Jordan

GEOGRAPHY, CLIMATE AND POPULATION

Geography

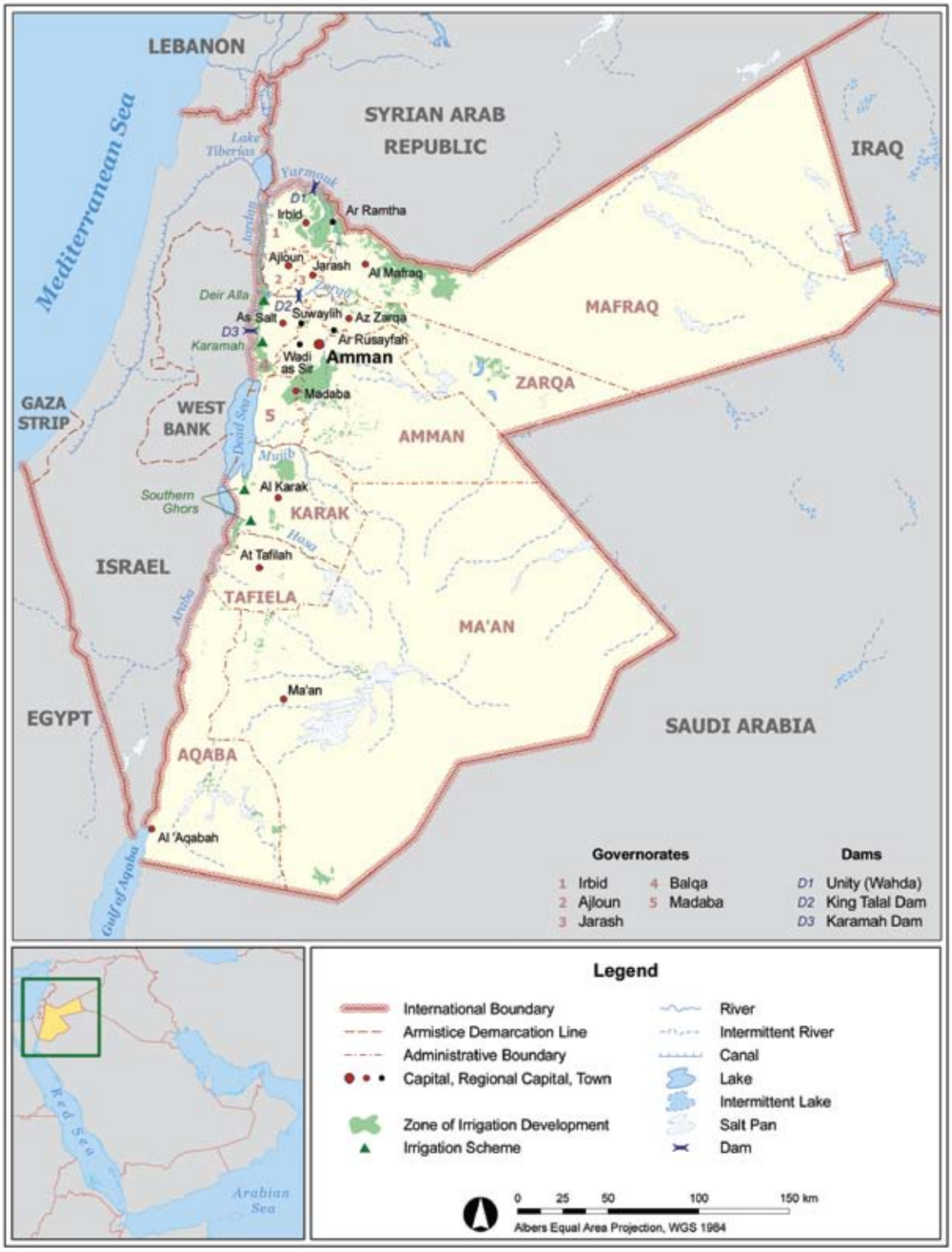
Jordan, with a total area of about 88 780 km², lies to the east of the Jordan River and is divided into twelve administrative governorates: Amman, Zarqa, Irbid, Mafraq, Ajloun, Balqa, Madaba, Karak, Tafileh, Ma'an and Aqaba. It is bordered to the north by the Syrian Arab Republic, to the northeast by 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**

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 m³/yr
Internal renewable water resources (long-term average)	-	0.682	10^9 m³/yr
Total actual renewable water resources	-	0.937	10^9 m³/yr
Dependency ratio	-	27.21	%
Total actual renewable water resources per inhabitant	2005	161	m³/yr
Total dam capacity	2007	275	10^6 m³
Water withdrawal			
Total water withdrawal	2005	940.9	10^6 m³/yr
- irrigation + livestock	2005	611.2	10^6 m³/yr
- municipalities	2005	291.3	10^6 m³/yr
- industry	2005	38.4	10^6 m³/yr
per inhabitant	2005	165.0	m³/yr
Surface water and groundwater withdrawal	2005	847.6	10^6 m³/yr
• as % of total actual renewable water resources	2005	90.5	%
Non-conventional sources of water			
Produced wastewater			10^6 m³/yr
Treated wastewater	2005	107.4	10^6 m³/yr
Reused treated wastewater	2005	83.5	10^6 m³/yr
Desalinated water produced	2005	9.8	10^6 m³/yr
Reused agricultural drainage water		-	10^6 m³/yr

groundwater aquifers. Total internal renewable groundwater resources have been estimated at 450 million m³/year, of which 253 million m³/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 m³/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 m³/year for 50 years. Other non-renewable water resources are found in the Jafer Basin, for which the annual safe yield is 18 million m³. The Water Authority of Jordan estimates that the total safe yield of fossil groundwater is 143 million m³/year for 50 years.

Ten dams have been constructed in the last five decades with a total capacity of around 275 million m³. The main dam is the King Talal Dam on the Zarqa River, with a total capacity of 80 million m³. 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 m³. 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 m³.

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).

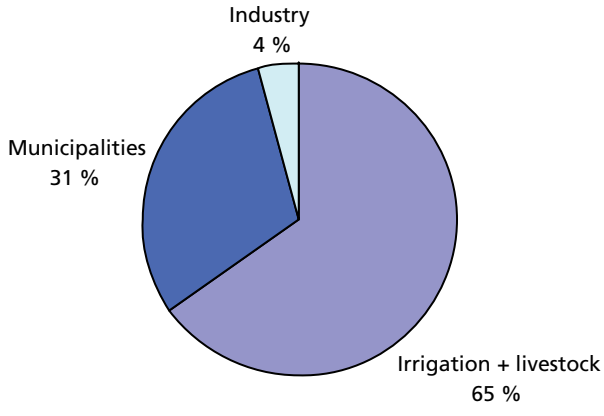
Water use

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.

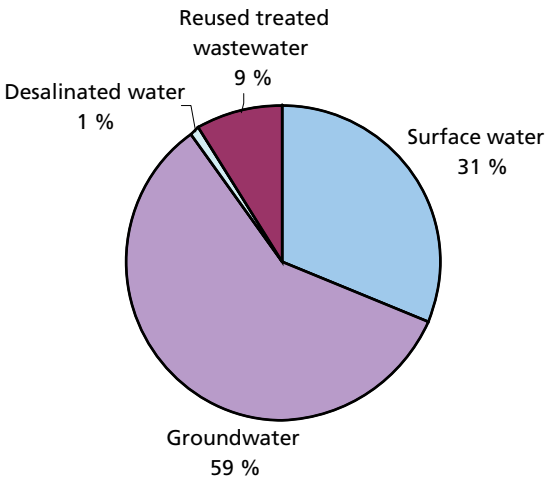
FIGURE 1
Water withdrawal by sector
Total: 0.941 km^3 in 2005



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

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.

FIGURE 3
Irrigation techniques
Total: 78 860 ha in 2004

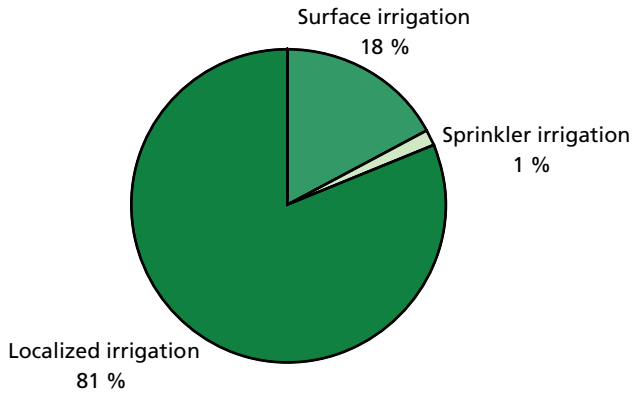
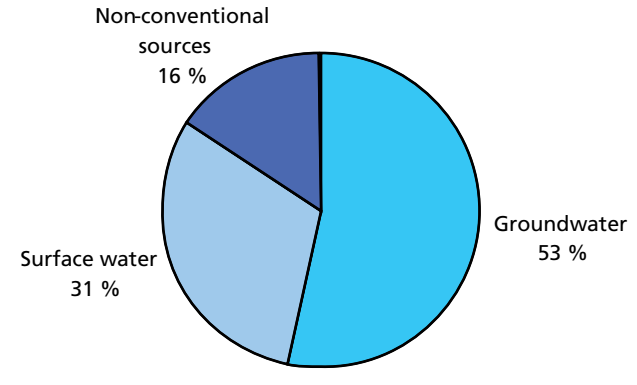


FIGURE 4
Source of irrigation water
Total: 78 860 ha in 2004

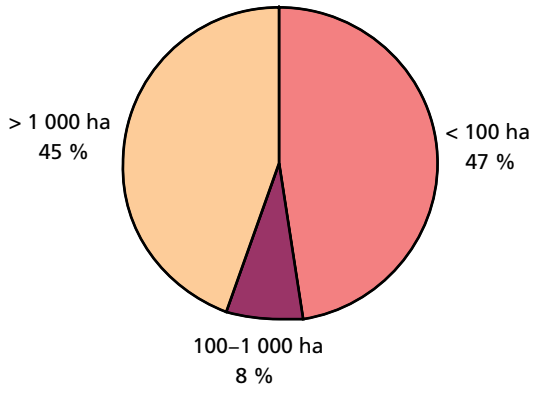


Streams and springs in the Side Wadis have been used for irrigation since the 1940s. A total area of about 1 500 ha is equipped for irrigation.

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

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 m³/ha for field crops (wheat and barley), 3 000–6 000 m³/ha for vegetables, 7 000 m³/ha for olives and grapes, 10 000–12 000 m³/ha for citrus and date palms and 18 000 m³/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 m³. 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 m³ of water. In the Highlands the average cost of irrigation water is between US$ 70 to 85 per 1 000 m³ and is increasing due to the rise in the cost of fuel.

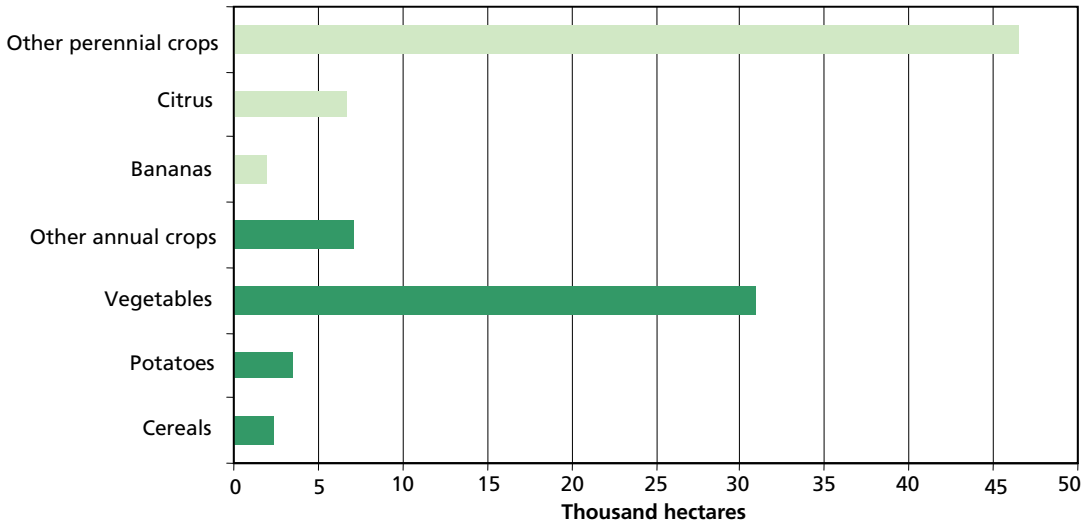
The government and the private sector work together to encourage farmers to adopt localized and sprinkler irrigation methods. Around 85 and 90 percent of

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).

MAIN SOURCES OF INFORMATION

Bani Hani, M. 1995. *Water policy reform in Jordan*. Paper prepared for the 12th FAO Regional Land and Water Commission, Beirut, December 1996.

Bani Hani, M. 2005. *Management of irrigation water in Jordan*. AARDO – International Workshop: Role of modern irrigation techniques in improving food security.

Directorate of Information and Computer (DIC). 2004. *Agriculture - Annual Report*.

Department of Planning and Information (DPI). From 1960s up to 2005. *Planning and information data in the Jordan Valley*.

Directorate of Planning and Water Resources. 1999, 2005. *Annual water budget*. Edited by MWI.

Directorate of Water Resources and Use and Control Center. 2004, 2005. *Water resources in the Jordan Valley.*

El Naser, H. and Elias, Z. 1993. *Jordan's water sector*. Country paper presented at the regional symposium on water use and conservation, organized by ESCWA and CEHA.

FAO. 2008. *Project Design & Management Training Programme for Professionals in the Water Sector in the Middle East*

FAO/ESCWA. 1994. *Land and water policies in the Near East Region*. Case studies on Egypt, Jordan and Pakistan. Amman, Jordan.

FAO/RNE. 2005. *Irrigated agriculture rigidities to marketing opportunities: Jordan case study.* Prepared by M. Bani Hani.

Green Cross Italy. 2006. *Water for Peace. The Jordan River Basin* http://www.greencrossitalia.it/ita/acqua/wfp/jordan_wfp_001.htm

Jordan Valley Authority (JVA). 2001. *Jordan Valley Development Law No.19 (1988) adjusted Law No. 30 (2001)*. Amman, Jordan.

Milich, L and Varady, G. 1998. *Openness, sustainability, and public participation in transboundary river-basin institutions. The Israel-Jordan Joint Water Committee (IJJWC)*

Ministry of Agriculture (MOA). 2005. *The national strategy for agricultural development*.

Ministry of Water and Irrigation (MWI). 2002. *Wastewater reuse*. Water demand management forum. 35 pp.

MWI. 2002. *Water sector planning & associated investment Program, 2002 – 2011*. Amman, Jordan.

Qasem, S. and Shatanawi, M. 1993. *Policies and strategies for the optimization of development and performance of irrigated agriculture in Jordan*. Ministry of Agriculture.

PRIDE and Chemonics International. 1992. *A water management study for Jordan*. USAID/Ministry of Water and Irrigation.

Salameh, H. 1991. *Jordan's water resources and their future potential*. Proceedings of the Symposium 27-28 October 1991. Published by Friedrich Ebert Stiftung. 1992. Amman, Jordan.

The Jordan Times. 2008. *Jordan, Syria to discuss Yarmouk basin, Wihdeh Dam storage.* Article 04/09/2008

Wangnick Consulting. 2002. *IDA Worldwide desalting plants inventory*. Report No. 17. Sponsored by the International Desalination Association (IDA).

World Bank. 1993. *Jordan river basin study*. The Regional Office for Integrated Development.