAR) ranging between 2.68 and 3.12 for the Al-Rustumia station and between 4.38 and 5.24 for the Al-Karkh station. The chloride content of wastewater of the Al-Karkh station is fairly high for surface irrigation and not recommended for sprinkler irrigation, while the chloride content of the Al-Rustomia station is appropriate for surface irrigation but generally inadequate for sprinkler irrigation. The bicarbonate content of wastewater from both stations is adequate for surface irrigation but inappropriate for sprinkler irrigation. The phosphorus and potassium contents of wastewater from both stations are fairly low. Contents of iron, magnesium, chromium, zinc, cobalt and boron in wastewater of both stations are generally within acceptable limits.

In 2002, the total installed desalination capacity was 384 513 m³/day. This refers to the installed gross capacity (design capacity) (Wangnick Consulting, 2002).

Water use

In 2000, total water withdrawal was estimated at 66 km³, of which 79 percent for agricultural purposes, 6.5 percent for domestic supplies and 14.5 percent for industrial use (ESCWA, 2005) (Table 2, Figure 1 and Figure 2).

Hydroelectric power generation is about 17 percent of current electrical energy production in Iraq. Existing power plants have been neglected

FIGURE 1
Water withdrawal by sector
Total: 66 km³ in 2000

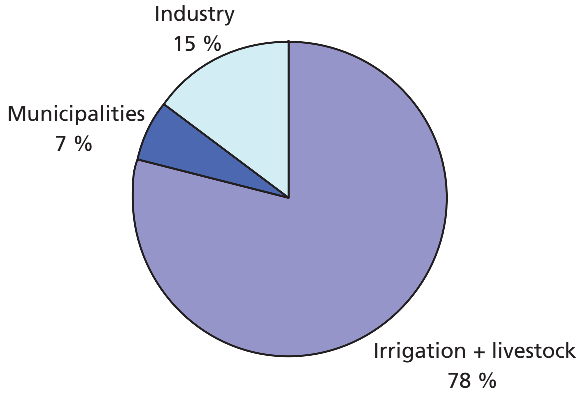
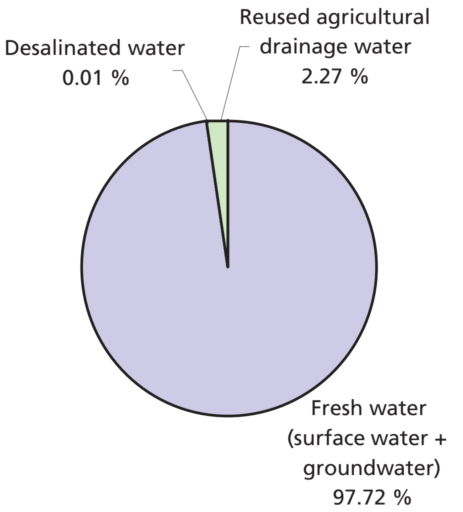


FIGURE 2
Water withdrawal by source
Total: 66 km³ in 2000



for over a decade and a number of new projects were suspended in the aftermath of the Gulf War. The volume and timing of water entering Iraq from neighbouring countries is a significant factor in hydropower production (UNDG, 2005).

International water issues

The water resources of Iraq depend largely on the surface water of the Tigris and Euphrates rivers and most of the natural renewable water resources of Iraq come from outside the country.

The protocol concerning the regulation of water use of the Euphrates and Tigris rivers dates back to 1946 when Turkey and Iraq agreed that the rivers' control and management depended to a large extent on the regulation of flow in Turkish source areas. At that time, 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 has unilaterally guaranteed to allow 15.75 km³/year (500 m³/s) of water of the Euphrates across the border to the Syrian Arab Republic, but no formal agreement has been reached so far on the sharing of the Euphrates water. According to an agreement between the Syrian Arab Republic and Iraq (1990), Syria agrees to share the Euphrates water with Iraq on a 58 percent (Iraq) and 42 percent (Syria) basis, which corresponds to a flow of 9 km³/year at the border with Iraq when using the figure of 15.75 km³/year from Turkey. Up to now, there has been no global agreement between the three countries concerning the Euphrates waters (FAO, 2004).

The construction of the Ataturk Dam, one of the projects of GAP 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 time that river flow would be interrupted for a period of one month, due to 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).

Turkey contributes about 90 percent of the total annual flow of the Euphrates, while the remaining part originates in the Syrian Arab Republic and very little is added in Iraq. Turkey also contributes 38 percent directly to the main Tigris River and another 11 percent to its tributaries, which join the main stream of the Tigris further downstream in Iraq. Most of the remainder comes from three tributaries originating in the Islamic Republic of Iran (FAO, 2004).

As shown, a number of crises have occurred in the Euphrates-Tigris Basin, partly due to 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 to be 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 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 veto right" over Turkey's development plans. Consequently, Turkey maintains that the Convention does not apply to it and is therefore not legally binding (Akanda *et al*, 2007). Problems regarding sharing water might arise between Turkey, the Syrian Arab Republic and Iraq, since according to different scenarios 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.

In 2002, a bilateral agreement between the Syrian Arab Republic and Iraq was signed concerning the installation of a Syrian pump station on the Tigris River for irrigation purposes. The quantity of water drawn annually from the Tigris River, when the flow of water is within the average, will be 1.25 km^3 with a drainage capacity proportional to the projected surface of 150 000 ha (FAO, 2002)

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 towards the solution of water-related problems among the three countries. The institute will conduct its studies at the facilities of the Atatürk 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

The oldest and most deeply rooted hydraulic civilization of the world started in Mesopotamia, from which agricultural and agro-ecological systems developed that are strongly related to the presence of water. The history of irrigation started about 7 500 years ago when the Sumerians built a canal to irrigate wheat and barley in Mesopotamia.

Irrigation potential is estimated at over 5.55 million ha, of which 63 percent in the Tigris Basin, 35 percent in the Euphrates Basin, and 2 percent in the Shatt Al-Arab Basin. Considering the soil resources, it is estimated that about 6 million ha are classified as excellent, good or moderately suitable for flood irrigation. With the development of water storage facilities, the regulated flow has increased and significantly changed the irrigation potential, which was estimated at 4.25 million ha only in 1976. However, irrigation development depends to a large extent on the volume of water released by the upstream countries.

The total managed water area was estimated at 3.5 million ha in 1990, all of it equipped for full or partial control irrigation (Table 3). The areas irrigated by surface water were estimated at 3 305 000 ha, of which 105 000 ha (3 percent) in the Shatt Al-Arab River Basin, 2 200 000 ha (67 percent) in the Tigris River Basin, and 1 000 000 ha (30 percent) in the Euphrates River Basin. However, not all these areas are actually irrigated, since a large part has been abandoned due to waterlogging and salinity. The areas irrigated from groundwater were estimated at 220 000 ha in 1990, with some 18 000 wells (Figure 3). About 8 000 ha were reported to be equipped for localized irrigation, but these techniques were not used. Water use efficiency at the farm level is reported to be poor.

In 1997, the total irrigated area was estimated at 3.4 million ha, of which 87.5 percent obtained water from river diversion, 9.2 percent from rivers using irrigation pumps,

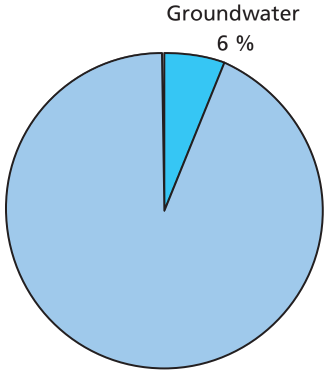
TABLE 3
Irrigation and drainage

Irrigation potential	2007	5 554 000	ha
Irrigation			
1. Full or partial control irrigation: equipped area	1990	3 525 000	ha
- surface irrigation		-	ha
- sprinkler irrigation		-	ha
- localized irrigation	1994	8 000	ha
• % of area irrigated from surface water	1990	93.8	%
• % of area irrigated from groundwater	1990	6.2	%
• % of area irrigated from mixed surface water and groundwater		-	%
• % of area irrigated from non-conventional sources of water		-	%
• area equipped for full or partial control irrigation actually irrigated	1997	3 404 000	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)	**1990**	**3 525 000**	**ha**
• as % of cultivated area	1990	59	%
• % of total area equipped for irrigation actually irrigated		-	%
• average increase per year over the last ... years		-	%
• 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)	**1990**	**3 525 000**	**ha**
• as % of cultivated area	1990	59	%
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		-	metric tons
• as % of total grain production		-	%
Harvested crops			
Total harvested irrigated cropped area	1998	2 428 000	ha
Annual crops: total	1998	2 068 000	ha
- Wheat	1998	717 000	ha
- Rice	1998	126 000	ha
- Barley	1998	785 000	ha
- Maize	1998	60 000	ha
- Millet	1998	3 000	ha
- Sorghum	1998	3 000	ha
- Other cereals	1998	1 000	ha
- Potatoes	1998	26 000	ha
- Pulses	1998	26 000	ha
- Vegetables	1998	226 000	ha
- Tobacco	1998	2 000	ha
- Cotton	1998	19 000	ha
- Soybean	1998	1 000	ha
- Sunflower	1998	49 000	ha
- Sesame	1998	23 000	ha
- Other annual crops	1998	1 000	ha
Permanent crops: total	1998	360 000	ha
- Sugar cane	1998	3 000	ha
- Citrus	1998	72 000	ha
- Other perennial crops	1998	285 000	ha
Irrigated cropping intensity (on full/partial control area actually irrigated)	1998	71	%

TABLE 3
Irrigation and drainage (continued)

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

FIGURE 3
Source of irrigation water
Total: 3 525 000 ha in 1990



3.1 percent from artesian wells and 1.2 percent from spring sources (FAO, 2003).

In December 1983 the first 87 500 ha stage of the massive Kirkuk Irrigation Project (renamed Saddam) was opened, of which more than 300 000 ha were eventually irrigated. In 1991 a large supplemental irrigation project, the North Al-Jazeera Irrigation Project, was launched in order to serve some 60 000 ha using a linear-move sprinkler irrigation system with water stored by the Mosul Dam (former Saddam Dam). Another irrigation project, the East Al-Jazeera Irrigation Project, involved the installation of irrigation networks on more than 70 000 ha of rainfed land near Mosul. These projects were part of a scheme to irrigate 250 000 ha of the Al-Jazeera plain. To the south of Baghdad, completed land reclamation schemes included Lower Khalis, Diwaniya-Dalmaj, Ishaqi, Dujaila and much of Abu Ghraib. The massive Dujaila project was intended to produce about 22 percent of Iraq's output of crop and animal products. Consultants have designed irrigation schemes for Kifl-Shinafiya, East Gharraf, Saba Nissan, New Rumaitha, Zubair, Bastora, Greater Musayyib and Makhmour. The project's main outfall canal, completed in December 1992, is known as the "Third River". It runs for 565 km from Mahmudiya, south of Baghdad, to Qurnah, north of Basra, and carries saline water to an outlet on the Gulf (Taylor & Francis Group, 2002).

More recently, a new development project on the "Dissemination of improved irrigation technologies" was introduced to increase wheat production. The target was to plant up to 0.5 million ha of wheat under supplemental irrigation by the year 2007. Currently, there are about 3 500 new farms in Mosul Province under supplemental irrigation, with an average size of holding of 25 ha per farm. Wheat is the major winter crop, covering 73 percent of the project area (ESCWA and ICARDA, 2003).

Role of irrigation in agricultural production, economy and society

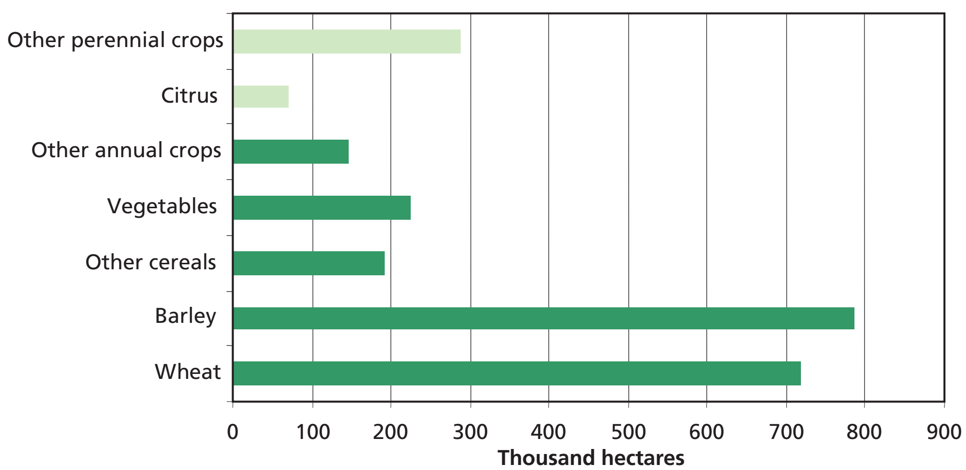
During the 1980s the State attempted to foster private sector investment in Iraq's agriculture. Oil revenues were used to acquire western technology and to lavish government subsidies on the sector. The government distributed high-yielding seeds and invested heavily in the irrigation infrastructure. The 1991 Gulf War resulted in significant damage to the irrigation and transportation infrastructure vital to Iraq's agricultural sector, but it is difficult to evaluate its extent or severity.

Between 75 and 85 percent of crop area is generally planted to grains (mostly wheat and barley). About one-third of Iraq's cereal production is produced under rainfed conditions in the foothills of the northwest in Iraqi-Kurdistan. Winter wheat and barley are planted in the fall (September–November) and harvested in the late spring (May–June). Yields on the rainfed crops are generally poor and vary significantly with rainfall amounts. The remaining two-thirds of Iraq's cereal production occur within the irrigated zone that runs along and between the Tigris and Euphrates rivers.

In 1991, there were 224 490 ha of irrigated wheat, with an average yield of 2.7 tons/ha, while the rainfed wheat area was estimated at 508 620 ha, with an average yield of 1.7 tons/ha. There were 200 770 ha of irrigated barley, with an average yield of 1.8 tons/ha, while the rainfed barley area was estimated at 323 730 ha, with an average yield of 1.3 tons/ha. In 1998 the total area planted with grain crops increased, giving 717 000 ha of irrigated wheat and 785 000 ha of irrigated barley (Table 3 and Figure 4). Other main irrigated crops are rice, maize, vegetables, sunflower, but also date and fruit trees, which are important for the economy of the southern part of the country. For the most part, a single crop is planted per year, although there is some multiple cropping of vegetables where irrigation water is available.

Record cropped areas were achieved in 1992 and again in 1993. However, agricultural productivity suffered from lack of fertilizers, agricultural machinery and the means of spraying planted areas with pesticides. Iraq's irrigation infrastructure fell into disrepair and salinity spread across much of the irrigated fields of central and southern Iraq. Moreover, a severe drought which persisted throughout much of the Middle East from 1999 through 2001 devastated crop output in Iraq. Cereal production in Iraq's rain-dependent northern zone was particularly hard hit, but even the irrigated production of the central and southern region suffered from diminished water availability (down to 43 percent of normal levels). As a result of the drought, Iraq's annual cereal production per capita plummeted from its already low 1999 level of 77 kg to only 39 kg by 2000. Shortage of fodder resulted in forced slaughter of sheep and compounded the impact

FIGURE 4
Irrigated crops
Total harvested area: 2 428 000 ha in 1998 (cropping intensity on equipped area actually irrigated: 71%)



of an outbreak of foot-and-mouth disease in 1998. An estimated one million head of livestock died due to lack of medicines (Schnepf, 2003).

Status and evolution of drainage systems

Throughout history the irrigated agriculture of Iraq's central and southern region has been menaced by salinization. Salinity was already recorded as a cause of crop yield reductions some 3 800 years ago. It spread across much of the irrigated fields as the Government ended its maintenance of the irrigation system. The water table of southern Iraq is saline and so close to the surface that it only takes a little injudicious over-irrigation to bring it up to root level and destroy the crop. High groundwater tables affect more than half of the irrigated land. Once severe salinization has occurred in soil, the rehabilitation process may take several years (Schnepf, 2003).

Half of the irrigated areas in central and southern Iraq were found to be degraded due to waterlogging and salinity in 1970. The absence of drainage facilities and, to a lesser extent, the irrigation practices (flooding) were the major causes of these problems. In 1978 a land rehabilitation programme was undertaken, comprising concrete lining for irrigation canals, and installation of field drains and collector drains. By 1989 a total of 700 000 ha had been reclaimed at a cost of around US$2 000/ha. According to more recent estimates 4 percent of the irrigated areas were severely saline, 50 percent medium saline and 20 percent slightly saline. Irrigation with highly saline waters (more than 1 500 ppm) has been practiced for date palm trees since 1977. The use of brackish groundwater is also reported for tomato irrigation in the south of the country.

Due to the relief and the sloping river beds the possibilities of draining the excess irrigation or flood water back to the rivers are few or none. A comprehensive network of sub-surface tile drains and surface drainage canals collects the drainage water from the agricultural fields and eliminates it through the Third River's main out-fall drain to the Shatt Al-Arab in an attempt to keep the irrigated lands free of salinization and waterlogging problems. Drainage water pumping stations are used to lift the effluent water to the main out-fall and onwards by gravity to the Gulf. Almost all land reclamation and development projects contain both irrigation and drainage components (FAO, 2003).

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

Institutions

Governance in Iraq is in a state of flux at present. The Ministry of Water Resources (MWR) is the bulk water supplier for the country and responsible for the whole national water planning, operating twenty-five major dams, hydropower stations and barrages and 275 irrigation pumping stations serving almost the entire irrigated area. The MWR comprises five commissions and eleven companies, employing 12 000 staff. Making the MWR functional again in the aftermath of the wars and collapse of the previous regime is a top priority and measures to achieve this are under way. Other key institutions related to water in Iraq include the Ministry of Agriculture, the Ministry of Energy, the Ministry of Municipalities and Public Works, the Ministry of Environment and other ministries and local governorates concerned with economic and human resources. Higher educational institutions could provide scientific support on water issues and potential human resources for the government. A few NGOs are springing up, such as the Iraq Foundation, which is dedicated to restoring the Mesopotamian marshlands (UNDG, 2005).

Policies and legislation

Water resources development and management plans were drawn up in the 1960s and 1980s. These studies included a comprehensive and detailed analysis of needs, opportunities and plans for the development and management of Iraq's water resources. Investments in water resources development over the years have generally followed the plans outlined in these documents. They have not been updated or revisited since their publication, but the population has grown substantially, much project development has taken place, multiple wars have been conducted, institutions and regimes have changed, and regional and world markets for products have become greatly altered (FAO, 2004).

A Law on Irrigation (No. 12 of 1995) and another on Environment (No. 3 of 1997) have been enacted (ESCWA, 2004).

ENVIRONMENT AND HEALTH

The present quality of water in the Tigris near the Syrian border is presumably good, including water originating in both Turkey and Iraq. Water quality degrades downstream, with major pollution inflows from urban areas such as Baghdad due to poor infrastructure for wastewater treatment. The water quality of the Euphrates entering Iraq is less than that of the Tigris, as it is currently affected by the return flow from irrigation projects in Turkey and the Syrian Arab Republic and is expected to get worse as more lands come under irrigation. The quality is further degraded as flood flows are diverted into off-stream storage in Tharthar and later returned to the river system. Salts in Tharthar are absorbed by the water stored there. The quality of water in both the Euphrates and Tigris is further degraded by return flows from land irrigated in Iraq as well as urban pollution. The amount and quality of water entering southern Iraq from Iranian territory is largely unknown, although it is clear that flows are impacted by irrigation return flow originating in the Islamic Republic of Iran (UNDG, 2005).

The deterioration of water quality and the heavy pollution from many sources are becoming serious threats to Iraq. One problem is the lack of any effective water monitoring network so that it is difficult to take measures to address water quality and pollution as it is impossible to identify the causes. Hence, the rehabilitation and reconstruction of the water monitoring network have becoming urgent to ensure water security.

The Mesopotamian Marshlands in the furthest downstream part of the Tigris and Euphrates Basin have been seriously damaged during the last two decades. Dewatering the marshland areas to foster agricultural production as well as to divert waters away from the marshes for political reasons has caused an adverse impact on the ecosystem and the indigenous populations. The historical marsh area of 17 000 km^2 has now shrunk to about 3 000 km^2 after construction of a number of dams upstream. The potential success of recent restoration efforts depends primarily on the availability of sufficient quantities of satisfactory quality water to the marshland areas.

The quantity and quality of water entering the Gulf is also an issue to be addressed since fisheries are an important food source for the region. Other environmental issues to be taken into account are the impact of water management and changed flow regimes on migrating fishes and terrestrial species and on the viability of riverine and floodplain ecosystems throughout the Tigris and Euphrates basins.

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

The development of irrigation as planned in the upstream countries, particularly the southeastern Anatolian (GAP) project in Turkey and the irrigation projects in the Syrian Arab Republic and in the Islamic Republic of Iran on tributaries of the Tigris and on the Dez and Karun, will reduce Iraqi irrigation potential unless an agreement is reached on the sharing of waters between the riparian countries. The regulation capacities on the Euphrates River are already greater than the entire average flow.

It has been pointed out in many quarters that the Tigris and Euphrates rivers are complicated, both politically and hydrologically, and therefore there is need for cooperation among riparian countries to ensure water security and to prevent potential water-related disputes in the future. Iraq is at the furthest downstream point of the Tigris and Euphrates rivers and a large part of the country's water resources originate in Turkey; moreover, almost all of the flow of the Karkheh River that runs through the marshes in southern Iraq before joining the Tigris and Euphrates originates in Iranian territory.

It is thought that between 2020 and 2030 a shortage may arise in the Tigris and Euphrates owing to growing demand in the riparian countries and that an emergency situation will develop already around 2020 because the expected annual 4 km^3 of water remaining as surplus in the two rivers will not be sufficient for the drainage of the Tigris and Euphrates Basin into the sea. Since water shortages are forecast to occur with the development of irrigation, solutions have to be found for an integrated basin-level planning of water resources development.

Undertaking improvement in water management in Iraq will require substantial investment, which must, at least initially, come from outside sources. Needs and opportunities for water-related investments must be identified and prioritized, costs estimated, economic feasibility determined, and financing and repayment plans prepared.

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Israel

GEOGRAPHY, CLIMATE AND POPULATION

Geography

Israel occupies a total area of about 20 770 km² (CIA, 2008). It is bordered by Lebanon in the north, the Syrian Arab Republic, the West Bank and Jordan in the east, and Egypt and the Gaza Strip in the south and southwest. The total border length is 857 km. It has coastlines on the Mediterranean in the west (194 km) and the Gulf of Eilat (also known as the Gulf of Aqaba) in the south (12 km). Administratively Israel is divided into 6 districts: Jerusalem, Haifa, Tel Aviv and the Northern, Central and Southern districts.

The country is divided into four regions:

- The Mediterranean coastal plain stretches from the Lebanese border in the north to Gaza Strip in the south, interrupted only by Cape Carmel at Haifa Bay. It is about 40 km wide at Gaza Strip and narrows toward the north to about 5 km at the Lebanese border.
- The central highland region. In the north of this region lie the mountains and hills of Upper Galilee and Lower Galilee; farther to the south are the Samarian Hills with numerous small, fertile valleys; and south of Jerusalem are the mainly barren hills of Judea. The central highlands average 610 metres in height and reach their highest elevation at Mount Meron, at 1 208 metres, in Galilee near Zefat (Safad). Several valleys cut across the highlands roughly from east to west; the largest is the Yizreel or Jezreel Valley (also known as the Plain of Esdraelon).
- The Jordan Rift Valley is a small part of the 6 500 km long Syrian - East African Rift. In Israel the Rift Valley is dominated by the River Jordan, Lake Tiberias (also known as the Sea of Galilee and to Israelis as Lake Tiberias), and the Dead Sea.
- The Negev Desert comprises approximately 12 000 square kilometres, more than half of Israel's total land area. Geographically it is an extension of the Sinai Desert, forming a rough triangle with its base in the north near Beersheba, the Dead Sea, and the southern Judean Hills, and its apex in the southern tip of the country at Elat. Topographically, it parallels the other regions of the country, with lowlands in the west, hills in the central portion, and the Nahal Ha'Arava as its eastern border.

In 2004, the agricultural area in Israel amounted to 428 000 ha. Of the total agricultural area 43 percent was in the Southern and Jerusalem Districts, 42 percent in the Northern and Haifa Districts and 13 percent in the Central and Tel Aviv Districts. Moreover 75 percent of the agricultural area was used by collective localities, 10 percent by other Jewish farms and 15 percent by non-Jewish farms (CBS, 2004). In 2005, the cultivated area covered 392 000 ha, of which 317 000 ha of annual crops and 75 000 ha of permanent crops (Table 1).

ISRAEL **FAO - AQUASTAT, 2008**

TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2008	2 077 000	ha
Cultivated area (arable land and area under permanent crops)	2005	392 000	ha
• as % of the total area of the country	2005	18.9	%
• arable land (annual crops + temp. fallow + temp. meadows)	2005	317 000	ha
• area under permanent crops	2005	75 000	ha
Population			
Total population	2005	6 725 000	inhabitants
• of which rural	2005	8.3	%
Population density	2005	323.8	inhabitants/km^2
Economically active population	2005	2 947 000	inhabitants
• as % of total population	2005	43.8	%
• female	2005	43	%
• male	2005	57	%
Population economically active in agriculture	2005	64 000	inhabitants
• as % of total economically active population	2005	2.2	%
• female	2005	20	%
• male	2005	80	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2007	161 820	million US$/yr
• value added in agriculture (% of GDP)	2005	1.8	%
• GDP per capita	2005	19 292	US$/yr
Human Development Index (highest = 1)	2005	0.932	
Access to improved drinking water sources			
Total population	2006	100	%
Urban population	2006	100	%
Rural population	2006	100	%

Climate

Israel has a Mediterranean climate characterized by long, hot, dry summers and short, cool, rainy winters, modified locally by altitude and latitude. The climate is determined by Israel's location between the subtropical aridity characteristic of Egypt and the subtropical humidity of the Levant or eastern Mediterranean. January is the coldest month, with temperatures from 5 to 10°C, and August is the hottest month at 18 to 38°C. About 70 percent of the average rainfall in the country falls between November and March, while the months June through August are often rainless. Rainfall is unevenly distributed, decreasing sharply as one moves southward. In the extreme south, rainfall averages less than 100 millimetres annually; in the north, average annual rainfall is more than 1 100 millimetres. Rainfall varies from season to season and from year to year, particularly in the Negev Desert. Precipitation is often concentrated in violent storms, causing erosion and flooding. During January and February, it may take the form of snow at the higher elevations of the central highlands, including Jerusalem (U.S. Library of Congress, 1988).

Population

The population of Israel is 6.7 million (2005), of which 8 percent is rural. The average annual population growth rate was 2 percent during the period 2000–2005. Population density is 324 inhabitants/km^2 but it is greatly dissimilar from one region to another (Table 1 and Table 2). In 2006, the whole population had access to safe drinking water and improved sanitation.

ECONOMY, AGRICULTURE AND FOOD SECURITY

In 2007 the Gross Domestic Product (GDP) was US$161.8 billion and, in 2005, agriculture accounted for less than 2 percent of GDP (Table 1). The economically active

TABLE 2
Area and population share by district in 2004 (Central Bureau of Statistics, 2005)

District	Area (%)	Population (%)
Jerusalem	3.0	12.1
Northern	20.7	17.0
Haifa	4.0	12.4
Central	6.0	23.5
Tel Aviv	0.8	17.1
Southern	65.5	14.3
Total	**100.0**	**96.4**

*In 2004, 3.6 percent of total population lived in Jewish localities in the Judea, Samaria and Gaza area

population is about 2.95 million (2005) of which 57 percent is male and 43 percent female. In agriculture, 64 000 inhabitants are economically active, of which 80 percent are male and 20 percent female.

Agricultural export (fresh and processed) for 2005 reached US$1 680 million, 4.6 percent of the country's total exports. Exported fresh produce amounted to US$1 024 million, mainly to the European Union, while exported processed food products totalled US$656 million. In addition, a total of US$1 900 million of agricultural inputs were exported (2004). This is the outcome of advanced agricultural technology, which has created a thriving industry with sophisticated industrial inputs. Hands-on experience in local agriculture serves as a laboratory for the development, design and manufacture of new input technologies.

Much of Israel's agriculture is based on cooperative communities (kibbutz and moshav), founded on nationally-owned land that is provided on a long-term lease. Some of these communities date back to the early 20th century. The kibbutz is a rural community of several hundred inhabitants who run a large communal production unit. Kibbutz members jointly own the means of production and share social, cultural, and economic activities. Currently, most of the kibbutz income comes from non-agricultural activities (industrial enterprises, agro-tourism and services) and many are undergoing extensive reorganization. Another type of cooperative community, based on 50 to 120 individual family farms, is the moshav, which is defined and registered as an "agricultural cooperative society". The moshav is based on the shared allocation of resources, such as farm land, water quotas, and other productive inputs, as well as, in some cases, the provision of packing and marketing facilities. The residents in both types of communities are provided with a package of municipal services. The kibbutz and moshav communities currently account for more than 80 percent of the country's agricultural produce. A third type of farming community is the non-cooperative moshav, a village of farmers on mostly privately-owned land. Some moshav farmers are organized in local cooperatives operating productive assets (such as packinghouses and wineries). In addition to the Jewish agricultural sector, Arab villages are located in Israel's rural areas. These villages focus mainly on the production of small livestock (sheep and goats), vegetables, field crops and olives (MARD, 2006).

WATER RESOURCES AND USE

Water resources

The only river in Israel is the Jordan. The main sources of fresh water in Israel include:

- Lake Kinneret or Lake Tiberias (the Sea of Galilee), which divides the upper and lower portions of the Jordan River system, is the only natural freshwater lake in Israel. It has traditionally provided about a third of the country's domestic, agricultural and industrial water requirements. Lake Tiberias' catchment area is 2 730 km^2 and the surface area of the lake is 165 km^2 with an estimated storage volume of 710 million m³. Lake Tiberias is the lowest freshwater lake in the world. The total average annual inflow of water into Lake Tiberias amounts to 1 km³, of which some 250 million m³ serve consumers in the region, about 450 million m³ are withdrawn from the lake to serve consumers throughout the country by means of the National Water Carrier and about 300 million m³ are lost by evaporation. The water level has been traditionally regulated between 209 m and 213 m below sea level.

- The Coastal Aquifer is a sandstone aquifer which extends along 120 kilometres of the Mediterranean coastline. It is naturally recharged by precipitation and artificially recharged by water from the National Water Carrier, effluents and excess irrigation water percolating from agricultural, industrial and domestic land uses as well as from streams and wadis. The aquifer is also a valuable storage basin since sandstone layers hold water efficiently. It has a mean annual recharge of 250 million m³ in addition to 50 million m³ of agricultural drainage water.
- The Mountain Aquifer (Yarkon-Taninim) is a limestone aquifer which underlies the foothills in the centre of the country. The basin is comprised of three subaquifers: the Western Basin, known as the Yarkon Taninim Aquifer, flows north and westward and discharges in the Taninim Springs on the Mediterranean coast while the Northeastern and Eastern Basins discharge in the Beit Shean Springs and the Jordan Rift Valley and Dead Sea. The Yarkon Taninim Aquifer is regenerated by precipitation with average annual renewable recharges of about 350 million m³.
- Relatively smaller aquifers are located in Western Galilee, Eastern Galilee, the Jordan Rift, and the Arava valley.

Total internal renewable water resources are estimated at 750 million m³/year (Table 3). About 250 million m³ is surface water and 500 million m³ groundwater and the overlap between surface water and groundwater is considered to be negligible. Surface water entering the country is estimated at 305 million m³/year, of which 160

TABLE 3
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	435	mm/yr
	-	9.0	10^9 m³/yr
Internal renewable water resources (long-term average)	-	0.75	10^9 m³/yr
Total actual renewable water resources	-	1.78	10^9 m³/yr
Dependency ratio	-	57.87	%
Total actual renewable water resources per inhabitant	2005	265	m³/yr
Total dam capacity		-	10^6 m³
Water withdrawal			
Total water withdrawal	2004	1 954	10^6 m³/yr
- irrigation + livestock	2004	1 129	10^6 m³/yr
- municipalities	2004	712	10^6 m³/yr
- industry	2004	113	10^6 m³/yr
• per inhabitant	2004	296	m³/yr
Surface water and groundwater withdrawal	2004	1 552	10^6 m³/yr
• as % of total actual renewable water resources	2004	87.2	%
Non-conventional sources of water			
Produced wastewater	2005	450	10^6 m³/yr
Treated wastewater	2005	283	10^6 m³/yr
Reused treated wastewater	2002	262	10^6 m³/yr
Desalinated water produced	2007	140	10^6 m³/yr
Reused agricultural drainage water		-	10^6 m³/yr

million m³ from Lebanon (including 138 million m³ from Hasbani), 125 million m³ from the Syrian Arab Republic, and 20 million m³ from the West Bank. Groundwater entering the country is estimated at 725 million m³/year, of which 325 million m³ from the West Bank, 250 million m³ from the Syrian Arab Republic (Dan Springs) and 150 million m³ from Lebanon (Lake Hulah). The total renewable water resources are thus 1 780 million m³/year, of which 92 percent is considered to be exploitable. About 25 million m³/year of groundwater flow from the country to the Gaza Strip.

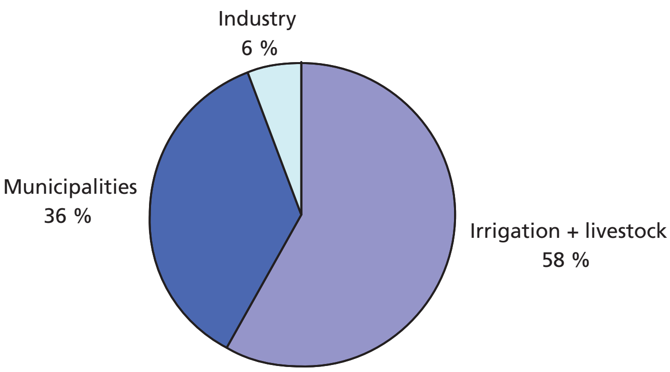
Mekorot, Israel's national water supply company, has built and operated small- and medium-size desalination facilities in the southern part of the country since the 1960s. Eilat at the southern tip of the country by the Red Sea was the first city to use desalination. Some 29 small plants generate 25 million cubic meters of water per year, mainly from brackish water. A decision to desalinate on a larger scale was taken in 2000 as a result of Israel's growing water scarcity. The national goal is to produce 750 million m³/year of desalinated water in 2020 (MAE, 2005). In the near future a string of desalination plants along the Mediterranean coast will produce 400 million cubic meters per year. One large plant for the desalination of seawater was recently completed on the Mediterranean coast, and is now producing 115 million cubic meters a year of potable water (MITL, 2008). Using the reverse osmosis process, this plant is generating water for about 60 cents per cubic meter. All tenders issued for desalination facilities stipulate stringent threshold levels for water quality and provide incentives for even higher water qualities, especially in terms of chloride levels, in order to allow for irrigation without the attendant problem of soil salinity. In 2002, the total installed gross desalination capacity (design capacity) in Israel was 439 878 m³/day or 160.6 million m³/year (Wangnick Consulting, 2002).

Out of a total of 450 million m³ of sewage produced in Israel, about 96 percent is collected in central sewage systems and 64 percent of the effluents are reclaimed (290 million m³); 283 million m³ are adequately treated. Local authorities are responsible for the treatment of municipal sewage. In recent years new or upgraded intensive treatment plants have been set up in municipalities throughout the country. The ultimate objective is to treat 100 percent of Israel's wastewater to a level enabling unrestricted irrigation in accordance with soil sensitivity and without risk to soil and water sources (MOE, 2005).

Water use

In 2004, water consumption amounted to 1.95 km³, almost identical to 2000 and 11 percent more than in 1986 (1.76 km³). Agriculture accounted for 58 percent whereas it was 64 and 71 percent in 1993 and in 1983, respectively. Municipal use accounted for 36 percent and industrial purposes for 6 percent (Table 3, Table 4 and Figure 1). Freshwater withdrawal amounted to almost 80 percent of the total actual renewable water resources (Figure 2).

FIGURE 1
Water withdrawal by sector
Total: 1.954 km³ in 2004



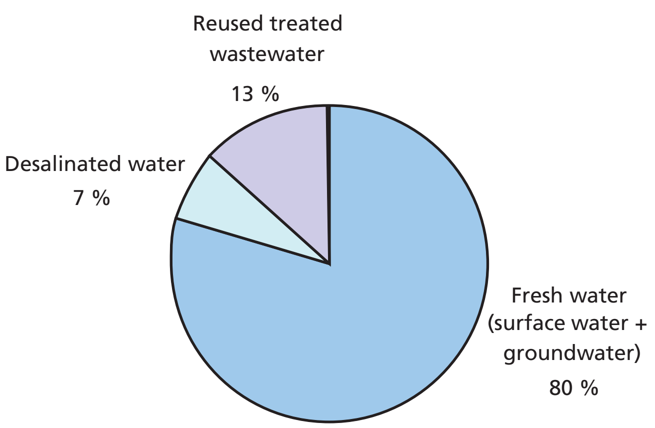
Successive years of drought have dramatically lowered water levels in all of the main reservoirs. In fact, 1998/99 was the worst drought year in Israel for the past 100 years. The following years were also characterized by less than average rainfall which led to a shortfall of some 0.5 million m³ in Israel's water balance each year, in

TABLE 4
Water consumption in Israel in million m³ (Statistical Abstract of Israel, 2006)

	1990		2000		2002		2003		2004	
	Vol.	%	Vol.	%	Vol.	%	Vol.	%	Vol.	%
Agriculture	1 216	67	1 138	59	1 021	56	1 045	56	1 129	58
Domestic purposes	482	27	662	34	688	38	698	38	712	36
Industrial uses	106	6	124	6	122	7	117	6	113	6
Total	**1 804**	**100**	**1 924**	**100**	**1 831**	**100**	**1 860**	**100**	**1 954**	**100**

comparison to an average year. The winters of 2002/03 and 2003/04 were characterized by average and higher than average rainfall which led to a significant rise in the water level of Lake Tiberias and in the collection of floodwater in catchment reservoirs. However, the country's aquifers have remained depleted. It is estimated that increased water demand and decreased water availability has led to a cumulative deficit of nearly 2 000 million m³.

FIGURE 2
Water withdrawal by source
Total: 1.954 km³ in 2004



The National Water Carrier of Israel (in Hebrew commonly called HaMovil) is the main water project of Israel. Its main task is to transfer water from the rainy north of the country to the centre and arid south and to enable efficient use of water and regulation of water supply in the country. Most of the water works in Israel are combined with the National Water Carrier, the length of which is about 130 kilometers. Early plans were made before the establishment of the state of Israel but detailed planning started only after Israel's independence in 1948. The construction of the project started during the planning phase, long before the detailed final plan was completed and signed in 1956. The carrier consists of a system of aqueducts, tunnels, reservoirs and large-scale pumping stations. Building the carrier was a considerable technical challenge as it traverses a wide variety of terrains and elevations

International water issues

In 1951, Jordan announced its plan to divert part of the Yarmouk River via the East Ghor Canal to irrigate the East Ghor area of the Jordan Valley. In response, Israel began construction of its National Water Carrier (NWC) in 1953, resulting in military skirmishes between Israel and the Syrian Arab Republic. In 1955, the Johnston Plan called for the allocation of 55 percent of available water in the Jordan River basin to Jordan, 36 percent to Israel, and 9 percent each to the Syrian Arab Republic and Lebanon, and was never signed by the countries involved, since the Arab riparians insisted that the United States government was not an impartial Third Party, but it has served as a general guideline for appropriations within the basin. In 1964, the NWC opened and began diverting water from the Jordan River valley. This diversion led to the Arab Summit of 1964 where a plan was devised to begin diverting the headwaters of the Jordan River to the Syrian Arab Republic and Jordan. From 1965 to 1967 Israel attacked these construction projects in the Syrian Arab Republic, and along with other factors this conflict escalated into the Six Day War in 1967 when Israel completely destroyed the Syrian diversion project and took control of the Golan Heights, the West Bank, and the Gaza Strip. This gave Israel control of the Jordan River's headwaters and significant groundwater resources. The most recent directly water-related conflict occurred in 1969 when Israel attacked Jordan's East Ghor Canal due to suspicions that Jordan was diverting excess amounts of water (Green Cross Italy, 2006). Later on, Israel and Jordan acquiesced to the apportionment contained in the non-ratified 1955 Johnston Plan for sharing the Jordan Basin's waters (Milich and Varady, 1998). In 1978, Israel invaded Lebanon, giving Israel temporary control of the Wazzani springs that feed the Jordan River. The Golan Heights have been under Israeli law, jurisdiction, and administration since 1981, which however has not been recognized by the United Nations Security Council.

In 1994, the Jordanian-Israeli Peace Treaty included agreed upon articles on water presented in Annex II – water related matters. According to the articles of this annex, Jordan is entitled to store 20 million m^3 of the Upper Jordan winter flow on the Israeli side (in Lake Tiberias) and get it back during the summer months. Jordan is entitled to get 10 million m^3 of desalinated water from the saline Israeli springs near Tiberias and until the desalination plant is erected Jordan can get this quantity in summer from Lake Tiberias. Jordan can build a regulating/storage dam on the Yarmouk downstream of the diversion point of Yarmouk water to the KAC. Jordan can also build a dam of 20 million m^3 capacity on the Jordan River and on its reach south of Lake Tiberias on the border between Jordan and Israel. Later, Jordan and Israel agreed to provide Jordan with 50 million m^3 of desalinated water from the Israeli saline springs south of Lake Tiberias, and until the desalination plant is erected, Israel is providing Jordan with 25 million m^3 from Lake Tiberias through the summer months. The regulating dam on the Yarmouk River was built and the water conveyor to transport water from Lake Tiberias in Israel to the KAC in Jordan was constructed just after the signing of the Peace Treaty.

More than 40 years of Israeli occupation of the West Bank and the Gaza Strip (WBGS) have been accompanied by a series of laws and practices targeting land and water resources in WBGS. Water resources were confiscated for the benefit of the Israeli settlements in the Ghor. Palestinian irrigation pumps on the Jordan River were destroyed or confiscated after the 1967 war and Palestinians are not allowed to use water from the Jordan River system. In other zones, the Israeli authorities introduced quotas on existing irrigation wells to restrict the amount of water pumped from these wells. Furthermore, the authorities did not allow any new irrigation wells to be drilled by Palestinian farmers, while it provided fresh water and allowed drilling wells for irrigation purposes at the Jewish settlements in the West Bank and Gaza Strip. In 1993, the "Declaration of Principles on Interim Self-Government Arrangements" was signed between Palestinians and Israelis, which called for Palestinian autonomy and the removal of Israeli military forces from the Gaza Strip and Jericho. Among other issues, this bilateral agreement called for the creation of a Palestinian Water Administration Authority and cooperation in the field of water, including a Water Development Program prepared by experts from both sides. In September 1995, the "Israeli-Palestinian Interim Agreement on the West Bank and the Gaza Strip", commonly referred to as "Oslo II", was signed. The question of water rights was one of the most difficult to negotiate, with a final agreement postponed to be included in the negotiations for final status arrangements. However a significant compromise was achieved between the two sides: Israel recognized Palestinian water rights (during the interim period a quantity of 70-80 million m^3 should be made available to the Palestinians), and a Joint Water Committee was established to cooperatively manage West Bank water and to develop new supplies. This Committee also supervises joint patrols to investigate illegal water withdrawals. No territory whatsoever was identified as being necessary for Israeli annexation due to access to water resources (Wolf, 1996). In 2003, the Roadmap for Peace, developed by the United States, in cooperation with

Russia, the European Union, and the United Nations (the Quartet), was presented to Israel and the Palestinian Authority, with the purpose of a final and comprehensive settlement of the Israel-Palestinian conflict.

In 1999, and due to drought, Israel decided to reduce the quantity of water piped to Jordan by 60 percent which led to a sharp response from Jordan. Disputes of this kind are not unexpected in the future; however, the peace agreements have had the benefit of restricting such conflicts to political rather than military solutions. The fact that the joint water commission for Israel and the Palestinian Authority has continued to meet to discuss critical issues even during the current period of hostilities illustrates the progress that has already been made (Green Cross Italy, 2006).

In 2002, the water resources of the Hasbani basin became a source of mounting tension between Lebanon and Israel, when Lebanon announced the construction of a new pumping station at the Wazzani springs. The springs feed the Hasbani River, which rises in the south of Lebanon and crosses the frontier to feed the Jordan and subsequently the Sea of Galilee, which is used as Israel's main reservoir. The pumping station was completed in October 2002. Its purpose was to provide drinking water and irrigation to some sixty villages on the Lebanese side of the Blue line. October 2002 also marked the high point of tension between Israel and Lebanon, with a real risk of armed conflict over the station. The Israelis complained about the lack of prior consultation whereas the Lebanese contended that the project was consistent with the 1955 Johnston Plan on the water resources of the region. The EU and USA both sent envoys to the region in late 2002 in response to the rising tensions (EU, 2004).

In 2008, negotiations between Israel and the Syrian Arab Republic were taking place with the objective of solving the Golan Heights conflict.

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

Since the early 1950s, intensive efforts have been invested in irrigation research. It was found that water use is much more efficient in pressurized irrigation than in surface irrigation. An irrigation equipment industry was established, mainly in kibbutzim, which developed innovative technologies and accessories such as drip irrigation (surface and subsurface), automatic valves and controllers, media and automatic filtration, low-discharge sprayers and mini-sprinklers, compensated drippers and sprinklers. Most of the irrigation is controlled by automatic valves and computerized controllers. Due to the division into plots and the harsh topographical conditions, only limited areas can be irrigated by mechanized systems, such as pivot irrigation. The innovative irrigation industry has a worldwide reputation and more than 80 percent of its production is exported.

In 2004, 225 000 ha were equipped for irrigation in Israel and localized irrigation (mostly drip irrigation) supplies over 75 percent of the total irrigated area (Table 5, Table 6 and Figure 3). Over the past fifty years, the average annual water application per hectare has decreased from 8 000 m^3 to 5 000 m^3, while agriculture has spread to the more arid regions in the south and east.

FIGURE 3
Irrigation techniques
Total 225 000 ha in 20044

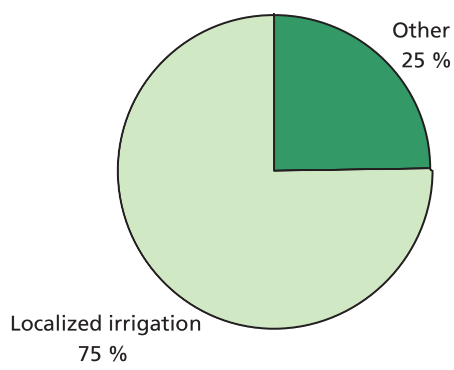


TABLE 5
Irrigation and drainage

Irrigation potential		**-**	**ha**
Irrigation			
1. Full or partial control irrigation: equipped area	2004	225 000	ha
- surface irrigation		-	ha
- sprinkler irrigation		-	ha
- localized irrigation	2004	168 750	ha
• % of area irrigated from surface water		-	%
• % of area irrigated from groundwater		-	%
• % of area irrigated from mixed surface water and groundwater		-	
• % of area irrigated from mixed 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)	**2004**	**225 000**	**ha**
• as % of cultivated area		57	%
• % of total area equipped for irrigation actually irrigated		-	%
• average increase per year over the last 7 years	1997-2004	2.1	%
• 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)	**2004**	**225 000**	**ha**
- as % of cultivated area		57	%
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	2002	181 570	ha
• Annual crops: total	2000	117 190	ha
- Field crops	2000	64 030	ha
- Vegetables (including potatoes)	2000	37 670	ha
- Melons	2000	10 060	ha
- Cotton	2000	11 000	
- Chickpeas	2000	7 500	
- Flowers (including garden plants)	2000	5 430	ha
• Permanent crops: total	2000	73 060	ha
Irrigated cropping intensity (on full/partial control area actually irrigated)		-	%
Drainage – Environment			
Total drained area	1987	100 000	ha
- part of the area equipped for irrigation drained	1987	100 000	ha
- other drained area (non-irrigated)	1987	0	ha
• drained area as % of cultivated area		-	%
Flood-protected areas		-	ha
Area salinized by irrigation	1993	27 820	ha
Population affected by water-related diseases		-	inhabitants

Production under protected conditions (obviously 100 percent irrigated) has become the principal way for Israeli growers to ensure a constant, year-round supply of high quality products, while minimizing chemical use. The total area covered with greenhouses, shade-houses and walk-in tunnels increased from 900 ha in the 1980s

TABLE 6
Use of land and water in agricultural production (MARD, 2004)

	Unit	1949	1970	1997	2001	2004
Total cultivated land	1 000 ha	165	411	410	-	380
Cultivated land under irrigation	1 000 ha	30	172	194	-	225
Water consumption	10^6 m³	257	1 340	1 287	1 021	1 129
Potable water	10^6 m³	-	-	-	563	601
Recycled and brackish water	10^6 m³	-	-	-	458	527

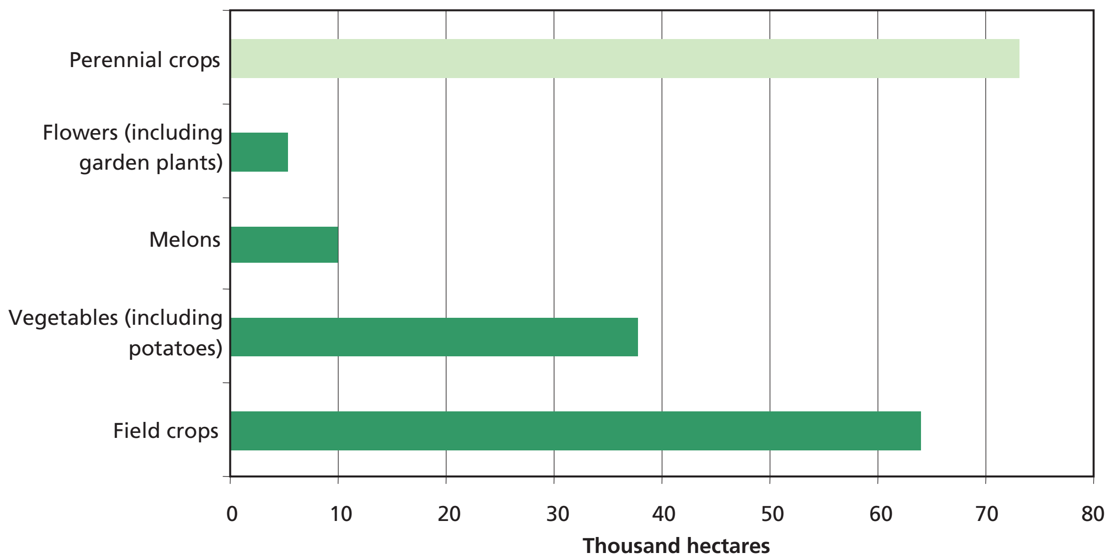
to about 6 800 ha in 2005, with 4 000 ha for vegetables and 2 800 ha for floriculture, representing an average annual growth of 5 to 8 percent. The average farm size is 4 ha for vegetable production and 1.2 ha for flower production (MARD, 2006).

Role of irrigation in agricultural production, the economy and society

In 2002, the total harvested irrigated area was 181 570 ha. In 2000, the harvested irrigated area was 190 250 and consisted of permanent crops (38 percent), field crops (34 percent), vegetables (20 percent including potatoes), melons (5 percent), and flowers (3 percent including garden plants) (Table 5, Table 7 and Figure 4).

Crops like flowers, vegetables and permanent crops are predominantly irrigated while 65 percent of field crops are rainfed. The main field crop is winter wheat but it is largely a non-irrigated crop, and therefore yields are dependent on the amount of rainfall and its distribution throughout the winter months. Wheat for grain is mostly grown in the country's dry southern regions and the north-eastern interior valleys, enabling extensive use of agricultural land. Almost the entire 11 000 ha of the cotton crop is drip-irrigated with Israeli-made equipment. Cotton yields per land unit are among the highest in the world, averaging 5.8 tonnes/ha for raw Acala cotton, with 2.0 tonnes of fibre, and 5.3 tonnes/ha for raw Pima cotton, with 1.8 tonnes of fibre. The cotton sector is totally mechanized. The introduction of effluents for irrigation has contributed to a significant reduction in growing costs. Moreover most sunflower crops are drip-irrigated, achieving significant savings in water: 1 800-2 500 m^3 of water

FIGURE 4
Irrigated crops
Total harvested area: 190 250 ha in 2000



are sufficient to produce two to 3 tonnes/ha. About 7 500 ha of irrigated chickpeas are grown and achieved a yield of 3 tonnes/ha in 2004-2005 (MARD, 2006).

Gross investments in farms amounted to US$500 million in 2004, of which 1 percent was devoted to irrigation systems (Table 8). Moreover, this sector represented 3 percent of the total net capital stock in farms (Table 9).

TABLE 7
Area of Field Crops, Vegetables, Potatoes and Melons in thousand hectares (CBS, 2006)

	2000	1999	1998	1995	1990	1980	1970
Field crops – Total	184.96	182.49	218.02	218.45	219.55	259.26	251.78
- Irrigated	64.03	69.57	83.41	79.75	90.37	76.76	63.73
- Rainfed	120.93	112.92	134.61	138.70	129.18	182.50	188.05
Vegetables, Potatoes, Melons - Total	55.11	55.54	53.76	55.83	46.07	35.52	34.57
Vegetables – Total	26.98	27.40	25.43	26.94	25.80	22.28	19.93
Potatoes – Total	11.29	10.61	8.95	8.12	6.25	5.02	4.83
Melons – Total	16.84	17.53	19.38	20.77	14.02	8.22	9.81
Watermelons: not irrigated	6.27	6.55	10.29	11.66	4.81	3.11	5.49
Watermelons: irrigated	7.10	7.68	6.29	5.45	4.52	2.13	2.10
Melons: not irrigated	0.51	0.56	0.78	1.47	1.64	1.12	1.58
Melons: irrigated	2.96	2.74	2.02	2.19	3.05	1.86	0.64

TABLE 8
Gross investments in farms ($US million, at current prices), by type of asset (CBS, 2006)

	2005	2004	2003	2000
GROSS INVESTMENT - TOTAL	470.48	450.15	375.65	375.21
Fruit plantations	60.30	57.56	52.57	61.94
Livestock (1)	6.74	5.92	9.35	11.62
Agricultural equipment and machinery (2)	247.34	251.08	193.08	180.73
Agricultural structures	125.90	96.19	70.37	39.73
Irrigation systems	4.60	4.68	4.86	8.34
Greenhouses (3)	13.25	10.47	11.00	41.98
Fish ponds/industrialized fishery	0.59	5.70	2.22	0.54
Land reclamation and drainage	11.76	18.55	32.20	30.33

1. Changes in livestock inventory, not in investment
2. Includes commercial vehicles over 4 tonnes
3. The investment is calculated according to changes in their area

TABLE 9
Capital stocks in farms ($US million, at 2000 prices), by type of asset (CBS, 2006)

	2005	2004	2003	2000
Gross Capital Stock TOTAL	**4281.26**	**4300.74**	**4446.92**	**4587.06**
Fruit plantations	837.15	838.42	855.57	835.27
Livestock	292.95	292.01	294.21	303.29
Agricultural equipment and machinery	1313.63	1292.58	1330.59	1287.65
Agricultural structures	1017.84	1008.70	1027.17	1134.76
Irrigation systems	147.73	177.58	223.36	311.43
Greenhouses	105.58	115.37	125.35	108.98
Fish ponds	135.91	138.06	147.27	173.27
Land reclamation and drainage	430.48	438.04	443.40	432.42
Net Capital Stock TOTAL	**2196.96**	**2177.69**	**2239.11**	**2293.00**
Fruit plantations	404.44	399.47	406.50	389.75
Livestock	292.95	292.01	294.21	303.29
Agricultural equipment and machinery	608.23	581.99	601.25	585.90
Agricultural structures	531.96	513.57	510.67	521.95
Irrigation systems	56.12	60.54	67.82	95.07
Greenhouses	35.89	44.11	53.59	51.08
Fish ponds	54.21	57.29	64.88	89.97
Land reclamation and drainage	213.16	228.70	240.18	255.99

Status and evolution of drainage systems

In 1987, the area equipped for irrigation drained was estimated at around 100 000 ha (Table 5), of which 94 000 ha of surface drainage and 6 000 ha of horizontal sub-surface drainage. In 1993, the area salinized by irrigation was 27 820 ha (ICID, 2007).

In 2004, land reclamation and drainage represented 4 percent of the gross investments and 10.5 percent of the total net capital stock in farms (CBS, 2006).

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

Institutions

The Water Commission, previously under the Ministry of Agriculture and Rural Development (MARD) but now under the Ministry of National Infrastructures (MNI), implements the water law, plans, develops, allocates, and manages water, and sets and annually revises water prices with the approval of a special parliamentary committee. Apart from the MARD and MNI, the Ministry of Finance (MOF) and the Ministry of Industry, Trade and Labour (MITL) also have a strong influence on the water sector. At the operational level, the Water Commission relies on Mekorot, a state-owned water company that produces and distributes around 70 percent of the water supply in the country. Mekorot operates the National Water Carrier, the pipeline system that moves water southwards from Lake Galilee to the Negev desert. In recent years, Mekorot has also entered spheres such as urban water retail, sewerage treatment, and sea water desalination. The Water Commission receives technical planning as well as research and development support from Tahal, a large engineering consulting firm. Although this firm had been the official and sole water planner for the past 20 years or so, now it is made to compete with other engineering companies within Israel to obtain project contracts from government (World Bank, 1999).

The Agricultural Extension Service of MARD focuses on all subjects related to agriculture, in particular water management, the promotion of water saving technologies and use of marginal water. It is financed by two sources: government funds (80 percent) and non-government sources, mainly production and marketing boards (20 percent). Generally services to farmers are free, although some supplementary advisory packages are provided upon specific request in exchange for payment.

The Ministry of Health (MOH) is responsible for the quality of drinking water in Israel. In order to assure water quality, the Ministry has promulgated regulations that specify water quality standards regarding its microbial, chemical, physical and radiological aspects.

The Yigal Allon Kinneret Limnological Laboratory (Israel Oceanographic and Limnological Research) carries out research aimed at understanding how present and future conditions might influence water quality and monitors major environmental factors which may affect the state of Lake Kinneret (Lake Tiberias).

Water management

Water is regarded as a national asset and is protected by law. Users receive their annual allocation from the Water Commission. The entire water supply is measured and payment is calculated according to consumption and water quality. Urban users pay much higher fees for water than farmers, including a water reclamation levy. Farmers pay differential prices for potable water. The first 60 percent of the allocation costs 20 cents per m^3, 60 percent to 80 percent costs 25 cents, and 80 percent to 100 percent costs 30 cents per m^3. This incremental price policy encourages water saving. Water scarcity and price policy necessitate the use of marginal water, such as brackish and reclaimed water. Brackish water is used for irrigation of salinity-tolerant crops like cotton. In several crops, such as tomatoes and melons, brackish water improves produce quality although lower yields are achieved. The use of reclaimed water for irrigation of edible crops requires a high level of purification. For that purpose, unique technology – Soil Aquifer Treatment (SAT) – is now being applied in the densely populated Dan region. After tertiary purification, the water percolates through sand layers, which serve as a biological filter, into the aquifer. From there it is pumped at nearly potable quality and can be used for unrestricted irrigation (MARD, 2006).

Groundwater and surface water are state property according to the Israel water law. Each year the Israel water commissioner allocates for each village an annual water quota for irrigation. Historically, initial quotas were determined according to factors such as: total land suitable for irrigation, soil type, population size, location, water usage prior to 1959 and political affiliation of the village. Water quotas are adjusted periodically in order to take into consideration new water sources and new villages. The price of water is determined by the commissioner using a three-tier price system. These price levels are determined according to historical quotas. Thus, the allotment of irrigation water and water prices are assumed to be exogenous to the farmers (World Bank, 2007).

Finances

Although water policy and administration are centralized with considerable political overtones, the water sector in Israel is subject to a much stronger economic influence than its counterparts in other countries. This is partly due to metered volumetric allocation and partly due to a relatively stricter economic water pricing system. While inter-sectoral water allocation is used to favour domestic and industrial sectors, water prices in these sectors are higher and cover full costs. Even though irrigation water is subsidized, the subsidy has declined from 75 to 50 percent since progressive block rate pricing was introduced in 1987 that penalizes large and fresh water consumers. Water wastage is the least in all sectors and water productivity has increased more than 250 percent in agriculture and 80 percent in industry (World Bank, 1999).

Policies and legislation

The 1959 Water Law that made water a nationalized public good remains the foundation for present water policy and water administration. According to that Law, all water is the property of the state, including waste, sewer and runoff water that can be used commercially. A landowner does not own the water under his/her land. The Law also created a permanent body known as the Water Commissioner (see above) to oversee and allocate water rights.

Israel's Water Law includes sewage water in its definition of "water resources." National policy calls for the gradual replacement of freshwater allocations to agriculture by reclaimed effluents. In the year 2002, treated wastewater constituted about 24 percent of consumption by the agricultural sector. It is estimated that effluents will constitute more than 40 percent of the water supplied to agriculture in 2010 (CBS, 2006).

ENVIRONMENT AND HEALTH

Israel's current water crisis is the result of both natural conditions (climate, geography and hydrology) and human activity. Natural constraints are exacerbated by anthropogenic impacts. Overpumping from aquifers to meet growing demands has led to the infiltration of seawater and salinity, the impoundment of springs has dried up perennial and ephemeral streams, and domestic, industrial and agricultural practices have contaminated water sources. The quality of the country's main water sources has been increasingly endangered by pollutant discharges from different sectors:

- The Coastal Aquifer is seriously threatened by chemical and microbial pollutants, salination, nitrates, heavy metals, fuels and toxic organic compounds. According to the most recent report of the Hydrological Service, about 15 percent of the total amount of water pumped from the Coastal Aquifer does not comply with existing drinking water standards for chloride and nitrate concentrations. Average chloride concentrations in the coastal aquifer are increasing at an average rate of 2 mg/l per year, reaching an average of 195 mg/l in 2002/03. Chloride concentrations below 250 mg/l and nitrate concentrations under 45 mg/l exist in only 50 percent of the water which is drawn from wells in the coastal basin. These concentrations are unsuitable for unrestricted agricultural irrigation. Nitrate concentrations in the Coastal Aquifer have increased considerably due to intensive use of fertilizers in agriculture and use of treated effluents for irrigation. Since 1950, average nitrate concentrations have increased from 30 mg/l to 63 mg/l today, with an annual rate of increase of about 0.6 mg/l. Concentrations exceeding 70 mg/l were measured in traditional agricultural areas in the centre of the country.

- Because of the deterioration in both the quantity and quality of the water in the Coastal Aquifer, the Yarkon-Taninim Aquifer is becoming a main supplier of drinking water in the country. Water levels in this aquifer have decreased while a gradual increase in chlorides has been noted over the years. This deep limestone aquifer is especially prone to contamination due to its karstic nature and the quick transit of pollutants through it. Overexploitation may lead to a rapid rate of saline water infiltration from surrounding saline water sources.
- Due to the continuous drop in water levels in Lake Tiberias since 1996, regulations have lowered the minimum "red line" from 213 meters below sea level to minus 215.5 meters in 2001. The risks associated with reduced water levels are enormous: ecosystem instability and deterioration of water quality, damage to nature and landscape assets, receding shorelines and adverse impacts on tourism and recreation. Salinity in the lake has been alleviated by diverting several major saline inputs at the northwest shore of the lake into a "salt water canal" leading to the southern Jordan River. This canal removes about 70 000 tonnes of salt (and 20 million m^3 of water) from the lake each year. The salt water canal is also used to remove treated sewage from Tiberias and other local authorities along the western shoreline away from Lake Tiberias and into the Lower Jordan River. In the catchment area, a concerted effort has been made to lower the nutrient load by changing agricultural and irrigation practices, by cutting back the acreage of commercial fishponds and by introducing new management techniques. Sewage treatment plants were improved and a new drainage network that recycles most of the polluted water within the watershed was constructed. Around the lake, public and private beaches and recreation areas with appropriate sanitary facilities were developed. Pollution and sewage from settlements and fishponds near the shores were treated and diverted from the lake. Next year, Mekorot, the national water company, will begin to operate a purification plant which will filter the water pumped from the Lake Tiberias and will allow Israel to comply with water turbidity standards set by the Ministry of Health.

The Dead Sea, located in the Syrian-African Rift Valley, is the lowest place on earth (416 meters below sea level). It is also the world's saltiest large water body, with a salt concentration ten times higher than that of the Mediterranean Sea. The Dead Sea has been threatened since the mid-twentieth century by declining water levels, at a rate of over one meter per year. Over the past 30 years, the Dead Sea has lost some 25 meters, mainly because water which previously fed into the Dead Sea is now diverted from the Sea of Galilee and the Yarmouk River to supply fresh water to Israel, Jordan and the Syrian Arab Republic. Furthermore, Dead Sea brine is withdrawn from the Dead Sea to supply the potash industries in Israel and Jordan. This negative water balance, which is expected to increase in the future, has a significant impact on existing and future infrastructure and development plans, natural and landscape values, the image of the region and the lives of local residents (MOE, 2004).

In 2004 an important amendment to the 1959 Water Law was passed, integrating nature's right to water and legitimizing this right statutorily. The Water Commission took a decision to allocate 50 million m^3 per year of freshwater to nature rehabilitation in the future. However, until this commitment is realized, there is no choice but to discharge surplus high quality effluents into rivers and wetlands (MOE, 2005b).

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

To reduce water demand and increase water supply, in July 2000 and in April 2001 the Ministerial Economic and Social Committee, headed by the Prime Minister, took among others the decisions to:

- Take steps to increase the efficiency of use and savings with the object of reaching additional savings of 200 million m^3 of freshwater per year for the next three years—half from municipal consumption and half from agricultural consumption;
- Establish plants for water desalination at a production capacity of 200 million m^3 with supply to start in 2004;
- Prepare a programme for the desalination of brackish water with an objective of 50 million m^3 over the next three years;
- Allocate 50 million m^3 of water for the conservation of nature;
- Remove obstacles to effluent reuse and advance plans for upgrading effluent quality to allow maximum use of effluents in agriculture, industry, nature and landscape, without harming the environment and groundwater;
- Reclaim contaminated wells and increase production and transport capacity;
- Contract a private developer for the supply of water from the deep-water aquifer in Mishor Rotem at a rate of 30 million m^3 per year;
- Increase water tariffs in order to reduce water demand for municipal gardening, home gardening, the domestic sector and the agricultural sector;
- Promulgate regulations on water savings in the urban sector including water-saving devices, car washing, facilities for water recycling, cooling towers, etc;
- Continue the public information campaign on water conservation until 2003;
- Establish an inter-ministerial team under the director general of the Prime Minister's Office for coordination and control purposes.

While Israel has one of the best performing water sectors in the world, it still faces crucial challenges most of which are characteristic of a mature water economy operating in an acute water stress condition. These challenges include:

- Addressing the potential side-effects for increasing brackish water and wastewater use in agriculture (e.g., groundwater contamination, soil sanity, and health hazards);
- Allowing and facilitating the exchange of water permits to promote market-based water allocation and compensation;
- Redefining the role of public agencies to avoid centralization and permit private sector participation;
- Making the Water Commission free from political pressures and rebuilding its own planning and regulatory capabilities;
- Building consensus on crucial areas of disagreement (e.g., supply augmentation through water transfers from Lebanon and Turkey and sea water desalination, installing national/regional carriers for saline/waste water collection and distribution, and decentralization and privatization of Mekorot); and
- Sharing water with Jordan and the Palestinian Authority and creating institutional structures for the joint management of shared groundwater aquifers.

The first three issues were addressed by the 1997 report of the Public Commission on Water Sector. With an already exhausted freshwater supply, an estimated future annual growth in water demand of 30 million m^3 means the inevitable need for costly options like sea water desalination (World Bank, 1999).

A study based on a Ricardian model tested the relationship between annual net revenues and climate across Israeli farms. Including the amount of irrigation water available to each farm, the model predicts that only modest climate changes are beneficial while drastic climate change in the long run will be harmful. Using the Atmospheric Oceanic Global Circulation Models Scenarios it was shown that farm net revenue was expected to increase by 16 percent in 2020 while in 2100 farm net revenue was expected to drop by 60 percent to 39 percent varying between the different scenarios. Although Israel has a relatively warm climate, a mild increase in temperature is beneficial due to the ability to supply international markets with farm products early in the season (World Bank, 2007).

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Jordan

GEOGRAPHY, CLIMATE AND POPULATION

Geography

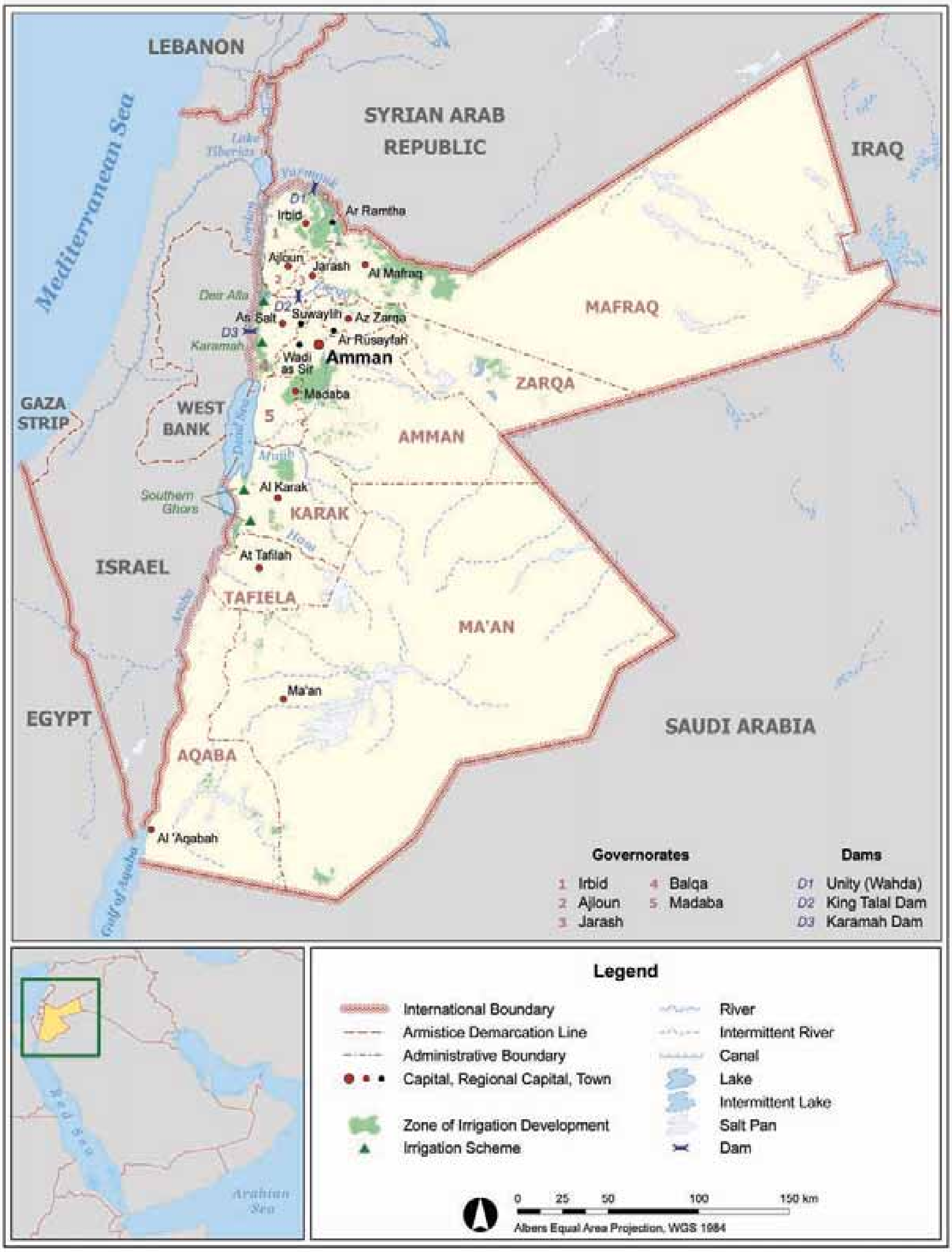
Jordan, with a total area of about 88 780 km², lies to the east of the Jordan River and is divided into twelve administrative governorates: Amman, Zarqa, Irbid, Mafraq, Ajloun, Balqa, Madaba, Karak, Tafileh, Ma'an and Aqaba. It is bordered to the north by the Syrian Arab Republic, to the northeast by Iraq, to the southeast and south by Saudi Arabia, to the far southwest by the Gulf of Aqaba (northern shore of the Red Sea) and to the west by Israel and the West Bank.

The country can be divided into four physiographic regions:

- The Jordan Rift Valley (JRV) along the western border of the country, with a total area of around 5 000 km², starts at Lake Tiberias in the north (212 m below sea level) and continues south through the Jordan Valley into the Dead Sea on the Israeli–Jordanian border (417 m below sea level). From the Dead Sea southwards, the Rift is occupied by the Wadi Araba, then the Gulf of Aqaba, and then the Red Sea.
- The Highlands to the east of JRV, with a total area of around 5 000 km², run from north to south. They consist of ranges of mountains and plains at an altitude between 600 and 1 600 m above sea level and numerous side wadis sloping towards the JRV.
- The plains, with a total area of around 10 000 km², extend from north to south along the western borders of the Al-Badiah desert region.
- The Al-Badiah desert region in the east, with a total area of around 69 000 km², is an extension of the Arabian Desert.

The government of Jordan is studying the possibility of restructuring the administrative governorates to match the four physiographic regions and implementing socioeconomic development programmes through elected councils, including the municipalities, in order to achieve the participation of public and local communities in the development of the country.

The land suitable for cultivation is around 886 400 ha, or around 10 percent of the total area of the country. In 2005, the total cultivated area was estimated at 270 000 ha, of which 184 000 ha consisted of annual crops and 86 000 ha of permanent crops (Table 1). However, occasionally half of the rainfed land is left fallow in a year due to fluctuating and unevenly distributed annual rainfall. For instance, the harvested annual crops area was 168 435 ha in 2003 and 76 266 ha in 2004. Moreover, it is estimated that between 1975 and 2000 around 88 400 ha of good rainfed land was lost due to urban expansion. Data for the last three decades show an increase in irrigated land and in land planted with permanent crops, mainly in rainfed land of the Highlands (DIC, 2004; MOA, 2005; DPI, 2005).



JORDAN **FAO - AQUASTAT, 2008**

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TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2005	8 878 000	ha
Cultivated area (arable land and area under permanent crops)	2005	270 000	ha
• as % of the total area of the country	2005	3.0	%
• arable land (annual crops + temp fallow + temp meadows)	2005	184 000	ha
• area under permanent crops	2005	86 000	ha
Population			
Total population	2005	5 703 000	inhabitants
• of which rural	2005	20.7	%
Population density	2005	64.2	inhabitants/km^2
Economically active population	2005	1 975 000	inhabitants
• as % of total population	2005	34.6	%
• female	2005	26.1	%
• male	2005	73.9	%
Population economically active in agriculture	2005	194 000	inhabitants
• as % of total economically active population	2005	9.8	%
• female	2005	70.1	%
• male	2005	29.9	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2007	15 830	million US$/yr
• value added in agriculture (% of GDP)	2007	3	%
• GDP per capita	2005	2 227	US$/yr
Human Development Index (highest = 1)	2005	0.773	
Access to improved drinking water sources			
Total population	2006	98	%
Urban population	2006	99	%
Rural population	2006	91	%

Climate

The climate of Jordan is semitropical in the JRV, Mediterranean in the Highlands and with continental influence in the eastern desert and plains region. Winter is the rainy season and is warm in the JRV, moderate to cool in the Highlands and extremely cold and dry in the desert land, whereas the summer is hot in the JRV, moderate in the Highlands and hot in the plains and the desert.

Rainfall varies considerably with location, mainly due to the country's topography. It usually occurs between October and May. Annual rainfall ranges between 50 mm in the eastern and southern desert regions to 650 mm in the northern Highlands. Over 91 percent of the country receives less than 200 mm of rainfall per year. Average annual rainfall registered from 1937/38 to 2004/2005 was 94 mm, although it was only 80 mm during the last ten years of this period (Directorate of Planning and Water Resources, 2005). The average for the period 1961–1990, given by IPCC, was 111 mm/year.

Population

The total population is about 5.7 million (2005), of which around 21 percent is rural (Table 1). The annual demographic growth is estimated at around 2.5 percent during recent years, not including fluctuations caused by international political events. Currently, more than 90 percent of the population is concentrated in the northwest quadrant of the country, where rainfall is highest and where most of the water resources are located.

In 2006, access to improved drinking water sources reached 98 percent (99 and 91 percent for the urban and rural population respectively). Sanitation coverage was 85 percent (88 and 71 percent for urban and rural population respectively).

ECONOMY, AGRICULTURE AND FOOD SECURITY

GDP was US$15.8 billion in 2007 (Table 1). Agriculture accounted for 3 percent of GDP, compared with 6 percent in 1992.

The total population economically active in agriculture is estimated at 194 000 inhabitants, amounting to 9.8 percent of the economically active population in 2005, of which 70 percent is female and 30 percent is male. In JRV around 350 000 people are the main beneficiaries of irrigated agriculture and women form an important component of the labour force. Foreign labour, mainly from Egypt, is common in irrigated agriculture in Jordan.

Irrigated agriculture covered around 33 percent of the cultivated area in 2004. Permanent crops represent 56 percent of harvested irrigated area and 78 percent of the harvested rainfed area. They consist of citrus, bananas, olives and vineyards. The main annual crops are vegetables, potatoes and cereals (wheat and barley). Besides the climate (drought, fluctuating rainfall and hot winds) the main difficulties for rainfed agriculture are the fragmentation of farm holdings and the erosion of top soils in the steep slopes, while the constraints for irrigated agriculture are the limited available water resources, overexploitation of groundwater, wastewater used in irrigation, silting of dams, and agricultural production marketing problems.

In 2004, total agricultural production reached 2.13 million tons, of which 69 percent were vegetables, 29.5 percent fruits from fruit trees and 1.5 percent field crops (cereals), which are consumed locally and exported to the markets of neighbouring countries. In spite of the low contribution of agriculture to GDP, both rainfed and irrigated agriculture are vital socioeconomic activities in the country. They are the source of fresh vegetables all year round, they play an important role in the national economy and they provide demographic stability in the rural communities and in the JRV region.

In general, the agricultural sector is subjected to strong competition from other sectors and receives few national or international investments in comparison with other economic activities.

WATER RESOURCES AND USE

Water resources

The average annual precipitation according to the observations made during the last seventy years is around 8.35 km^3/year, fluctuating from 2.97 (1998/1999) to 17.8 km^3/year (1966/1967) (Directorate of Planning and Water Resources, 2005).

Total internal renewable water resources are estimated at 682 million m^3/year (Table 2). Long-term average internal renewable surface water resources are approximately 485 million m^3/year. They reached 533 and 652 million m^3 in 2004 and 2005 respectively (Directorate of Planning and Water Resources, 2005). Surface water resources are unevenly distributed among 15 basins. River flows are generally of a flash-flood nature, with large seasonal and annual variation. The largest source of external surface water is the Yarmouk River, which enters from the Syrian Arab Republic after first forming the border with it. It then joins the Jordan River coming from Israel, taking its name. The natural annual flow of the Yarmouk River is estimated at about 400 million m^3, of which about 100 million m^3 are withdrawn by Israel. However, the total actual flow is much lower at present as a result of the drought and the upstream Syrian development works of the 1980s. The Yarmouk River is the main source of water for the King Abdullah Canal (KAC) and is thus considered to be the backbone of development in the Jordan Valley. A main tributary of the Jordan River, controlled by the King Talal Dam and also feeding the KAC, is the Zarqa River. There are also 6–10 small rivers, called "Side Wadis" going from the mountains to the Jordan Valley. Other basins include the Mujib, the Dead Sea, Hasa and Wadi Araba.

Jordan's groundwater is distributed among twelve major basins, ten of which are renewable groundwater basins and two in the southeast of the country fossil

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	94	mm/yr
	-	8.345	10^9 m^3/yr
Internal renewable water resources (long-term average)	-	0.682	10^9 m^3/yr
Total actual renewable water resources	-	0.937	10^9 m^3/yr
Dependency ratio	-	27.21	%
Total actual renewable water resources per inhabitant	2005	161	m^3/yr
Total dam capacity	2007	275	10^6 m^3
Water withdrawal			
Total water withdrawal	2005	940.9	10^6 m^3/yr
- irrigation + livestock	2005	611.2	10^6 m^3/yr
- municipalities	2005	291.3	10^6 m^3/yr
- industry	2005	38.4	10^6 m^3/yr
per inhabitant	2005	165.0	m^3/yr
Surface water and groundwater withdrawal	2005	847.6	10^6 m^3/yr
• as % of total actual renewable water resources	2005	90.5	%
Non-conventional sources of water			
Produced wastewater			10^6 m^3/yr
Treated wastewater	2005	107.4	10^6 m^3/yr
Reused treated wastewater	2005	83.5	10^6 m^3/yr
Desalinated water produced	2005	9.8	10^6 m^3/yr
Reused agricultural drainage water		-	10^6 m^3/yr

groundwater aquifers. Total internal renewable groundwater resources have been estimated at 450 million m^3/year, of which 253 million m^3/year constitute the base flow of the rivers. Groundwater resources are concentrated mainly in the Yarmouk, Amman–Zarqa and Dead Sea basins. The safe yield of renewable groundwater resources is estimated at 275.5 million m^3/year. At present most of it is exploited at maximum capacity, in some cases beyond safe yield. Of the twelve groundwater basins, six are being overexploited, four are balanced and two are underexploited. Overexploitation of groundwater resources has degraded water quality and reduced exploitable quantities, resulting in the abandonment of many municipal and irrigation water-well fields, such as in the area of Dhuleil. The main non-renewable aquifer presently exploited is the Disi aquifer (sandstone fossil) in southern Jordan, with a safe yield estimated at 125 million m^3/year for 50 years. Other non-renewable water resources are found in the Jafer Basin, for which the annual safe yield is 18 million m^3. The Water Authority of Jordan estimates that the total safe yield of fossil groundwater is 143 million m^3/year for 50 years.

Ten dams have been constructed in the last five decades with a total capacity of around 275 million m^3. The main dam is the King Talal Dam on the Zarqa River, with a total capacity of 80 million m^3. The Unity Dam on the Yarmouk River shared between Jordan and the Syrian Arab Republic will be completed in 2007 and will have a total reservoir capacity of 110 million m^3. All the dams, except the Karamah Dam on Wadi Mallaha, are built on the Side Wadis with their outlets to JRV and are used to store floods and base flows, regulate water and release it for irrigation. According to the water annex in the Jordanian–Israeli treaty, a regulating dam was built on the Yarmouk River downstream of the diversion point of KAC. Another dam should be built in the lower water course of the Jordan River on the border between Jordan and Israel. The dam capacity will be 20 million m^3.

Over the last three decades sewage water networks have been constructed in cities and towns to serve around 70 percent of the population in Jordan. Twenty-three sewage treatment plants are in operation and the treated wastewater is used in irrigation. More than 80 percent of sewage water of the Greater Municipality of Amman is treated in four plants and then released into the Zarqa River. The mixed water is then stored in the King Talal Dam reservoir to be used in irrigation in the middle Jordan Valley irrigation schemes (this involves 78 percent of the treated wastewater). A small quantity (around 9 percent) is used for irrigation in the Zarqa River catchment area. Treated wastewater from the other plants is used around the plants and/or mixed with surface water to irrigate areas in the Side Wadis. The wastewater entering the treatment plants reached 101.8 and 107.4 million m^3 in 2004 and 2005 respectively, while reused treated wastewater in these two years was around 86.4 and 83.5 million m^3 respectively. Reused wastewater is an essential element of Jordan's water strategy. Sewage treated wastewater should be the most important source of water in irrigation in the near future.

Under Jordanian law it is forbidden to discharge untreated wastewater into the watercourses or to use it for irrigation. Houses and industries that are not connected to the sewerage network and use the cesspools, haul the septic water to existing wastewater treatment plants or to a special dump area. The septic haulers are not closely regulated, and the origins of much of the septic water are not precisely known (MWI, 2002).

In 2002, the total installed gross desalination capacity (design capacity) in Jordan was 11 163 m^3/day (Wangnick Consulting, 2002). Desalinated water production became significant only in 2005, reaching 10 million m^3/year (Table 2).

Water use

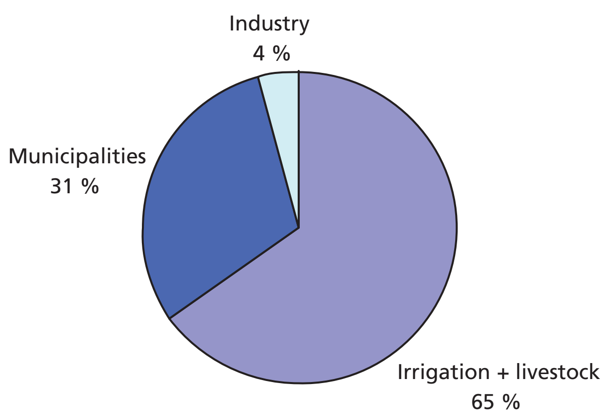
Water withdrawal varies according to the year. It was around 866 and 941 million m^3 in 2004 and 2005 respectively. In 2005, agricultural water withdrawal accounted for 65 percent of the total water withdrawal and water withdrawal for domestic and industrial purposes accounted for 31 and 4 percent respectively (Table 2 and Figure 1).

During periods of water shortage strict measures are taken, such as rationing water allocations and reducing or banning the cultivation of irrigated summer vegetables. Overexploitation of renewable groundwater resources by farmers is a common practice. It reached 158 million m^3 in 2002 and in 2003, 147 million m^3 in 2004 and 144 million m^3 in 2005 (Figure 2).

Treated wastewater is discharged to open wadis where it flows either to the reuse sites or to dams and is then mixed with rainwater or base flows. Different irrigation methods are used depending on the effluent quality, the type of crops irrigated and the availability of mixing water. Furrow, flooding and localized irrigation methods are used. Sprinkler irrigation is not used, in compliance with the Jordanian Standards for reuse from a health point of view. Also, chloride concentration in effluents exceeds the permissible limit for the use of sprinklers, which affects the crops adversely.

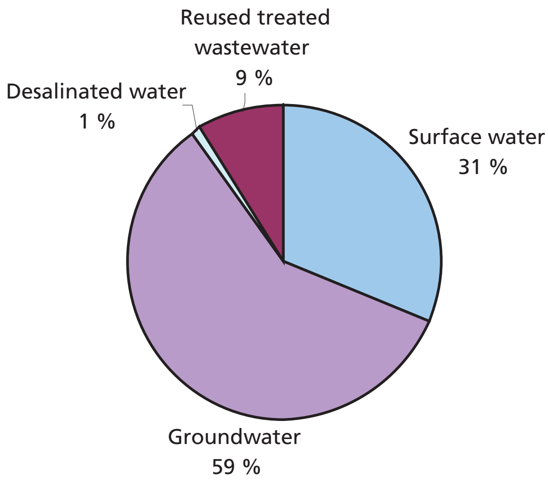
Although most of the treated wastewater flows by gravity to wadis and reservoirs, effluents from plants are pumped to reuse sites such as Madaba, Aqaba, Kufranja and Ma'an. Part of the effluent from Aqaba and Madaba is disposed of through evaporation when the quantity exceeds agricultural needs. While some factories and industries reuse part of the industrial water on a small scale and mainly for cooling purposes, this

FIGURE 1
Water withdrawal by sector
Total: 0.941 km^3 in 2005



water is generally reused for on-site irrigation (MWI, 2002).

FIGURE 2
Water withdrawal by source
Total: 0.941 km³ in 2005



International water issues

Most of Jordan's water resources are shared with other countries. The Yarmouk/Jordan River is the largest river of the country, where water allocation to riparian countries is one of the most difficult regional issues. Failure so far to develop a unified approach to managing these water resources has encouraged unilateral development by the various riparian countries.

In 1951, Jordan announced its plan to divert part of the Yarmouk River via the East Ghor Canal to irrigate the East Ghor area of the Jordan Valley. In response, Israel began construction of its National Water Carrier (NWC) in 1953, resulting in military skirmishes between Israel and the Syrian Arab Republic. In 1955, the Johnston Plan called for the allocation of 55 percent of available water in the Jordan River basin to Jordan, 36 percent to Israel, and 9 percent each to the Syrian Arab Republic and Lebanon. It was never signed by the countries involved, since the Arab riparians insisted that the United States government was not an impartial third party, but it has served as a general guideline for appropriations within the basin. In 1964, the NWC opened and began diverting water from the Jordan River Valley. This diversion led to the Arab Summit of 1964 where a plan was devised to begin diverting the headwaters of the Jordan River to the Syrian Arab Republic and Jordan. From 1965 to 1967 Israel attacked these construction projects in the Syrian Arab Republic, and along with other factors this conflict escalated into the Six Day War in 1967 when Israel completely destroyed the Syrian diversion project and took control of the Golan Heights, the West Bank and the Gaza Strip. This gave Israel control of the Jordan River's headwaters and significant groundwater resources. The most recent directly water-related conflict occurred in 1969 when Israel attacked Jordan's East Ghor Canal following suspicions that Jordan was diverting excess amounts of water (Green Cross Italy, 2006). Later on, Israel and Jordan acquiesced to the apportionment, contained in the non-ratified 1955 Johnston Plan for sharing the Jordan Basin's waters (Milich and Varady, 1998).

Jordan is adversely affected by unilateral water development projects by the Syrian Arab Republic in the Upper Yarmouk Basin and by Israel in the Upper Jordan River and the occupied Golan Heights. Despite agreements with the Syrian Arab Republic and Israel, Jordan received only around 119 and 92 million m³/year from Yarmouk water and Lake Tiberias in 2004 and 2005 respectively. This is only approximately 10 percent of the total flow of the Upper Jordan and Yarmouk rivers. It is also much less than the water share from these two basins proposed by the Johnston plan during negotiations in 1950s.

Although no comprehensive agreement exists on sharing the jointly-owned water resources, eleven plans for water use were prepared between 1939 and 1955. The last one was the Johnston Plan of 1955, allocating water between Jordan and the Syrian Arab Republic. In 1987, Jordan and the Syrian Arab Republic signed an agreement to build the Unity Dam on the Yarmouk River with a height of 100 m and a storage capacity of 225 million m³. In 2003, the height of the dam was reduced to 87 m and the storage capacity became 110 million m³. The dam (RCC type) will be completed in 2007. Jordan and Israel reached a compromise on water rights issues in the Jordan River Basin. The Jordanian–Israeli Peace Treaty, which was signed in October 1994, includes agreed articles on water presented in Annex II – Water Related Matters. According to the articles of this annex, Jordan is entitled to store 20 million m³ of the Upper Jordan winter flow on the Israeli side (in Lake Tiberias) and take it back during the summer months. Jordan is entitled to 10 million m³ of desalinated water from the saline Israeli springs near Tiberias and until the desalination plant is erected Jordan can get this quantity in summer from Lake Tiberias. Jordan can build a regulating/storage dam on the Yarmouk downstream of the diversion point of Yarmouk water to the KAC. Jordan can also build a dam of 20 million m³ capacity on the Jordan River and on its reach south of Lake Tiberias on the border between Jordan and Israel. Later, Jordan and Israel agreed to provide Jordan with 50 million m³ of desalinated water from the Israeli saline springs south of Lake Tiberias and until the desalination plant is erected Israel is providing Jordan with 25 million m³ from Lake Tiberias through the summer months. The regulating dam on the Yarmouk River was built and the water conveyor to transport water from Lake Tiberias in Israel to the KAC in Jordan was constructed just after the signing of the Peace Treaty.

In 2007, Jordan and the Syrian Arab Republic agreed to expedite the implementation of agreements signed between the two countries, especially with regard to shared water in the Yarmouk River Basin. They also agreed to continue a study on the Yarmouk River Basin based on previous studies. Currently, the Joint Jordanian–Syrian Higher Committee is discussing how to make use of the Yarmouk River Basin water and how to protect Yarmouk water against depletion. Talks will also include preparations for winter and storage at Al Wihdeh Dam. The establishment of the Wihdeh Dam was designed to enhance the supply of potable water to Jordan by providing it with 80 million m³ annually – 50 million m³ for drinking purposes and 30 million m³ for irrigation in the Jordan Valley. The dam was also created to enhance the environmental situation of the area surrounding the Yarmouk River Basin and activate tourism, in addition to generating power. The Syrian authorities have shown an understanding of Jordan's limited water resources (The Jordan Times, 2008).

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

Land suitable for irrigated cultivation is estimated at around 840 000 ha. However, taking into consideration available water resources, the irrigation potential is about 85 000 ha, including the area currently irrigated. The total area equipped for irrigation is estimated at 78 860 ha (2004) (Table 3).

Although irrigation has been reported in Jordan for a very long time, particularly in the JRV, intensive irrigation projects have been implemented since 1958, when the Government decided to divert part of the Yarmouk River water and constructed the East Ghor Canal (later named King Abdullah Canal or KAC). The King Talal Dam on the Zarqa River also diverts the water into the KAC. The canal was 70 km long in 1961 and was extended three times between 1969 and 1987 to reach a total length of 110.5 km. The construction of dams on the Side Wadis and the diversion of the flows from other wadis allowed the development of irrigation over a large area. At the same time, wells were drilled in the Jordan valley to abstract groundwater, not only for domestic purposes but also for irrigation.

Irrigation projects from surface water resources are mainly located in the JRV and the Side Wadis linked with the Jordan River Basin. Irrigation schemes in the JRV have been constructed, restored, operated and maintained by the government. In the first projects in the north, concrete-lined canals were constructed equipped with all

TABLE 3
Irrigation and drainage

Irrigation potential			**85 000**	**ha**
Irrigation				
1. Full or partial control irrigation: equipped area		2004	78 860	ha
- surface irrigation		2004	13 860	ha
- sprinkler irrigation		2004	1 000	ha
- localized irrigation		2004	64 000	ha
• % of area irrigated from surface water		2004	30.9	%
• % of area irrigated from groundwater		2004	53.3	%
• % of area irrigated from mixed surface water and groundwater			-	%
• % of area irrigated from mixed non-conventional sources of water		2004	15.9	%
• area equipped for full or partial control irrigation actually irrigated		2004	72 009	ha
- as % of full/partial control area equipped		2004	91.3	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)			-	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)		**2004**	**78 860**	**ha**
• as % of cultivated area		2004	26.8	%
• % of total area equipped for irrigation actually irrigated		2004	91.3	%
• average increase per year over the last 9 years		1995-2004	-0.89	%
• 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)		**2004**	**78 860**	**ha**
• as % of cultivated area		2004	26.8	%
Full or partial control irrigation schemes	**Criteria**			
Small-scale schemes	< 100 ha	2004	37 500	ha
Medium-scale schemes		2004	6 000	ha
large-scale schemes	> 1 000 ha	2004	35 360	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	99 029	ha
• Annual crops: total		2004	43 909	ha
- Wheat		2004	1 676	ha
- Barley		2004	684	ha
- Potatoes		2004	3 483	ha
- Pulses		2004	927	ha
- Vegetables		2004	30 946	ha
- Other annual crops		2004	6 193	ha
• Permanent crops: total		2004	55 120	ha
- Bananas		2004	1 900	ha
- Citrus		2004	6 638	ha
- Other perennial crops (mainly olives, date palm, grapes)		2004	46 582	ha
Irrigated cropping intensity (on full/partial control area actually irrigated)		2004	138	%
Drainage - Environment				
Total drained area		2005	10 506	ha
- part of the area equipped for irrigation drained		2005	10 506	ha
- other drained area (non-irrigated)			-	ha
• drained area as % of cultivated area		2005	3.9	%
Flood-protected areas			-	ha
Area salinized by irrigation		1989	2 280	ha
Population affected by water-related diseases			-	inhabitants

irrigation structures to convey and distribute irrigation water on a volumetric basis. Additional irrigation schemes were carried out during the 1970s and 1980s following the extension of the KAC and through construction of dams and diversion of side wadis springs and streams. From the 1990s onwards, the open canal irrigation schemes were converted to pressurized irrigation systems.

Irrigated land in the JRV is divided into farm units from 3 to 5 ha in size, totalling 10 916 in number. By law the farm units cannot be subdivided and the Jordan Valley Authority (JVA) regulations do not allow farmers to own more than 20 ha. Farm units receive a flow from 4 to 8 litres/sec under 2.6 to 3.6 atmospheres pressure, so that farmers apply sprinkler or localized irrigation methods on their farm units. In 2006, the area equipped for irrigation in the JRV reached 35 360 ha, which represents 83 percent of the total irrigation potential area in the JRV. Part of the equipped area, however, is not yet functional. In fact, 6 000 ha in the Karamah irrigation district (14.5 km irrigation project) consisting of 1 558 farm units are still not distributed among farmers due to water shortage in the valley. About 900 ha (307 farm units) are still under construction and will be operational in 2007.

Irrigation is also reported in the Highlands, mainly dependent on groundwater resources by constructing very deep wells. The Water Master Plan, prepared in 1977, enabled Jordan to locate the groundwater basins. The government encourages the private sector to invest in irrigation from groundwater resources. The Agricultural Credit Corporation (ACC) provides farmers with soft loans to drill tube wells, install diesel pumps, reclaim and level the land, and put it under sprinkler or localized irrigation. In the mid 1980s large agricultural companies were allowed to invest in irrigation in the southeast of the country, using fossil groundwater. The Disi Irrigation Project, one of the largest schemes in Jordan covering a total area of 3 000 ha, is supplied with fossil groundwater. The total area equipped for irrigation from groundwater resources owned and operated by the private sector reached 36 000 ha for small farmers and 6 000 ha for large agricultural companies.

Streams and springs in the Side Wadis have been used for irrigation since the 1940s. A total area of about 1 500 ha is equipped for irrigation.

The techniques used by farmers changed gradually from surface irrigation (32 and 18 percent in 1991 and 2004 respectively) to localized irrigation (60 and 81 percent in 1991 and 2004 respectively) (Figure 3). In 2004, 53 percent of the area under irrigation used groundwater, 31 percent surface water and 16 percent treated wastewater mixed with surface water (Figure 4). In 2004, the total number of greenhouses was 23 779 in the JRV, with a total area of 1 189 ha and 11 075 ha in the Highlands, with a

FIGURE 3
Irrigation techniques
Total: 78 860 ha in 2004

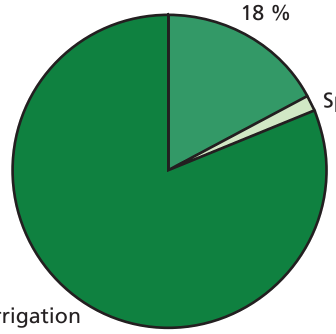
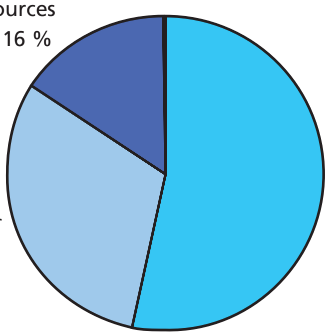
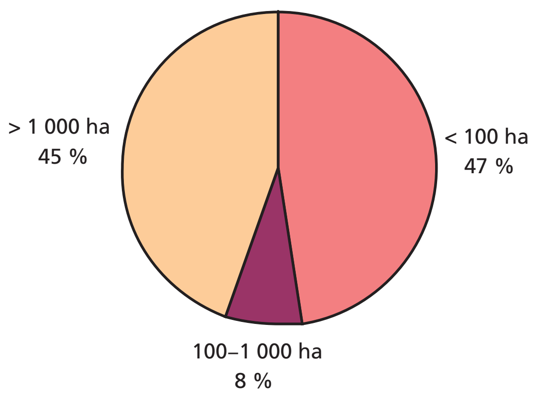


FIGURE 4
Source of irrigation water
Total: 78 860 ha in 2004



total area of 554 ha. Small schemes (< 100 ha) cover 47 percent of total equipped area for irrigation, medium size schemes (100–1 000 ha) 8 percent and large schemes (>1 000 ha) 45 percent (Figure 5).

FIGURE 5
Type of irrigation schemes
Total: 78 860 ha in 2004



Role of irrigation in agricultural production, economy and society

Irrigated crops in Jordan are field crops (cereals), vegetables (mainly tomatoes, cucumber, squash, eggplants, pepper, cabbage, cauliflower and potatoes) and trees (citrus, bananas, olives and vineyards). Field crop production comes mostly from rainfed areas and varies in quantity from year to year due to the amount and distribution of rain. Vegetables, the production of which is higher than the needs of local markets, come mostly from irrigated areas (Table 4). Citrus and bananas are grown only in the Jordan Valley. In 2004, about 91 percent of the area equipped for irrigation, or 72 009 ha, was actually irrigated and the total harvested irrigated area was 99 029 ha (71 percent in the JRV and 29 percent in the Highlands including Side Wadis) (Table 3 and Figure 6). Vegetables covered 42 percent of the harvested irrigated area and represented 69 percent of the total quantity of agricultural production.

Crop water requirements are evaluated at around 4 000 m^3/ha for field crops (wheat and barley), 3 000–6 000 m^3/ha for vegetables, 7 000 m^3/ha for olives and grapes, 10 000–12 000 m^3/ha for citrus and date palms and 18 000 m^3/ha for bananas. The introduction of modern irrigation and agricultural techniques led to a noticeable increase in agricultural yield per unit of irrigated land and unit of water. The yield of tomatoes increased from 10 tonnes/ha to 60 tonnes/ha in open fields under drip irrigation and up to 200 tonnes/ha in the greenhouses. Cucumber gave 40 tonnes/ha in open fields and 120 tonnes/ha inside the greenhouses. In the JRV, bananas, citrus and grapes yields are around 8, 20 and 28 tonnes/ha respectively under improved water management.

Water charges in the JRV irrigation schemes have increased many times. The latest tariff takes into consideration the crop water requirements, which are highest for trees, mainly bananas and citrus. The average collected rate is around US$ 21 (15 Jordan Dinars) per 1 000 m^3. However, in order to recover the full operation and maintenance cost, the average water charge value should be raised to US$ 38 per 1 000 m^3 of water. In the Highlands the average cost of irrigation water is between US$ 70 to 85 per 1 000 m^3 and is increasing due to the rise in the cost of fuel.

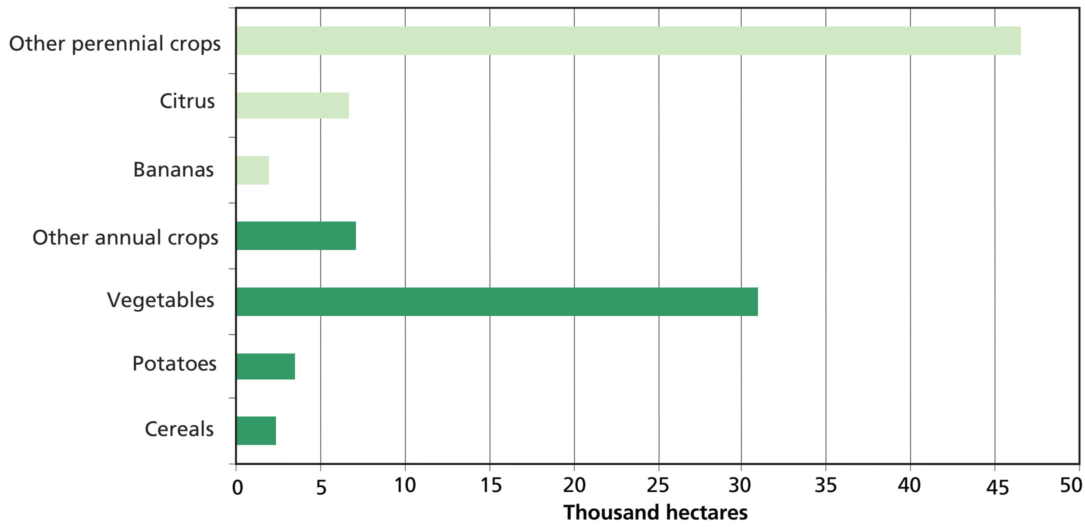
The government and the private sector work together to encourage farmers to adopt localized and sprinkler irrigation methods. Around 85 and 90 percent of

TABLE 4
Harvested annual and permanent crops area in Jordan (2004)

Type of crop	Irrigated (ha)			Rainfed (ha)			Total (ha)
	Highlands	JRV	Sub-total	Highlands	JRV	Sub-total	
Annual crops	24 455	19 454	43 909	32 173	183	32 356	76 265
Permanent crops	45 909	9 211	55 120	113 909	93	114 002	169 122
Total harvested area	**70 364**	**28 665**	**99 029**	**146 082**	**277**	**146 358**	**245 387**

From the annual report of the Ministry of Agriculture

FIGURE 6
Irrigated crops
Total harvested area: 99 029 ha in 2004 (cropping intensity on equipped area actually irrigated: 138%)



the areas equipped for irrigation of the JRV and Highlands respectively are using localized irrigation methods. In the southeast fossil basins, 1 000 ha are irrigated with central pivot sprinkler systems. The on-farm installation cost of localized and sprinkler irrigation is US$ 1 286/ha and US$ 1 429/ha respectively. The cost of surface irrigation development in public and private schemes is US$ 5 250/ha and US$ 4 300/ha respectively while the cost of operation and maintenance (O&M) is US$ 187/ha and US$ 860/ha per year respectively.

Agricultural water management activities are undertaken by men. Operation and maintenance of the drip, bubbler and sprinkler irrigation systems is carried out by male workers and farmers, who are trained by private irrigation companies. Women play a role in harvesting, grading, packing and loading of vegetables and fruits. They are also involved in agricultural processing plants, for example in the JRV tomatoes are processed by women from the surrounding communities.

Status and evolution of drainage systems

In the JRV, open drains were constructed in parallel with the irrigation infrastructure in the irrigation schemes. Subsurface drains were constructed in many farm units facing waterlogging and salinity of top soils. In 1992, drainage existed on about 4 000 ha of the irrigated area, mainly open drains, and all by gravity. In 2004, the total area equipped for irrigation having a drainage system was around 10 500 ha in irrigation schemes north of the Dead Sea. Southern Ghor irrigation schemes contain open main drains and plans are under way to construct subsurface drains in the farm units affected by the salinity of Dead Sea water on around 5 400 ha. The cost of drainage development in the JRV schemes is US$ 9 520/ha.

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

Institutions

The ministries in charge of the water sector and the institutions involved in irrigation are:

- the Ministry of Water and Irrigation (MWI) in cooperation with the Jordan Valley Authority (JVA) and the Water Authority of Jordan (WAJ)
- the Ministry of Agriculture (MOA)
- the Ministry of Environment (MOE)
- the Ministry of Health (MOH)
- the National Center for Agricultural Research and Technology Transfer
- the Water and Environment Research and Study Center, University of Jordan.

The MWI was established in 1988 with the JVA and the WAJ under its umbrella. The Minister of Water and Irrigation is the Chair of the Board of Directors of the WAJ and the JVA. Before the establishment of the MWI, the JVA and the WAJ were two autonomous authorities directly under the responsibility of the Prime Minister of Jordan.

The main concerns of the MWI are:

- formulating and implementing an irrigation policy and strategy;
- planning and developing water resources and controlling water allocation and use;
- preparing a water master plan and the annual water balance budget;
- establishing a water data centre;
- human resources development and training programmes for the water sector;
- public awareness programmes.

The JVA is in charge of the integrated development plan in the JRV. Its main tasks are:

- construction, operation and maintenance of dams in the Side Wadis and in the JRV;
- construction, operation and maintenance of public irrigation schemes in JRV;
- delivering and distributing irrigation water to farmers and collecting irrigation water charges;
- encouraging farmers to adopt modern irrigation methods and to save water and improve farm irrigation efficiency;
- working with international donors and farmers on farm irrigation practices and scheduling;
- implementing emergency plans to face water shortage in dry years and seasons;
- implementing public awareness and water conservation programmes in irrigation.

The WAJ is responsible for:

- providing licences to farmers to utilize groundwater for irrigated agriculture, checking the drilling of tube wells and carrying out the testing of the yield of the wells;
- checking the abstraction from the tube well in the groundwater basins, pursuant to Law No 83 (2003) to reduce overexploitation of renewable groundwater resources practiced by farmers.

The Ministry of Health (MOH) is responsible for ensuring the safety of drinking water. The MWI, MOH and the General Corporation for Environmental Protection (GCEP) under MOE all monitor water quality.

Water management

The main objective of water management programmes is to optimize water use in irrigation, adopt modern irrigation and agricultural techniques and increase the yield of irrigated crops and the income per unit of land and water.

The main entities involved in irrigation water management are:

- the MWI, in association with the JVA and WAJ and the MOA;
- the private sector through agricultural companies specialized in irrigation and manufacturers of drip irrigation facilities;

- international donors through grants to the MWI, JVA and directly to farmers.

Private agricultural and irrigation companies provide financial and technical support to farmers. They train farmers in farm irrigation and agricultural techniques. They deliver irrigation equipment, greenhouses and modern agricultural supplies to thousands of irrigation farms throughout the country. They provide farmers with small desalination units to improve the quality of water for irrigation.

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 Jordan. 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).

Finances

In public irrigation schemes in the JRV the government is fully responsible for the cost of construction, restoration and O&M. The construction costs of the irrigation schemes and dams are covered by international loans and the national budget. O&M costs are allocated annually in the national budget. Collected water charges cover less than 60 percent of total O&M costs. Irrigation water is subsidized by the government.

In the private sector irrigation projects, investors and owners pay the full cost of construction and renovation and annual running O&M costs. The Agricultural Credit Corporation, private banks and agro-irrigation companies are financial sources for most irrigation activities in private farms.

In 2002, the MWI published the "Water sector planning & associated investment programme 2002–2011". The goals are to unify water sector projects, create uniform project baselines, schedule projects based on multiple scenarios, identify the role for private sector participation (PSP), and identify least cost solutions for development projects.

Jordan has been giving priority to the development of its limited water resources for different purposes. Limited financial and technical resources have forced Jordan to seek the assistance of international donors and development funds to implement intensive water development plans over the last five decades. Irrigation has been a major issue in the three- and five-year socio-economic development plans carried out by the government in the second half of last century.

Policies and legislation

In 2002, the MWI published the Jordan Water Policy and Strategy consisting of the following:

- water strategy for Jordan (2002)
- groundwater management policy (1998)
- water utility policy (1998)
- irrigation water policy (1998)
- wastewater management policy (1998).

The issues covered by the Irrigation Water Policy are the sustainability of irrigation water resources, development and use, research and technology transfer, farm water management, irrigation water quality, management and administration, water pricing, regulation and control and irrigation efficiency.

Laws, bylaws and regulations are imposed to enable the relevant bodies to fulfil their responsibilities and perform their duties regarding water, irrigation and irrigated agriculture, such as the MWI bylaw, the JVA, WAJ, and MOA laws, the Environment Law and the Public Health Law. The latest bylaw prepared by the MWI and approved by the government is the Bylaw No. 85/2003 to control groundwater abstraction and reduce the overexploitation and depletion of the groundwater aquifers by farmers in the country.

Environment and health

The development of water resources for irrigation and expansion of the irrigated area, which is cultivated intensively, are causing negative impacts, such as:

- Soil erosion on steep lands due to heavy rains and flood leads to an increase in sediment loads in the dams-reservoirs and the washing away of fertile top soils in the Highlands and the Side Wadis. Heavy silt loads in KAC water resulted on many occasions in a suspension of water pumping in the Deir Alla Amman domestic water supply project during some winter months with heavy rainfall.
- Deterioration in the quality of irrigation water is caused by sewage-treated wastewater, particularly in drought years. Improving the treatment process and installing desalination plants are expected to overcome this problem.
- Heavy use of pesticides, insecticides and animal (poultry) fertilizer is deteriorating the soil, affecting the quality of agricultural products, mainly vegetables, and causing a fly problem in the JRV in winter, which is annoying the inhabitants and threatening tourism.
- Plastic sheets used in the greenhouses and in drip irrigation (mulch) affect the fertility of the soil.
- Overexploitation of groundwater due to intensive irrigation reduces the yield of the tube wells and increases pumping costs due to a drop in the water table of the aquifers.
- There is a large drop in the water surface in the Dead Sea and a dangerous reduction in its water area. The level of the Dead Sea was said to fall each year by 85 cm due to extensive water use in the Jordan Basin.
- There is a lack of sewage water networks in towns and villages in the JRV and other irrigated areas. Houses depend on septic tanks to handle sewage water.

On the other hand, some positive impacts of irrigated agriculture include:

- access to improved and safe drinking water facilities for the majority of the inhabitants in the JRV and other irrigated areas;
- expansion of the green cover;
- production of fresh vegetables all around the year;
- increase in the socioeconomic standard of people in the JRV due to the integrated development plan carried out by JVA in that region.

Much of Amman's wastewater treated effluent is discharged in the Zarqa River and is impounded by the King Talal Dam, where it is blended with fresh floodwater and subsequently released for irrigation use in the Jordan Valley. The increased supply of water to Jordan's cities came about at the expense of spring flows discharging into such streams as the Zarqa River, Wadi Shueib, Wadi Karak, Wadi Kufrinja and Wadi Arab. The flow of freshwater in these streams was reduced as a result of increased pumping from the aquifers and the flow was replaced with the effluent of treatment plants, a process that transformed the ecological balance over time (MWI, 2002).

Contaminated water is a source of many human infections, causing diarrhoea and other diseases. In Jordan, the most common parasite causing diarrhoea is *Entamoeba histolyca,* while *Salmonella* and *Shigella* are the most common bacteria. Naturally, children are more exposed to such infections than adults.

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

Within the years to come Jordan will have developed all its available water resources. The available renewable water will never be enough to meet the escalating water demand. The water deficit for all uses is expected to grow from 224 million m^3 in 1995 to 437 million m^3 in 2020 and will have to be met by mining groundwater at rates not exceeding the safe yields, desalination of brackish and saline water and seawater, rationing of the water demand and improving water management in the country.

In the long term, actions to introduce integrated planning and reallocate water among other economic sectors should be considered. Water needs to be reallocated between the different water using sectors to ensure the limited water resources are used economically. Irrigated agriculture cannot increase due to the unavailability of water resources. Sewage treated wastewater will increase to more than 245 million m^3 and will form a major portion of agricultural water to replace the freshwater reallocated for domestic and municipal purposes.

In the near future, agricultural water management will need to take into consideration the following aspects:

- control of abstraction from groundwater basins in order to reduce overexploitation;
- improvement of the water quality in irrigation through desalination (desalination of King Talal Dam water and of Karamah Dam water);
- increasing water use efficiency by adopting efficient localized farm irrigation methods and irrigation scheduling. Efforts from donors in this field should be promoted and coordinated;
- increasing the net benefit per unit of land and water. High value cash crops with low water requirements should be promoted, while crops with high water requirements should be reduced based on water saving and marketing opportunities;
- participation of farms in O&M of public sector irrigation schemes;
- full recovery of O&M costs.

Cropping patterns in irrigated agriculture based on water saving and agricultural marketing opportunities in Europe and the neighbouring countries will be important in promoting the role of agriculture in the national economy and competing with the products of other countries in the local and international markets in this era of world trade and globalization. Private sector investments should be encouraged in irrigated agriculture to face the challenges of the new era.

The MWI's strategy is to make full use of the wastewater effluent for restricted irrigated agriculture. Implementing this strategy requires that the quality of the wastewater effluents meet the Jordanian standards and WHO guidelines for irrigation water quality. The MWI has adopted a new overall water strategy and new policy statements in four water sub-sectors: utilities, irrigated agriculture, wastewater management and groundwater management. These documents strongly suggest that the government is committed to:

- maximize integrated socioeconomic returns to water
- sustain irrigated agriculture in the JRV
- increase wastewater services and manage wastewater so that it can be available for irrigated agriculture
- protect the groundwater quality
- limit the abstraction of groundwater to sustainable yield.

The highest priority is to upgrade the existing treatment plants and the monitoring facilities so that they comply fully with the effluent water quality standards (MWI, 2002).

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Kuwait

GEOGRAPHY, CLIMATE AND POPULATION

Geography

Kuwait, with a total area of 17 820 km², lies at the head of the Persian Gulf. It is bordered in the north and northwest by Iraq, in the west and south by Saudi Arabia and it overlooks the Persian Gulf to the east. The land is generally flat with slightly undulating desert plains sloping gently towards the northeast, reaching an altitude of about 300 metres above sea level. Most of the area is desert with a few oases.

In 2003, the total cultivated area covered 7 050 ha, of which about 80 percent was occupied by annual crops (Table 1). The arable land of Kuwait is characterized by a soil with a sandy texture, containing 80–90 percent sand. It has good drainage and airing characteristics but a very low water retention capacity. It is very poor in organic matter and the nutritional elements needed by plants. Hard pans (locally known as "gutch") prevail at different depths of the soil, and are a constraint on water permeability.

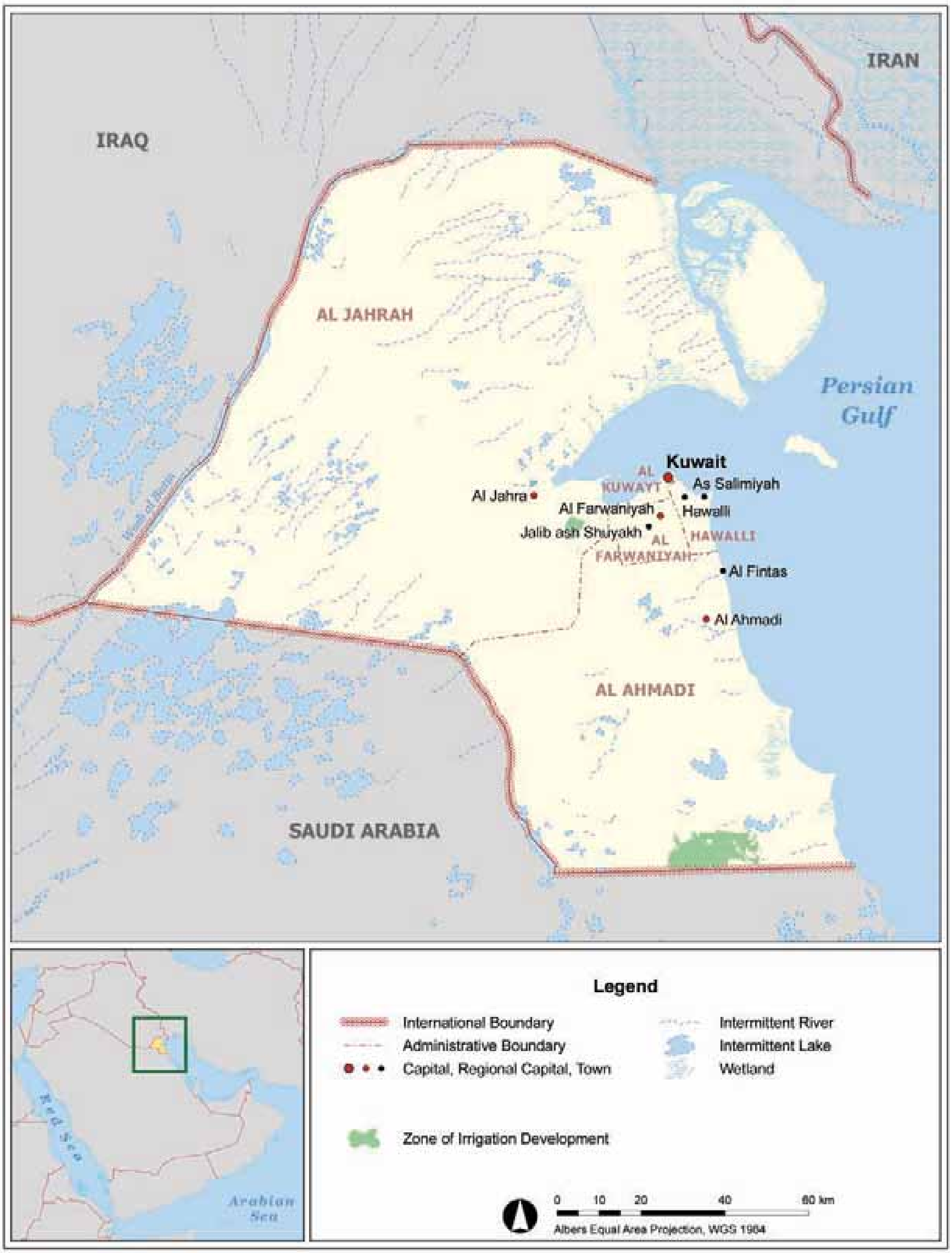
About 154 000 ha have been judged as potentially cultivable land. However, it is almost completely covered by permanent pasture. Estimates for crop production potential vary between 25 000 and 37 500 ha, mainly located in: i) the Al Wafra area near the southern border where there are an estimated 1 495 farms that cover a total area of 10 000 ha; ii) the Al Abdali area near the northern border that contains 810 farms in a total area estimated at 20 000 ha; iii) the Al Sulaibiya agricultural area in the centre of the country, where the soil is much better, as it is deep with a sandy texture, good drainage characteristics and good airing and without salt, hard pans or impermeable layers; the number of productive farms in this area, covering an area of about 5 000 ha, is estimated at 68, including 13 vegetable and crop farms, 37 cattle farms, 4 sheep and goat farms, and 14 poultry farms.

Climate

Kuwait has a desert climate characterized by a long, dry, hot summer, with temperatures reaching more than 45 °C with frequent sandstorms, and a cooler winter, with temperatures sometimes even falling below 4 °C. The rainy season extends from October to May. Over an area of about 100 km² annual rainfall is less than 100 mm, while in the remaining part it varies between 100 and 300 mm. The long-term average annual rainfall for the whole country is about 121 mm. In recent years rainfall has varied between 106 and 134 mm/year.

Population

Total population is 2.69 million (2005), of which only 4 percent is rural (Table 1). However, exact figures are difficult to give because of the large amount of immigrant labour. For example, in 1994 about 63 percent of the total population was estimated to



KUWAIT **FAO - AQUASTAT, 2008**

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TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2005	1 782 000	ha
Cultivated area (arable land and area under permanent crops)	2003	7 050	ha
• as % of the total area of the country	2003	0.4	%
• arable land (annual crops + temp. fallow + temp. meadows)	2003	5 665	ha
• area under permanent crops	2003	1 385	ha
Population			
Total population	2005	2 687 000	inhabitants
• of which rural	2005	3.6	%
Population density	2005	151	inhabitants/km^2
Economically active population	2005	1 469 000	inhabitants
• as % of total population	2005	54.7	%
• female	2005	25.6	%
• male	2005	74.4	%
Population economically active in agriculture	2005	15 000	inhabitants
• as % of total economically active population	2005	1.0	%
• female	2005	0	%
• male	2005	100	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2006	102 100	million US$/yr
• value added by agriculture (% of GDP)	2000	0	%
• GDP per capita	2005	30 071	US$/yr
Human Development Index (highest = 1)	2005	0.891	
Access to improved drinking water sources			
Total population		-	%
Urban population		-	%
Rural population		-	%

be non-Kuwait residents. The average population density is 151 inhabitants/km^2, but varies widely from one region to another. The annual population growth, including both Kuwaiti and non-Kuwait residents, is estimated at 3 percent (2005).

ECONOMY, AGRICULTURE AND FOOD SECURITY

The economy is dominated by petroleum, which accounts for 90-95 percent of merchandise export earnings, 80 percent of budget revenues and around 40 percent of nominal gross domestic product (GDP). The GDP is US$102.1 billion (2006) (Table 1). Agriculture (including fisheries) accounts for almost 0 percent of GDP and does not offer an important source of employment. The total economically active population is about 1.47 million (2005) of which 74 percent is male and 26 percent female. Around 1 percent of the economically active population works in agriculture, almost all foreigners (2005). Most farm owners are investors and also have other sources of income.

Livestock production is an important component of the agricultural sector and contributes about 67 percent to total agricultural GDP, as compared to 23 percent for plant production and 10 percent for fisheries.

WATER RESOURCES AND USE

Water resources

The prevailing hyper-arid climate of Kuwait is not favourable to the existence of any river systems in the country. There are no permanent rivers or lakes, but small wadis develop in the shallow depressions in the desert terrain. Surface runoff sometimes occurs in the large wadi depressions during the rainy season. Flash floods are reported to last from only a few hours to several days. Due to the extremely high evaporation losses and the high deficit in soil moisture, only a small percentage of the precipitation infiltrates into the groundwater supply. Internal renewable groundwater sources are negligible. Groundwater inflow has been estimated at about 20 million m³/year through lateral underflow from Saudi Arabia (Table 2).

Thick geological sequences are of sedimentary origin from the Palaeocene to Recent, in two groups known as Hasa and Kuwait. The Hasa group, which consists of limestone, dolomite, anhydrite and clays, comprises three formation units, known as Umm er Radhuma in the Palaeocene to the Middle Eocene, Rus in the Lower Eocene, and Damman in the Middle Eocene. The Kuwait group, which consists of fluvial sediments of sand and gravel, calcareous sand and sandstone with some clays, gypsums, limestone, and marls, comprises three formation units, known as Ghar in the Miocene, Fars in the Pliocene, and Dibdibba in the Pleistocene (UNU, 1995).

Groundwater can be divided into the following three categories according to its salt content (Public Authority of Agriculture Affairs and Fish Resources, 2006):

- Fresh groundwater: its content of soluble salt is less than 1 000 mg/l and such water is not used for agriculture but is considered as a strategic freshwater reservoir for drinking water purposes. It is mostly available in the two fields of Rawdatian and Umm Al Eish. These freshwater lenses are formed due to a combination of unique conditions that include high intensity rainfall of short duration, and a geomorphology and lithology that enable rapid infiltration to the underlying groundwater. From historical pumping and water quality variation data acquired between 1963 and 1977, the sustainable extraction rate for Rawdatain and Umm Al Eish, which would avoid the upcoming of deeper saline water, is estimated to be 5 500 and 3 500 m³/day respectively (Kwarteng *et al*, 2000).
- Brackish groundwater: its soluble salt content is from 1 000 to 7 000 mg/l and is used for agricultural and domestic purposes and as drinking water for cattle. This water is produced from the Al Shaya, Al Qadeer, Al Solaybeia, Al Wafra and Al Abdali fields. The production capacity of these fields is around 545 000 m³/day.
- Saline groundwater: the soluble salt content in this water is between 7 000 to 20 000 mg/l and it is therefore not appropriate for agricultural or domestic use.

In general groundwater quality and quantity are deteriorating due to the continuous pumping of water. In Al Wafra in the south, 50 percent of the wells pumped water

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	121	mm/yr
	-	2.16	10^9 m³/yr
Internal renewable water resources (long-term average)	-	0	10^9 m³/yr
Total actual renewable water resources	-	0.02	10^9 m³/yr
Dependency ratio	-	100	%
Total actual renewable water resources per inhabitant	2005	7.4	m³/yr
Total dam capacity		-	10^6 m³
Water withdrawal			
Total water withdrawal	2002	913.2	10^6 m³/yr
- irrigation + livestock	2002	491.9	10^6 m³/yr
- municipalities	2002	400.5	10^6 m³/yr
- industry	2002	20.8	10^6 m³/yr
per inhabitant	2002	375	m³/yr
Surface water and groundwater withdrawal	2002	415	10^6 m³/yr
• as % of total actual renewable water resources	2002	2 075	%
Non-conventional sources of water			
Produced wastewater	2003	244	10^6 m³/yr
Treated wastewater	2005	250	10^6 m³/yr
Reused treated wastewater	2002	78	10^6 m³/yr
Desalinated water produced	2002	420.2	10^6 m³/yr
Reused agricultural drainage water		-	10^6 m³/yr

with a salinity level higher than 7 500 ppm in 1989, reaching 75 percent and 85 percent in the years 1997 and 2002 respectively. In Al Abdali in the north, these figures were estimated at 55, 75 and 90 percent respectively.

The first plant for desalinating sea water was established at Al Ahmadi port in 1951, with a capacity of 364 m^3/day. The production capacity increased over the years until it reached 1.1 million m^3/day, while maximum consumption reached 0.9 million m^3/day in the summer of 1995 (PAAFR, 2006). In 2002 the annual quantity of desalinated water produced was 420 million m^3 (FAO, 2005). The problem with seawater distillation is the high cost of the multi-stage flash (MSF) evaporation process. The cost of the thermal process is largely dependent on the rate of energy (fuel) consumption for operating the system, which can account for as much as about 50 percent of the water unit cost, thus being sensitive to the unstable world market price of crude oil (UNU, 1995).

Over 90 percent of the population is connected to a central sewerage system. This offers an important potential for treated wastewater reuse that can contribute to alleviating the water shortage problem. However, various conditions affect the quality and quantity of sanitary sewage from the time it enters the local collector sewers until it is converted to sludge and treated sewage effluent at the sewage treatment plants. Qualitative and quantitative monitoring of the system and of the effluent from the time it leaves treatment plants to the end use for irrigation is essential to prevent the potential hazards associated with wastewater reuse. The sewerage system consists of an assemblage network that is based on gravity and which collects wastewater and transfers it to 60 pump stations (17 main and 43 secondary) from which it is pumped into pipelines all the way to wastewater treatment plants (WWTP) where it is treated. Total length of pipelines is 650 km. The sewerage system collects over 90 percent of the raw domestic and some industrial wastewater (220 million m^3/yr), in addition to part of the storm water runoff in the residential areas which are connected to the sewerage system. The main WWTP, including those in operation, planning and implementation, are shown in Table 3 where the current treated volumes are indicated. Wastewater treatment has two main purposes: i) to protect public health and the environment; ii) to use treated wastewater for irrigation to compensate for the water deficit. In 2002 the wastewater treated represented 152 million m^3 of which 78 million m^3 was reused, which means an increase of 48 and 50 percent respectively compared to 1994. In 2005 the total amount of treated sewage water was estimated at 250 million m^3/year (FAO, 2005). Treatment plants are gradually being upgraded to advanced levels of treatment with the first plant (Al Solaybeia) planned to begin operating by the end of 2004 using a very advanced level of treatment, the RO-Plant (FAO, 2005).

Water use

In 2002 the total water withdrawal was around 913 million m^3, compared to 538 million m^3 in 1993 (Table 4 and Table 5). The per capita water consumption in Kuwait is high.

TABLE 3
Current and projected treated wastewater production in Kuwait

Plant	Effluent production in m^3/d		Remarks
	Design	2004	
Al Ardiya	150 000	270 000	To be replaced by the Al Solaybeia plant
Al Rigga	100 000	180 000	Tertiary treatment by sand filtration
Al Jahra	70 000	66 000	Same
Al Hayman	10 000	10 000	Tertiary treatment by sand filtration plus UV disinfection
Al Wafra	10 000	4 000	SBR
Total		**530 000**	

A new wastewater treatment plant at Sulaibiya, considered one of the biggest and most advanced (RO-wastewater) plants in the world, should now be in operation with a design capacity of 425 000 m^3/day

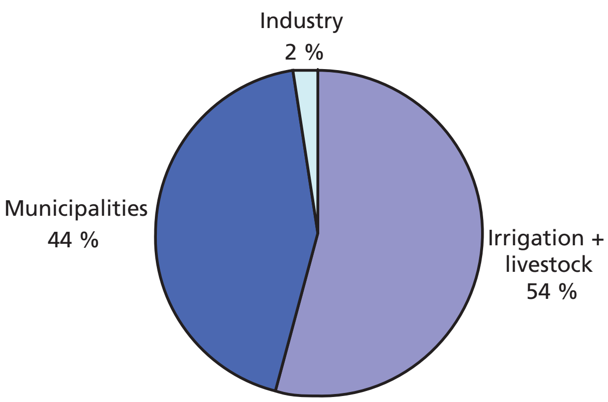
TABLE 4
Water resources availability and use in 2002 (million m^3/yr)

Source of water	Water availability	Water use
Desalinated water	420.2	420.2
Treated wastewater effluents	152	78
Brackish water (MOE 94% and Kuwait Oil Co. 6%)	115	415
Groundwater from private farms' boreholes	1 047	
Total	**1 734.2**	**913.2**

TABLE 5
Water use in 2002 (million m^3/yr)

Uses	Desalinated water	Reused treated wastewater	Brackish groundwater	Total	%
Potable	368.5	-	32.0	400.5	43.86
Landscape	6.9	12.0	25.9	44.8	4.91
Agricultural	27.0	66.0	300.0	393.0	43.03
Industrial	17.8	-	3.0	20.8	2.28
Others	-	-	54.1	54.1	5.92
Total	**420.2**	**78.0**	**415.0**	**913.2**	**100.00**
%	**46.0**	**8.5**	**45.5**	**100.0**	

FIGURE 1
Water withdrawal by sector
Total: 0.913 km^3 in 2002



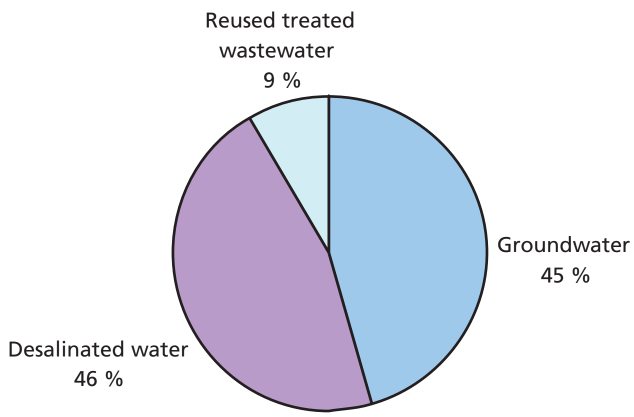
54 percent of the water withdrawn was used for agriculture, 44 percent for municipal purposes and 2 percent for industrial purposes (Figure 1). Of the 492 million m^3 withdrawn for agriculture, 80 percent was used for productive agriculture, 9 percent for landscape greening and 11 percent for garden watering (but it also includes some non-drinking uses at household level). Of the water withdrawn for productive agriculture, 300 million m^3 is brackish water from private farms' boreholes at Al Abdali and Al Wafra (based on 12 hours operation and 270 days/year with an average discharge of 40 m^3/h per well). 66 million m^3 are treated wastewater effluent (50 percent tertiary treatment and 50 percent more advanced treatment).

Fresh groundwater withdrawal amounts to 255 million m^3/year, leading to an extraction of more than 12 times the annual groundwater inflow (20 million m^3) (Figure 2). Farmers are only allowed to withdraw water from the Kuwait group aquifer and there were about 1 767 wells in 1994. The water used for livestock purposes is pumped by the Ministry of Electricity and Water (MEW) from the Damman group aquifer through deep artesian wells. Continued heavy extraction was estimated to have led to a decline in the groundwater level of 200 metres by the year 2000.

Overdrafting of brackish groundwater over the past decades has led to high drawdown and at times even depletion as well as increased salinity levels. Its use for agriculture is limited to plant species that tolerate high salinity levels. As an example, in 1985 crop irrigation was being carried out by pumping 53–67 million m^3 of brackish groundwater per year from the well fields in Al Wafra and Abdali-Um Nigga. Existing yield, estimated potential yield, and water salinity of each well field at that time are shown in Table 6 (UNU, 1995).

Desalinated seawater is currently used for all purposes, although the largest share is allocated to the drinking supply. Treated wastewater effluent is usually a mix of tertiary and more advanced treatment of wastewater. Tertiary treated sewage water is mainly used for the irrigation of fodder crops and date palms and also for landscaping.

FIGURE 2
Water withdrawal by source
Total: 0.913 km³ in 2002



During the period 1925-1950, Kuwait imported freshwater from the Shatt al-Arab in Iraq, some 100 km northwest from Kuwait, to supplement the water obtained from wells. Further exploitation of water resources was initiated by the rapid development of the oil industry and commerce in the 1950s, when shortage problems became a constraint to economic development (UNU, 1995).

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

Irrigation in Kuwait started in the late 1950s. Initially surface irrigation techniques (furrow and basin irrigation) were used. Sprinkler irrigation was introduced in 1977, using treated wastewater. Localized irrigation was introduced in 1979, first for agricultural production in greenhouses, but from 1981 onwards also for irrigation in open fields in order to preserve the water resources.

In 1994 the total water managed area, all with full or partial control irrigation, was 4 770 ha, which is in fact equal to the cultivated area, as the entire cultivated area is irrigated. Out of this area, almost 61 percent was irrigated with groundwater (Figure 3). Surface irrigation is the main irrigation technology used in Kuwait, covering 63 percent of the area equipped for irrigation (Figure 4). Localized and sprinkler irrigation cover 24 and 13 percent respectively. In 2003, the total area equipped for irrigation was 7 050 ha (Table 7).

There are three types of farming in the irrigation sector:

TABLE 6
Well fields in Kuwait in 1985 (Kuwait Institute for Scientific Research, 1990)

Field	Aquifer	Number of wells	Yield (million m³/year)		Salinity (TDS, mg/l)	Purpose
			Existing	Potential		
Rawdatain and Um Al Eish	Dibdibba F	52	2.5	6.6	700-1 200	water supply
Shigaya A, B. C	Kuwait G	60	53	66	3 000-4 000	water supply
Shigaya D, E	DammanF	54	-	42	3 000-4 500	water supply
Solaybeia	Damman F	133	25-33	33	4 500-5 500	water supply
Abduliya	Damman F	14	8	-	4 500	water supply
Wafra	Kuwait G	(110)	33-42	50	4 000-6 000	irrigation
Abdali Um Nigga	Dibdibba F	(110)	20-25	33-42	3 000-7 000	irrigation

FIGURE 3
Source of irrigation water
Total: 4 770 ha in 1994

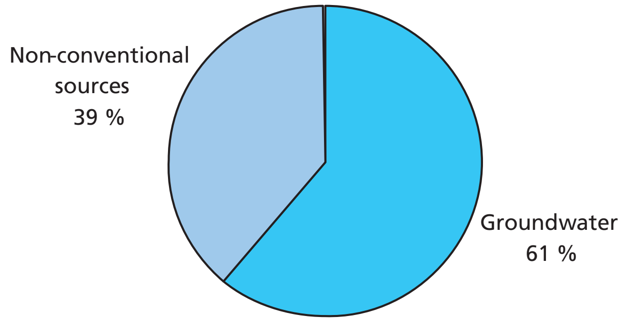
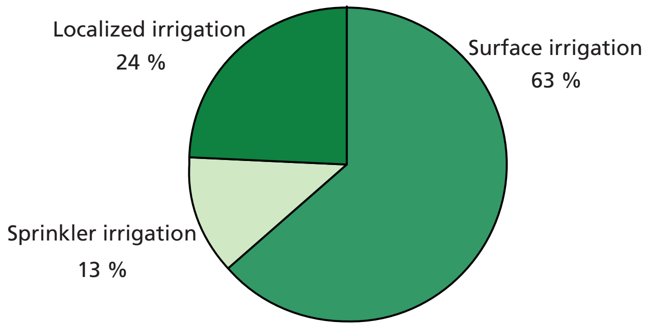


FIGURE 4
Irrigation techniques
Total: 4 770 ha in 1994



- Private farms, which are leased by the government to investors (25 years renewable) and operated by labourers. These are the most numerous. The smaller ones are mostly located in Al Wafra in the south, the larger ones in Al Abdali in the north;
- Institutional schemes, which are operated by the government through the Public Authority for Agricultural Affairs and Fish Resources (PAAFR);
- Company-owned schemes such as the United Company for Agricultural Production, located in Al Solaybeia in the centre of the country.

Role of irrigation in agricultural production, the economy and society

The cost of irrigation development for small schemes (< 10 ha), equipped with localized irrigation including one well and a pump, amounts to US$19 000/ha. The cost decreases as the irrigation scheme size increases and for large schemes (> 30 ha) it is about US$15 000/ha. Annual operation and maintenance costs per ha are estimated at 2 percent of the investment costs.

There are no water charges for groundwater use. Farmers are charged for desalinated water use and the charge varies from US$0.9/$m^3$ for small schemes to US$1.5/$m^3$ for large schemes. The treated sewage water charge is US$0.07/$m^3$.

In 2006, about 45 percent of the harvested land was devoted to vegetable production, mainly tomatoes, eggplants, cucumbers and sweet peppers, and 19 percent concerned cereals, mainly barley and wheat. Date palm trees are the most important fruit trees grown, which occupy about 20 percent of the cultivated land. The remaining crops grown are potatoes and some other annual and permanent crops (Figure 5). In 2003, agricultural production included 207 000 tonnes of vegetables, 18 000 tonnes of fruits and about 3 300 tonnes of cereals.

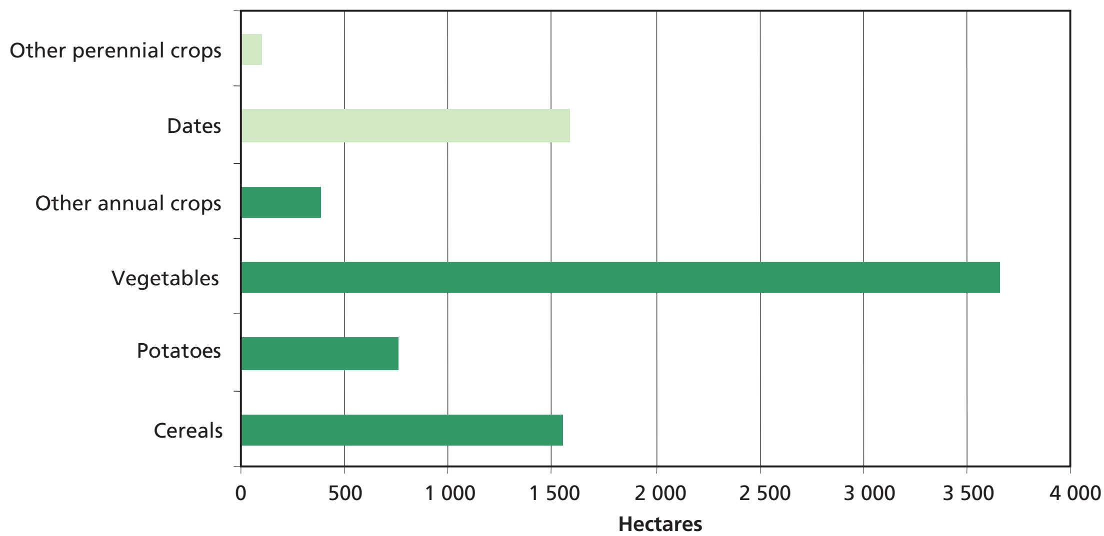
Status and evolution of drainage systems

Impervious layers exist at various depths in the Al Wafra area creating waterlogging in some areas. In 1994 this was estimated at 2 840 ha, due to poor natural drainage. On-farm drainage systems have not yet been developed, but some studies related to this subject are being conducted by the Public Authority for Agricultural Affairs and Fish Resources (PAAFR) and the Ministry of Electricity and Water (MEW). Small-scale subsurface drainage systems were installed in some public gardens (2 ha). The area salinized by irrigation was estimated at 4 080 ha in 1994.

TABLE 7
Irrigation and drainage

Irrigation potential	**-**	**25 000**	**ha**
Irrigation			
1. Full or partial control irrigation: equipped area	2003	7 050	ha
- surface irrigation	1994	3 020	ha
- sprinkler irrigation	1994	600	ha
- localized irrigation	1994	1 150	ha
• % of area irrigated from surface water	1994	0	%
• % of area irrigated from groundwater	1994	61	%
• % of area irrigated from mixed surface water and groundwater	1994	0	%
• % of area irrigated from non-conventional sources of water	1994	39	%
• area equipped for full or partial control irrigation actually irrigated	2003	100	ha
- as % of full/partial control area equipped		-	%
2. Equipped lowlands (wetland, ivbs, flood plains, mangroves)	2003	0	ha
3. Spate irrigation	2003	0	ha
Total area equipped for irrigation (1+2+3)	**2003**	**7 050**	**ha**
• as % of cultivated area	2003	100	%
• % of total area equipped for irrigation actually irrigated	2003	100	%
• average increase per year over the last 9 years	1994-2003	4.4	%
• power irrigated area as % of total area equipped	1994	100	%
4. Non-equipped cultivated wetlands and inland valley bottoms	2003	0	ha
5. Non-equipped flood recession cropping area	2003	0	ha
Total water-managed area (1+2+3+4+5)	**2003**	**7 050**	**ha**
• as % of cultivated area	2003	100	%
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	2006	3 833	metric tonnes
• as % of total grain production	2006	100	%
Harvested crops			
Total harvested irrigated cropped area	2006	8 055	ha
• Annual crops: total	2006	6 363	ha
- Wheat	2006	290	ha
- Barley	2006	1 263	ha
- Potatoes	2006	760	ha
- Vegetables	2006	3 660	ha
- Other annual crops	2006	390	ha
• Permanent crops: total	2006	1 692	ha
- Dates	2006	1 589	ha
- Other perennial crops	2006	103	ha
Irrigated cropping intensity (on full/partial control irrigation: equipped area)	2003	106	%
Drainage – Environment			
Total drained area	1994	2	ha
- part of the drained area equipped for irrigation		-	ha
- other drained area (non-irrigated)		-	ha
• drained area as % of cultivated area	1994	0.04	%
Flood-protected areas		-	ha
Area salinized by irrigation	1994	4 080	ha
Population affected by water-related diseases		-	inhabitants

FIGURE 5
Irrigated crops
Total harvested area: 8 055 ha in 2006 (cropping intensity on equipped area actually irrigated: 106%)



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

Institutions

The main institutions involved in water resources management are:

- The Public Authority for Agricultural Affairs and Fish Resources (PAAFR), established in 1983. Traditionally, the PAAFR was affiliated to the Ministry of Public Works (MPW), but recently it has been moved under the Council of Ministers in order to provide it with more autonomy. The PAAFR is responsible for managing the agricultural economic development and enhancing food security. Administratively, the PAAFR is organized into five main sectors: i) animal resources, ii) fisheries resources, iii) plant resources, iv) landscaping, v) finance and administration (FAO, 2005). The Soil and Water Division is responsible for the design and evaluation of farm irrigation systems, testing irrigation equipment, crop water requirement research, monitoring of groundwater quality and quantity and water resources planning. The Landscape and Greenery Department is responsible for irrigation designs for highways and forestry areas.
- The Ministry of Electricity and Water (MEW), established in 1962: responsible for studies, development, exploration, monitoring and giving licences for drilling and using groundwater;
- The Ministry of Public Works (MPW), established in 1962: responsible for sewage water networks and collection reservoirs, wastewater treatment and utilization and water quality monitoring laboratories. Also responsible for the delivery of treated sewage effluent to farms and public gardens.
- The Kuwait Institute for Scientific Research (KISR): in charge of research related to water resources with the Water Resources Division and Environment and the Urban Development Division.
- The Environmental Public Authority (EPA), in charge of monitoring water quality, with water analysis laboratories, a research and studies centre and a soil and arid land division.
- The Ministry of Health (MOH).

Water management

In addition to government institutions, several farmers' associations and cooperatives are active in the agricultural and fisheries sector, including the two agricultural cooperative societies in Al Wafra and Al Abdali, the Kuwaiti Farmers' Federation, the Kuwait Association of Fishermen, the Animal Wealth Cooperative Society, the Federation of Fresh Milk Producers and the Society for Poultry Growers (FAO, 2005).

Finances

The Industrial Bank of Kuwait (IBK) is responsible for administering the "Agriculture and fisheries credit portfolio", which is a fund earmarked for soft loans for investment in agriculture and fisheries (FAO, 2005).

ENVIRONMENT AND HEALTH

The only natural freshwater resource of Kuwait occurs as lenses floating on the saline groundwater in the northern part of the country near to the oil fields. Rainwater is the only means of recharging this limited groundwater resource. This groundwater is used as bottled drinking water and the fresh groundwater aquifer is considered as a strategic drinking water reserve for Kuwait. As a result of the 1991 Gulf War, the upper soil layer was contaminated by crude oil and crude oil combustion products, which are potential pollutants likely to affect the groundwater resources (Literathy *et al, 2003*).

In Kuwait, as in other countries of the world, the main concerns in water recycling and reuse are: (a) reliable treatment of wastewater to meet strict water quality requirements for the intended reuse, (b) protection of public health and (c) gaining public acceptance. In the case of reusing recycled water for irrigation of vegetables and other crops that are consumed uncooked or for green residential spaces with high public contact and for groundwater recharge, several public health concerns are encountered.

While potable reuse of treated wastewater is still a distant possibility, groundwater recharge with advanced wastewater treatment technologies is a viable option. However, in Kuwait, as well as in other countries in the region, a lack of experimental data on groundwater recharge from local research means that efforts should be focused in that direction (Angelakis *et al*, 2005).

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

Kuwait is planning to reclaim more land in order to provide food for the population by putting it under irrigation. This will increase irrigated areas and boost demand for water in the irrigation sector. Faced with these conditions, it is imperative to rationalize the water use efficiency of the existing water resources and to increase the supply as much as possible. The water economy of the country is based on non-conventional sources of water. The use of treated wastewater becomes one of the most important solutions for extending irrigation of agricultural crops and landscape. While its use poses potential health hazards and environmental problems, these could be faced effectively with the available technology and good management. It is the main source of non-conventional water that can be used in a cost-effective manner for irrigation. Desalinated water can also be used, but because of its high cost only high-value cash crops produced under intensive conditions are cost-effective today (FAO, 2005).

Waterlogging and salinization problems are prevalent, which underlines the urgent need to improve drainage, both for agricultural and landscaping areas and to convince the farmers/users of the need for adequate drainage facilities.

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Lebanon

GEOGRAPHY, CLIMATE AND POPULATION

Geography

Lebanon, with a total area of 10 400 km², is situated east of the Mediterranean Sea and bordered by the Syrian Arab Republic to the north and east and by Israel to the south. It is a mountainous country, stretching about 60 km in width from west to east and about 225 km along the Mediterranean coast from north to south. About 8 percent is covered by forest and Mediterranean brushwood.

Administratively, Lebanon was divided until 2003 into six mohafazats or governorates (Beirut, North, Mount Lebanon, South, Nabatiyeh and Bekaa). In 2003, two new mohafazats were created (Akkar and Baalbeck Hermel). Topographically, there are four parallel areas running north-south which are, from west to east, as follows:

- a flat, narrow coastal strip parallel to the Mediterranean sea;
- the Lebanon Mountains, a chain with mid-range mountains up to 1 000 m above sea level and high mountains reaching 3 087 m above sea level at Qurnat as Sawda in northern Lebanon;
- the fertile Bekaa Valley at around 900 m above sea level;
- the Anti-Lebanon mountainous chain, which rises to 2 800 m and stretches across the eastern border with the Syrian Arab Republic.

About 70 percent of Lebanon’s land consists of carbonate rocks from the Middle Jurassic to the Eocene period. The soils of Lebanon are typically Mediterranean, generally calcareous except for the sandy soils formed on the basal cretaceous strata of the Akkar Plain and the alluvial soils of central and western Bekaa Valley. Lebanon has a complex landform consisting of sloping and steep lands. The high slope gradient is a major physical factor, exacerbating water erosion of the upper layer of the soil and leading to a weak structure and reduced water-holding capacity.

The cultivable area is estimated at 360 000 ha, or 35 percent of the total area. In 2005, the cultivated area was 328 000 ha, of which 186 000 ha annual crops and 142 000 ha permanent crops (Table 1), amounting to increases of 63 and 68 percent respectively since 1993. The two main agricultural regions are the Bekaa Valley, accounting for 42 percent of the total cultivated area, and North Lebanon, which accounts for 26 percent. In 1999, the harvested crop area, including both rainfed and irrigated production, consisted of fruit trees (26 percent), cereals (22 percent), olives (22 percent), vegetables (19 percent) and industrial crops (11 percent) (MOA and FAO, 2000).

Climate

The climate of Lebanon is typically Mediterranean, with heavy rains in the winter season (November to May) and dry and arid conditions in the remaining seven months of the year. However, the influence of the Mediterranean Sea, the topographic features,

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and the Syrian Desert in the north creates a variety of microclimates within the country with contrasting temperatures and rainfall distribution. On the coast, the average annual temperature is 20 °C, ranging from 13 °C in winter to 27 °C in summer whereas the average annual temperature in the Bekaa valley is lower at 16 °C, ranging from 5 °C in winter to 26 °C in summer; nevertheless, at higher elevations in the mountain zones the average annual temperature is below 10 °C, ranging from 0 °C in winter to 18 °C in summer. Average annual rainfall is estimated at 823 mm although this varies from 700 to 1 000 mm along the coastal zones and from 1 500 to 2 000 mm on the high mountains, decreasing to 400 mm in the eastern parts and to less than 200 mm in the northeast. Above 2 000 m, precipitation is essentially niveus and helps to sustain a base yield for about 2 000 springs during the dry period. Precipitation in dry years can be as little as 50 percent of the average. Rainfall occurs on 80 to 90 days a year, mainly between October and April. About 75 percent of the annual stream flow occurs in the five-month period from January to May, 16 percent from June to July and only 9 percent in the remaining five months from August to December.

The National Meteorological Service has identified eight ecoclimatic zones based on rainfall:

- the coastal strip, which includes the northern, central and southern coasts;
- the Lebanon Mountains, which are divided into the northern and central mountains;
- the Bekaa Valley, which is divided into the northern (interior Asi-Orontes), central (interior Litani) and southern (interior Hasbani) regions.

Mean annual potential evapotranspiration ranges from 1 100 mm on the coast to 1 200 mm in the Bekaa Valley, with maximum values recorded in July. Generally, fewer adverse effects are observed on the coast than in the Bekaa Valley, where effects due to wind and high vapour pressure deficit are dominant (LNAP, 2002).

TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2005	1 040 000	ha
Cultivated area (arable land and area under permanent crops)	2005	328 000	ha
• as % of the total area of the country	2005	31.5	%
• arable land (annual crops + temp fallow + temp. meadows)	2005	186 000	ha
• area under permanent crops	2005	142 000	ha
Population			
Total population	2005	3 577 000	inhabitants
• of which rural	2005	12	%
Population density	2005	343.9	inhabitants/km²
Economically active population	2005	1 337 000	inhabitants
• as % of total population	2005	37.4	%
• female	2005	30.4	%
• male	2005	69.6	%
Population economically active in agriculture	2005	35 000	inhabitants
• as % of total economically active population	2005	2.6	%
• female	2005	40	%
• male	2005	60	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2007	24 000	million US$/yr
• value added in agriculture (% of GDP)	2007	6	%
• GDP per capita	2005	6 011	US$/yr
Human Development Index (highest = 1)	2005	0.772	
Access to improved drinking water sources			
Total population	2006	100	%
Urban population	2006	100	%
Rural population	2006	100	%

Population

The total population is 3.58 million (2005), of which around 12 percent is rural (Table 1). Population density is 344 inhabitants/km^2. The annual demographic growth rate was estimated at 1 percent in the period 2000–2005. In 2006, the whole population had access to improved water sources. In 2000, 98 percent of the total population had access to improved sanitation (100 and 87 percent in urban and rural areas respectively).

ECONOMY, AGRICULTURE AND FOOD SECURITY

In 2007, Lebanon's Gross Domestic Product (GDP) was US$24 billion (Table 1). Agriculture accounted for 6 percent of GDP and the service sector for more than two-thirds. The total economically active population is 1.34 million, or slightly more than 37 percent of the total population (2005) and in 2003 the unemployment rate was 18 percent. The economically active population in agriculture is estimated at 35 000 (2005), of which 40 percent is female. The agricultural labour force declined from 25 percent in 1967 to less than 9 percent in 1990 and less than 3 percent of the total economically active population in 2005. However, agriculture remains an important source of income in rural areas and although it is difficult to estimate the number of full-time farmers, most families have agriculture as a part-time activity.

The main agricultural products are citrus fruits, grapes, tomatoes, apples, vegetables, potatoes, olives, tobacco, poultry, sheep and goats. Lebanon is an exporter of fruit and vegetables, it is self-sufficient in poultry and produces 45, 15 and 10 percent respectively of its pulses, wheat and sugar needs. It imports 78 percent of its dairy and meat products. In 2005, agricultural exports were estimated at US$196 million, or 17.3 percent of total exports, while agricultural imports were US$1 230 million.

According to the last census carried out by the Ministry of Agriculture in 1999 (almost 30 years after the previous one) there were 194 829 farm holdings (an increase of 39 percent compared with 1970), 87 percent of which had less than 2 ha of cultivated land.

WATER RESOURCES AND USE

Water resources

While Lebanon is in a relatively favourable position as far as rainfall and water resources are concerned, constraints for development consist in the limited availability of water during the seven dry summer months due to the very low water storage capacity, the difficulty of capturing the water close to the sea, and the shortcomings of the existing water delivery systems and networks. The total length of streams in Lebanon is 730 km, mainly on the western side of the mountains, which have steep slopes. Annual internal renewable water resources are estimated at about 4.8 km^3. Annual surface runoff is around 4.1 km^3 and groundwater recharge 3.2 km^3, of which 2.5 km^3 constitutes the base flow of the rivers. About 1 km^3 of this flow comes from over 2 000 springs with an average unit yield of about 10–15 l/s, sustaining a perennial flow for 17 of the total of 40 major streams in the country.

The annual net exploitable surface water and groundwater resources, water that Lebanon can technically and economically recover during average rainfall years, are estimated at 2.080 km^3, consisting of 1.580 km^3 of surface water and 0.500 km^3 of groundwater.

In total, there are about 40 major streams in Lebanon and, based on the hydrographic system, the country can be divided into five regions:

- the Asi-Orontes Basin in the north; the Asi-Orontes River flows into the Syrian Arab Republic in the northeast of the country;
- the Hasbani Basin in the southeast; the Hasbani River, which flows into Israel in the southeast of the country, is a tributary of the Jordan river;
- the Litani Basin in the east and south; the Litani River reaches the sea in the southwest of the country;

- all the remaining major coastal river basins; the northern El Kebir River Basin is shared with the Syrian Arab Republic, the river itself forming part of the border between the two countries before flowing into the sea;
- all the small, scattered and isolated sub-catchments remaining in-between, with no noticeable surface stream flow, such as the endorheic catchments and isolated coastal pockets.

The first three river basins cover about 45 percent of the country. The Asi-Orontes and Hasbani rivers are transboundary rivers, while the Litani River flows entirely within Lebanon. With a total length of 170 km it is the longest river in Lebanon. Its catchment area is about 2 180 km^2, equal to some 20 percent of the total area of the country. Average annual water flowing in the Litani River is 475 million m^3. In the coastal regions, there are about 12 perennial rivers originating in the western slopes of the mountain ranges and flowing from east to west to the sea. The coastal rivers have relatively small catchments (200 km^2 on average) and small courses (< 50 km). The major replenishment of rivers in Lebanon comes from precipitation, as well as from snowmelt and springs. However, a drastic decrease in the river flow has been recorded in the last three decades.

There are eight major aquifers, with a total estimated volume of 1 360 million m^3. Exploitable groundwater ranges from 400 to 1 000 million m^3 (Samad, 2003). The presence of fissures and fractures encourages snowmelt and rainwater to percolate and infiltrate deep into the ground and feed these aquifers. Water may reappear at lower elevations as springs that flow into rivers. Springs are commonly found in Lebanon because of the highly fractured geologic rocks, and because of the existing inter-bed rock formation of differing permeability, which is a feature of the whole country. In total, there are about 2 000 major springs and many other minor springs in Lebanon, generating an estimated flow of 1 150 million m^3/year. Other springs are commonly found along the coast or in the submarine area. They are also called “non-conventional” springs because it is more or less impossible to capture their water before it flows into the sea.

Since Lebanon is at a higher elevation than its neighbours it has practically no incoming surface water flow. The flow of 76 million m^3/year of the El Kebir River on the border between Lebanon and the Syrian Arab Republic is thought to be generated by the 707 km^2 bordering Syrian catchment areas. There might also be some groundwater inflow from these areas, but no figures on quantities are available.

Total surface water outflow is estimated at 735 million m^3/year, of which 160 million m^3 to the sea. Surface water outflow to the Syrian Arab Republic is estimated at 415 million m^3 through the Asi-Orontes River. Surface water flow into northern Israel from the Hasbani/Wazani complex is estimated at 160 million m^3/year.

The transboundary Mount Hermon aquifer contributes to the discharges of the Banias springs in the Golan and the Dan springs in Israel. The total groundwater outflow is estimated at about 1 020 million m^3/year. Of this total, 740 million m^3 is estimated to flow to the sea, 150 million m^3 to Israel (Hulah Lake) and 130 million m^3 to the Syrian Arab Republic (Dan Springs).

The geological conditions make construction of storage dams difficult. The largest artificial lake in Lebanon is located in the southern part of the fertile Bekaa Valley on the Upper Litani River, known as the Qaraoun Reservoir. Constructed in the 1960s, it has a total capacity of about 220 million m^3 and effective storage of 160 million m^3 (60 million as the inter-annual reserve). It supplies in turn three hydroelectric plants generating about 7 to 10 percent (about 190 MW) of Lebanon’s total annual power needs. Moreover, the Qaraoun Reservoir potentially provides every year a total of 140 million m^3 for irrigation purposes (110 for South Lebanon and 30 for Bekaa), and 20 million m^3 for domestic purposes to the South. On the other hand, the Green Plan, which is a public authority established in 1963 for the development of water reservoirs, and the private sector and NGOs have already developed hundreds of small earth and concrete storage ponds, with a maximum capacity per unit of 0.2 million m³. During the period 1964–1992 the Green Plan led to a total of 3.5 million m³ of earth pounds and 0.35 million m³ of concrete pounds. The Litani River Authority implemented three hillside stock ponds in the early 1970s, for a total storage capacity of about 1.8 million m³. The Bisri Dam on the Awali River is currently in the final design stage; it will have a storage capacity of 128 million m³ and is intended mainly for supplying water to Greater Beirut. The Khardaleh Dam on the middle reach of the Litani River, with the same planned storage capacity of 128 million m³, has been put on hold at the preliminary design stage because of the prevailing adverse security situation in the southern border region. In 2007, a new artificial reservoir and dam, named Shabrouh, was inaugurated with a storage capacity of 8 million m³. It is located near the ski resort town of Faraya and provides water for domestic and irrigation purposes. The project will help alleviate water shortages in the Qadaa Kesrouan and parts of the Metn regions.

Lebanon generates an estimated 310 million m³ of wastewater per year (Table 2), of which 249 million m³ is produced by the domestic sector with a total BOD load of 99 960 tonnes and an estimated 61 million m³ by industry. This represents an increase of 88 percent compared with 1991 when 165 million m³ was generated. In 2006, treated wastewater was only 4 million m³, of which 2 million m³ was destined for agricultural purposes, and the rest disposed of in the marine environment by direct diversion to the rivers, or it was infiltrated by deep seepage to groundwater. The potential for reuse of domestic wastewater is estimated at around 100 million m³/year. Some illicit irrigation from untreated wastewater is practised. Another source of non-conventional water is desalinated sea water, which is estimated to be 47.3 million m³ (Mdalal, 2006).

Water use

It is difficult to determine the exact figure for water withdrawal and to make a realistic breakdown between the different sectors. Most private wells are unlicensed and therefore not monitored. In addition, a large share of water in public distribution systems is lost through system leakages. There is 35–50 percent seepage from the water supply networks, which is almost all infiltrated to the aquifers and the extracted again via tube wells, especially in the Greater Beirut metropolitan area.

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)		823	mm/yr
		8.559	10^9 m³/yr
Internal renewable water resources (long-term average)		4.800	10^9 m³/yr
Total actual renewable water resources		4.503	10^9 m³/yr
Dependency ratio		0.79	%
Total actual renewable water resources per inhabitant	2005	1 259	m³/yr
Total dam capacity	2005	225.65	10^6 m³
Water withdrawal			
Total water withdrawal	2005	1 310	10^6 m³/yr
- irrigation + livestock	2005	780	10^6 m³/yr
- municipalities	2005	380	10^6 m³/yr
- industry	2005	150	10^6 m³/yr
• per inhabitant	2005	366	m³/yr
Surface water and groundwater withdrawal	2005	1 096	10^6 m³/yr
• as % of total actual renewable water resources	2005	24	%
Non-conventional sources of water			
Produced wastewater	2001	310	10^6 m³/yr
Treated wastewater	2006	4	10^6 m³/yr
Reused treated wastewater	2006	2	10^6 m³/yr
Desalinated water produced	2006	47.3	10^6 m³/yr
Reused agricultural drainage water	2001	165	10^6 m³/yr

In 2005, water withdrawal was estimated at 1 310 million m³, of which almost 60 percent was for agricultural purposes, 29 percent for municipal use and 11 percent for industry (Table 2 and Figure 1). Groundwater and surface water account for 53.4 percent and 30.2 percent respectively of total water withdrawal. Recycled irrigation drainage accounts for 12.6 percent, desalinated water for 3.6 percent and reused treated wastewater for 0.2 percent (Figure 2). The share of water withdrawal for agriculture is likely to decrease over the coming years as more water will have to be diverted for municipal and industrial purposes. It is estimated that 700 million m³ of water per year is used for hydropower, with direct restitution to the natural river course. Agricultural water withdrawal assessment is based on 11 200 m³/ha per year from surface water and 8 575 m³/ha per year from groundwater. Domestic water use is estimated on the basis of 220–250 litres per person per day during the dry period and 200 litres per person per day during the wet period. Few data are available on the current or expected water needs of the industrial sector. It is estimated that between 60 and 70 percent of water used by industry comes from groundwater and the remainder is drawn from surface water resources.

FIGURE 1
Water withdrawal by sector
Total: 1.310 km³ in 2005

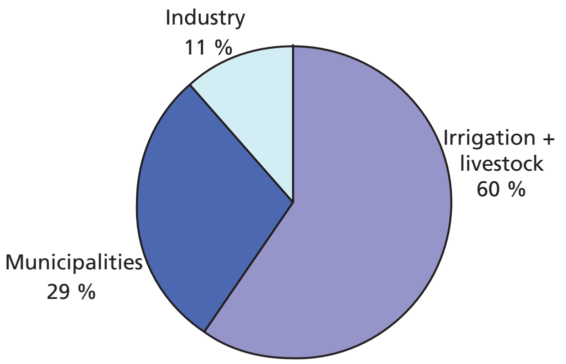
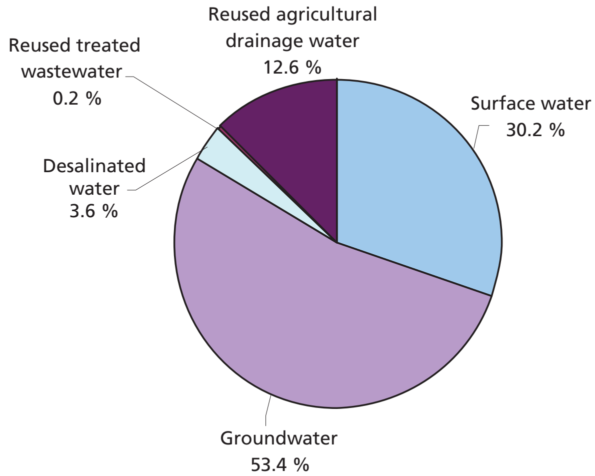


FIGURE 2
Water withdrawal by source
Total: 1.310 km³ in 2005



Groundwater abstraction is secured by means of wells, which tap the major aquifers. Around 1 000 wells are scattered in the area of Beirut, with depths varying between 50 and 300 m and an average individual discharge of 35 l/s. Overpumping from wells in the Beirut area explains salt water intrusion.

International water issues

In 1978, Israel invaded Lebanon, giving Israel temporary control of the Wazzani spring/stream feeding the Jordan River.

In August of 1994, the Lebanese and Syrian governments reached a water-sharing agreement concerning the Asi-Orontes River, according to which Lebanon receives 80 million m³/year if the Asi-Orontes River's flow inside Lebanon is 400 million m³ or more during that given year. If this figure falls below 400, Lebanon's share is adjusted downward, relative to the reduction in flow. Wells in the river's catchment area that were already operational before the agreement are allowed to remain in use, but no new wells are permitted. The Asi-Orontes River rises in an area north of the city of Ba'albeck and flows through the Syrian Arab Republic before entering Iskenderun

TABLE 3
Irrigation and drainage

Irrigation potential			**177 500**	**ha**
Irrigation				
1. Full or partial control irrigation: equipped area		2000	90 000	ha
- surface irrigation		2000	57 200	ha
- sprinkler irrigation		2000	25 100	ha
- localized irrigation		2000	7 700	ha
• % of area irrigated from surface water		2000	44.5	%
• % of area irrigated from groundwater		2000	22.2	%
• % of area irrigated from mixed surface water and groundwater		2000	33.3	%
• % 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)		**2000**	**90 000**	**ha**
• as % of cultivated area		2000	27.1	%
• % of total area equipped for irrigation actually irrigated			-	%
• average increase per year over the last 7 years		1993-2000	0.4	%
• 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)		**2000**	**90 000**	**ha**
• as % of cultivated area		2000	27.1	%
Full or partial control irrigation schemes	**Criteria**			
Small-scale schemes	< 100 ha	2000	24 400	ha
Medium-scale schemes		2000	22 070	ha
large-scale schemes	> 1 000 ha	2000	43 530	ha
Total number of households in irrigation		1998	98 465	
Irrigated crops in full or partial control irrigation schemes				
Total irrigated grain production			-	metric tons
- as % of total grain production			-	%
Harvested crops				
Total harvested irrigated cropped area		2003	105 293	ha
• Annual crops: total		2003	81 213	ha
- Wheat		2003	16 940	ha
- Barley		2003	5 140	ha
- Maize		2003	3 490	ha
- Other cereals		2003	61	ha
- Potatoes		2003	19 166	ha
- Other roots and tubers		2003	4 156	ha
- Pulses		2003	4 310	ha
- Vegetables		2003	14 341	ha
- Tobacco		2003	8 983	ha
- Groundnuts		2003	718	ha
- Flowers		2003	508	ha
- Other annual crops		2003	3 400	ha
• Permanent crops: total		2003	24 080	ha
- Bananas		2003	2 754	ha
- Citrus		2003	16 426	ha
- Other perennial crops		2003	4 900	ha
Irrigated cropping intensity (on full/partial control area equipped)		2000	117	%
Drainage - Environment				
Total drained area		2001	10 000	ha
- part of the area equipped for irrigation drained		2001	3 000	ha
- other drained area (cultivated non-irrigated)		2001	7 000	ha
• drained area as % of cultivated area		2001	3.2	%
Flood-protected areas			-	ha
Area salinized by irrigation		2001	1 000	ha
Population affected by water-related diseases			-	inhabitants

(Alexandretta) and emptying into the Mediterranean Sea. The Al-Azraq spring is a very important Lebanese tributary to the Asi-Orontes River; its annual flow is more than 400 million m^3 (Amery, 1998).

In 2002, the water resources of the Hasbani basin became a source of mounting tension between Lebanon and Israel, when Lebanon announced the construction of a new pumping station at the Wazzani springs. The springs feed the Hasbani river, which rises in the south of Lebanon and crosses the Blue Line frontier to feed the Jordan and subsequently the Sea of Galilee, which is used as Israel's main reservoir. The pumping station was completed in October 2002. Its purpose was to provide drinking water and irrigation for some sixty villages on the Lebanese side of the Blue Line. October 2002 also marked the high point of tension between Israel and Lebanon, with a real risk of armed conflict over the station. The Israelis complained about the lack of prior consultation whereas the Lebanese contended that the project was consistent with the 1955 Johnston Plan for the water resources of the region. The EU and the United States both sent envoys to the region in late 2002 in response to the rising tensions (EU, 2004).

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

Irrigation potential, based on soil and water resources, is estimated at 177 500 ha. The irrigated area in Lebanon increased from 23 000 ha in 1956 to 54 000 ha in 1966 and then went down to 48 000 ha in the early 1970s. In 1993, the total area equipped for irrigation was estimated at 87 500 ha, of which 67 500 ha for perennial irrigation and 20 000 ha for seasonal irrigation, using spring water. In 2000, the area equipped for irrigation was estimated at 90 000 ha (Comair, 2005).

Surface irrigation, mainly of the basin and furrow type, is practised on 57 200 ha (Table 3 and Figure 3). It usually comprises diversion or simple intake structures on streams or springs, open concrete main canals, and earth or concrete secondary canals. Sprinkler irrigation is practised on 25 100 ha, especially where potatoes and sugar beet are cultivated in the central Bekaa Plain. Localized irrigation is practised on 7 700 ha, especially in north Bekaa (Qaa region) and in the coastal region.

The main sources of irrigation water are the Litani river and the Litani-Awali complex of water resources. In 2000, it was estimated that 44 percent of the area was irrigated from surface water, 22 percent from groundwater (deep wells, recharge wells and springs) and the remaining part from mixed surface water and groundwater (Figure 4). At the start of the 1990s, the use of groundwater for irrigation increased in view of the delay in the implementation of government schemes. Individual farmers in the schemes who faced water shortages increasingly relied on supplementary supply from groundwater by means of private wells and in 1992–95 about 2 000 wells were added to an overall total of more than 10 000 wells, especially in the southern coastal hills and in the north and middle of Bekaa Central Plain.

Both public and private irrigation schemes exist. The public irrigation sector, essentially unchanged since 1970, consists of 5 large-scale schemes (> 1 000 ha) and 62 medium-scale

FIGURE 3
Irrigation techniques
Total: 90 000 ha in 2000

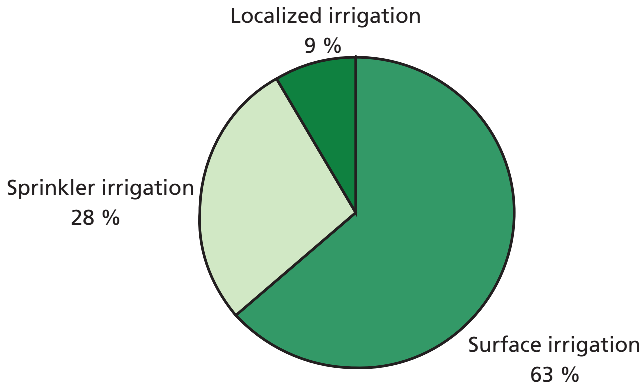


FIGURE 4
Source of irrigation water
Total: 90 000 ha in 2000

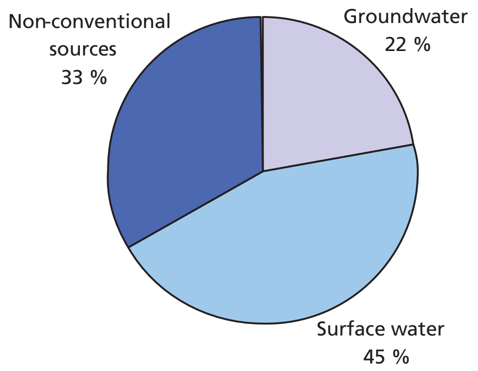
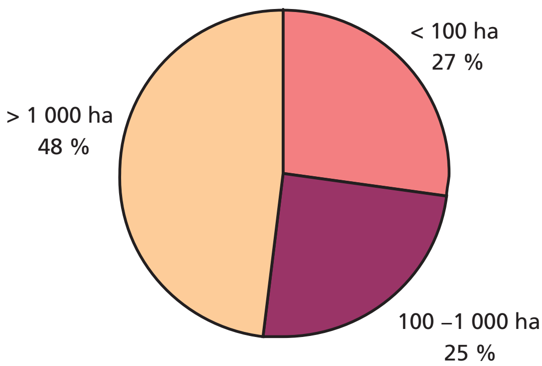


FIGURE 5
Type of irrigation schemes
Total: 90 000 ha in 2000



(100–1 000 ha) and small-scale (< 100 ha) schemes. Only two schemes use pressurized irrigation systems and the rest use open canals for conveyance of water and surface irrigation technologies, which are shifting to localized irrigation. The average plot size in public irrigation schemes is 1.8 ha. Most of the schemes are 25–50 years old, are poorly maintained and in an advanced state of deterioration. If water has to be pumped from perennial rivers or wells, the main problem is the increasing cost of pumping combined with poor efficiency in the distribution network. During the period 1994–2000, in order to improve the efficiency of water conveyance and distribution, the government rehabilitated a total irrigated area of 28 000 ha, including 24 irrigation schemes, of which 5 medium-scale and 19 small-scale. In 2000, small schemes (< 100 ha) covered 27 percent of the total equipped area for irrigation, medium size schemes (100–1 000 ha) 25 percent and large schemes (>1 000 ha) 48 percent (Figure 5).

Role of irrigation in agricultural production, economy and society

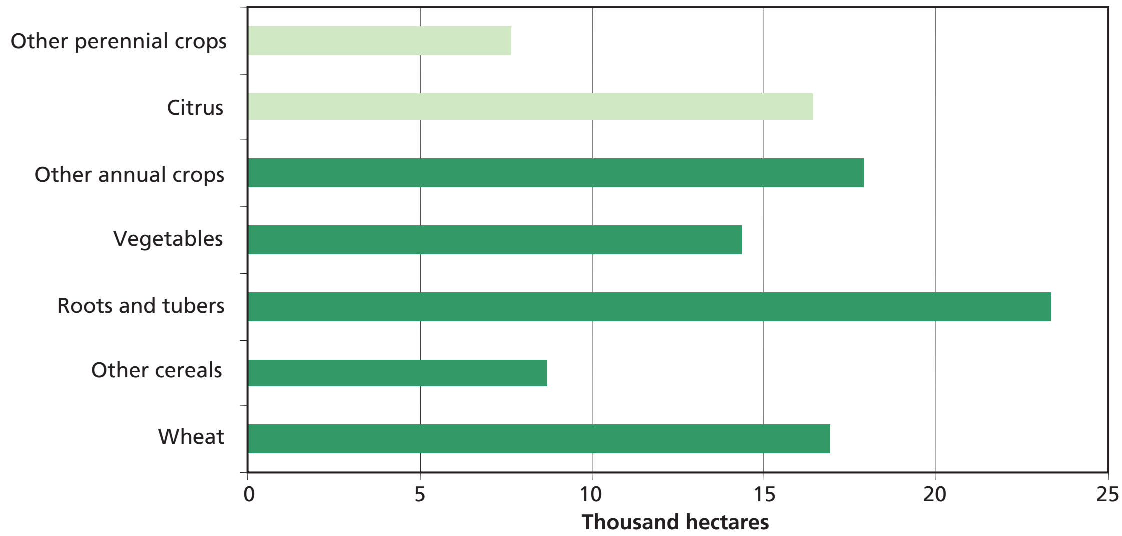
In 2003, the harvested irrigated area was 105 293 ha, half of which (51 percent) was in the Bekaa Valley (MOA and FAO, 2000). Annual crops represent 77 percent of the total harvested irrigated area. The main irrigated crops are cereals (24 percent, mainly wheat), potatoes (18 percent), citrus (16 percent) and vegetables (14 percent) (Table 3 and Figure 6).

According to the national census carried out in 1999, 60 percent of the cultivated area in farm holdings exceeding 10 ha was irrigated, while this share was around 42 percent in those from 4 to 10 ha and 30 percent in the farm holdings covering less than 4 ha (Choueiri, 2002).

The average cost for irrigation development ranges from $US2 500/ha for small schemes, $US3 750/ha for medium schemes and between $US4 000 and 7 000/ha for large schemes. Estimates for operations and maintenance (O&M) costs are $US40/ha per year for small schemes with gravity surface irrigation. In medium schemes these costs range from $US100/ha per year for gravity surface irrigation to $US600/ha per year for private wells, while in large schemes they range from $US400/ha per year for private pumping in rivers to $US600/ha per year for tube wells.

O&M are limited to very specific needs. The maintenance budget allocated by the Ministry of Energy and Water (MEW) is very low and does not cover the required maintenance costs. Operation costs are only used to control water distribution systems in the public schemes. Water is distributed during a certain period based on the

FIGURE 6
Irrigated crops
Total harvested area: 105 293 ha in 2003 (cropping intensity on equipped area: 117% in 2000)



irrigated area. One or more persons are hired in the irrigation season to implement the irrigation schedule. In general, maintenance improves when management is ensured by municipalities or the regional water authorities.

Status and evolution of drainage systems

In general, drainage is not considered a critical need in Lebanon. The amount of agricultural land suffering from drainage problems is fairly limited and is mainly in South Bekaa (about 5 000 ha) and in the Bequaia Plain in Akkar (about 4 000 ha). In 2001, the total drained area was around 10 000 ha (Table 3), of which 30 percent was in the area equipped for irrigation and 70 percent in rainfed areas (ICID, 2007). River calibration is done to protect against flood damage and waterlogging, especially the Litani River, upstream of Qaraoun Lake, where the drainage and calibration works realized in the 1970s helped to alleviate the flood damage on about 1 500 ha. The "Improvement of irrigation management in Lebanon and Jordan" project (IRWA), in collaboration with LRA, undertakes the rehabilitation of 11 points in the Litani and its tributaries. An assessment after the execution of five points shows and amelioration of 50 percent.

Future drainage development involves completing and achieving the calibration of the Litani River and its seven tributaries in the South Bekaa Plain, in order to reclaim about 1 500 ha of the waterlogged area and to facilitate the drainage works in another risky area of 3 500 ha which is also exposed to frequent floods from rivers. Crop yield increase due to improved drainage is estimated at 40-60 percent. Environmental issues, such as the preservation of marshy lowlands for migratory birds, should also be given consideration. About 1 000 ha is said to be salinized by irrigation.

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

Institutions

Under Law No. 221/2000, several institutions are in charge of water-related issues (Hamamy, 2007).

The Ministry of Energy and Water (MEW) is composed of two directorates: the General Directorate of Hydraulic and Electric Resources and the General Directorate of Operation. MEW implements water policy and extends and monitors the implementation of hydraulic and electric projects. It applies laws regarding the protection of public water and its use and it has the administrative guardianship (supervision) over the Water and Wastewater Establishments. It controls hydraulic and electric concessions and applies the mine laws.

The Establishments enjoy financial and administrative autonomy in their areas. They are in charge of hydraulic projects, irrigation, investments and feasibility studies relating to the master plan prepared by MEW. They implement, operate, maintain and recover costs pursuant to the provisions of Law No. 221/2000. They draw up their tariffs and business plan, which is updated on a yearly basis.

The Ministry of Public Health monitors and controls water quality. The Meteorological Service of Civil Aviation of the Ministry of Public Works collects precipitation data. Municipalities and the Ministry of Interior and Municipalities are responsible for the collection of wastewater.

The Green Plan (GP) works under the sponsorship of the Ministry of Agriculture and is responsible for constructing earth ponds and small water reservoirs.

The Litani River Authority (LRA) is the only water authority to retain special responsibilities and functions that extend beyond its administrative region (the natural boundaries of the Litani Basin). It is responsible for developing and managing irrigation water and associated works in southern Bekaa and South Lebanon. It is also in charge of measuring surface water along the Lebanese territory. Law No. 221/2000 provides a two-year transitional period for reorganizing the existing water boards into regional water authorities.

Water management

Technical aspects of irrigation management include the implementation of cost-benefit analyses for medium and large irrigation projects and cost-recovery of water delivery over time. Historically, the utilization of large pumps to lift water from deep wells, combined with the cost of pumping water, has led to high costs of irrigation water to farmers. Added to this, the quality of water available to farmers has gradually deteriorated due to heavy use of agricultural inputs. The small size of irrigation schemes, land fragmentation and poor services have left a gap in water management policy in Lebanon. Experience of local water management derives from specific cases of rehabilitation of public schemes using both traditional and pressurized irrigation systems. In private schemes considerable experience was gained in irrigation management because more investment was made in the sector.

Recently, increasing attention has been paid to water management issues and the improvement of water use efficiency, such as by using appropriate irrigation methods and water harvesting techniques. Research conducted at the Department of Irrigation and Agrometeorology of the Lebanese Agricultural Research Institute (LARI) and at the American University of Beirut, Faculty of Agriculture and Food Science focuses on improving water use efficiency both in irrigated and rainfed agriculture (Karam *et al*, 2003, 2005, 2006). Field research dealing with supplemental irrigation of cereals and legumes is important because it leads to an increase in yield in scarce water environments. However, the dissemination of results and transfer of knowledge to end-users at on-farm level is still inadequate.

In some public schemes geared to demand, an engineering approach has been adopted to water management, focusing on improving network performance and distribution uniformity and applying a sustainable water tariff system. However, the non-existence of water-user associations led to bad water management at scheme and on-farm levels. In private irrigation schemes, instead, experience in water management was gained through increasing investment in the sector and the presence of highly qualified workers.

To overcome problems of water scarcity, the government initiated a water management policy in the early 1990s based on:

- rehabilitation of the already existing irrigation schemes
- reorganization of the water sector
- launch of the ten-year master plan for water storage in dams and earth ponds
- implementation of new irrigation schemes using advanced pressurized distribution systems.

Finances

The water sector in Lebanon has always suffered from a lack of a shared policy. On the one hand, it is said that the criterion for water allocation should be economic water use efficiency i.e. the cash produced per unit intake of water and that this can only be achieved by high water prices coupled to a free water market. On the other hand, it is also recognized that there are barriers to the application of a strict pricing mechanism, such as feasibility (water is often not metered), existing legal and historical water rights, and a social environment in which water is perceived as a common heritage. Therefore, price differentiation as a means to deal with scarcity is an option presently available only to a relatively small number of well-equipped irrigation consortia in regions where it is legally feasible and socially acceptable. Nowadays, there is general agreement that water resources are being depleted and that this rate is not sustainable. Scarce water resources are increasingly being used for high-value crops, shown for example by the large increase in the production of fruit and vegetables in greenhouses, where the water-delivery infrastructure is relatively advanced and more efficient.

Agriculture, and more precisely the irrigation sector, has always suffered from a lack of incentives to farmers. Water assigned by rotation and/or with a fixed flow rate hampers the application of water-saving techniques, contrary to volume-related price structures. In addition, even where the water intake is metered, levies amount to a minimal fraction of the value of the cash crops harvested. Therefore water prices, perceived as high in the range of prices that are seen as socio-economically acceptable, have very little impact on farmers' behaviour. An example of a good incentive was the one offered by the public sector, which provided farmers in the South Bekaa Irrigation Scheme with irrigation equipment to efficiently irrigate 900 ha of reclaimed soils. This helped to reduce the water use per ha from 15 000 m^3/year where furrow irrigation was used, to 6 500 m^3/year using localized irrigation. In other areas, drip irrigation contributed to water savings of more than 50 percent compared with furrow irrigation.

Between 1 January 1992 and 31 December 2000, the Council for Development and Reconstruction (CDR) awarded 129 contracts worth a total of US$409.2 million in the water supply sector in Lebanon (CDR, 2001). By March 2001, 60 percent of the awarded projects had been completed. About 95 percent of the contracts involved capital costs, almost 4 percent consisted in technical assistance and only 1 percent was allotted to O&M.

Policies and legislation

In 2000, the Government of Lebanon approved a reorganization plan for the water sector, including irrigation water, drinking water and wastewater, with the aim of better management, maintenance and effectiveness in the water sector. Law No. 241 (29/5/2000) reorganized the existing 22 water boards into four Regional Water Authorities: North Lebanon for the Governorate of North Lebanon, Beirut and Mount Lebanon for the Governorates of Beirut and Mount Lebanon, South Lebanon for the Governorates of South Lebanon and Nabatiyeh, and Bekaa for the Governorate of Bekaa. Working under the auspices of the Ministry of Energy and Water (MEW), the four authorities are in charge of managing irrigation water, drinking water and wastewater. Their responsibilities extend to water policy planning at national level, measurement of water flows in rivers and measurement of groundwater recharge, construction of water storage capacities (dams, reservoirs and earth ponds), monitoring the quality of drinking water and treated wastewater, water pricing, and water legislation. They are also responsible for studying, rehabilitating, implementing and managing water projects in the country (adduction and distribution network).

Law No. 221/2000 empowers the regional water authorities to set and collect water tariffs for domestic and agricultural use. Subscription fees for domestic water supply vary depending on water availability and distribution costs: gravity distribution is cheapest while distribution by pumping is far more expensive. In the Beirut area, where water tariffs are high, water is conveyed long distances and/or pumped from deep wells. In some parts of northern Lebanon, where water tariffs are low, water is available from springs and delivered by gravity. In 2001, tariffs ranged from US$43 to US$153/year for 1 m^3/day gauge subscription, which is equivalent to US$0.12 to US$0.42 per m^3 water per day per household assuming consumption of 1 m^3 of water per day. However, most households incur additional expenses to meet their water requirements. In fact, most households pay much more on a per cubic meter basis for two main reasons: (i) frequent and periodic water shortages and (ii) the need to buy water from private haulers, at a cost that is typically around US$5–US$10 per m^3. In public irrigation schemes where water is delivered by gravity, water is charged at a flat rate per cropped area. In the irrigation schemes of the Litani, where water is delivered by means of pressurized pipes, volumetric metering is provided. This is the case of the Saida-Jezeen irrigation scheme and in some parts of the South Bekaa Irrigation Scheme. As an example, water charges vary between US$260/ha in the Qasmieh-Ras-El Ain Irrigation scheme in south Lebanon to US$30–150 /ha in the Danneyeh and Akkar irrigation schemes in northern Lebanon.

ENVIRONMENT AND HEALTH

Water quality is adversely affected by agricultural, industrial and domestic wastewater. Leaching of pesticides and fertilizers from agriculture pollutes both groundwater and surface water. Industries release a wide range of chemical effluents, especially into surface water and coastal water. Open dumping also affects surface water quality. It is difficult to estimate accurately the pollution loads into water bodies from the different economic sectors. It can happen that disposal of sewage and industry effluents into the rivers is followed by abstraction from the same rivers at a point further downstream for water supply and irrigation, sometimes even irrigation of salad vegetables. A National Emergency Reconstruction Program (NERP) was launched in the early 1990s, which conceived the design and construction of discharge networks of wastewater and the establishment of treatment plants in almost all the Lebanese coastal and inland cities. In 1995, a Damage Assessment Report was prepared to formulate a policy framework for the wastewater sector throughout the country.

Water-related diseases, especially diarrhoea, are one of the leading causes of mortality and morbidity among children less than five years old. In addition, health problems resulting from exposure to water pollutants often result in health care costs and absence from work. Typhoid and hepatitis due to poor water quality result in a larger number of sick persons in the mohafazats of North Lebanon, South Lebanon and Nabatiyeh (ACS, 2006). In addition to health impacts, poor water quality increases the cost of water treatment and encourages people to buy more bottled water than they would normally purchase if they had access to good quality drinking water. A recent study (2007) elaborated by IDRC, CNRS, DSA and LRA focused on an ecosystem approach for the sustainable management of the Litani basin.

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

The Water Plan 2000–2010 was published by MEW in 1999. It defines the strategy to satisfy Lebanon's future water needs, estimated at 2.6 km^3 in 2010 (Hamamy, 2007). The total cost will be US$1.327 billion, of which almost two-thirds is allocated to increasing the water supply through the construction of dams and reservoirs. The strategy consists of six parts:

- to increase the water supply by building 26 dams and 6 lakes, which will increase the storage capacity to 800 million m^3 by 2010;
- to extend the drinking water projects, and develop, rehabilitate, and maintain the adduction networks;
- to increase the quantity of irrigation water;
- to build 20 wastewater treatment plants in 12 coastal regions until 2020 for the treatment of 80 percent of the produced volume of wastewater;
- to maintain and clean the river courses;
- to rehabilitate and extend electrical equipment in order to reach the villages not yet connected to the public utility network.

Public sector irrigation schemes suffer from poorly maintained distribution canals and ditches, leading to high water losses and low irrigation efficiencies (not exceeding 40 percent). Therefore, the focus should not only be on increasing the water supply, but also on improving water efficiency (water metering, removing illegal connections, introducing on-farm practices for the efficient use of irrigation water, etc.). In this respect, the establishment of water users' associations (WUAs) is important since they create an essential link between the water-providing institutions and the farmers.

The Government is planning to implement large-scale irrigation projects and to modernize the traditional irrigation networks, thus saving water and allowing the irrigation of an additional 74 000 ha by the year 2015. The potential increase in irrigation includes 23 500 ha in southern Bekaa Valley and 5 000 ha lying on both sides of the Litani River, which require drainage systems. Other planned irrigated lands are 5 000 ha in the Ammiq area in southern Bekaa, 7 000 ha in Hirmil in northern Bekaa, and 4 000 ha in the Plain of Akkar in northern Lebanon. A total of 35 000 ha are suitable for irrigation in southern Lebanon, including 1 200 ha near Saida. In the Kassmieh region, currently 4 000 ha are equipped for irrigation and 3 600 ha are actually irrigated, saving water should increase the irrigated area by 2 000 ha. In the coastal plain, 58 000 ha can be irrigated by coastal rivers and aquifers.

An important first step in the overall process of a long-term water management policy in Lebanon is the forging of a good operational partnership among the main actors in the water sector, namely the Ministry of Energy and Water (MEW), the four regional water authorities, the Litani River Authority, the Ministry of Agriculture and the Ministry of Environment as well as the various private actors.

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Occupied Palestinian Territory

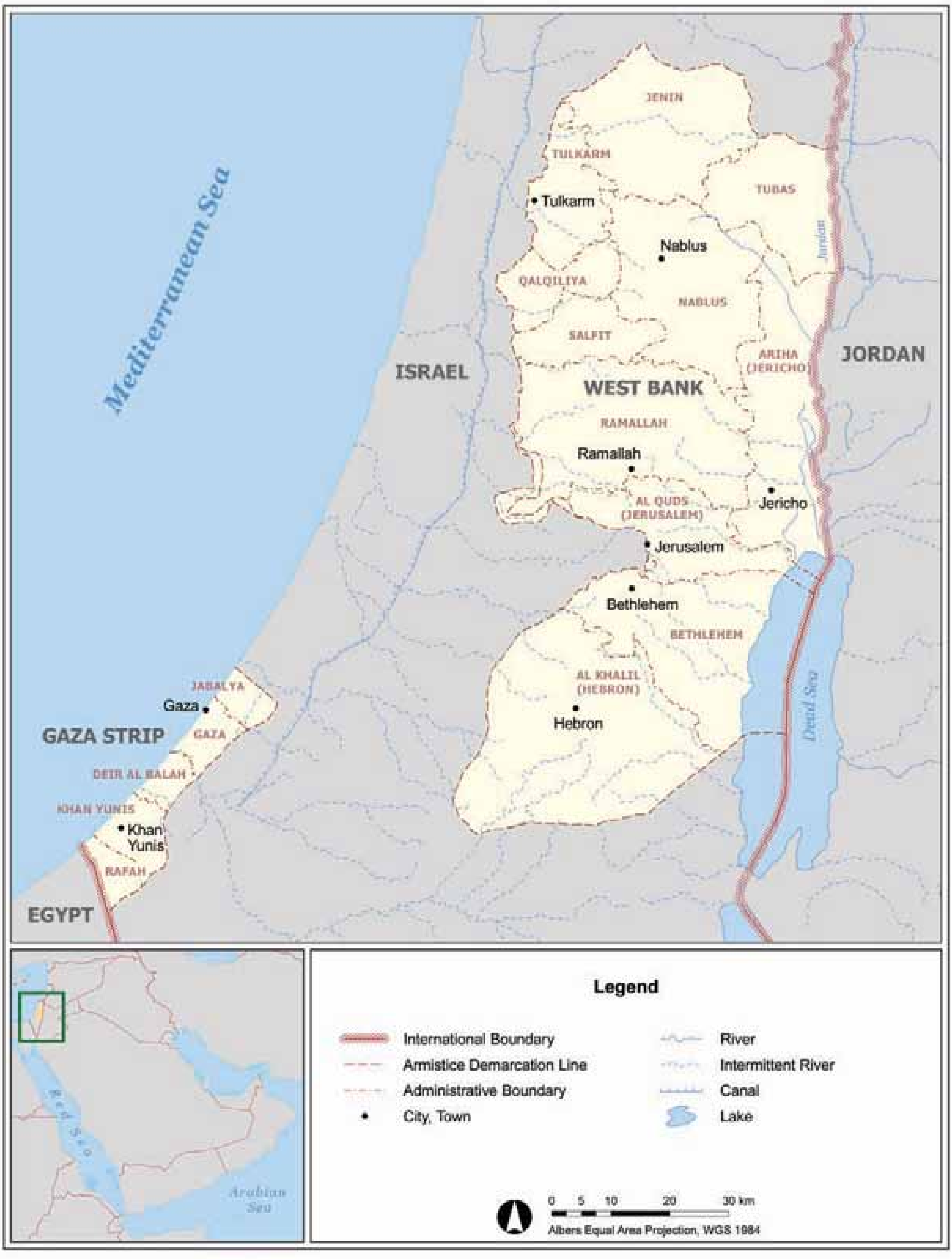
GEOGRAPHY, CLIMATE AND POPULATION

Geography

The Occupied Palestinian Territory has a total area of 6 020 km^2 (Table 1). The West Bank is a landlocked territory on the west bank of the Jordan River with a total area of 5 655 km^2, surrounded by Jordan to the east and Israel to the south, west and north. The Gaza Strip is a narrow coastal strip of land along the Mediterranean Sea with a total area of 365 km^2, bordering with Egypt to the south and Israel to the north and east. It takes its name from Gaza, its main city. Under existing arrangements (2008) the Occupied Palestinian Territory is not recognized as a fully sovereign state and it only has full control of parts of the West Bank and Gaza Strip. The fully controlled part, known as Area A, comprises the Gaza Strip and all of the eight largest West Bank municipalities, except 20 percent of Hebron which is under Israeli control. These municipalities include Ramallah, Jenin, Tulkarem, Nablus, Hebron, Bethlehem, Jericho and Quaqilye. Area B includes about 100 separate areas of rural land, delineated in the "Oslo Accords" maps, in which the Palestinian Authority has control over civil administration but the Israeli Authorities have control over all aspects of security. The Israeli authorities remain in full control of Area C, which amounts to about 59 percent of the West Bank.

The limestone hills of the West Bank act as a porous sponge which absorbs most of the rainwater falling on it, and much of this emerges as springs in valleys and along the margins of the highlands both east and west. Farming in the Occupied Palestinian Territory is largely determined by a variety of agro-ecologic conditions, influenced by altitude, proximity to sea and soils. Moving from east to west there are five main zones: the Jordan Valley, eastern slopes, central highlands, semi-coastal and coastal regions (FAO, 2001).

In 1998, the total cultivated area amounted to 185 011 ha of which 90 percent lie in the West Bank. Fruit trees occupied 113 840 ha of which 105 483 ha in the West Bank and 8 357 ha in the Gaza Strip (Table 2 and Table 3). With the exception of the Gaza Strip, the Jordan Valley and some parts of Qalqilya, most fruit trees are grown under rainfed conditions. Olives constitute over 70 percent of the area planted with fruit trees, while almonds and grapes occupy 8 and 7 percent respectively. Field crops are planted on 52 011 ha (48 075 ha in the West Bank and 3 936 ha in the Gaza Strip), but only in Jericho are they predominantly under irrigation. Wheat and barley are, with 32 and 28 percent respectively of the area under field crops, the main field crops planted. Field crops can also be found intercropped in orchards, especially while the trees are still young. Vegetables, grown in the open, in low plastic tunnels and in greenhouses, are planted on 19 160 ha (13 144 ha in the West Bank and 6 016 ha in the Gaza Strip). Tomatoes, squash and potatoes occupy the majority of land under vegetables (between 10 to 15 percent



OCCUPIED PALESTINIAN TERRITORY **FAO - AQUASTAT, 2008**

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TABLE 1
Basic statistics and population in the Occupied Palestinian Territory

Physical areas			
Area of the territory	2005	602 000	ha
Cultivated area (arable land and area under permanent crops)	2005	222 000	ha
• as % of the total area of the territory	2005	36.9	%
• arable land (annual crops + temp. fallow + temp. meadows)	2005	107 000	ha
• area under permanent crops	2005	115 000	ha
Population:			
Total population	2005	3 702 000	inhabitants
• of which rural	2005	28.1	%
Population density	2005	615	inhabitants/km^2
Economically active population	2005	1 066 000	inhabitants
• as % of total population	2005	28.8	%
• female	2005	27.4	%
• male	2005	72.6	%
Population economically active in agriculture	2005	108 000	inhabitants
• as % of total economically active population	2005	10.1	%
• female	2005	71.3	%
• male	2005	28.7	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2007	4 010	million US$/yr
• value added in agriculture (% of GDP)	2000	9.5	%
• GDP per capita	2005	1 083.2	US$/yr
Human Development Index (highest = 1)	2005	0.731	
Access to improved drinking water sources			
Total population	2004	92	%
Urban population	2004	94	%
Rural population	2004	88	%

each). The majority of vegetables are grown under irrigation, although watermelon, cucumber and some pulses tend to be grown under rainfed conditions (FAO, 2001).

In 2005, the total cultivated area in the Occupied Palestinian Territory was 222 000 ha, of which 107 000 ha annual crops and 115 000 ha permanent crops (Table 1).

Climate

The climate in Occupied Palestinian Territory is predominantly of the eastern Mediterranean type with cool and rainy winters, hot dry summers and an annual rainfall in the range of 100–700 mm.

The following are the five major zones based on several factors including climate, topography, soil types and farming systems:

- *The Jordan Valley Region* lies 90–75 m above sea level with an annual rainfall of only 100–200 mm. Soil salinization is a major problem. Irrigation is essential for farming operations and winter vegetables and grapes are the main irrigated crops.
- *The Eastern Slopes Region* is a transitional zone between the Mediterranean and Desert climate with rainfall of 150–300 mm/year. The main economic activity is livestock. There is also some spring-irrigated agriculture.
- *The Central Highlands Region* extends the length of the West Bank with mountains ranging from 400–1 000 m. Annual rainfall varies between 300 mm in the south to 600 mm in the north. Agriculture is primarily rainfed and includes olives, stone fruits, field crops, etc.
- *The Semi-Coastal Region* has an elevation of 100–300 m above sea level. Rainfall varies from 400–700 mm/year. It supports the same rainfed crops as the Central Highlands Region but it also has a limited irrigated area under vegetables.

➢ *The Coastal Plain* is the Gaza Strip. It has a rainfall of 200–400 mm/year. The soils are fertile. Irrigated agriculture is substantially practiced using groundwater. Citrus fruits and vegetables, the latter both in the open and under plastic, are extensively grown. Overexploitation of the aquifer has led to extensive seawater intrusion and salinization of the water.

Population

In 2005, the total population of the Occupied Palestinian Territory reached about 3.7 million (Table 1), of which 62 percent in the West Bank and 38 percent in the Gaza Strip (Table 2 and Table 3). The annual demographic growth rate was estimated at 3.3 percent during the period 2000-2005. About 73 percent of the population had access to improved sanitation in 2004 (78 and 61 percent in urban and rural areas, respectively) and 92 percent had access to improved water sources (94 and 88 percent in urban and rural areas, respectively).

ECONOMY, AGRICULTURE AND FOOD SECURITY

In 1970 agriculture was the dominant sector in the Occupied Palestinian Territory economy, providing employment for a large part of the population and 36 percent of the GDP. Since then, agriculture's role in the economy has declined and the contribution of agriculture to the GDP was 9.5 percent in 2000 (Table 1). The agricultural sector remains, however, the main shock absorber and plays a major role in poverty alleviation and in achieving a certain level of food security for a considerable portion of the population. Most Palestinians benefit from the flexibility and sustainability of the agricultural sector in meeting basic food requirements. Statistical data indicate that this sector plays a crucial role in ensuring job opportunities and employment. In addition,

TABLE 2
Basic statistics and population in the West Bank

Physical areas			
Area of the territory	2005	565 500	ha
Cultivated area (arable land and area under permanent crops)	1998	166 702	ha
• as % of the total area of the territory	1998	29.5	%
• arable land (annual crops + temp. fallow + temp. meadows)	1998	61 219	ha
• area under permanent crops	1998	105 483	ha
Population			
Total population	2005	2 302 000	inhabitants
• of which rural	2005	47.0	%
Population density	2005	407.1	inhabitants/km^2
Economically active population	-	-	inhabitants
• as % of total population	-	-	%
• female	-	-	%
• male	-	-	%
Population economically active in agriculture	-	-	inhabitants
• as % of total economically active population	-	-	%
• female	-	-	%
• male	-	-	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	-	-	million US$/yr
• value added in agriculture (% of GDP)	-	-	%
• GDP per capita	-	-	US$/yr
Human Development Index (highest = 1)	-	-	
Access to improved drinking water sources			
Total population	-	-	%
Urban population	-	-	%
Rural population	-	-	%

TABLE 3
Basic statistics and population in the Gaza Strip

Physical areas			
Area of the territory	2005	36 500	ha
Cultivated area (arable land and area under permanent crops)	1998	18 309	ha
• as % of the total area of the territory	1998	50.2	%
• arable land (annual crops + temp fallow + temp. meadows)	1998	9 952	ha
• area under permanent crops	1998	8 357	ha
Population			
Total population	2005	1 400 000	inhabitants
• of which rural	2005	5.4	%
Population density	2005	3836	inhabitants/km^2
Economically active population	-	-	inhabitants
• as % of total population	-	-	%
• female	-	-	%
• male	-	-	%
Population economically active in agriculture	-	-	inhabitants
• as % of total economically active population	-	-	%
• female	-	-	%
• male	-	-	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	-	-	million US$/yr
• value added in agriculture (% of GDP)	-	-	%
• GDP per capita	-	-	US$/yr
Human Development Index (highest = 1)	-	-	
Access to improved drinking water sources			
Total population	-	-	%
Urban population	-	-	%
Rural population	-	-	%

agriculture has provided work for more than 39 percent of those who work in informal sectors and supports a significant proportion of Palestinian families who cultivate their lands for survival. The unemployment rate increased to 35.2 percent in the Gaza Strip and 26.1 percent in the West Bank.

Recent studies carried out in the West Bank revealed several forms of tenancy. Approximately 30 percent of the holdings are owned and farmed by the owners, 36 percent are sharecropped and the third type of tenancy is an outright rental system. Under the sharecropping system the owner usually shares in decision-making regarding agricultural activities and provides water, in the case of irrigated crops, and shares in the cost of purchased inputs. The tenant provides the labour requirements and a part of the inputs. Farm production is usually divided on a fifty-fifty basis.

The role of women in agriculture is not adequately documented but it is estimated that 71 percent of the population economically active in agriculture is female. Moreover their labour in the sector, which is substantial, is considered as family labour. Average wages for working women are lower than those for men, usually amounting to about 80 percent of the latter.

Rainfed farming predominates in the West Bank and covers about 94 percent of the total cultivated area, mostly in the Western Highlands, while in the Gaza Strip more than half of the cultivated land is irrigated. In 2003, the total irrigated land in the Occupied Palestinian Territory amounted to about 24 000 ha. Of this area 11 400 ha are in Gaza Strip, 5 400 ha in the semi-coastal area of the West Bank and about 7 000 ha in the rest of the West Bank, primarily in the Jordan Valley. Irrigated crops include citrus fruits, various kinds of vegetables, including tomatoes, cucumbers, eggplants cauliflower and others. Strawberries and cut flowers are also grown. Rainfed crops include olives (over 80 percent of all perennials), grapes, figs, almonds, plums, cereals and pulses.

An increasing number of Palestinian households are becoming food insecure in the Gaza Strip, following the declining cash income and employment, and because of the declining supply and increasing price of imported food commodities. In general, the nature of the food insecurity problem in the Occupied Palestinian Territory is essentially due to:

i. reliance on imports of basic staples (wheat/rice);
ii. lack of adequate purchasing power of the poor linked to inadequate means of employment, particularly at times of border closures;
iii. inadequate food distribution due primarily to lack of geographical contiguity;
iv. weak and inadequate domestic policies geared to increasing productivity and improving food security (FAO, 2001 and 2006). In March/April 2006, the food security situation further deteriorated with the outbreak of avian influenza.

WATER RESOURCES AND USE

Water resources

The water resources in the Occupied Palestinian Territory include mainly groundwater and a little bit of surface water. The groundwater regime in the five agro-ecological zones of the territory is a multiaquifer and subaquifer system that comprises several rock formations from Cretaceous to Recent age. Most of the formations are composed of carbonate rocks, mainly limestone, dolomite, chalk, marl and clay. The various formations occur in a series of aquifers and aquacultures, in which groundwater is found in shallow, intermediate and deep aquifers. These Rock formations outcrop (i.e., expose at the surface) throughout the West Bank constituting recharge areas for this hydrological system. In addition, there is another local aquifer in the Jordan Valley area, which comprises the alluvial deposits of the Pleistocene age. The main Gaza Aquifer is a continuation of the shallow sandy/sandstone coastal aquifer of Israel (shared aquifer) which is of the Pliocene-Pleistocene geological age. This aquifer is divided into three subaquifers that overlie each other and are separated by impervious and/or semi-impervious silty clayey layers. The base of the aquifer consists of impermeable marly clay (Saqiah formation) of Pliocene age. The thickness of the coastal aquifer varies throughout the region gradually increasing from about 5 to 60 m in the east to about 10 to 160 m in the west along the coast. The aquifer is highly permeable with a transmissivity of about 1 000 m^2/day and an average porosity of 25 percent. The only permanent river which can be used as a source of surface water in the West Bank is the Jordan River, which flows from north to south from an elevation of 2 200 m above mean sea level at Mount Hermon to about 395 m below mean sea level at the Dead Sea. The Jordan River flows along a straight distance of about 140 km with a river length of about 350 km due to its tortuous path. The slope of the land and accordingly that of the river bed is slight and directed toward the south. Much steeper gradients than the Jordan River itself were found in all of its tributaries. The catchment area of the Jordan River and Dead Sea basin comprises some 40 650 km^2 (Isaac, 1999).

The total internal renewable groundwater resources in the Occupied Palestinian Territory are estimated at 740 million m^3/year of which 694 million m^3 is produced in the West Bank and 46 million m^3 in the Gaza Strip. The total internal renewable surface water resources are estimated at 72 million m^3/year in the West Bank whereas it is considered negligible in the Gaza Strip. The overlap between surface water and groundwater is considered to be zero, giving a total of 812 million m^3/year for the total internal renewable water resources (IRWR) in the Occupied Palestinian Territory. As far as external renewable water resources are concerned, the total flow of 1 578 million m^3/year from the Jordan River is unavailable because it involves brackish water and moreover this water is denied to the Palestinians. About 15 million m^3/year of surface water and 10 million m^3/year of groundwater enter from Israel into the Gaza Strip. This makes the total actual renewable water resources in the Occupied Palestinian Territory

837 million m^3/year, of which 766 million m^3/year in the West Bank and 71 million m^3/year in the Gaza Strip (Table 4 and Table 5). Surface water and groundwater outflow from the West Bank to Israel are estimated at 20 and 325 million m^3/year respectively.

In the Gaza Strip overexploitation of the aquifer has already resulted in seawater intrusion. In the West Bank both well and spring water are available. The quality of the groundwater, particularly in the Gaza Strip and to a much lesser extent in the West

TABLE 4
Water: sources and use in the West Bank

Renewable freshwater resources			
Precipitation (long-term average)	-	409	mm/yr
	-	2.313	10^9 m^3/yr
Internal renewable water resources (long-term average)	-	0.766	10^9 m^3/yr
Total actual renewable water resources	-	0.766	10^9 m^3/yr
Dependency ratio	-	0.0	%
Total actual renewable water resources per inhabitant	2005	333	m^3/yr
Total dam capacity	1997	0	10^6 m^3
Water withdrawal			
Total water withdrawal	2000	157	10^6 m^3/yr
- irrigation + livestock	2000	89	10^6 m^3/yr
- municipalities	2000	59.4	10^6 m^3/yr
- industry	2000	8.6	10^6 m^3/yr
• per inhabitant	2000	91.5	m^3/yr
Surface water and groundwater withdrawal	2000	157	10^6 m^3/yr
• as % of total actual renewable water resources	2000	20.5	%
Non-conventional sources of water			
Produced wastewater	-	-	10^6 m^3/yr
Treated wastewater	-	-	10^6 m^3/yr
Reused treated wastewater	-	-	10^6 m^3/yr
Desalinated water produced	-	-	10^6 m^3/yr
Reused agricultural drainage water	-	-	10^6 m^3/yr

TABLE 5
Water: sources and use in the Gaza Strip

Renewable freshwater resources			
Precipitation (long-term average)	-	300	mm/yr
	-	0.11	10^9 m^3/yr
Internal renewable water resources (long-term average)	-	0.046	10^9 m^3/yr
Total actual renewable water resources	-	0.071	10^9 m^3/yr
Dependency ratio	-	35.2	%
Total actual renewable water resources per inhabitant	2005	51	m^3/yr
Total dam capacity	1997	0	10^6 m^3
Water withdrawal			
Total water withdrawal	2000	133	10^6 m^3/yr
- irrigation + livestock	2000	85	10^6 m^3/yr
- municipalities	2000	42	10^6 m^3/yr
- industry	2000	6	10^6 m^3/yr
• per inhabitant	2000	127.5	m^3/yr
Surface water and groundwater withdrawal	2000	123	10^6 m^3/yr
• as % of total actual renewable water resources	2000	173.2	%
Non-conventional sources of water			
Produced wastewater	-	-	10^6 m^3/yr
Treated wastewater	1998	10	10^6 m^3/yr
Reused treated wastewater	-	-	10^6 m^3/yr
Desalinated water produced	-	-	10^6 m^3/yr
Reused agricultural drainage water	-	-	10^6 m^3/yr

Bank, has drastically deteriorated over the last twenty years due to over-pumping and subsequent salinization.

The water conveyance systems from springs to farms (often several kilometres downstream) consist of open earthen or lined canals and earthen buffer pools (usually plastic lined), the bad conditions of which are responsible for substantial losses of water through seepage and evaporation. These losses are estimated at about 15 million m^3/year. On the other hand water conveyance systems from wells to farms are made of closed systems and water losses at farm gate are usually minimal (FAO, 2001).

Due to lack of authority and Israeli restrictions, no dams were built on wadis to collect natural runoff from watersheds including urban runoff. With the increase of urbanization in the Occupied Palestinian Territory, more runoff is observed during winter months. There is a good opportunity to build dams on the major wadis of the West Bank such as El-Faria, El-Auja and Qilt. These wadis drain significant runoff amounts to the Dead Sea basin. Initial investigations showed a possibility of utilizing 13 million m^3/year of runoff water by constructing dams on these wadis. Due to their location and to the water quality, these dams could be utilized for agricultural purposes. Another importance for these dams would be to store water from the springs which are located along these wadis during winter months when most of the discharge of these springs is lost due to a lack of storage facilities. Israeli Authorities constructed a storage dam on the El-Faria wadi east of Jiftlik after signing the Oslo Accords. This construction shows the feasibility of dam construction on such wadis. The other option for rainwater harvesting is utilizing small-scale storage facilities such as ponds and cisterns. There are many villages in the West Bank which still utilize cisterns for domestic purposes. Due to lack of quality monitoring for these cisterns, it is recommended that water be supplied through pipe networks for domestic purposes for these villages. Cisterns could be converted for agricultural use through small-scale home gardening. In recent years and due to water restrictions, many farmers have built ponds to collect runoff water from the roofs of greenhouses. This practice has proved to be feasible and economical and helps the sustainability of irrigated agriculture.

There are only a few wastewater treatment plants the West Bank (Al-Bireh, Ramallah, Tulkarm and Hebron), and not a single one is working properly. Thus, those plants are under reconstruction, rehabilitation, and/or expansion. There are three locations with wastewater treatment facilities in the Gaza Strip: Gaza town, Jabalia and Rafah. Reused treated wastewater in the Gaza Strip accounts for 10 million m^3.

Brackish water is available in Gaza Strip due to the low quality of groundwater there and at brackish water springs in the West Bank such as the El-Fashka spring. Brackish water could be utilized to irrigate crops which can tolerate salinity. Desalination and mixing with fresh water are also alternatives for brackish water use. However, desalination costs are still too high for agriculture to pay for them. Currently, some brackish water from irrigation wells in the Ghor area is being mixed with spring water to allow its use in agriculture.

Water use

The total water withdrawal in the Occupied Palestinian Territory is estimated at about 418 million m^3/year, of which 189 million m^3 or more than 45 percent for agriculture (2005) (Table 6 and Figure 1). In 2000, agriculture utilized about 174 million m^3/year of which 89 and 85 million m^3 in the West Bank and Gaza Strip respectively (Table 4, Table 5, Figure 2 and Figure 3). Irrigated agriculture plays a significant role in the economy of the Occupied Palestinian Territory. Thus almost 53 percent of the total agricultural production in the West Bank is produced from only 7 percent of the land which is under irrigation. In 2005, domestic and industrial water withdrawal was estimated at 200 and 29 million m^3 respectively (PASSIA, 2003). Water in the West Bank is derived from two sources, wells and springs, while the Gaza Strip is entirely dependent

TABLE 6
Water withdrawal in the Occupied Palestinian Territory

Water withdrawal			
Total water withdrawal	2005	418	10^6 m^3/yr
- irrigation + livestock	2005	189	10^6 m^3/yr
- municipalities	2005	200	10^6 m^3/yr
- industry	2005	29	10^6 m^3/yr
• per inhabitant	2005	113	m^3/yr
Surface water and groundwater withdrawal	2005	408	10^6 m^3/yr
• as % of total actual renewable water resources	2005	48.7	%

on wells. In 2005, 125 million m^3 of the water withdrawn for irrigation came from wells (40 million m^3 in the West Bank and 85 million m^3 in the Gaza Strip) and the remaining 49 million m^3 came from springs in the West Bank. In 2005, groundwater accounted for 408 million m^3 and reused treated wastewater accounted for 10 million m^3 (Figure 4 and Figure 5).

The Occupied Palestinian Territory wells are 100-150 m deep, have a diameter of about 0.5 m and are iron lined. Every well has been allocated an annual quota, following the Israeli-Palestinian Agreement, and they are monitored by means of flow meters checked jointly and annually. Pumping equipment for Palestinian owned wells and conveyance systems are said to be very old, resulting in low efficiency and high operation costs. On-farm irrigation is drip irrigation and in a few cases by sprinklers and flooding. In addition to these wells there are many illegal wells operating, particularly in the Gaza Strip, which are responsible for a substantial extraction of groundwater and a negative effect on the water balance of the aquifer. Salinization of the water from the shallow aquifer irrigation wells is also increasing in the West Bank particularly in the Jordan Valley.

FIGURE 1
Water withdrawal in the Occupied Palestinian Territory
Total 0.418 km^3 in 2005

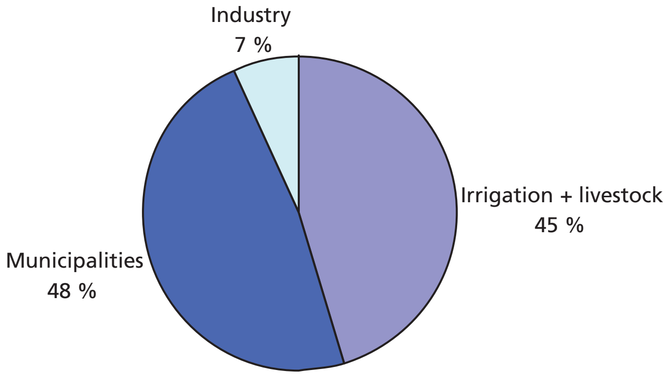
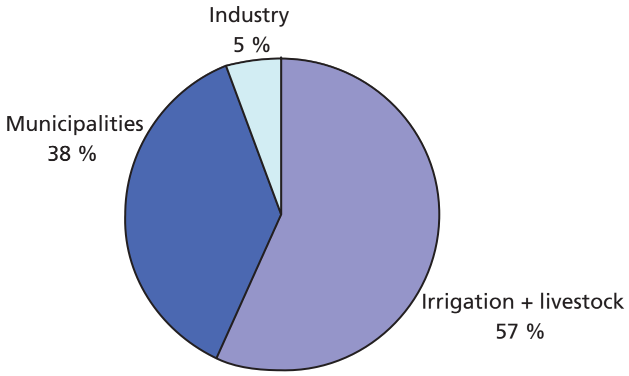


FIGURE 2
Water withdrawal by sector in the West Bank
Total: 0.157 km^3 in 2000



Wells primarily used for irrigation are usually owned by big landowners who sell water to smaller or landless farmers. Those used for domestic water supply are mainly controlled by municipalities, cooperatives or village councils. Springs on the other hand are either jointly or communally owned. Some have no clear ownership rights, which invariably leads to poor maintenance and management. There were 527 springs in the West Bank (1998), but only 114 of these had a minimum discharge of 0.1 litre/second. Most of

FIGURE 3
Water withdrawal by sector in the Gaza Strip
Total: 0.133 km³ in 2000

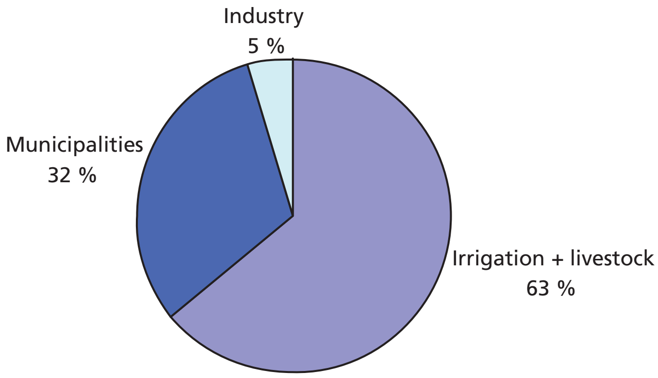


FIGURE 4
Water withdrawal by source in the Occupied Palestinian Territory
Total: 0.418 km³ in 2005

these springs are used for irrigation only; about 16 however are used for domestic water purposes.

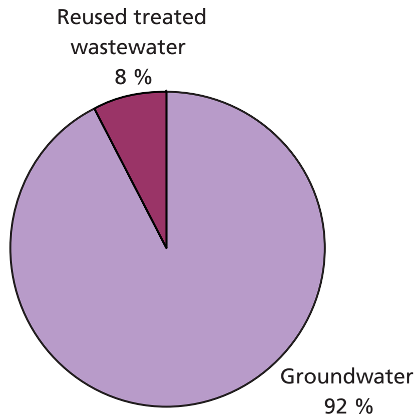
Since the current water extraction from wells cannot be increased in order to maintain a balance between water recharge and extraction, and the spring water flow is basically influenced by the prevailing rainfall, the only way to achieve an early increase in the total water available is through improving the conveyance systems to avoid losses through seepage and evaporation and improving on-farm application and water management practices. It is estimated that improvements in water management applications could reduce amount of water needed for irrigation by around 20 million m³/year. Attention also needs to be focused on crops with a higher return per m³ of water utilized. Crops such as bananas and citrus fruits among others have a low return per m³ of water utilized. Greenhouse crops on the other hand, produced during the winter months with lower evapotranspiration requirements, return higher dividends per m³ of water utilized. Attention also needs to be focused on the potential use of tertiary treated sewage water for agriculture, the potential development of the Eastern Aquifer with a yield of about 80 million m³/year (as indicated in the Oslo Accords) as well as the possible desalination of brackish water existing in both the Gaza Strip and the West Bank and currently estimated at 90 million m³/year.

Domestic water, usually piped, is available in all municipalities and larger villages. Metering is widely used. In many cases the distribution system is however antiquated and there is an urgent need for its gradual replacement. Old and leaky pipes are widespread and water losses in the distribution system and through unregistered connections are estimated to reach some 45 percent. This figure is by far too high for a water deficit region like the Occupied Palestinian Territory. These losses should be gradually reduced to about 20 percent (and probably less) through the replacement of worn out pipes, better connections and certainly by better policing to ensure legal connections to the system by all the users.

International water issues

During the Six Day War, in 1967, Israel took control of the Golan Heights, the West Bank, and the Gaza Strip. This gave Israel control of the Jordan River's headwaters and significant groundwater resources.

FIGURE 5
Water withdrawal by source in the Gaza Strip
Total 0.133 km³ in 2000



More than thirty years of Israeli occupation of the West Bank and Gaza Strip have been accompanied by a series of laws and practices targeting land and water resources in the Occupied Palestinian Territory. Water resources were confiscated for the benefit of the Israeli settlements in the Ghor. Palestinian irrigation pumps on the Jordan River were destroyed or confiscated after the 1967 war and Palestinians were not allowed to use water from the Jordan River system. In other zones, the Israeli authorities introduced quotas on existing irrigation wells to restrict the amount of water pumped from these wells. Furthermore, the authorities did not allow any new irrigation wells to be drilled by Palestinian farmers, while it provided fresh water and allowed drilling wells for irrigation purposes in the Jewish settlements in the Occupied Palestinian Territory. In 1993, the "Declaration of Principles on Interim Self-Government Arrangements" was signed between Palestinians and Israelis, which called for Palestinian autonomy and the removal of Israeli military forces from Gaza and Jericho. Among other issues, this bilateral agreement called for the creation of a Palestinian Water Administration Authority and cooperation regarding water, including a Water Development Program prepared by experts from both sides, which would also specify the mode of cooperation in the management of water resources in the Occupied Palestinian Territory. Between 1993 and 1995, Israeli and Palestinian representatives negotiated to broaden the provisional agreement to encompass more the West Bank territory. In September 1995, the "Israeli-Palestinian Interim Agreement on the West Bank and the Gaza Strip", commonly referred to as "Oslo II", was signed. The question of water rights was one of the most difficult to negotiate, with a final agreement postponed to be included in the negotiations for final status arrangements. However a significant compromise was achieved between the two sides: Israel recognized Palestinian water rights (during the interim period a quantity of 70-80 million m³ should be made available to the Palestinians), and a Joint Water Committee was established to cooperatively manage the West Bank water and to develop new supplies. This Committee also supervised joint patrols to investigate illegal water withdrawals. No territory whatsoever was identified as being necessary for Israeli annexation due to access to water resources (Wolf, 1996). In 2003, the Roadmap for Peace, developed by the United States in cooperation with the Russian Federation, the European Union, and the United Nations (the Quartet), was presented to Israel and the Palestinian Authority, with the purpose of achieving a final and comprehensive settlement of the Israeli-Palestinian conflict.

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

There are 80 000 ha suitable for irrigation in the Occupied Palestinian Territory of which 61 000 ha in the West Bank and 19 000 ha in the Gaza Strip. In 2003, about 24 000 ha of this land were irrigated, of which 12 600 ha in the West Bank and 11 400 ha in the Gaza Strip (Table 7 and Table 8).

Table 9 shows the distribution of irrigation technologies in the semi-coastal zone which is typical when irrigation water sources come from irrigation wells. In general drip and trickle irrigation systems are used to irrigate vegetables in the coastal, semi-coastal and the Ghor areas. A small percentage of vegetables are still irrigated by traditional methods as well as most citrus trees.

There are still a few earth canals used in certain areas of the West Bank, such as the El-Faria and Bethan springs (producing about 10 million m^3/year) and parts of Auja (producing about 12 million m^3/year on average). In these areas, water is distributed with no charge to the farmer and the sizes of farms are usually small which increases the number of farmers sharing such sources. These canals require high maintenance costs due to weed growth and land slides in hilly areas. They also suffer from high deep-percolation and evaporation losses. Concrete canals are also used, especially in the Jericho area and parts of Auja, to convey and distribute water from natural springs

TABLE 7
Irrigation and drainage in the West Bank

Irrigation potential			**61 000**	**ha**
Irrigation				
1. Full or partial control irrigation: equipped area		2003	12 600	ha
- surface irrigation		-	-	ha
- sprinkler irrigation		-	-	ha
- localized irrigation		-	-	ha
• % of area irrigated from surface water		-	-	%
• % of area irrigated from groundwater		2003	100	%
• % of area irrigated from mixed surface water and groundwater		-	-	%
• % of area irrigated from non-conventional sources of water		-	-	%
• area equipped for full or partial control irrigation actually irrigated		-	-	ha
- as % of full/partial control area equipped		-	-	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)		-	-	ha
3. Spate irrigation		-	-	ha
Total area equipped for irrigation (1+2+3)		**2003**	**12 600**	**ha**
• as % of cultivated area		-	-	%
• % of total area equipped for irrigation actually irrigated		-	-	%
• average increase per year over the last ... years		-	-	%
• 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**	**12 600**	**ha**
• as % of cultivated area		-	-	%
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		-	-	ha
• Annual crops: total		-	-	ha
• Permanent crops: total		-	-	ha
Irrigated cropping intensity (on full/partial control area actually irrigated)		-	-	%
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 8
Irrigation and drainage in the Gaza Strip

Irrigation potential			**19 000**	**ha**
Irrigation:				
1. Full or partial control irrigation: equipped area		2003	11 400	ha
- surface irrigation		-	-	ha
- sprinkler irrigation		-	-	ha
- localized irrigation		-	-	ha
• % of area irrigated from surface water		-	-	%
• % of area irrigated from groundwater		2003	100	%
• % of area irrigated from mixed surface water and groundwater		-	-	%
• % of area irrigated from non-conventional sources of water		-	-	%
• area equipped for full or partial control irrigation actually irrigated			-	ha
- as % of full/partial control area equipped			-	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)		-	-	ha
3. Spate irrigation		-	-	ha
Total area equipped for irrigation (1+2+3)		**2003**	**11 400**	**ha**
• as % of cultivated area		-	-	%
• % of total area equipped for irrigation actually irrigated			-	%
• average increase per year over the last ... years			-	%
• 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**	**11 400**	**ha**
• as % of cultivated area		-	-	%
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		-	-	ha
• Annual crops: total		-	-	ha
• Permanent crops: total		-	-	ha
Irrigated cropping intensity (on full/partial control area actually irrigated)		-	-	%
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 9
Distribution of irrigation methods in the semi-coastal zone (West Bank)(1994/1995)

	Areas (ha)			
	Drip	Sprinklers	Traditional	Total
Vegetables	2 036.8	312.0	18.8	2 367.6
Fruit trees	97.0	514.5	1 095.3	1 706.8
Fodder	-	38.0	-	38.0
Total	**2 133.8**	**864.5**	**1 114.1**	**4 112.4**

to farms. The conveyance efficiency is high in such canals when they are maintained with good linings. Any losses are due to evaporation. Farmers usually use plastic lined pools to store their shares of fresh spring water and mix them with brackish well water. Then water is pumped and applied through trickle irrigation systems. From nearly all wells in the Occupied Palestinian Territory water is pumped into steel pipes which convey the water to the irrigation systems directly in the farms. This includes the coastal, the semi coastal and large parts of the Ghor and semi-Ghor zones. As the pumping costs are high, the cost per unit water is high and thus farmers need to use better distribution and conveyance efficiencies through the use of pipes. Furthermore, most farms irrigated by wells use pressurized irrigation systems, so farmers have to use the pressure head applied by the turbine pumps at the well to supply their irrigation systems with the needed pressure.

Surface irrigation systems are used either in areas irrigated by natural springs (Faria, Bethan, Nassarieh and Aqrabanieh) or for irrigating citrus trees, using basins or furrows. Basin irrigation is used mostly for irrigating trees, mainly citrus. For every tree, a small basin is constructed and water is distributed to the basins through small earth ditches and in some case using polyethylene pipes. Furrows of a helical type to minimize tail water runoff are still used to irrigate vegetables in some areas irrigated by natural springs. Application efficiency of surface irrigation systems rarely reaches 60 percent.

Solid set sprinklers are usually used to irrigate potatoes, onions, carrots, radishes and spinach. These sprinklers are often used to supply the water needed for land preparation in greenhouses and to supply water to cabbages at certain growth stages. The cost of solid set sprinklers is about US$4 000/ha including sprinklers, polyethylene pipes, fittings and valves.

Micro sprinklers are also used to irrigate fruit trees, especially citrus trees. Two sprinklers are usually installed per tree. The cost of these systems depends on the density of the sprinklers in the farm and the type of cropping (trees or densely planted vegetables). For trees, the cost of these systems is about US$3 500/ha. Application efficiency of sprinkler irrigation systems can reach 85 percent. However, due to poor design and operation of such systems the efficiency is usually less. Due to the inflexibility of water supplies, farmers sometimes tend to operate such systems for several hours. This results in application rates that are higher than the infiltration capacity of soil. Therefore, water is lost in the form of surface runoff which causes soil erosion and loss of nutrients. Most vegetable crops are irrigated using trickle irrigation.

Role of irrigation in agricultural production, economy and society

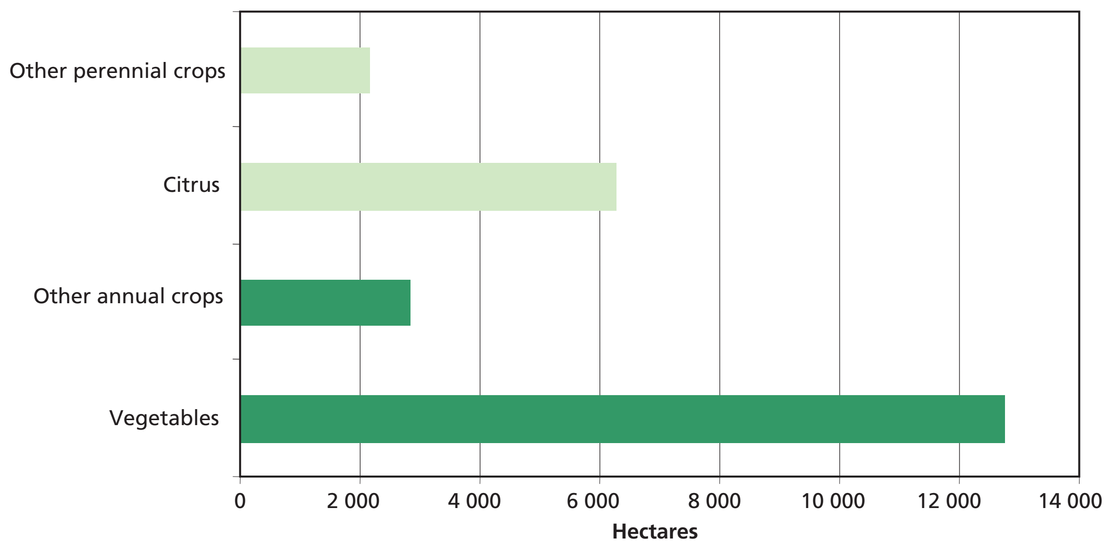
Open field vegetables are grown in the five agro-climatic zones. Common crops include tomatoes, cucumbers, eggplants and squashes. The timing for planting each type of vegetables is site dependent. For the Ghor area, they are either planted in late summer/early fall (August-October), or in late winter/early spring (January-February). Vegetables are not usually planted during summer months in the Ghor area due to the high temperatures there. In other climatic zones, most vegetables are usually planted during most of the year except winter. Frost spills are a major concern for farmers growing open field vegetables especially during late fall or early spring. Frost is possible in all climatic zones, although it is rare in the Ghor. Open field vegetables cover more than 8 900 ha or 70 percent of the total area of vegetables in the Occupied Palestinian Territory (Table 10 and Figure 6). The percentage is higher in the Ghor area than other areas due to the lower possibility of frost in that area. Productivity of open field vegetables depends on the type of vegetables and ranges from about 7 tonnes/ha for green beans to about 70 tonnes/ha for tomatoes. On average, productivity is about 25.7 tonnes/ha for open field vegetables.

Low plastic tunnels provide some protection from frost for vegetables. However, they are less efficient than plastic houses. Farmers tend to use these tunnels especially in the Ghor area to provide protection against frost and improve the agricultural microclimate. Productivity in these tunnels is usually higher than that in open field

TABLE 10
Cropping pattern for irrigated agriculture in the Occupied Palestinian Territory (1996/1997)

Areas (ha) and Cropping pattern		Coastal	Semi coastal	Mountains	Ghor & semi	Total
Fruits	Citrus	4 381.2	1 384.3	10.1	485.5	6 261.1
	Bananas	0	0	0	577.0	577.0
	Other fruits	1 321.5	119.4	1.1	142.5	1 584.5
	Sub sum	5 702.7	1 503.7	11.2	1 205.0	8 422.6
Vegetables	Open field	2 818.0	1 663.6	219.9	4 229.1	8 930.6
	Greenhouses	859.7	891.0	13.2	70.5	1 834.4
	Tunnels	638.7	674.0	0.1	680.8	1 993.6
	Sub sum	4 316.4	3 228.6	233.2	4 980.4	12 758.6
Field crops		1 436.0	397.7	0.7	1 004.4	2 838.8
Total area	**ha**	**11 455.1**	**5 130.0**	**245.1**	**7 189.8**	**24 020.0**
Total water use	million m³/year	60.0	20.8	1.7	64.3	146.8
Production	Tonnes	341 930	189 713	5 500	199 353	736 496

FIGURE 6
Irrigated crops in the Occupied Palestinian Territory
Total harvested area: 24 021 ha in 1997



agriculture and less than that in greenhouses. Low plastic tunnels cover about 2 000 ha with a productivity of 28.3 tonnes/ha.

Plastic houses allow good control of the climate, thus allowing vegetables to be planted all year in most areas in the Occupied Palestinian Territory, but they are mostly used in the coastal and semi-coastal zones. This could be attributed to the availability of irrigation water in these zones and to the warm winter climate with low possibility of frost (but not as warm as the Ghor where production is possible in open field conditions during winter). New vegetable varieties have been introduced which are suitable for the area and have high productivity. On average, productivity in plastic houses is about 95 tons/ha, but will be much higher for certain crops such as cucumbers and tomatoes where productivity is 150 tons/ha or more. Plastic houses cover more than 1 800 ha. This area has been continuously increasing over time.

Field crops include potatoes and onions in addition to forages and grain crops. Field crops cover about 2 800 ha with a productivity of 20.7 tonnes/ha. This high average is attributed to the large areas of potatoes and onions and the low areas of forages and grain crops. Grain crops such as wheat and barley are rarely planted under irrigated agricultural conditions with the exception of the Ghor area, where rainfall is not sufficient for planting grain field crops which are frequently planted as part of crop rotation. In areas irrigated by springs, farmers plant some field crops such as wheat, barley and alfalfa as part of their crop rotation.

Irrigated fruit trees planted in the Occupied Palestinian Territory are mainly citrus trees in the coastal and semi-coastal areas and bananas in the Ghor. In the coastal zone, the area of citrus trees was reduced from about 7 000 ha in the early 1990s to about 4 300 ha in 1996/1997. Many of these citrus trees are in poor condition and lack proper maintenance and enough water due to the low availability of water, the low quality of irrigation water and the possible loss of these lands to urbanization as a result of high land prices there. In the semi-coastal areas, the conditions of citrus farms are better than those in the Gaza Strip due to better water availability and quality. Citrus trees cover about 1 400 ha in this zone with a productivity of about 35 tonnes/ha. There are about 280 ha of citrus trees located within the El-Faria wadi which is located within two agroclimatic zones (Ghor and semi Ghor). Jericho district has about 140 ha of citrus trees which depend mainly on spring water. However, the dominant fruit trees in Jericho are bananas covering 580 ha. Although bananas consume more water than citrus trees, they sell at higher prices in the local markets, making their plantation economically feasible in the Ghor.

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

Institutions

The Minister of Agriculture assisted by a Deputy Minister heads the Ministry of Agriculture (MOA). It is made up of 13 Directorates covering all aspects of the agricultural sector, such as planning, marketing, soils and irrigation, land development, forests and rangeland, extension, veterinary/animal health, plant protection, fisheries etc. There are 17 Regional Departments of Agriculture, covering the whole of the Occupied Palestinian Territory, which deal with the specific requirements in research/ extension at regional level.

An extended system of adaptive research and farmer training/extension was developed during the British Mandate and also under Jordanian authority. After the Israeli occupation in 1967, research and extension services were placed under the supervision of the Israeli Ministry of Agriculture, and benefited from an influx of resources and new technology. In the 1980s, funding gradually decreased, and activities virtually collapsed. Although NGOs have attempted to fill the gap left by public services, their efforts have been scattered and have fallen short of the needs of most farmers.

Institutional development was one of the first priorities of the Palestinian National Authority. At present agricultural research is carried out through the National Agricultural Research Centre (NARC) in eleven research stations in the Occupied Palestinian Territory, although they are operating at a low level.

The Ministry of Agriculture (MOA) also provides formal agricultural extension services from 17 centres throughout the Occupied Palestinian Territory. A total of 220 extension workers provide services free of charge to the farmers. In general the number of staff available is adequate for current needs; however adequate funding and staff mobility is a constraint on the optimum operation of these services, and there is an acute shortage of specialist officers for extension, research, development and planning. As a result of these inadequacies the MOA is not in a position to accept its responsibilities in full. In contrast some of the NGOs have acquired such experience and as a result there is at times some underlying tension between the MOA and NGOs.

The Palestinian Water Authority (PWA) was established by Law 2/1996 and is an institution with an independent status. It is responsible for the development and management of the Occupied Palestinian Territory water resources. It is also charged with implementing all the agreed elements regarding water (Article 40) from the Oslo Accords. In implementing its mandate it issues permits, licenses and concessions for any type of water utilization or wastewater use and has the responsibility of implementing all policies approved by the National Water Council. The PWA is under the direct authority of the President of the PNA.

The Palestinian Hydrology Group (PHG) is a non-profit, non-governmental organization established in 1987 with the aim of protecting and developing the water resources of the Occupied Palestinian Territory. Its main activities are currently concentrated on the rehabilitation of springs and on promoting the use of cisterns (repair of old or construction of new ones) for collecting and storing rain water for use by families, schools, clinics and so on. The PHG is also involved in small-scale wastewater treatment and reuse for irrigating small home gardens. Another section of the PHG is involved in hydrological/geological studies and in water policy aspects.

Water management

The PWA prepared the National Water Plan of 2000 which is the strategic plan for the water sector until the year 2020. The plan describes the role of the service providers and shifts the functions of the PWA to regional utilities in terms of operations, maintenance, repairs, wastewater collection and treatment, bulk water supply, water reuse and allocation for industrial and agriculture use. The PWA will license and monitor drilling, abstraction and discharge (Husseini, 2004).

High water losses are observed for several reasons:

- Most irrigation wells were drilled in the late 1950s or early 1960s, during which period the irrigation distribution systems were also established. Therefore, most of the irrigation water infrastructure is old and extremely inefficient. Distribution systems at springs are mostly earth or concrete canals with very low conveyance and distribution efficiency.
- In most irrigation wells, water is pumped directly to the farmer without any storage facilities. Therefore, water is managed and scheduled according to supply availability and not according to irrigation demands. This results in a low efficiency of water use at farming level. The problem is more serious at springs where high discharge variability is a major problem in reducing the efficiency of spring water use. Storage structures would reduce the effects of variability in spring discharge and improve the efficiency of water use at the farm level.
- Many practices such as the use of traditional irrigation methods are considered inefficient and result in losses of water at farming level. A lack of water measuring devices and irrigation scheduling tools at the farm level leads to reduced water use efficiency.
- Many irrigation water sources such as wells and springs are shared or owned by groups of farmers with efficient institutional and organizational structures which could introduce or implement policies and strategies to improve the efficiency of water use. The dimensions of land tenure are also usually small for irrigated agriculture which can not absorb the water shares from irrigation wells or springs which are divided in terms of units of time. This problem arises more in greenhouses where the sizes are small and the water shares from wells cannot be utilized without an efficient organizational structure for distributing water among farmers and allowing them to irrigate several farms at the same time with a fair distribution method.

Policies and legislation

Water-related laws date back to the Ottoman Empire period, followed by the British, Jordanian/Egyptian, Israeli and now the Palestinian Authorities. Each ruling power has enacted new laws and created different water-related institutions.

During the British Mandate Period (1922-1948) the British regulated issues related to sewerage, drainage and water use within municipalities and enacted legislation to control the scarce water resources and ensure an adequate supply for domestic use.

During the Jordanian Period in the West Bank (1948-1967) the policies considered were to:

- introduce water management related laws and concepts
- require registration and licensing of use
- limit quantities used for various uses (agriculture, domestic)
- establish water allocation principles
- empower municipalities to distribute water
- set rules for pollution of springs, canals, pools cisterns and so on
- create the West Bank Water Department to supply water to Jerusalem, Ramallah, Bethlehem and neighbouring towns and villages

Egypt did not extend its laws to Gaza (1948-1967) nor did it create new laws in the water area. The British Mandate laws continued to apply.

During the Israeli Period (1967-1994), Israel controlled the water resources as to use, management, quality, allocation and supply and distribution. Law No. 2 of 1967 declared all water resources to be State Property.

The Palestinian Authority (1994-present) faced a legal challenge in the water sector since administration and regulations were severely underdeveloped. In 1996, Law No. 2 set out the objectives, functions, duties and responsibilities of the Palestinian Water Authority (PWA). In 1997, Presidential decree No. 66 established the regulations of the water sector and its rules and procedures. Law No.3 of 2002 encompasses all water sector issues. It aims to develop and manage the water resources, increase capacity, improve quality and preserve and protect against pollution and depletion. The major departures in this Law from Israeli legislation are that water is deemed a public property (owned by the people) not state property, the state manages water resources and private use is licensed as well as all other uses (Husseini, 2004).

ENVIRONMENT AND HEALTH

In the past few years there has been a lot of urban expansion at the expense of the best agricultural lands and in Jenin, Tulkarm, Qalqilya and Gaza Strip in particular urban expansion is taking a lot of irrigated land. There are many irrigation wells in these areas which are either pumping less than their quotas or not pumping at all as a result of land losses for urban areas. Instead of expanding cities towards lands not suitable for agriculture in the mountains of Tulkarm, Jenin and Qalqilya, municipalities are expanding their boundaries towards the fertile plains which are used for irrigated agriculture.

Improper farming practices such as the excessive use of fertilizers and pesticides are negatively affecting land and water resources. Excessive fertilization in greenhouses with improper and insufficient leaching is increasing soil salinities to levels unsuitable for vegetable production. Leaching of fertilizers and pesticides to groundwater is threatening the water quality for both domestic and agricultural sectors.

Treated wastewater is becoming a highly important source of irrigation water in the Near East region. Utilizing wastewater for reuse in agriculture requires building wastewater collection and treatment systems. Up to now, the collection infrastructure has been under-designed and only a few cities have such an infrastructure. Wastewater treatment plants are not treating wastewater to levels which allow its reuse. Significant investment is needed to construct wastewater collection and treatment systems in the Occupied Palestinian Territory.

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

Strategic options for alleviating constraints include:

- Political negotiations with Israel on land and water rights,
- Rehabilitation of the irrigation infrastructure, which should be given the highest priority to develop irrigated agriculture. This includes rehabilitation of irrigation wells, springs and water distribution systems.
- Regulation and monitoring of water, fertilizer and pesticide use.
- Construction of storage reservoirs in irrigated areas to store water from wells when supply exceeds demand. Those reservoirs will supply water when demand increases depending on the time of the day. It is suggested that farmers' water user associations are to be created to manage such reservoirs. Water gauges should be installed at each farm to measure the volume of water consumed by the farmer. A group of wells could use one storage reservoir. Gauges at wells measure the amount of water supplied from each well to estimate the amounts of water shares owned by each individual.
- Improving on-farm water management, which requires adding essential equipment to the farm such as water flow meters, pressure gauges and tensiometers in the field. Training for the use of such equipment will be needed. This is to be accompanied by increasing water supply reliability and flexibility through storage reservoirs to allow the farmer to add water according to crop demands. Other water management practices on the farm level include replacing old surface irrigation systems by new systems especially for citrus trees. Incentives for farmers could include subsidizing irrigation equipment and other equipment needed for improving water use efficiency.
- As the sizes of farms are small, there is a need to form some water user associations to manage water in a collaborative way to achieve an optimal distribution of water. Such associations should include all users in the same area depending on the sources of water. Managing a water storage facility for several wells requires an association for all farmers using these sources to set up schedules for water and to cooperate on maintenance and operation of the system.
- Without solving marketing problems for irrigated agricultural products, this sector will find it very difficult to expand and improve. Farmer unions are a tool to solve the problems farmers are facing, including marketing. Although farmers' cooperatives have not been very successful in solving problems faced by farmers, such cooperatives still are the best tool if farmers understand that cooperative work is a worthwhile commitment.
- Encouraging the private sector to improve the agricultural industry and construct storage, grading and processing facilities. This could be done through incentives such as reducing income taxes on such facilities and allowing importing such technology with tax exemptions.
- Wastewater reuse could be done in stages. The first stage would be to utilize wastewater for restricted crops such as fodder crops and fruit trees. A good example of crops that can utilize wastewater is citrus trees in Gaza, Tulkarm, Qalqilya and Jenin. After gaining experience in wastewater treatment and reuse, a move towards unrestricted crops could be made.

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