Oman

GEOGRAPHY, CLIMATE AND POPULATION

Geography

The Sultanate of Oman occupies the south-eastern corner of the Arabian Peninsula and has a total area of 309 500 km². It is bordered in the northwest by the United Arab Emirates, in the west by Saudi Arabia and in the southwest by Yemen. A detached area of Oman, separated from the rest of the country by the United Arab Emirates, lies at the tip of the Musandam Peninsula on the southern shore of the Strait of Hormuz. The country has a coastline of almost 3 165 km, from the Strait of Hormuz in the north to the borders of the Republic of Yemen in the southwest, overlooking three seas: the Persian Gulf, the Gulf of Oman and the Arabian Sea.

Administratively the country comprises five regions (A Dakhiliyah, Al Batinah, Al Wusta, Ash Sharqiyah and Al Dhahirah) and four governorates (Muscat, Musandam, Dhofar and Al Buraymi). It can be divided into the following physiographic regions:

- The coastal plain. The most important parts are the Batinah Plain in the north, which is the principal agricultural area, and the Salalah Plain in the south. The elevation ranges between 0 near the sea to 500 metres further inland.
- The mountain ranges, which occupy 15 percent of the total area of the country. There is the mountain range that runs from Musandam in the north to the Ras Al-Hadd in the southeast. In the north close to the Batinah Plain is the Jebel Al Akhdar with a peak of 3 000 metres. Other mountains are located in the Dhofar province, in the extreme southern part of the country, with peaks from 1 000 to 2 500 metres.
- The internal regions. Between the coastal plain and the mountains in the north and south lie the internal regions, with elevations not exceeding 500 metres. This part covers 82 percent of the country with mainly desert, sand and gravel plains. It includes part of the Rub' al Khali, also known as the Empty Quarter or the Great Sandy Desert.

The soils are coarse textured (sandy or coarse loamy) with a high infiltration rate. The soil pH is moderately to strong alkaline and the organic matter is very low.

The cultivated area was 58 850 ha in 2004, of which 12 793 ha consisted of annual crops and 46 057 ha of permanent crops (Table 1). Oman counts five distinct agricultural regions. Going roughly from north to south, they include the Musandam Peninsula, the Batinah coast, the valleys and the high plateau of the eastern region, the interior oases, and the Dhofar region. Over half of the agricultural area is located on the Batinah Plain in the north covering about 4 percent of the area of the country.

OMAN

FAO - AQUASTAT, 2008

Disclaimer

The designations employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of the Food and Agriculture Organization of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2005	30 950 000	ha
Cultivated area (arable land and area under permanent crops)	2004	58 850	ha
• as % of the total area of the country	2004	0.19	%
• arable land (annual crops + temp. fallow + temp. meadows)	2004	12 793	ha
• area under permanent crops	2004	46 057	ha
Population			
Total population	2005	2 567 000	inhabitants
• of which rural	2005	21.3	%
Population density	2005	8.3	inhabitants/km²
Economically active population	2005	977 000	inhabitants
• as % of total population	2005	38.1	%
• female	2005	17.3	%
• male	2005	82.7	%
Population economically active in agriculture	2005	317 000	inhabitants
• as % of total economically active population	2005	32.4	%
• female	2005	6.6	%
• male	2005	93.4	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2006	35 730	million US$/yr
• value added by agriculture (% of GDP)	2000	2	%
• GDP per capita	2004	9 583	US$/yr
Human Development Index (highest = 1)	2005	0.814	
Access to improved drinking water sources			
Total population	2000	82	%
Urban population	2000	85	%
Rural population	2000	73	%

Climate

Generally, the climate is considered to be arid and semi-arid but differs from one region to another. It is hot and humid during summer in the coastal areas and hot and dry in the interior regions with the exception of some higher lands and the southern Dhofar region, where the climate remains moderate throughout the year. Potential evaporation varies from 1 660 mm/year on the Salalah plain in the south to 2 200 mm/year in the interior. In the north and centre of Oman rainfall occurs during the winter, from November to April, while a seasonal summer monsoon, from June to September, occurs in the southern parts of the country (Dhofar) causing a temperature change. The volume of average annual rainfall of the country has been estimated at 19.25 km^3, which is equal to 62 mm (Ministry of Regional Municipalities, Environment and Water Resources, 2005), varying from less than 20 mm in the internal desert regions to over 300 mm in the mountain areas.

Population

The total population is 2.57 million (2005), of which around 21 percent is rural (Table 1). Population density is thus a little more than 8 inhabitants/km^2. The annual demographic growth rate was estimated at 2.9 percent between 1990 and 2000 and 1 percent between 2000 and 2005.

In 2000, 82 percent of the population had access to improved drinking water sources (85 and 73 percent for urban and rural populations respectively). The sanitation coverage was 97 percent for the urban population in 2006.

ECONOMY, AGRICULTURE AND FOOD SECURITY

Agricultural production played a significant role in the national economy in the period preceding the discovery of oil. Nowadays the national economy is dominated by its dependence on crude oil. In 2006 the Gross Domestic Product (GDP) was

US$35.7 billion, and agriculture accounted for almost 2 percent of GDP (2000). The economically active population is 977 000 (2005) of which 83 percent is male and 17 percent female. About one-third of this is economically active in agriculture, of which 93 percent is male and 7 percent female (Table 1).

The contribution of local agricultural products to food security is almost constant: 36 percent of the total consumption, in spite of the increase in population and the decrease of the harvested crop land from 72 000 ha in 2000 to 63 606 ha in 2004 because of drought and changes in land use policy. All cultivated areas are irrigated and the main crops are dates (more than half of the cultivated area) and fodder (more than one-fifth). While agricultural production has improved greatly, water shortage in some regions, salinity increase in wells and surface irrigation are limitative factors in terms of productivity.

Agricultural production takes place predominantly on small farm units. More than 91 percent of the total farm holdings occupy less than 5 ha and cover more than 52.4 percent of the total cropped land. Production is market-oriented and uses new farming technologies including hybrid seeds, commercial fertilizers and pesticides, mechanization and water saving irrigation systems.

WATER RESOURCES AND USE

Water resources

Total internal renewable water resources are estimated at 1.4 km^3/year (Table 2). About 1.05 km^3 is surface water and 1.3 km^3 groundwater, while 0.95 km^3 is considered to be the overlap between surface water and groundwater.

Several important aquifers exist in Oman. The main aquifer systems include the alluvial aquifers, the regional quaternary aquifers, the aquifers of the Hadramawt Group and the aquifers of the Fars Group. Some of these aquifer systems are part of large regional aquifers that extend throughout the Middle East. Fresh groundwater is mostly available in the northern and southern extremities of Oman where precipitation and recharge occur. Most of the groundwater in other areas is brackish to saline. There are several hundred springs in Oman and most of them are located in the mountainous areas. These springs vary according to their discharge, temperature and water quality (Ministry of Regional Municipalities, Environment and Water Resources, 2005).

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	62	mm/yr
	-	19.19	10^9 m^3/yr
Internal renewable water resources (long-term average)	-	1.400	10^9 m^3/yr
Total actual renewable water resources	-	1.400	10^9 m^3/yr
Dependency ratio	-	0	%
Total actual renewable water resources per inhabitant	2005	545	m^3/yr
Total dam capacity	2006	88.38	10^6 m^3
Water withdrawal			
Total water withdrawal	2003	1 321	10^6 m^3/yr
- irrigation + livestock	2003	1 168	10^6 m^3/yr
- municipalities	2003	134	10^6 m^3/yr
- industry	2003	19	10^6 m^3/yr
• per inhabitant	2003	526.1	m^3/yr
Surface water and groundwater withdrawal	2003	1 175	10^6 m^3/yr
• as % of total actual renewable water resources	2003	83.9	%
Non-conventional sources of water			
Produced wastewater	2000	90	10^6 m^3/yr
Treated wastewater	2006	37	10^6 m^3/yr
Reused treated wastewater	2006	37	10^6 m^3/yr
Desalinated water produced	2006	109	10^6 m^3/yr
Reused agricultural drainage water		-	10^6 m^3/yr

The main reliable source of water is internal groundwater. Apart from some significant wadis like Dayqah and Quriyat that have an average flow of 60 million m^3/year or Halfayn which covers a catchment area of 4 373 km^2 (Ministry of Regional Municipalities, Environment and Water Resources, 2005), in nearly all wadis surface water runoff only occurs for some hours or up to a few days after a storm, in the form of rapidly rising and falling flood flows. Since the infiltration capacity of coarse alluvium and fissured rock is high, groundwater can be recharged quite easily.

Oman has large amounts of water in aquifers that were replenished a long time ago when wet climate conditions prevailed. The present recharge is very low, if any. Those non-renewable resources exist in the Dhofar (Najd), Al Dahra (Al Massrat) and Sharqia (Rimal al Sharqia) regions. The government decided to use those aquifers to supply water for urban use and as a reserve for the future.

Since 1985, 31 major recharge dams have been constructed together with many smaller structures in order to retain a portion of the peak flows, thus giving more scope for groundwater recharge. In 2006, the total dam capacity was 88.4 million m^3. A 100 million m^3 dam is under construction and expected to be finished in 2009.

Desalination plants make an important contribution to water supplies where natural water resources are inadequate. Sea water desalination in Oman started to supply potable water to Muscat and the coastal area in the early 1970s. In 2002, the total installed gross desalination capacity (design capacity) was 322 579 m^3/day or 118 million m^3/year (Wangnick Consulting, 2002). The total production is around 109 million m^3/year (2006), whereas it was 34 million m^3 in 1995. The desalination plants should provide 80 percent of the potable water supply by the year 2010.

In 2000, the total produced wastewater was 90 million m^3. In 2006, 37 million m^3 were treated and reused. The use of treated effluent is limited to landscape irrigation using sprinkler, drip and bubbler systems. The Muscat Municipality has major plans to extend its sewage collection and treatment system. At present the total water treatment in the municipality is about 25 000 m^3/day but in the near future 70 000 m^3/day should be generated. Treatment plants exist in each region. The recent water treatment station built in Salalah city (south of Oman) will produce about 40 000 m^3/day. The effluent undergoes an effective tertiary treatment, one of the best in the world according to world standards in this field.

Water use

In 2003, the total water withdrawal was 1 321 million m^3 of which 88.4 percent was withdrawn for agricultural purposes, 10.1 percent for municipal purposes and 1.5 percent for industrial purposes (Table 2, Figure 1 and Figure 2).

The water balance shows that in many areas demand for water exceeds natural replenishment. For instance in coastal areas, over withdrawal has led to saline water intrusion and a deterioration in the water quality. At present, groundwater depletion is estimated at around 134 million m^3/year.

As traditional water structures, the Al Zaijrah and Birkat systems have a particular importance in Oman

FIGURE 1
Water withdrawal by sector
Total: 1 321 km^3 in 2003

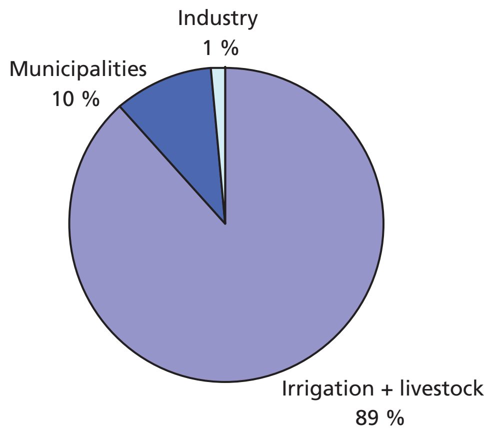


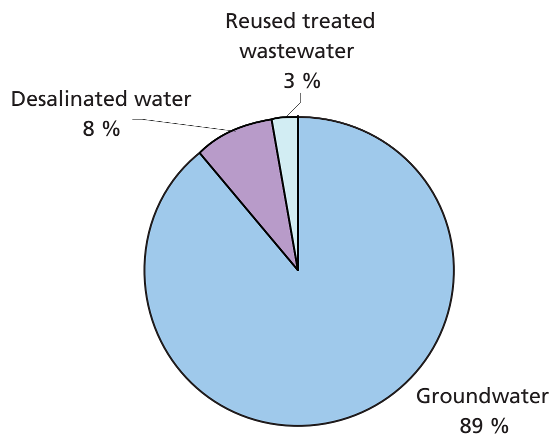
TABLE 3
Irrigation and drainage

Irrigation potential		-	-	ha
Irrigation				
1. Full or partial control irrigation: equipped area		2004	58 850	ha
- surface irrigation		2004	46 658	ha
- sprinkler irrigation		2004	6 654	ha
- localized irrigation		2004	5 538	ha
• % of area irrigated from surface water		2004	0	%
• % of area irrigated from groundwater		2004	100	%
• % of area irrigated from mixed surface water and groundwater		2004	0	%
• % of area irrigated from mixed non-conventional sources of water		2004	0	%
• area equipped for full or partial control irrigation actually irrigated			-	ha
- as % of full/partial control area equipped			-	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)			-	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)		**2004**	**58 850**	**ha**
• as % of cultivated area		2004	100	%
• % of total area equipped for irrigation actually irrigated			-	%
• average increase per year over the last 11 years		1993-2004	-0.41	%
• power irrigated area as % of total area equipped		2004	84.1	%
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**	**58 850**	**ha**
- as % of cultivated area		2004	100	%
Full or partial control irrigation schemes	**Criteria**			
Small-scale schemes	< 2 ha	2004	23 456	ha
Medium-scale schemes		2004	22 548	ha
large-scale schemes	> 8 ha	2004	12 847	ha
Total number of households in irrigation		1993	62 411	
Irrigated crops in full or partial control irrigation schemes				
Total irrigated grain production (wheat and barley)		2004	4 162.6	metric tonnes
• as % of total grain production		2004	100	%
Harvested crops:				
Total harvested irrigated cropped area		2007	67 087	ha
• Annual crops: total		2007	12 661	ha
- Wheat		2007	311	ha
- Barley		2007	1 171	ha
- Sorghum		2007	2 346	ha
- Other cereals		2007	3 256	ha
- Potatoes		2007	310	ha
- Sugar cane		2007	40	ha
- Vegetables		2007	5 229	ha
• Permanent crops: total		2007	54 426	ha
- Date palms		2007	32 759	ha
- Bananas		2007	2 436	ha
- Fodder		2007	15 817	ha
- Citrus fruits		2007	1 232	ha
- Coconuts		2007	449	ha
- Other perennial crops		2007	1 733	ha
Irrigated cropping intensity (on full/partial control area equipped)		2004	108	%
Drainage - Environment				
Total drained area		2006	0	ha
- part of the area equipped for irrigation drained		2006	0	ha
- other drained area (non-irrigated)		2006	0	ha
• drained area as % of cultivated area		2006	0	%
Flood-protected areas			-	ha
Area salinized by irrigation			-	ha
Population affected by water-related diseases			-	inhabitants

(Ministry of Regional Municipalities, Environment and Water Resources, 2005):

- Al Zaijrah is a system in which water is extracted from a dug well, originally by using animals, which was the main traditional method of lifting water for agriculture from dug wells till the introduction of pumps in the 1950s. The Zaijrah consists of one or two Manjur (well-wheels) made from individual wedge-like sections of acacia wood, which are fitted around a central hub and bound tightly with strips of leather or shark skin.
- A Birkat is a cistern, which is a traditional system designed to collect and store rainfall-generated flows. It comprises an excavated chamber or a naturally occurring hollow structure. For centuries the utilization of birkats has been vital for the survival and development of many remote settlements in the Musandam peninsula where they serve as the only source of water to meet domestic and livestock requirements.

FIGURE 2
Water withdrawal by source
Total: 1 321 km³ in 2003



IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

Although 2.2 million ha are considered suitable for agriculture, there is no figure on the irrigation potential taking into consideration both land and water resources. All agriculture in Oman is irrigated and the equipped area increased from about 28 000 ha in the 1970s to 61 550 ha in 1993, of which 34 930 ha, or almost 57 percent, was located in the Al Batinah province in the north. In 2004, the equipped area for irrigation was 58 850 ha, of which over 50 percent was located in Batinah region.

All areas equipped for irrigation are irrigated from groundwater sources (wells, Falaj). While the area under sprinkler and localized irrigation has tripled over the last 10 years, the traditional surface irrigation system remains the most common irrigation technique covering almost 80 percent of the area equipped for irrigation (Table 3 and Figure 3). Sprinkler and localized irrigation systems, also called modern irrigation systems as opposed to traditional surface or flood irrigation systems, are mainly found on new farms. Half of them were subsidized by the government, meaning that the Ministry of Agriculture and Fisheries (MAF) is following up its efforts to introduce modern irrigation techniques. In order to encourage farmers to take up the new techniques,

FIGURE 3
Irrigation techniques
Total: 58 850 ha in 2004

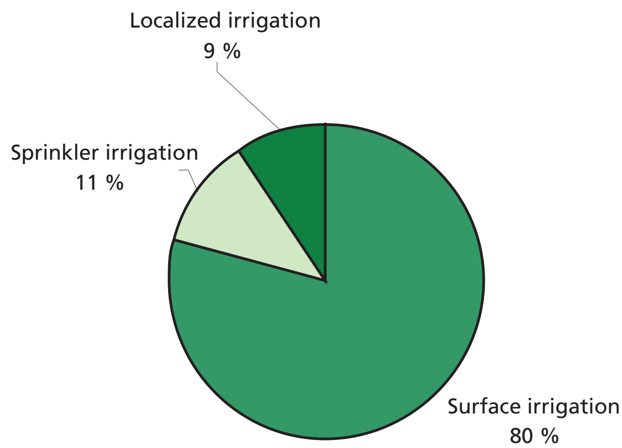
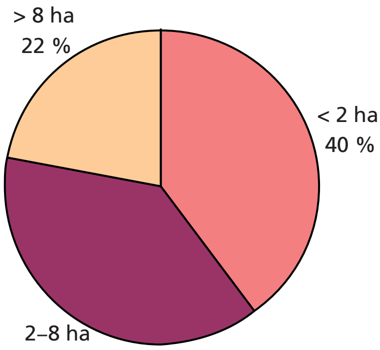


FIGURE 4
Type of irrigation schemes
Total: 58 850 ha in 2004



the MAF has approved financial and technical assistance to small farmers. The feasibility of modern irrigation systems has been proven as well as their good results on yield increase and water saving.

In 2004, small schemes (< 2 ha) covered 40 percent of the total equipped area for irrigation, medium size schemes (2-8 ha) 38 percent and large schemes (>8 ha) 22 percent (Figure 4).

In most parts of Oman irrigation systems have been improved gradually which is reflected by the increase in agricultural production: first with the improvement of the water lifting device, then with cemented lined channels and then with piped systems.

The falaj system ('aflaj' in plural) is the traditional method developed centuries ago for supplying water for irrigation and domestic purposes. Many of the systems currently in use are estimated to be over a thousand years old. The falaj comprises the entire system:

i. the source, which might be the upper reaches of wadis from which water is diverted, a qanat, or a spring;
ii. the conveyance system, which is usually an open earth or cement-lined ditch;
iii. the delivery system.

The falaj has assumed a social significance and well established rules of usage, maintenance and administration have evolved. Based on the source, three types of falaj can be distinguished:

1. he Ghaily falaj, which is a simple diversion and canalization of surface wadi flow; it uses normally open channels to collect and transfer the water; it dries out after long periods of drought with low rainfall since it depends on a shallow underground water table;
2. the Iddi or Dawoodi falaj, also called qanat, which is a very ancient system for extracting water from the water table by gravity, through a nearly horizontal gallery; this type of falaj has a system of deep and long channels, the lengths of which sometimes extend to 16 km, while the whole falaj network may reach 45 km;
3. the Aini falaj, which is a simple canalization of springs.

The flow of water in a falaj system is continuous and the distribution of water is divided into periodic units by the owner of the falaj. According to the national falaj inventory undertaken in 1997, the total number of working aflaj in the Sultanate is 3 017, covering a total irrigation area of 21 606 ha (Table 4). The mean annual flow of these aflaj is about 552 million m^3 and water losses are estimated at about 128 million m^3/year. Water quality is high, even though in a few cases salinity reaches 1 500 µS/cm.

Both hand-dug and tubewells are increasingly being constructed to supplement the falaj water, especially in the coastal areas. In 1993, for 47 percent of the total number of 62 411 households involved in irrigation, wells were the main source of water, 39 percent relied on falaj water, while the remaining 14 percent had access to both sources. Water pumping through wells now represents 67 percent of total groundwater withdrawal, while falaj water represents 33 percent. About 84 percent of the total area equipped for irrigation is power irrigated.

TABLE 4
Distribution of Falaj in Oman by region according to the National Falaj inventory, 1997

Regions	Al Batinah	Al Dhakliah	Al Dhahera	Al Sharqiah	Musqat	Total
Area (ha)	5 594	7 895	3 527	4 326	225	21 606
No Falaj	1 209	501	473	661	173	3 017

Role of irrigation in agricultural production, economy and society

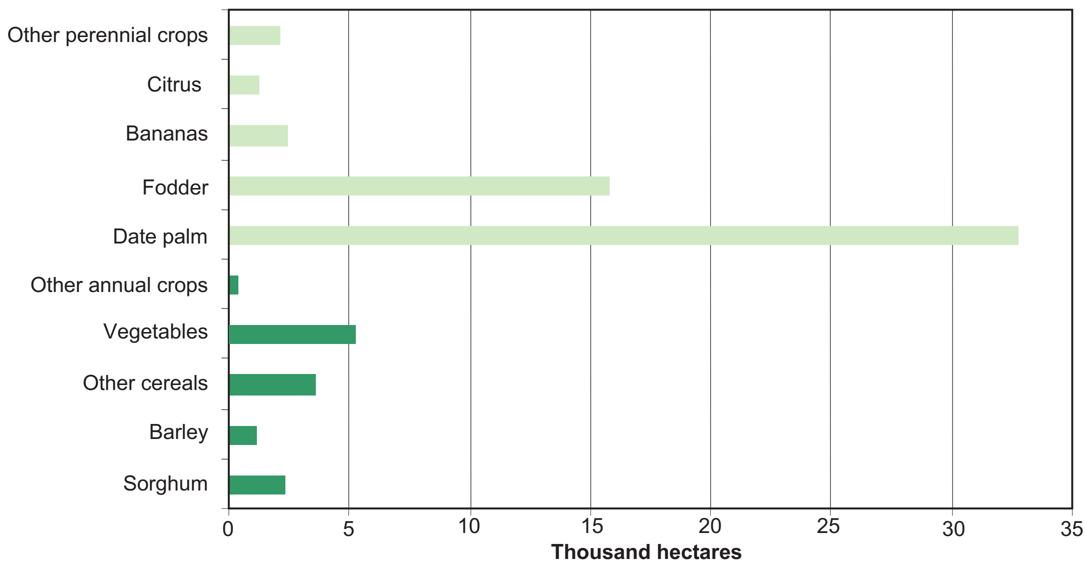
In 2007, the total harvested area was 67 087 ha of which 81 percent were permanent crops (Table 3 and Figure 5). Date palms covered almost 50 percent of the harvested area, fodder 24 percent and cereals 11 percent. There are more than 8 million date palms in Oman, distributed along the coast of Batinah and the oases in different regions. Total date production in 2007 was estimated at 255 870 tonnes whereas fodder production was around 610 300 tonnes. In 2004, the harvested area was estimated at 63 606 ha of which 33 050 ha were located in the Al Batinah area.

The average cost of installing sprinkler and localized irrigation systems is estimated at US$4 300/ha for large and medium schemes and US$6 144/ha for small schemes, meaning an increase of 32 and 39 percent respectively compared to 1996. The combined capital, maintenance and energy cost of pumping groundwater from a typical dug well for traditional irrigation is estimated at about US$0.021/$m^3$ for average conditions. Pumping costs from a tubewell for a modem irrigation system, requiring a larger pumping head, are between US$0.031 and 0.039/$m^3$.

The amount of water used for irrigation depends on the type of crop and the cropping system adopted, as well as on the climate of the regions. It varies from 16 700 to 20 800 m^3/ha per year depending on the regions and from 4 000 to 27 400 m^3/ha per year according to the type of crops. The net return on water from agriculture is generally marginal in northern Oman. In Salalah returns are much better because crop water requirements are lower and higher value crops are grown, such as bananas and coconuts.

Only men are involved in agricultural water management. Women are involved in product harvesting and processing as well as taking care of the animals.

FIGURE 5
Irrigated crops
Total harvested area: 67 087 ha in 2007 (cropping intensity on equipped area: 108% in 2004)



Status and evolution of drainage systems

A study carried out in 1994 on the salinity of soils in general in Oman states that an area of 11.7 million ha, which is 38 percent of the total area of Oman, is affected by salinity. Agricultural water withdrawal has resulted in a decline of groundwater levels and falaj flows in most regions. It has also caused an increase in the average salinity of water used in agriculture. For more than 10 years saline water intrusion in coastal areas has been occurring so much that productive farms are being abandoned. No drainage is practiced.

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

Institutions

Until May 2001, the Ministry of Water Resources (MWR) was in charge of water resources assessment, whereas the Ministry of Agriculture and Fisheries (MAF) was in charge of irrigation. However, in May 2001, the MWR was abolished and its activities were transferred to the Ministry of Regional Municipalities and Environment and Water Resources (MRMEWR).

Water management

Three broadly-based programmes have been set up by the government related to: (i) the improvement of data collection; (ii) a detailed assessment of the water resources; (iii) a study of water demand and its spatial distribution. The government also has plans to relocate some of the large-scale farms in the Batinah and Salalah Plains, where the water resources are overutilized, to areas with underutilized water resources. Several water conservation initiatives have been developed, such as leakage control in municipal water supply schemes and the improvement of irrigation methods through subsidy programmes. Public awareness of water resource issues has created a general and focused understanding of the overall situation and of the specific contribution each citizen can make.

A number of national priorities and strategies related to water resources development have been developed including the following:

- achieve optimum utilization of available natural resources
- continue the exploration for water resources
- continue the construction of recharge dams and other hydrological structures
- maximize agricultural productivity within the natural limitations of climate and water resources availability and sustainability
- conserve water for the agricultural sector through: (i) moving high water consuming crops to brackish water areas; (ii) limiting cultivation of perennial grasses and high water consuming crops; (iii) promoting seasonal crops and limiting perennial cultivation; (iv) promoting modern irrigation techniques; (v) promoting the use of brackish water for agricultural use;
- extend wastewater collection measures and promote wastewater reuse
- increase the use of desalinated water for domestic purposes
- protect the groundwater resources in qualitative as well as quantitative terms
- control saline water intrusion by reducing abstraction to below the long-term recharge rate
- expand monitoring of water use

Policies and legislation

With Oman having entered the arena of recent developments in 1970 and with the increasing demand for water, legislation was prepared to safeguard interests with regard to the rights established by customs and traditions. Many plans and programmes were set up to increase the efficiency of water use.

In 1988, Royal Decree No. 83/88 declared the water resources of Oman to be a national resource. This is the most far-reaching and important piece of legislation on water resources. Oman has several laws on water resources and the main measures taken for water management and conservation are:

- no wells may be constructed within 3.5 km of the mother well/source of the falaj
- permits are required for the construction of new wells, for deepening existing wells, for changes in use and for installing a pump
- all drilling and well digging contractors are required to register with the Ministry of Regional Municipalities, Environment and Water Resources (MRMEWR) on a yearly basis
- the MRMEWR has the cooperation of other government agencies such as the Ministry of the Interior and the Royal Oman Police in dealing with offenders
- no extension of existing agriculture lands and no cultivation of new lands are allowed

Royal Decree No 72/89 was issued for the application of modern irrigation systems in the Batinah region with the intention of rationalizing water use, increasing agricultural production and improving its quality. As an incentive to the farmers to introduce the systems the Government provided a financial subsidy to alleviate the cost burden.

In 2000, a new Royal Decree, No 29/2000, defined water as a national asset to be protected and regulated activities related to wells and aflaj and the use of wells for desalination.

In 2001, Royal Decree No 114/2001 on conservation of the environment and prevention of pollution regulated the disposal of solid and hazardous waste, pollution control and the issuing of permits for discharging untreated wastewater (MRMEWR, 2005).

ENVIRONMENT AND HEALTH

The quality of the water in the wells differs from place to place. In places near the sea the Electric Conductivity (EC) may reach 10 dS/m, owing to the pumping of groundwater at rates higher than the secured discharges leading to saline sea water intrusion into the agricultural lands. In most of the coastal area salinity has increased gradually since 1988 when the expansion of agriculture reached its peak. The south Batinah areas in particular have suffered from a progressive salinity increase over the last decade owing to the wide expansion of agriculture while other areas showed a gradual increase. The increasing salinity is probably the single most economically devastating water resource problem facing the country at present.

The use of agrochemicals, both fertilizers and pesticides, is a widespread and potentially serious hazard to groundwater quality where, as in most of the Sultanate, groundwater is unconfined and most soils are sandy loam with low organic content (low water-holding capacity and high deep-percolation). The government is strict about the use of all types of agrochemicals. Since 1973, over 50 separate pieces of environmental legislation have been enacted in connection with various aspects of the environment, covering topics ranging from the protection of fish, flora and fauna, to waste disposal and quality standards for drinking water and the reuse of treated sewage effluent.

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

A National Water Resources Master Plan was prepared in 2000 to establish a strategy and plan for the period 2001-2020 for the sustainable development, management and conservation of water resources in the Sultanate of Oman. The Plan was based on general and resource studies, economic studies and some limited social studies as well as institutional and implementation support studies. The technical basis for the Plan comprises the assessments of water availability, development potential and demand for water.

In general terms, it was concluded that there is a requirement for an additional supply and/or adjustment of water use to yield overall about 330 million m^3/year in order to meet future additional priority demands and restore the existing deficit during the Master Plan period. In view of the current high levels of water consumption by farmers using wells, demand management and water quality conservation measures were investigated in order to determine how consumption could be reduced to sustainable levels and the implications of such measures were evaluated. Some of these measures would need the support of a legislative, regulatory or institutional nature delivered at a national or regional level (Ministry of Regional Municipalities, Environment and Water Resources, 2005).

With the aim of increasing irrigation efficiency, the government committed itself to encouraging the introduction of localized irrigation systems. The introduction of these systems is considered to be one of the most important projects implemented by the Ministry of Agriculture and Fisheries (MAF) to conserve water and achieve agricultural development. The MAF has set the standard specifications and the technical terms for the implementation of modern irrigation systems, as well as for the calculation of crop water requirement for different areas. According to the agricultural census 2004-2005, 19 percent of the harvested area was under modern irrigation: 52 percent of harvested vegetables area was under modern irrigation, 42 percent of fodder but only 9 percent of field crops and 6 percent of dates and other fruits.

MAIN SOURCES OF INFORMATION

Al-Mamari, S. 2002. *Improvement and development of irrigation water management in the Aflaj system*.

Al-Mamari, S. 2007. *The role of modern irrigation technology in saving water and increasing production*.

Department of Agricultural Statistics, MAF. 2005. *Agricultural census 2003/2005*.

Ministry of Agriculture and Fisheries (MAF). Undated. *Development and optimization of the use of water resources in the Sultanate of Oman*.

Ministry of National Economy (MONE). 2006. *Statistical year book 2006*.

Ministry of Regional Municipalities, Environment and Water Resources (MRMEWR). 2005. *Water resources in Oman*.

Ministry of Water Resources (MWR). 1991. *National water resources master plan*.

MWR. 2000. *National water resources master plan*.

World Bank. 1988. *Sultanate of Oman: Recent economic developments and prospects*. Report No 6899-OM. Washington DC.

Qatar

GEOGRAPHY, CLIMATE AND POPULATION

Geography

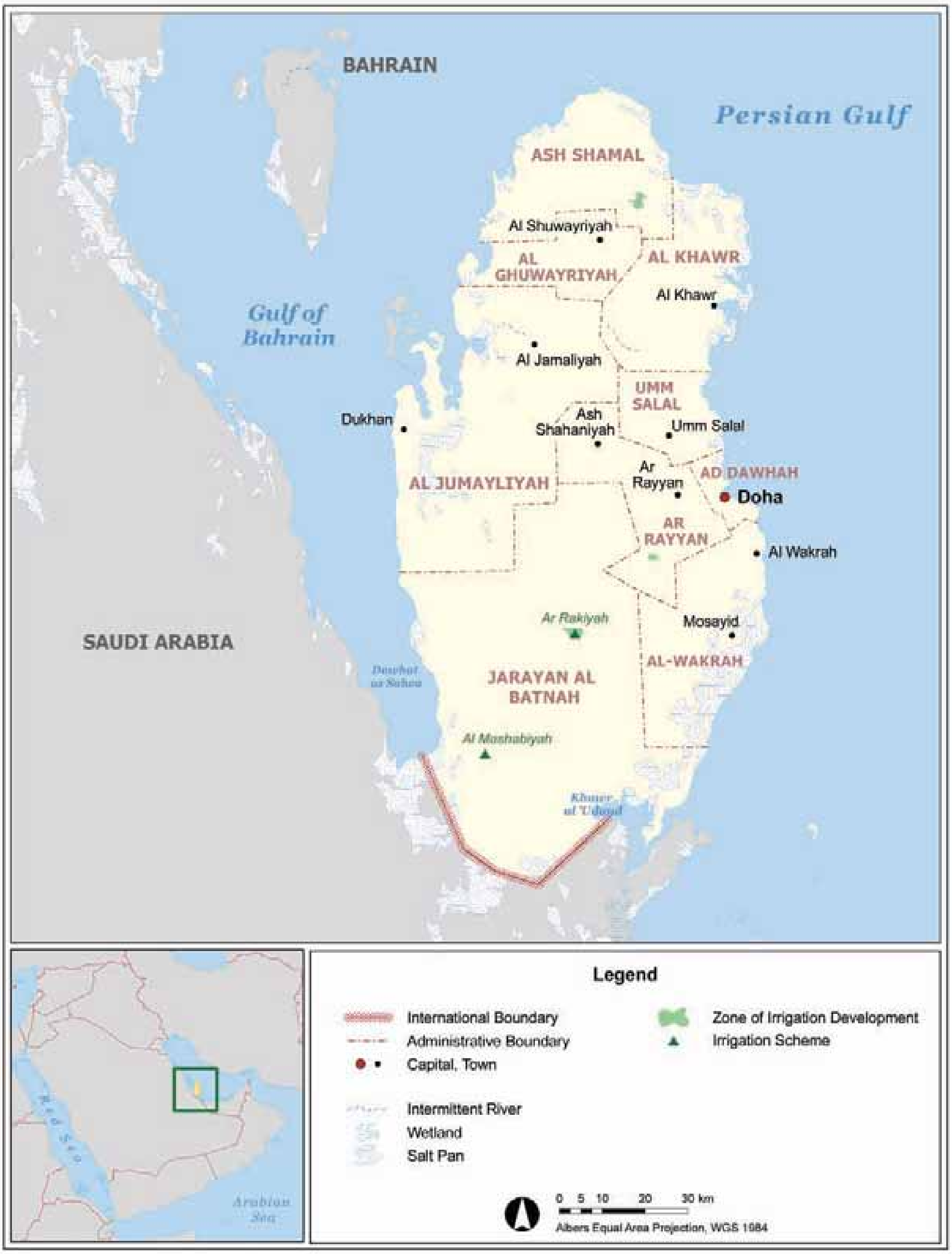
Qatar is a small peninsula in the Persian Gulf covering an area of approximately 11 000 km^2 including a number of small offshore islands. Its maximum length is about 180 km along the north-south axis, while the east-west width is 85 km at its widest point. It is bounded by the Persian Gulf on all sides except in the south where it touches the eastern province of Saudi Arabia.

The elevation of the country decreases from 100 m above sea level in the south to less than 50 m in the north. Qatar is a rocky desert area with scattered oases formed by 850 separate depressions. In these depressions colluvial soils made up of calcareous loam, sandy loam and sandy clay loam have accumulated to depths ranging from 30 to 150 cm, overlying limestone debris and bedrock. These depression soils are locally known as rodat and constitute the main agricultural soils of the country. Highly saline depression soils, locally known as sabkha, occur mainly along the coasts of Umm Said, Dukhan and the southern boundary of Qatar. In southern Qatar the depressions are often more crater-like in appearance, with the bottoms usually covered by aeolian sands.

The total cultivated area is 6 322 ha, including 67 ha of greenhouses (Table 1). The total area of arable land is 2 651 ha, which includes 1 190 ha of vegetable crops and 1 461 ha of field crops. The area under permanent crops amounts to 3 412 ha and comprises 1 478 ha of perennials and forage crops and 1 934 ha of fruit trees (DAWR, 2002). The land suitable for irrigation is 52 128 ha and most of it is classified as having marginal suitability for irrigation (Awiplan Qatar & Jena-Geos, 2005). All cultivated areas are irrigated thus representing 12.1 percent of the land suitable for irrigation.

Climate

Qatar lies in the northern hemisphere desert. The country has an extensive hydrological and meteorological data collection network which has been operative since 1972. The data are monitored by 25 manual and 25 automatic rain gauges and 3 manual and 3 automatic agrometeorological stations, spread over a wide geographical area. The arid desert climate is characterized by scanty rainfall with an annual average of about 80 mm over the period 1972–2005. Rainfall is extremely unpredictable and highly erratic, both in time and space. Because of its low intensity and variability, it is not considered reliable for supplementing irrigation and maintaining agriculture, yet it represents the main source of irrigation water in the form of recharge to groundwater. Other climatic characteristics are high temperatures during summer (> 40 °C), high evaporation rates with an annual average of 2 200 mm, very strong winds and high relative humidity (Abu Sukar *et al*, 2007). Evapotranspiration ranges from less than 2 mm/day in December to a maximum of 10 mm/day in June.



QATAR

FAO - AQUASTAT, 2008

TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2005	1 100 000	ha
Cultivated area (arable land and area under permanent crops)	2004	6 322	ha
• as % of the total area of the country	2004	0.6	%
• arable land (annual crops + temp. fallow + temp. meadows)	2001	2 651	ha
• area under permanent crops	2001	3 412	ha
Population			
Total population	2005	813 000	inhabitants
• of which rural	2005	7.6	%
Population density	2005	74	inhabitants/km^2
Economically active population	2005	486 000	inhabitants
• as % of total population	2005	59.8	%
• female	2005	18	%
• male	2005	82	%
Population economically active in agriculture	2005	5 000	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$)	2005	42 460	million US$/yr
• value added by agriculture (% of GDP)	-	-	%
• GDP per capita	2005	52 276	US$/yr
Human Development Index (highest = 1)	2005	0.875	
Access to improved drinking water sources			
Total population	2006	100	%
Urban population	2006	100	%
Rural population	2006	100	%

Population

In 2005, the population was estimated at 813 000 inhabitants with an average population density of 74 inhabitants/km^2 (Table 1). The annual population growth rate, based on the last two censuses of 1997 and 2004, is approximately 5.2 percent. The male population is around double the female population. The preponderance of a male population during the last three decades is because of Qatar's vast economic growth and its heavy dependence on a non-Qatari labour force. Over 82 percent of the population lives in the Greater Doha (Doha and Ar-Rayyan cities) (The Planning Council, 2005). All the population has access to clean drinking water. The existing sewage network covers about 68 percent of all buildings and 95 percent of the buildings of the capital Doha are covered by the sewage networks (Public Works Authority, 2005).

Economy, agriculture and food security

Virtually all economic activity depends on oil, gas and its derivatives. The total Gross Domestic Product (GDP) with the prices of 2005 was US$42.5 billion, giving an annual per capita income of US$52 276 (Table 1). The contribution of agriculture to the economy is negligible. According to the agricultural census (2000/2001), the number of permanent agricultural workers excluding fishery workers is 11 773, of whom only a very few are Qatari (DAWR, 2002).

Qatar is considered to be one of the countries enjoying high economic growth rates, as well as high levels of human development, which qualify it to rank first among Arab countries and 35th worldwide according to the Human Development Report (2005). The average life expectancy at birth is 74 years (2005). Government support programmes related to public housing, subsidies of essential goods and health, education, electricity and water services have all led to a rise in the living standards of those with a limited income. Civil organizations who have adopted numerous programmes and activities have also contributed to raising the living standards of low income families by providing them with direct assistance, in addition to developing their potential and turning them into productive members who contribute to the increase of family income.

The development of the agricultural sector is limited by several factors, such as scarce water resources, low water quality, unfertile soils, harsh climatic conditions and poor water management. All these factors have contributed to low crop yields and resulted in the importing of most agricultural products, dates being the only exception.

WATER RESOURCES AND USE

Water resources

There are no permanent rivers in Qatar. Direct and indirect recharge of groundwater from rainwater forms the main natural internal water resource. Two-thirds of the land surface is made up of some 850 contiguous depressions with interior drainage and with catchment areas varying from 0.25 km² to 45 km² and with a total aggregate area of 6 942 km². While direct recharge from rainfall might take place during very rare heavy storms, the major recharge mechanism is an indirect one through runoff from surrounding catchments and the pounding of water on the depression floor. Surface runoff typically represents between 16 and 20 percent of rainfall. Of the amount reaching the depressions, 70 percent infiltrates and 30 percent evaporates. The average annual groundwater recharge from rainfall is estimated internally at 55.9 million m³/year (Table 2). In addition there is an inflow of groundwater from Saudi Arabia estimated at 2.2 million m³/year, making the average total renewable groundwater resources 58.1 million m³/year for the period 1972–2005 (DAWR, Groundwater Unit, 2006).

There are two main aquifers that are used to provide fresh groundwater. The uppermost is a chalky limestone referred to as the Rus aquifer. This overlies the important Umm er Rhaduma which is a major aquifer throughout the Gulf region. The salinity level of these two aquifers in northern and central Qatar varies from 500 to 3 000 mg/l and increases towards the sea reaching 10 000 mg/l near the coasts. In the extreme south-western region of Qatar, in the vicinity of Abu Samra, the Alat member of the Upper Dammam Formation creates an artesian aquifer whose recharge

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	80	mm/yr
	-	0.88	10^9 m³/yr
Internal renewable water resources (long-term average)	-	0.056	10^9 m³/yr
Total actual renewable water resources	-	0.058	10^9 m³/yr
Dependency ratio	-	3.45	%
Total actual renewable water resources per inhabitant	2005	71	m³/yr
Total dam capacity		-	10^6 m³
Water withdrawal			
Total water withdrawal	2005	444	10^6 m³/yr
- irrigation + livestock	2005	262	10^6 m³/yr
- municipalities	2005	174	10^6 m³/yr
- industry	2005	8	10^6 m³/yr
• per inhabitant	2005	546	m³/yr
Surface water and groundwater withdrawal	2005	221	10^6 m³/yr
as % of total actual renewable water resources	2005	381	%
Non-conventional sources of water			
Produced wastewater	2005	55	10^6 m³/yr
Treated wastewater	2006	58	10^6 m³/yr
Reused treated wastewater	2006	43	10^6 m³/yr
Desalinated water produced	2005	180	10^6 m³/yr
Reused agricultural drainage water		-	10^6 m³/yr

source is in Saudi Arabia. The aquifer is of limited extent with an average thickness of 15 m. The total depth of wells ranges from 22 to 80 m below the ground surface. Generally salinity ranges from 4 000 to 6 000 mg/l. The Aruma aquifer in southwest Qatar comprises approximately 130 metres of granular limestone belonging to the Aruma Formation. The drilling data of exploratory and production wells indicate the occurrence of relatively good quality water (with a salinity level of about 4 000 mg/l) at depths of 450–650 m in southwest Qatar.

The non-conventional sources of water in Qatar are desalinated sea water and treated sewage effluent. The quantity of municipal wastewater produced in the country was 55 million m^3 in 2005 and the quantity treated (98 percent tertiary treatment) was 53 million m^3 (Public Works Authority, 2005). In 2002, the total installed gross desalination capacity (design capacity) in Qatar was 762 932 m^3/day or 278 million m^3/year (Wangnick Consulting, 2002). In 2005, the total desalinated sea water produced was 180 million m^3 (Water and Electricity Company, 2007).

Water use

In 2005, total water withdrawal was estimated at 444 million m^3, of which 262 million m^3 or 59 percent for agricultural purposes, 39 percent for municipal purposes and 2 percent for industrial use (Figure 1). In 1994 total water withdrawal was estimated at 292 million m^3, of which 74 percent for agricultural purposes, 23 percent for municipal use and 3 percent for industrial use. Desalinated water provides 99 percent of the drinking water (Table 3). Of the total reused treated wastewater of 43 million m^3 (an increase of more than 70 percent since 1994), 26 percent was supplied to Doha to be used for landscape irrigation, the remaining part being conveyed via pipelines for irrigation of forage crops in two farms (DAWR, Irrigation and Drainage Unit, 2006; Water and Electricity Company, 2007; Public Works Authority, 2005). All water used for irrigation is pumped from wells and from the sewage treatment plants to the farms and Doha. There is no pricing system and water is given free to the farmers.

The rate of groundwater depletion is estimated at 69 million m^3/year (average for the period 1972–2005). As an example for one year, total groundwater extraction in 2005 was estimated at 221 million m^3 (Figure 2). In the same year the groundwater recharge from rainfall was estimated to be about 25 million m^3, against a long-

FIGURE 1
Water withdrawal by sector
Total: 0.444 km^3 in 2005

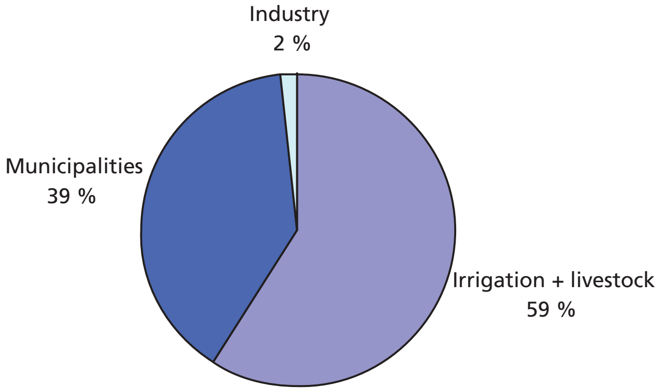


FIGURE 2
Water withdrawal by source
Total: 0.444 km^3 in 2005

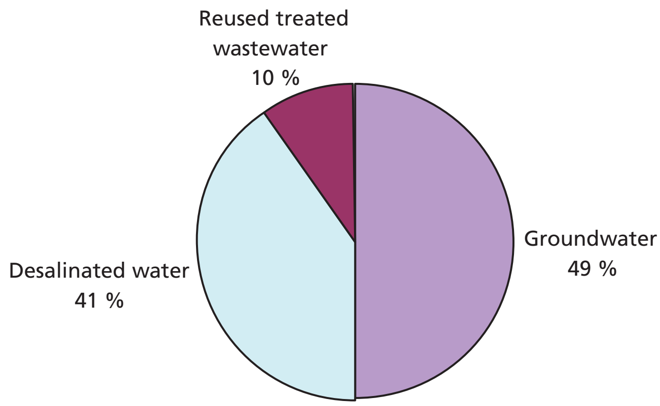


TABLE 3
Water withdrawals by different sectors in Qatar (2005)

	Agriculture		Domestic		Industry		Total	
	million m³/year	%	million m³/year	%	million m³/year	%	million m³/year	%
Groundwater	218.3	83.5	2.4	1.4	-	-	220.7	49.7
Treated sewage water	43.2	16.5	-	-	-	-	43.2	9.7
Desalinated water	-	-	171.8	98.6	8.4	100.0	180.2	40.6
Total	**261.5**	**100.0**	**174.2**	**100.0**	**8.4**	**100.0**	**444.1**	**100.0**
% by sector	**58.9**	**-**	**39.2**	**-**	**1.9**	**-**	**100.0**	**-**

term annual average of almost 56 million m^3 (see above). Return flow from irrigation was estimated at 55 million m^3 and subsurface outflow at 18 million m^3. This means that mining of groundwater was 159 million m^3 in 2005 (by calculating total groundwater extraction plus subsurface outflow and subtracting groundwater recharge from rainfall and return flow from irrigation).

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

Recently a study on land suitable for irrigation was conducted. The suitability index was based on the mean values of soil texture, soil depth, $CaCo_3$ content, gypsum content, salinity and alkalinity, drainage and slope degree. About 44 500 ha were found to be marginally suitable for irrigation outside the farms and 7 628 ha marginally and moderately suitable within the farms (Awiplan Qatar & Jena-Geos, 2005).

As in any other arid region, agriculture in Qatar is not possible without irrigation. The part of land suitable for irrigation that can be considered when assessing irrigation potential depends on the future availability of alternative sources of water, because groundwater is already being depleted at the recorded present rate of abstraction. In 2004, there were 1 192 registered farms in the country, of which 945 were actually operative. The area equipped for irrigation was estimated at 12 935 ha (Table 4), while 6 322 ha were actually irrigated, which is 49 percent of the equipped area (DAWR, Agricultural and Statistics Section, 2006). In 1993 the area equipped for irrigation was 12 520 ha, of which 8 312 or 66 percent was actually irrigated.

Surface irrigation (basins and furrows) is the most commonly used irrigation technique (Figure 3). The total area equipped for sprinkler irrigation is 1 813 ha and the total area equipped for localized irrigation is 1 415 ha according to the agricultural census of 2000/2001 (Table 5). Examples of relatively large-scale projects that use modern irrigation techniques are the Ar Rakiyah project, where 20 centre pivots cover 813 ha, and the Al Mashabiyah project, where 14 000 date palms are irrigated by bubblers and more than 800 ha of vegetables are irrigated by drippers on experimental and private farms.

Most of the water used in irrigation is groundwater, with very low water use efficiency (Figure 4). The water is pumped from the wells via pipelines with a conveyance efficiency of about 90 percent. However, the application efficiency is estimated at 50 percent, thus making the overall irrigation efficiency 45 percent.

FIGURE 3
Irrigation techniques
Total: 12 935 ha in 2001

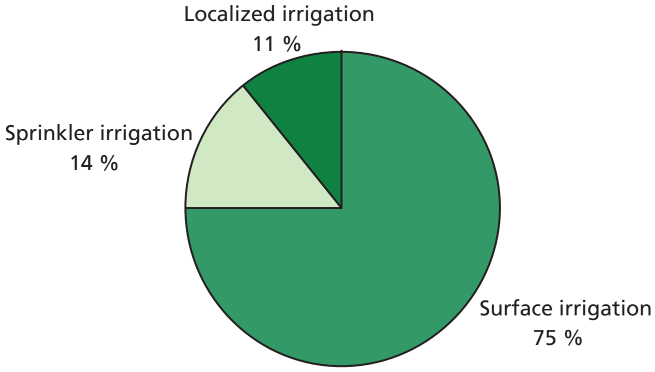


TABLE 4
Irrigation and drainage

Irrigation potential		**-**	**52 128**	**ha**
Irrigation				
1. Full or partial control irrigation: equipped area		2001	12 935	ha
- surface irrigation		2001	9 707	ha
- sprinkler irrigation		2001	1 813	ha
- localized irrigation		2001	1 415	ha
• % of area irrigated from surface water		2001	0	%
• % of area irrigated from groundwater		2001	93.4	%
• % of area irrigated from surface water and groundwater		2001	0	%
• % of area irrigated from non-conventional sources of water		2001	6.6	%
• area equipped for full or partial control irrigation actually irrigated		2004	6 322	ha
- as % of full/partial control area equipped		2001	47	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)			-	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)		**2001**	**12 935**	**ha**
• as % of cultivated area		2001	200	%
• % of total area equipped for irrigation actually irrigated		2001	47	%
• average increase per year over the last 8 years		1993-2001	0.4	%
• power irrigated area as % of total area equipped		2001	100	%
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)		**2001**	**12 935**	**ha**
• as % of cultivated area		2001	200	%
Full or partial control irrigation schemes	**Criteria**			
Small-scale schemes	< 20 ha	2001	1 703	ha
Medium-scale schemes		2001	5 272	ha
Large-scale schemes	> 100 ha	2001	5 960	ha
Total number of households in irrigation				
Irrigated crops in full or partial control irrigation schemes				
Total irrigated grain production (wheat and barley)		2004	3 106.4	metric tonnes
• as % of total grain production		2004	100	%
Harvested crops				
Total harvested irrigated cropped area		2004	6 928	ha
• Annual crops: total		2004	3 745	ha
- Wheat		2004	10	ha
- Barley		2004	1 027	ha
- Maize		2004	93	ha
- Other cereals		2004	204	ha
- Potatoes		2004	2	ha
- Vegetables		2004	1 343	ha
- Fodder (annual)		2004	1 066	ha
• Permanent crops: total		2004	3 183	ha
- Fodder (permanent)		2004	1 478	ha
- Citrus		2004	140	ha
- Other perennial crops		2004	1 565	ha
Irrigated cropping intensity (on full/partial control area actually irrigated)		2004	110	%
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 5
Distribution of full/partial control irrigation techniques (Agricultural Census, 2000/2001)

Irrigation technique	Area (ha)	(%)
Surface (basins & furrows)	9 707.2	75
Sprinkler (centre pivot)	1 510.0	12
Sprinkler (overhead)	303.5	2
Dripper	868.6	7
Bubbler	546.0	4
Total	**12 935.3**	**100**

FIGURE 4
Source of irrigation water
Total: 12 935 ha in 2001

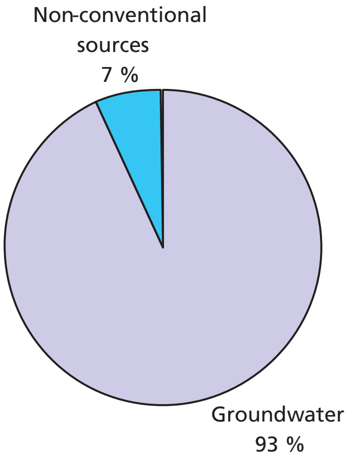
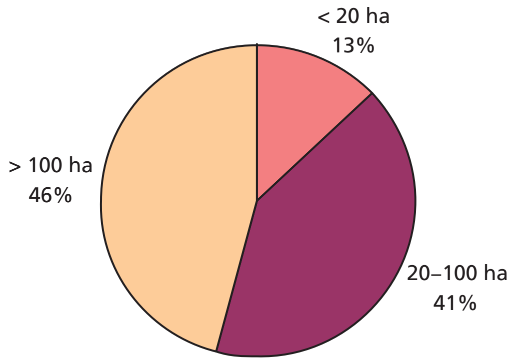


FIGURE 5
Type of irrigation schemes
Total: 12 935 ha in 2001



Role of irrigation in agricultural production, economy and society

There is great potential for increasing water use efficiency by shifting from surface irrigation techniques to sprinkler and localized irrigation. If modern irrigation techniques are adopted, together with improved cultural practices, the water use of the major crops could be in the range shown in Table 6. This would lead to saving 35–40 percent of the present crop water consumption. The cost of modern irrigation techniques using PVC pipes (excluding pumps, conveyance pipes and installation) is estimated at US$3 300/ha for an overhead sprinkler system, US$2 200/ha for a bubbler system and US$3 800/ha for a drip system (Hashim, 2005).

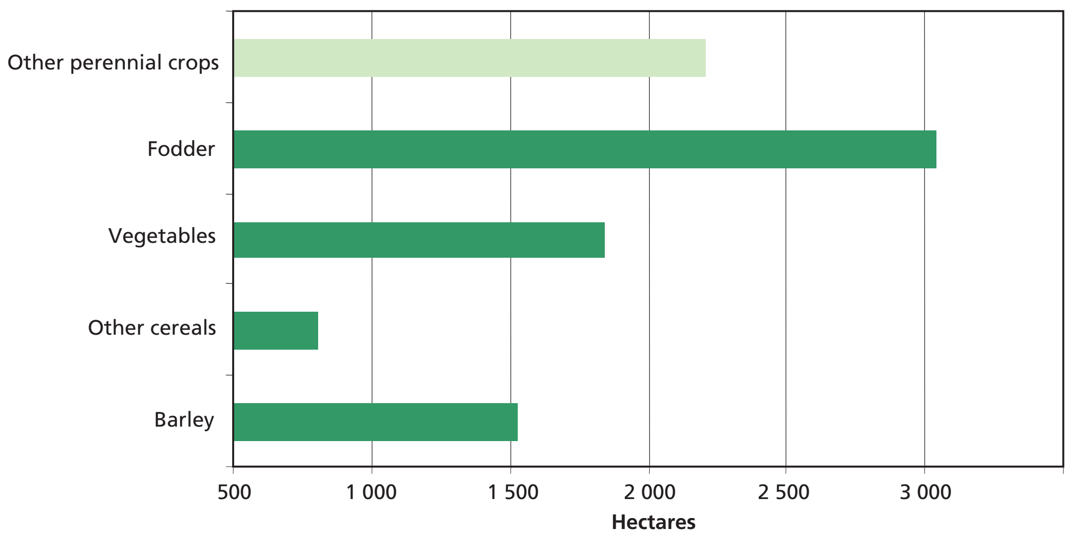
Small schemes (< 20 ha) cover 13 percent of the total equipped area for irrigation, medium size schemes (20-100 ha) 41 percent and large schemes (> 100 ha) 46 percent (Figure 5). All agricultural land in Qatar is owned by Qatari nationals, but farming is not the primary occupation of these landowners. Farming is carried out by expatriates, mainly Palestinians, Iranians and Egyptians. The landowners either employ expatriate farm managers or let their farm to expatriate tenants on short-term leases. There are five commercial agricultural companies and 17 farms are public and state-owned (The Planning Council, 2005).

Major irrigated crops are green fodder, vegetables, fruit trees and cereals (Figure 6). Tomatoes are the main winter vegetable and melons the main summer vegetable. The main fruit trees are dates and citrus. Alfalfa is the main green fodder crop. Barley is the main cereal, with a small quantity of wheat and maize (DAWR, Agricultural and Statistics Section, 2006).

TABLE 6
Average water use for major crops in Qatar, results of irrigation experiments (DAWR)

Crop	Irrigation method	Soil texture	Water quality (dS/m)	Water use (mm)
Alfalfa/	Sprinkler (overhead)	Coarse sand	5.50	3 600
Rhodes grass	Center pivot	Sandy loam	3.10	3 200
Barley	Sprinkler (Conventional)	Coarse sand	6.25	800
	Center pivot	Sandy loam	3.10	600
Tomatoes	Drip	Sandy loam	4.33	690
Onions	Spray	Sandy loam	4.33	630
	Sprinkler	Coarse sand	5.28	1 040
Potatoes	Drip	Sandy clay loam	4.33	430
	Sprinkler	Coarse sand	5.28	740
Squash	Drip	Sandy clay loam	4.33	380
Date Palms	Bubbler	Sand	7.50	1 200

FIGURE 6
Irrigated crops
Total harvested area: 6 928 ha in 2004 (cropping intensity on equipped area actually irrigated: 110%)



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

Institutions

The main ministries and institutions responsible for water development, planning and management are:

- the Ministry of Municipal Affairs and Agriculture (MMAA) represented by the General Directorate of Research and Agricultural Development, responsible for the management of groundwater use in agriculture; it comprises the following water-related departments:
  - Department of Agricultural and Water Research (DAWR) which consists of five sections and two laboratories: Water Research Section, Soil Research Section, Agricultural Research Section, Agricultural Economics and Statistics Section, Agricultural Extension Section, Central Agricultural Laboratory and Plant Tissue Culture Laboratory;
  - Agricultural Development Department (ADD);

  - The Department of Public Gardens and Landscaping which manages landscape irrigation with treated sewage effluent;
  - Agricultural Information Centre (AIC), responsible for the digital mapping and processing of groundwater, soils and as-built survey of farm boundaries;

- Drainage Affairs of Public Work Authority, which is responsible for the collection of wastewater and its treatment and distribution to the farms and the Doha landscape;
- Qatar General Electricity and Water Corporation (KAHRAMAA), responsible for providing desalinated water for drinking and industrial use;
- Qatar Electricity and Water Company (QEWC), responsible for the desalination of water and selling it to the General Electricity and Water Corporation;
- Supreme Council for Environment and Natural Reserves (SCENR), responsible for the protection of water resources;
- Planning Council, concerned with planning for water and other resources;
- The Central Laboratory, Ministry of Public Health, which is responsible for analyses of chemical and biological contaminants in drinking water and treated sewage effluent.

The Permanent Water Resources Committee (PWRC) was established in April 2004 under a decree by H.H. the Amir of the State of Qatar and via Decision No. 7/2004 of the Council of Ministers. Its objectives include contributing to securing ample water resources in quality and quantity for various uses for the benefit of society, the health of the environment, the integration of management, the development and preservation of water resources, coordination between the country's authorities concerned with water resources and the reinforcement of public awareness of the importance and value of water.

Water management

Qatar has carried out a number of programmes and studies, issued water laws, and established committees for the consolidation of integrated water resources management, the most important of which are the following:

- Increasing natural recharge: The drilling of wells (with a special design including a perforated casing and graded gravels) in depressions to depths that reach the water bearing formations will accelerate the natural recharge of floodwater. The project started in 1986 and 341 recharge wells have been drilled since then (DAWR, Groundwater Unit, 2006). Continuation of this project will make rapid recharge possible from the occasional storm runoff that accumulates in depressions before its loss through evaporation. Experiments reveal that drilling wells in depressions could accelerate the recharge of floodwater by up to 30 percent.
- Development of water monitoring and irrigation scheduling: The water monitoring development programme has been promoted through a telemetry system at 3 automatic agrometeorological stations, 25 hydrometeorological stations and 48 hydrogeological stations. These automatic stations provide reliable data for irrigation scheduling and designing irrigation systems.
- Artificial recharge of groundwater: The Rus and upper Umm er Radhuma aquifers in northern Qatar have been heavily exploited for agricultural purposes. The total abstraction is far in excess of the average natural recharge. To solve this problem, a study concerning the artificial recharge of freshwater in the aquifer system was conducted in the period from 1992 to 1994. The objective of the study was to determine the feasibility of a large-scale artificial recharge project to augment the depleting northern groundwater aquifer and improve the water quality. The study indicates that the artificial recharge freshwater recovery efficiency, called 'the user specific recovery efficiency' (water salinity range 1 000–3 600 mg/l) could reach 100 percent in Rus and transition Rus/Umm er Radhuma.

- Development of deep aquifers: A recent study indicates that the development of the aquifer is constrained by several factors. These factors include depth of occurrence (450-650 m), low well production levels of up to 15 l/s at a drawdown of more than 100 m and salinity within the range of 4 000 to 6 000 mg/l.
- Increasing treatment and reuse of wastewater: The Drainage Affairs increased the volume of treated sewage effluent (TSE) through the connection of more residential areas to the public sewer and extension to Doha South and Doha West Treatment Plants. The amount of TSE increased from 46 million m^3 in 2004 to 58 million m^3 in 2006 and the amount reused in forage production and irrigation of landscape increased from 39 million m^3 to 44 million m^3 during the same period.
- Irrigation research and studies: Irrigation research and studies over the last ten years have included crop water requirements of the major crops in Qatar, irrigation with saline water, optimizing the use of TSE for forage production, the economics of protected agriculture when using desalinated water, optimum use of water resources in agriculture and modernizing irrigation in the Qatari farms.

Finances

The Agricultural Development Department (ADD) supports crop production by subsidizing seeds, fertilizers, pesticides, insecticides and services such as land cultivation and levelling. The magnitude of subsidies ranges from 25 to 75 percent of the cost depending on the productivity of the farm, the application of modern techniques and water use efficiency.

Policies and legislation

Based on the recommendations of the Department of Agriculture and Water Research (DAWR), an Ameri Decree (No.1 of 1988) was issued governing the drilling of wells and use of groundwater. The Ministry of Municipal Affairs and Agriculture (MMAA) formed the “Permanent Committee for farms, wells and organizing farmers’ affairs” which is responsible, in addition to other duties, for implementing the groundwater laws. Unfortunately, the only articles which have been implemented are those connected with granting permits for drilling, altering and modifying wells. What is required now is to put into action the articles concerning water use, protection and conservation.

It is thought that public awareness could be one of the most effective measures for mitigating water-related hazards and combating desertification. Proper education and training programmes could result in considerable water saving and consequently lead to cancelling some of the expensive water enhancement projects or at least postpone their implementation. Qatar has launched several public awareness, training and education programmes on conserving water resources and combating desertification. The programmes have been carried out by the DAWR, the SCENR (Supreme Council for Environment and Natural Reserves) and the Qatar Electricity and Water Company). The ‘Environmental-Friends Centre’, an NGO, has also participated in increasing public awareness especially among students and young people. The salient features of these programmes include the following:

- Organizing field days and exhibitions;
- Conducting specialized lectures, seminars, conferences, symposiums and workshops;
- Issuing technical bulletins, folders and posters;
- Displaying films, presenting TV and radio programmes and publishing articles in newspapers;
- Running campaigns;
- Arranging competitions among school children;
- Celebrating World Water Day (22 March), Gulf Cooperation Council (GCC)

Water Week (22–28 March), Arab Environmental Day (14 October), Qatari Environmental Day (26 February) and Gulf Environmental Day (24 April).

ENVIRONMENT AND HEALTH

Several practical problems are associated with using saline water on the Qatari farms. The most serious ones are groundwater pollution, degradation of soils and consequent abandonment of farms. Groundwater pollution is caused by several factors, the main one being uncontrolled and excessive pumping from wells. The present extraction rate is estimated to be about four times the average recharge from rainfall, which leads to a lowering of the water table and the consequent up-flow of brackish water from the underlying aquifer, thus increasing the water salinity. The average annual rate of increase in water salinity in the wells during the period 1982–2004 was estimated at 2.2, 1.6 and 1.7 percent for representative farms in northern, central and southern regions of the country respectively (Table 7). Seawater intrusion is a common worldwide problem along sea coasts, peninsulas and islands. In Qatar the problem is more severe, because the high permeability of the fractured limestone aquifer containing freshwater permits the rapid intrusion of seawater. The return flow from irrigation to groundwater reservoirs is estimated at an average of 25 percent of the gross water application. This has been determined from lysimeter observations. Although this irrigation return flow increases the recharge to groundwater, it deteriorates the water quality because the percolating poor quality water dissolves salts from the soil and underlying strata and carries them to those aquifers bearing relatively fresh water. Moreover farmers sometimes use large quantities of low quality water to wash the salts away and avoid plants wilting and also apply heavy chemical fertilizers to increase the yield. This practice is not necessarily beneficial, because it may contribute to groundwater pollution. On the Government Experimental Farm, drainage water analysis shows a significant increase in nitrate derived from nitrogenous fertilizers.

Scarcity of water resources, severe climatic conditions, pollution of groundwater, unsuitable cropping patterns, incorrect cultural practices, overgrazing and socioeconomic development all lead to soil degradation and cause desertification. In addition to these factors, improper farm layouts and erroneous irrigation designs together with poor water management intensify the problem of desertification. The accumulation of salts year after year degrades the soils and renders them unproductive and is considered the main reason for abandonment of farms. Most of the degraded soils are found in farms located near the coasts because of the effect of the high saline irrigation water or in inland farms where heavy textured soils become saline. Of a total number of 434 farms during the 1975/76 season, 259 were in operation and 175 abandoned. During

TABLE 7
Average annual rate of increase in wells water salinity (%) at representative farms of different regions in Qatar during the period 1982/83–2003/04

Region	Farm No.	1982/83 Average E.C.	2003/04 Average E.C.	Average annual rate of increase in the farms	Average annual rate of increase in the region
		(dS/m)	(dS/m)	(%)	(%)
North	110	3.2	3.7	0.74	2.19
	143	1.6	2	1.19	
	199	1.6	2.5	2.68	
	690	1.5	2.8	4.13	
Centre	248	3.3	3.9	0.87	1.65
	260	2.7	4	2.29	
	741	0.8	1.1	1.79	
South	561	4.6	6.5	1.97	1.70
	516	4	5.6	1.90	
	746	3.5	4.4	1.22	

the 2004/05 season the total number of farms increased to 1 285 and abandoned farms numbered 293 (DAWR, Irrigation and Drainage Unit, 2006). There is no irrigation induced waterlogging in the farms because the water table is very deep. However, waterlogging occurs in the non-irrigated areas of the sabkha soils and covers an area of 61 000 ha approximately (Awiplan Qatar & Jena-Geos, 2005).

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

The national strategy and policy for the development of water resources and irrigation consists of a short-term strategy and a long term strategy.

The short-term strategy aims at improving the present water use situation. To prevent further depletion and pollution of groundwater the following measures will be implemented in the near future:

- Water meters will be installed in all wells;
- After the installation of water meters, it should be ensured that the water allocated for each farm shall not be exceeded;
- The farm owner shall not irrigate more than the area specified and shall not install any water conveyance and irrigation systems in contravention of the instructions issued by the DAWR;
- The owner of the farm shall be required to take all necessary steps for the protection and maintenance of wells, pumps, conveyance and distribution pipelines, irrigation systems and all control devices.

Notwithstanding the implementation of groundwater laws, the DAWR has taken several steps to improve irrigation efficiency and increase crop production:

- Adoption of cropping patterns for each farm in accordance with the salinity of irrigation water and characteristics of the soil;
- A ban on the drilling of new boreholes in the areas most affected where there is excessive abstraction or where the water salinity of wells exceeds 12 000 μmhos/cm;
- Stop awarding permits for establishing new farms or extending existing farms until the aquifer has returned to its equilibrium state;
- Encourage the shift to protected agriculture;
- Make full use of non-conventional water resources for crops irrigation. This includes the use of treated sewage effluent and the possible use of desalinated groundwater for irrigation and cooling greenhouses;
- Study the possibility of introducing a pricing system for water consumption with penalties for extravagant water use and incentives for water saving;
- Provide interest-free loans to farmers to promote modern irrigation systems with a repayable period of several years.

The MMAA is planning to implement a technical study and survey for the development of groundwater resources over the next two years. This study includes the mechanism of natural and artificial recharge, monitoring the new wells network, monitoring the groundwater rate of recharge and abstraction and water quality, preparation of a 3-D groundwater flow model and establishment of groundwater geographic information system.

The Permanent Water Resources Committee (PWRC) has launched a long-term programme for integrated water resource management in Qatar. The general objective of the program is to formulate a comprehensive National Water Resources Management and Development Strategy (NWRMDS) with a planning vision up to the year 2050.

The future demand to meet the municipal and industrial requirements can be achieved by increasing the capacity of the existing desalination plants and from building new desalination plants. Food self-sufficiency is not a practical policy and taking into account land availability and climate factors, the amount of food capable of being produced will be based on the following water resources for irrigation:

- The safe yield of groundwater, which is 58 million m^3/year (DAWR, Groundwater Unit, 2006);
- Availability of TSE, which is expected to be 129 million m^3 in 2013, 193 million m^3 in 2020 and 255 million m^3 in 2050 (Public Works Authority, 2005);
- Availability of Gas-to-Liquid treated industrial wastewater which is expected to reach a ceiling of 50 million m^3/year after several years;
- Other water resources could be investigated for technical and economic feasibility including:
  - Reuse of drainage water under Doha city (20 million m^3/year of TDS in the range of 7 000 mg/l) for irrigating salt-tolerant crops (Public Works Authority, 2005);
  - Seeding of clouds for enhancement of water resources;
  - Using desalinated water for irrigation and cooling greenhouses.

The long-term strategy includes the implementation of artificial recharge of groundwater in the northern aquifer. The main objective of this project is to restore the groundwater reservoir to its state of balance during the 1970s.

MAIN SOURCES OF INFORMATION

Abu Sukar, H.K., Almerri, F.H., Almurekki, A.A. 2007. *Agro-hydro-meteorological data book for the State of Qatar*. DAWR.

Awiplan Qatar & Jena-Geos. 2005. *Soil classification and land use specifications for the State of Qatar, Phases 1 & 2*. DAWR.

Department of Agricultural and Water Research (DAWR). 2002. *Agricultural census results 2000/2001*. Ministry of Municipal Affairs and Agriculture (MMAA). Doha, Qatar.

DAWR, Agricultural and Statistics Section. 2006. *The annual book of agricultural statistics 2004*. MMAA. Doha, Qatar.

DAWR, Groundwater Unit. 2006. *Groundwater data and balance*.

DAWR, Irrigation and Drainage Unit. 2006. *Wells water survey in the Qatar Farms*.

Halcrow-Balfour Ltd. 1981. *Master Water Resources and Agricultural Development Plan*. Ministry of Industry and Agriculture.

Hashim, M.A. 2005. *Modernizing irrigation in the Qatari farms*.

Hashim, M.A. and A. Abdul Malik. 2005. Water-related ecological hazards and their mitigation in Qatar. In: *Proceedings. WSTA Seventh Gulf Water Conference*. 19–23 November, 2005, Kuwait. Vol. II, pp 917-932.

Public Works Authority, Drainage Affairs. 2005. *Treated sewage effluent*.

The Planning Council, the General Secretariat. 2005. *Annual statistical abstract*. Doha, Qatar.

The Planning Council, the General Secretariat. 2006. *Sustainable development in State of Qatar*. Doha, Qatar.

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

Water and Electricity Company. 2007. *Desalination of water*.

Saudi Arabia

GEOGRAPHY, CLIMATE AND POPULATION

Geography

The Kingdom of Saudi Arabia, with a total area of about 2.15 million km², is by far the largest country on the Arabian Peninsula. It is bordered in the north by Jordan, Iraq and Kuwait, in the east by the Persian Gulf with a coastline of 480 km, in the southeast and south by Qatar, the United Arab Emirates, Oman and Yemen, and in the west by the Red Sea with a coastline of 1 750 km.

It can be divided into four main physiographic units:

- the Western Mountains, called the Arabian Shield, with the highest peak at 2 000 metres above sea level and crossed by deep valleys;
- the Central Hills, which run close to the western mountains and lie in the centre of the country. Their elevation ranges from 900 to 1 800 metres above sea level;
- the Desert Regions, which lie to the east of the Central Hills, with elevations ranging from 200 to 900 metres. Sand dunes are commonly found in these deserts;
- the Coastal Regions, which include the coastal strip along the Red Sea with a width of 16 to 65 km. The important part is the Tahama Plain in the south. The plain on the eastern side overlooks the Persian Gulf, is generally wide and includes the region of oases

The cultivable area has been estimated at 52.7 million ha, which is almost 25 percent of the total area. In 2005, the cultivated area was 1 213 586 ha, of which 1 011 923 ha consisted of annual crops and 201 663 ha of permanent crops (Table 1). The cultivated area in 2005 was 23 percent less than it was in 1992. The area under annual crops decreased by 33 percent, while the area covered by permanent crops increased by 111 percent.

Climate

Saudi Arabia lies in the tropical and subtropical desert region. The winds reaching the country are generally dry, and almost all the area is arid. Because of the aridity, and hence the relatively cloudless skies, there are great extremes of temperature, but there are also wide variations between the seasons and regions. In the central region, the summer (May to October) is overwhelmingly hot and dry, with maximum temperatures of over 50 °C, while the winter is dry and cool with night temperatures close to freezing. There can be severe frost generally and even weeks of snow in the mountains. The western and eastern regions are hot and humid in the summer months, with maximum temperatures around 42 °C, while the winters are warm. Prevailing winds are from the north and when they blow coastal areas become bearable in the summer and even pleasant in winter. The northwardly wind produces sand and dust storms that can decrease visibility to a few metres in some areas.

SAUDI ARABIA **FAO - AQUASTAT, 2008**

Disclaimer

The designations employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of the Food and Agriculture Organization of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2005	214 969 000	ha
Cultivated area (arable land and area under permanent crops)	2005	1 213 586	ha
• as % of the total area of the country	2005	0.6	%
• arable land (annual crops + temp. fallow + temp. meadows)	2005	1 011 923	ha
• area under permanent crops	2005	201 663	ha
Population			
Total population	2005	24 573 000	inhabitants
• of which rural	2005	11.5	%
Population density	2005	11.4	inhabitants/km^2
Economically active population	2005	8 694 000	inhabitants
• as % of total population	2005	35.4	%
• female	2005	21	%
• male	2005	79	%
Population economically active in agriculture	2005	600 000	inhabitants
• as % of total economically active population	2005	6.9	%
• female	2005	9	%
• male	2005	91	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2007	381 680	million US$/yr
• value added in agriculture (% of GDP)	2007	3	%
• GDP per capita	2005	12 843	US$/yr
Human Development Index (highest = 1)	2005	0.812	
Access to improved drinking water sources			
Total population	1990	89	%
Urban population	2006	97	%
Rural population	1990	63	%

In the north, annual rainfall varies between 100 and 200 mm. Further in the south, except near the coast, annual rainfall drops below 100 mm. The higher parts of the west and south do, however, experience appreciable rainfalls and over some small areas 500 mm/year is not uncommon. Long-term average annual precipitation has been estimated at 245.5 km^3/year, which is equal to 114 mm/year over the whole country.

Population

The total population is 24.6 million (2005) of which 11.5 percent is rural (Table 1). In 2005, about 76 percent were estimated to be Saudi nationals. During the period 2000-2005, the annual demographic growth rate in Saudi Arabia was 2.7 percent.

In 2006, 97 percent of the urban population had access to improved water sources. In 2006, the whole urban population had access to improved sanitation.

ECONOMY, AGRICULTURE AND FOOD SECURITY

In 2007, the national Gross Domestic Product (GDP) was US$381.7 billion (Table 1). The share of GDP accounted for by agriculture rose during the 1980s, mainly as a result of the decline in revenue from the petroleum sector and government efforts to pursue a policy of greater self-sufficiency in agriculture. It was 8.8 percent in 1993. Since the late 1990s it has fallen again, mainly as a result of the decline in subsidies from the government to national farmers in an effort to reduce water consumption in agriculture. In 2007, agriculture accounted for only 3 percent of GDP. The total economically active population was 8.7 million or over 35 percent of the total population (2005). The population economically active in agriculture was estimated at 600 000 in 2005, of which only 9 percent was female.

Even though environmental conditions are not ideal, Saudi Arabia has always attached great importance to the agricultural sector and has given it priority in its various development plans. The sector is expected to achieve the goals of economic development among which food security, diversification of the production base and minimization of the reliance on petroleum as a main source for the national income. Various government policies and programmes have been devised and implemented in the past so as to permit the achievement of such goals.

These policies and programmes included a great deal of support and encouragement for the private sector to invest in the agricultural sector, such as subsidies, interest-free loans, and free distribution of uncultivated land, in addition to the development of infrastructure (roads, dams, irrigation and drainage canals), extension services, protection, quarantine, research services and training of agricultural workers, farmers and their sons. All this led to the achievement of self-sufficiency for some important food crops such as wheat, dates, table eggs, fresh milk and some vegetable products, besides increasing the levels of self-sufficiency for other vegetables, fruits, poultry meat and lean meat (FAO, 2007).

WATER RESOURCES AND USE

Water resources

Heavy rainfall sometimes results in flash floods of short duration. River beds are dry for the rest of the time. Part of the surface runoff percolates through the sedimentary layers in the valleys and recharges the groundwater, while some is lost through evaporation. The largest quantity of runoff occurs in the western region, which represents 60 percent of the total runoff although it covers only 10 percent of the total area of the country. The remaining 40 percent of the total runoff occurs in the far south of the western coast (Tahama), which only covers 2 percent of the total area of the country. Total renewable surface water resources have been estimated at 2.2 km^3/year, most of which infiltrates to recharge the aquifers. Total renewable groundwater resources have been estimated at 2.2 km^3/year and the overlap at 2 km^3/year, which brings the total Internal Renewable Water resources (IRWR) to 2.4 km^3/year. Total groundwater reserves (including fossil groundwater) have been estimated at about 500 km^3 of which 340 km^3 are probably abstractable at an acceptable cost in view of the economic conditions of the country.

Groundwater is stored in six major consolidated sedimentary old-age aquifers located in the eastern and central parts of the country. This fossil groundwater, formed some 20 000 years ago, is confined in sand and limestone formations of a thickness of about 300 m at a depth of 150 – 1 500 m. Fossil aquifers contain large quantities of water trapped in fissures. For example, the Saq aquifer in the eastern part of the country extends over 1 200 km northwards. Nevertheless all of these aquifers are poorly recharged (water entered these aquifers thousands of years ago), yet continuously ‘mined’. The natural recharge of these aquifers is only about 3.5 million m^3/day, or 1.28 km^3/year. These resources are precious as they are not the product of an ongoing hydrological cycle. According to the Water Atlas of Saudi Arabia, these resources are estimated at 253.2 km^3 as proven reserves, while the probable and possible reserves of these aquifers are 405 and 705 km^3 respectively. In a similar study the Ministry of Planning (MOP) showed that the reserves amount to 338 km^3 with secondary reserves reaching 500 km^3 (probable). Estimates made by the Scientific Research Institute’s Water Resources Division at Dahran city of 36 000 km^3 are more than seventy times higher than the above estimates. However, they estimated 870 km^3 as being economically abstractable which is somewhat closer to the above figures. Furthermore, they stressed that with technological advances more amounts could be utilized. An engineering firm, the Saudi Arabia Engineering Consult, gave an estimate of about 2 175 km^3. These studies may indicate that the estimates of the ministries are very conservative (Al-Mogrin, 2001). In total, an estimated 394 million m^3/year flow from aquifers from Saudi Arabia to Jordan (180), Bahrain (112), Iraq (80), Kuwait (20), and Qatar (2).

In 2004, there were approximately 223 dams of various sizes for flood control, groundwater recharge and irrigation, with a collective storage capacity of 835.6 million m^3. A major dam, the King Fahd dam in Bisha in the southwest with a capacity of 325 million m^3, was built in 1997 and there are plans to build another 17 dams.

Saudi Arabia is the largest producer of desalinated water from the sea. In 2004 there were 30 desalination and power plants. There were 24 plants on the west coast and six on the east coast. In 2006, 1.03 km^3 of desalinated water were produced (Table 2). The water produced is used for municipal purposes. The quantities produced cover some 48 percent of municipal uses. In fact, the desalinated water produced is sometimes exported to distant cities. For instance, in 2004 some 528 million m^3 were produced on the western coast of which over 50 percent was exported to the city of Jiddah, while 536 million m^3 were produced on the eastern coast, of which over 65 percent was exported to the city of Riyadh, which is located in the centre of the country at about 400 km from the sea on both sides. The total length of pipelines used for the transmission of desalinated water is about 4 156 km. The capacity of desalinated water reservoirs amounted to 9.38 million m^3.

In 2002 total treated wastewater reached almost 548 million m^3, of which 123 million m^3 were reused. In 2003 70 sewage treatment plants were in operation. The use of treated wastewater is still limited at present (166 million m^3 in 2006), but it represents a potentially important source of water for irrigation and other uses.

Water use

It is estimated that in 2006 total water withdrawal was at 23.7 km^3, an increase of 40 percent compared to 1992, shared between the various sectors as follows: agriculture 88 percent, municipal 9 percent, and industry 3 percent (Table 2 and Figure 1). The boom in desert agriculture tripled the volume of water used for irrigation from about 6.8 km^3 in 1980 to about 21 km^3 in 2006. The total surface water and groundwater withdrawal represented 936 percent of the total renewable water resources. Groundwater resources of Saudi Arabia are being depleted at a very fast rate (Table 2). Most water withdrawn comes from fossil, deep aquifers and some predictions suggest that these resources may not last more than about 25 years. The quality of the abstracted water is also likely

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	114	mm/yr
	-	245.1	10^9 m^3/yr
Internal renewable water resources (long-term average)	-	2.4	10^9 m^3/yr
Total actual renewable water resources	-	2.4	10^9 m^3/yr
Dependency ratio	-	0	%
Total actual renewable water resources per inhabitant	2005	98	m^3/yr
Total dam capacity	2004	835.6	10^6 m^3
Water withdrawal			
Total water withdrawal	2006	23 666	10^6 m^3/yr
- irrigation + livestock	2006	20 826	10^6 m^3/yr
- municipalities	2006	2 130	10^6 m^3/yr
- industry	2006	710	10^6 m^3/yr
• per inhabitant	2006	963	m^3/yr
Surface water and groundwater withdrawal	2006	22 467	10^6 m^3/yr
• as % of total actual renewable water resources	2006	936	%
Non-conventional sources of water			
Produced wastewater	2000	730	10^6 m^3/yr
Treated wastewater	2002	547.5	10^6 m^3/yr
Reused treated wastewater	2006	166	10^6 m^3/yr
Desalinated water produced	2006	1 033	10^6 m^3/yr
Reused agricultural drainage water		-	10^6 m^3/yr

TABLE 3
Irrigation and drainage

Irrigation potential			-	**ha**
Irrigation				
1. Full or partial control irrigation: equipped area		2000	1 730 767	ha
- surface irrigation		1992	547 000	ha
- sprinkler irrigation		1992	1 029 000	ha
- localized irrigation		1992	32 000	ha
• % of area irrigated from surface water		2000	0	%
• % of area irrigated from groundwater		2000	97	%
• % of area irrigated from mixed surface water and groundwater		2000	0	%
• % of area irrigated from non-conventional sources of water		2000	3	%
• area equipped for full or partial control irrigation actually irrigated		1999	1 191 351	ha
- as % of full/partial control area equipped		2000	69	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)		2000	0	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)		**2000**	**1 730 767**	**ha**
• as % of cultivated area			-	%
• % of total area equipped for irrigation actually irrigated		2000	69	%
• average increase per year over the last 8 years		1992–2000	0.9	%
• power irrigated area as % of total area equipped		2000	97	%
4. Non-equipped cultivated wetlands and inland valley bottoms		2000	0	ha
5. Non-equipped flood recession cropping area		2000	0	ha
Total water-managed area (1+2+3+4+5)		**2000**	**1 730 767**	**ha**
• as % of cultivated area			-	%
Full or partial control irrigation schemes	**Criteria**			
Small-scale schemes	< 5 ha	1992	450 000	ha
Medium-scale schemes		1992	730 000	ha
large-scale schemes	> 200 ha	1992	428 000	ha
Total number of households in irrigation		1992	188 370	
Irrigated crops in full or partial control irrigation schemes				
Total irrigated grain production (wheat and barley)		2006	2 538 000	metric tons
• as % of total grain production		2006	100	%
Harvested crops:				
Total harvested irrigated cropped area		2006	1 213 587	ha
• Annual crops: total		2006	1 011 924	ha
- Wheat		2006	490 272	ha
- Sorghum		2006	143 745	ha
- Barley		2006	22 091	ha
- Maize		2006	12 123	ha
- Millet		2006	6 119	ha
- Other cereals		2006	229	ha
- Vegetables		2006	113 122	ha
- Potatoes		2006	14 709	ha
- Sesame		2006	2 216	ha
- Fodder		2006	207 298	ha
• Permanent crops: total		2006	201 663	ha
- Citrus		2006	10 848	ha
- Fruit		2006	190 815	ha
Irrigated cropping intensity (on full/partial control area actually irrigated)		1999	101	%
Drainage - Environment				
Total drained area		2007	10 850	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

to deteriorate with time because of the flow of low quality water in the same aquifers towards the core of the depression at the point of use. In 2003 there were 5 661 government wells assigned for municipal purposes and 106 370 multipurpose private wells. Treated wastewater is used to irrigate non-edible crops, for landscape irrigation and for industrial cooling, while desalinated water is used for municipal purposes (Figure 2).

FIGURE 1
Water withdrawal by sector
Total 23 666 km³ in 2006

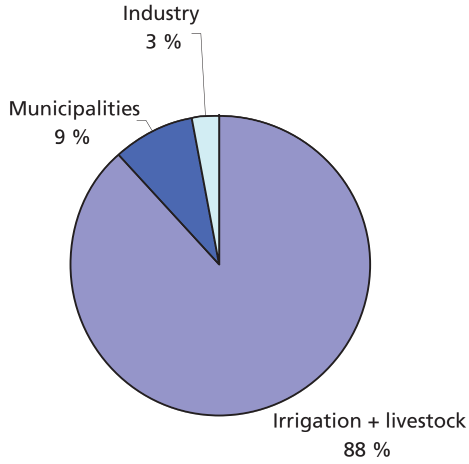
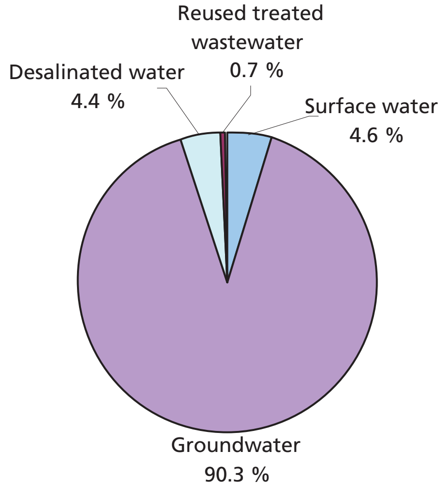


FIGURE 2
Water withdrawal by source
Total 23 666 km³ in 2006



IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

In 2000, 1 730 767 ha were equipped for irrigation, meaning an average increase of 0.9 percent per year since 1992. Only around 70 percent were actually irrigated (Table 3 and Table 4). The source of water is almost exclusively fossil groundwater (more than 95 percent) (Figure 3).

Localized and sprinkler irrigation, called modern irrigation, covers about 66 percent, while the remaining 34 percent is under surface irrigation, called traditional irrigation (Figure 4). The largest irrigated areas are located in the regions of Riyadh, Quassim, Jazan, Hail, Eastern, and Al Jouf.

There are three types of schemes that differ in terms of size, level of modernization and ownership (Figure 5):

- Very large private societies, such as National Agricultural Development Societies and Companies, are owned by private firms belonging to one or several owners. Some of these farms have an area of tens of square kilometers.
- Large to medium size farms of a few hundred hectares owned by private individuals.
- Medium to small farms, most of which existed prior to the agricultural development boom that started in the mid-1970s.

The first two categories of farms are located in regions with important and good quality groundwater aquifers and are specialized in terms of production, depending on the region and its vocational production potential. The most important crops are fodder for dairy production, date palms, vegetables, cereals, citrus fruits, olives and tropical fruits. They originate from the land distribution by the government in the late 1970s and early 1980s as part of the policy to develop agriculture.

TABLE 4
Total actually irrigated area by irrigation method and region (Agricultural census, 1999)

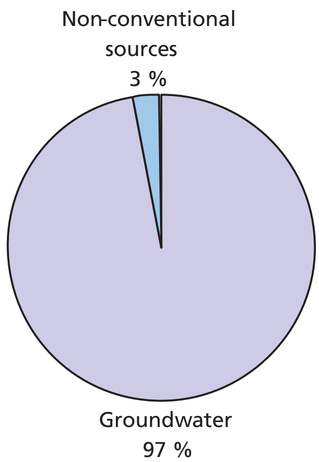
	Traditional irrigation		Modern irrigation		Total	
Region	Area (ha)	%	Area (ha)	%	Area (ha)	%
Riyad	43 010	15	243 275	85	286 286	24
Makkah	43 924	98	1 032	2	44 957	4
Madinah	26 618	93	2 020	7	28 638	2
Quassim	15 541	7	208 712	93	224 253	19
Eastern	16 081	15	92 987	85	109 067	9
Asir	22 232	99	296	1	22 527	2
Tabuk	5 113	11	42 057	89	47 169	4
Hail	12 368	10	116 139	90	128 507	11
Northern	19	14	114	86	133	0
Jazan	177 375	99	1 995	1	179 370	15
Najran	8 811	69	4 008	31	12 819	1
Baha	2 658	98	55	2	2 713	0
Jouf	11 688	11	93 224	89	104 912	9
Total (*)	**385 438**	**32**	**805 913**	**68**	**1 191 351**	**100**

(*) The area for grains, vegetables, and forage grown under permanent crops is not included.
Modern irrigation generally refers to trickle irrigation for trees and sprinkler irrigation for grains and forage.

Both categories are equipped with pressurized or modern irrigation technologies and are run as 'capitalist' enterprises by foreign managers and technicians, with the exception of a few cases where surface irrigation methods still prevail. The existence of modern irrigation techniques is not however necessarily an indication of high water use efficiency. No data are available on the amounts of water used by these farms, but as a general rule there is overuse in most, if not all, farms.

The existence of such large estates may not be compatible with the available water resources. Non-sustainability of the water resources used jeopardizes the sustainability of the farms themselves and puts at stake the profitability of the investments made. In many regions of the country several of these farms have already abandoned business as a result of groundwater depletion or non-profitability of the investments made. Based on the information and data available, all farms have been installed with no prior sound assessment of water resources to determine the extent of safe use or even the rate and duration of use in the case of limited fossil water.

FIGURE 3
Source of irrigation water
Total 1 730 767 ha in 2000

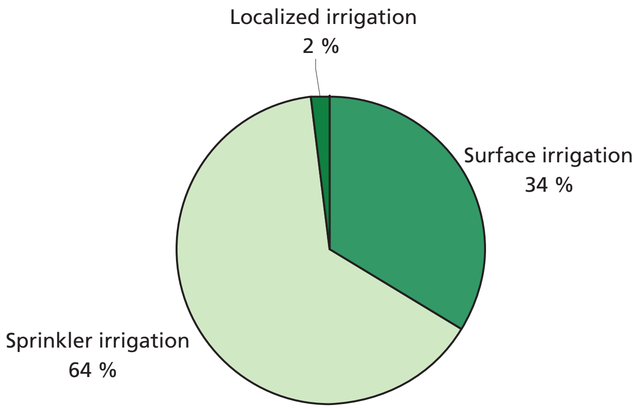


As far as the third category is concerned, some of these farms went out of business either because of their non-viable sizes or the incapacity of their owners to drill wells or both. They are less specialized in production compared with the first two and less modernized. Their irrigation systems and practices are essentially traditional, with low efficiency surface irrigation methods (FAO, 2007).

Role of irrigation in agricultural production, economy and society

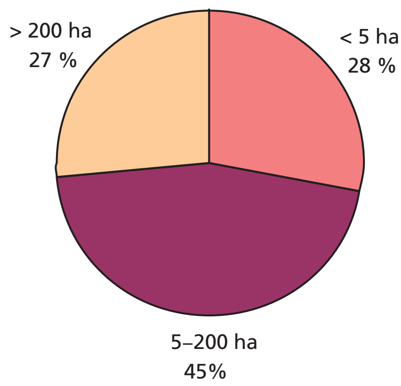
Of the area equipped for irrigation, estimated at 1 730 767 ha in 2000, on average 1 213 586 ha were actually irrigated during the period 2001–2005. In 2006 the harvested irrigated crop area covered around 1 214 000 ha, of which 56 percent consisted of cereals (mainly wheat, following sorghum and barley), 17 percent of fodder, 17 percent of permanent crops (mainly date palms) and 9 percent of vegetables (Table 3 and Figure 6). In 1999 permanent crops were predominantly irrigated by surface irrigation, while annual crops were mainly benefiting from pressurized irrigation methods (Table 5).

FIGURE 4
Irrigation techniques
Total 1 608 000 ha in 1992



Irrigation development in Saudi Arabia was the result of government policies to boost agricultural production in the 1970s. Well digging permits were granted to farmers and private companies in the regions where explorations by the public sector had revealed the existence of groundwater. The permits allowed farmers to drill wells with interest-free loans and with a subsidy of 50 percent of the cost of pumping stations. In addition, farmers could get interest free-loans for equipping their farms with modern irrigation systems, such as centre pivots, as well as for other purposes. At present about two thirds of the irrigated area is equipped with modern irrigation systems.

FIGURE 5
Type of irrigation schemes
Total 1 608 000 ha in 1992



To promote the generalization of modern irrigation techniques, the Ministry of Agriculture (MOA) is currently providing subsidized tree seedlings, but only to those farms already equipped with these systems. In fact, subsidized seedlings have been provided for around twenty years in order to promote the production of fruit crops, such as citrus trees in Najran, tropical species in Jizan, palm trees in several regions and other types elsewhere (olive trees, etc.) This is actually encouraging farmers to switch from wheat to fruit trees as a result of the government policy to reduce the area cropped by wheat by reducing the quantity of wheat purchased from farmers. However, depending on the area involved in the shift from wheat to fruit trees, it may well be that reducing the wheat area will actually result in putting more pressure on water resources once the trees become adult. Being perennial crops, fruit trees require more water than the annual cereals on an equal area basis.

Reducing the quantity of wheat purchased by the government from farmers has resulted in a gradual decrease in annual production over more than five years from over 4 million tonnes at the beginning of the 1990s to about 2 million tonnes. Other measures taken by the government with the objective of 'reducing pressure on water' include: banning wheat and forage exports and not purchasing barley from farmers (FAO, 2007). In general, the production of cereals is about 60 percent of what it was at the beginning of the 1990s.

TABLE 5

Total harvested irrigated area by crop type and irrigation method (Agricultural census, 1999)

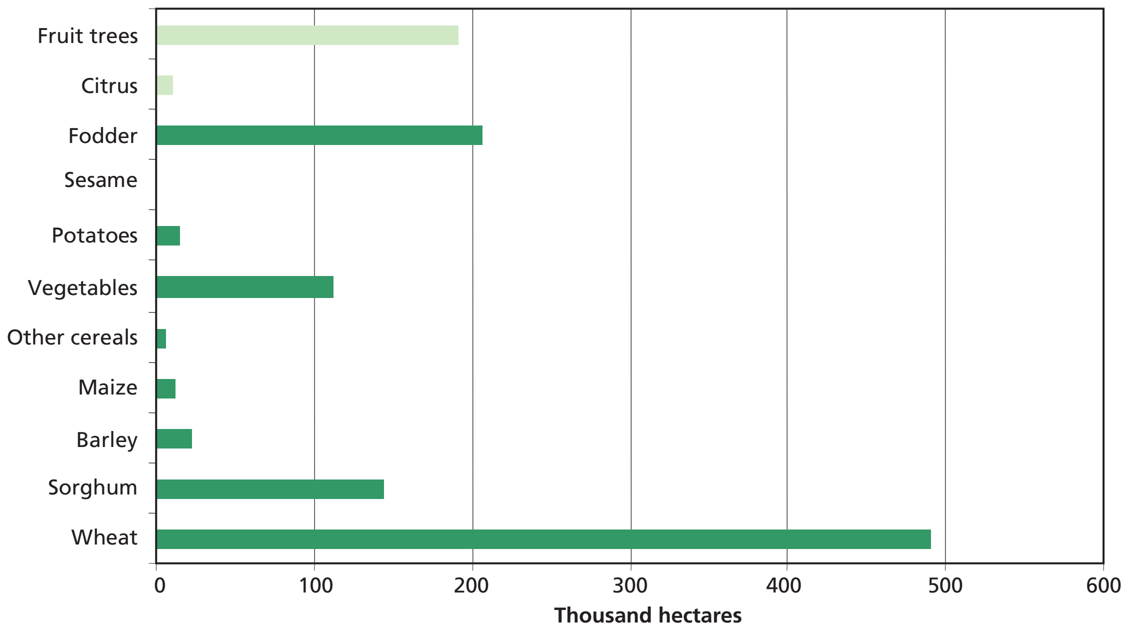
	Traditional irrigation		Modern irrigation		Total	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Permanent crops	136 177	74	47 368	26	183 545	15
- Date Palm	117 473	83	24 098	17	141 571	12
- Citrus	3 320	41	4 708	59	8 028	1
- Grapes	3 463	46	4 088	54	7 551	1
- Olives	4 047	39	6 434	61	10 481	1
Temporary crops	273 053	27	748 361	73	1 021 413	85
- Cereals	182 342	26	510 544	74	692 886	58
- Vegetables	34 658	38	55 703	62	90 361	7
- Fodder	56 053	24	182 114	76	238 166	20
Total (*)	**409 229**	**34**	**795 728**	**66**	**1 204 958**	**100**

(*)The area for grains, vegetables, and forage grown under permanent crops is not included
Modern irrigation generally refers to trickle irrigation for trees and sprinkler irrigation for grains and forage.
The area for modern vegetables includes 3 214 ha of cultivation in greenhouses.

FIGURE 6

Irrigated crops

Total harvested area 1 213 587 ha in 2006 (In 1999, cropping intensity on equipped area actually irrigated: 101%)



Status and evolution of drainage systems

Drainage problems occur in several parts of the country because of the existence of shallow, impermeable layers. About 10 850 ha, equivalent to 0.6 percent of the equipped area for irrigation, have drainage facilities under governmental management (Table 3). The drainage systems mainly consist of open drainage canals. In several projects, such as the Al-Hassa irrigation project in the east, agricultural drainage water is reused for irrigation after being mixed with fresh groundwater.

Soil salinity is being noticed in parts of the newly developed areas because of poor irrigation water quality and the poor drainage conditions of some soils.

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

Institutions

In 2001 a Ministry of Water was created to contain part of the Ministry of Municipal and Rural Affairs (MOMRA) and part of the former Ministry of Agriculture and Water (MOAW). This new ministry was responsible for supervising the water sector, developing water related policies and setting up mechanisms and instruments aimed at managing the water resources and water services delivery in an efficient and sustainable way. In 2004 the Ministry of Water also became responsible for the electricity sector and was restructured as the Ministry of Water and Electricity (MOWE) in order to ensure optimum coordination between the development of water desalination and electricity production.

The Water Sector within the MOWE has two main programmes:

- ➢Water resources development, which includes all activities related to geological and hydrological studies, wastewater reuse investigations, well drilling and dam construction, and the preparation of the national water plan
- ➢Drinking water supply, which includes the construction of drinking water supply networks to various towns and cities that do not have local water authorities or municipalities

The Ministry of Agriculture (MOA) is responsible for the scheme's operation and maintenance programme, while on-farm water management is the farmers' responsibility. The Ministry is responsible for issues affecting more than one farmer, such as for example irrigation networks, drainage, pest control and so on.

In January 2005 the MOA created the General Administration of Irrigation Affairs (GAIA), following the creation of the MOWE that inherited the MOA's water sector. The GAIA is responsible for organizing, planning, monitoring, developing, operating and maintaining irrigation and drainage projects and programs, together with the application of modern systems, the determination of crop water requirements, as well as ensuring that irrigation water will have no harmful effects on public health.

The National Irrigation Authority (NIA) started operating in 1982 in the Province of Riyadh to reuse the largest amount of treated wastewater in Saudi Arabia, amounting to 33 percent of the total annually treated effluent, mainly for irrigation. The NIA is responsible for the operation of the infrastructure and the monitoring of water reuse practices and the compliance of farmers with standards and guidelines. In 2004 it covered a total of 455 farms for a total area of 17 429 ha (about 12 000 ha irrigated). The average distributed volume of wastewater is about 50 million m^3 per year.

The Al-Hassa Irrigation and Drainage Authority (HIDA) is part of the MOA and is in charge of hydrological studies and data collection to improve the use of water for irrigation. It is also responsible for irrigation water conservation, estimation of crop water requirements, irrigation water distribution to the farms and the operation and maintenance of irrigation and drainage canal systems in the irrigation schemes managed by the MOA.

The Irrigation and Drainage project in Domat AI Jandal (IDD) started in 1989. It consists of a collective project covering a designated area of 1 600 ha, serving about 2 000 farms in Al-Jouf in the northern part of the country.

The Saline Water Conversion Corporation (SWCC) is responsible for the construction, operation and maintenance of desalination plants.

Water management

Due to the government's awareness of the scarcity of water, the MOA implemented several measures to encourage farmers to apply irrigation water saving techniques. Furthermore, some of the subsidies and support programmes that contributed to the depletion of groundwater resources in agriculture have been discontinued or revised. A collaborative programme has been initiated with the World Bank to provide technical assistance in reorganizing the water sector as a whole.

The MOA provides technical training courses and workshops regarding irrigation water management for its employees as well as others in different public and private sectors. Some courses are coordinated with international organizations, such as the FAO. Unfortunately the MOA lacks sound and effective extension services, has no strategy for capacity building, and has weak information management systems. Furthermore, no water user associations exist in the country.

An academic association was recently created, the Saudi Water Science Society hosted by the King Fahd University of Petroleum and Minerals. Its main purpose is to provide a union of experts, scientists, businessmen, and so on, all of whom have an interest in water concerns and issues in the country.

Policies and legislation

Since the creation of the MOWE, various water laws are under revision and reformulation to assure institutional compatibility with the new institutional structure. At the same time the MOA is reviewing agricultural policy. Currently there still are grey areas with overlapping responsibilities regarding irrigation and the control and implementation of water reuse for irrigation.

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

Irrigated agriculture has reached a stage where it needs a reform that focuses on productivity and sustainability of the investment made by the public sector and private farmers, as well as the rational use of its limited water resources. Irrigated agriculture is leading to the depletion of several aquifers and is putting the sustainability of the investments made at risk. Water productivity is still relatively low despite the introduction of modern irrigation techniques. The Ministry of Agriculture is developing a new agriculture strategy geared towards a greater macro-economic development of the sector, while sustaining the basic resources and increasing their productivity.

A “Future Plan for Agriculture” (draft version of November 2004) was developed in studies carried out by the PARCI (King Saud University). With regard to land and water resources, the plan calls for (FAO, 2007):

- Reducing water demand through a policy of diversification of agricultural production, taking into account the comparative advantages of each region in the country;
- Stopping expansion of high water consuming crops such as dates and forage;
- Concentrating on high added value crops;
- Stopping the distribution of agricultural land except in regions with sufficient renewable water resources;
- Improving irrigation water management and using modern irrigation methods, and stopping any support for well digging or water extraction;
- Estimating crop water requirements;
- Encouraging farmers to make use of tools that help manage irrigation water better, such as soil probes for a better scheduling of irrigation water deliveries;
- Respecting standards set by the MOA for digging wells, in collaboration with well digging companies;
- Taking a decision to solve the situation of open hand-dug wells, either through the use of adequate piping systems or closing these wells and digging others;
- Controlling water consumption through the use of meters for measuring the amount of water flowing out of the wells;
- Water pricing for all water used above the crop water requirements, starting with agricultural companies and specialized farms;

- Intensifying agricultural extension so as to make farmers more aware of the need to conserve water resources and to encourage a new dynamic in the role of agricultural associations and cooperatives in this respect;
- Establishing as a condition for the issuance of permits for agricultural projects the use of water conserving irrigation techniques, as well as an assessment of the relative characteristics of the region and its water potential;
- Expanding the use of treated wastewater in the agriculture and industry sector;
- Orienting and supporting research aimed at producing crop varieties that are resistant to drought, salinity or acid soils.

The next step for the MOA is to create an irrigation strategy that includes all its actions and activities in order to achieve the goals developed in the agriculture plan by 2020.

MAIN SOURCES OF INFORMATION

Abdallah E. Dabbagh and Wali A. Abderrahman. 1996. Management of groundwater resources in Saudi Arabia under various irrigation water use scenarios. In: *Arabian Journal of Science and Engineering*.

Alamoud, A. and Aldakheel, Y. 2003. *The importance of renewable water in agricultural development in Saudi Arabia* (in Arabic). Presented at the Symposium on Water as a Strategic Challenge Facing Humanity. Ministry of Electricity and Water and Ministry of Higher Education, Riyadh.

Aldakheel, Y. 2005. *Water governance as part of IWRM in arid regions: a case study of Saudi Arabia*. Seminar on Water Governance: Role of Stakeholders. ESCWA, UN. 14–15 November 2005. Beirut, Lebanon.

Ali A. Al Jaloud. 1991. *Agriculture and fertilizer use in Saudi Arabia*. Research Institute of Natural Resources and Environment. Country paper for expert consultation on fertigation/chemigation, Cairo, Egypt, 8–11 September 1991.

Al-Mogrin, S. 2001. Treatment and reuse of wastewater in Saudi Arabia. In: *Proceedings, Expert Consultation for Launching the Regional Network on Wastewater in the Near East.*

Department of Economical Studies and Statistics. 2006. *Agricultural statistical yearbook*. Ministry of Agriculture.

FAO. 2007. *Improvement of irrigation water management in the Kingdom of Saudi Arabia*. UTFN/SAU/011/SAU.

General Statistics Authority. 2005. *General population census*. Ministry of Economics and Planning.

Library of Congress. 2006. *Country profile: Saudi Arabia, September 2006*. Federal Research Division.

Ministry of Agriculture and Water. 1984. *Water Atlas of Saudi Arabia*.

Ministry of Higher Education. 1999. *Atlas of Saudi Arabia*.

Ministry of Water and Electricity. 2004. *Water projects in Saudi Arabia*.

Saline Water Conversion Corporation. 2002 and 2003. *Annual reports.*

Walid A. Abderrahman. 1994. *Advanced and modern efficient irrigation technology in the Arab World*.

Syrian Arab Republic

GEOGRAPHY, CLIMATE AND POPULATION

Geography

The Syrian Arab Republic, with a total area of 185 180 km², is bordered in the north by Turkey, in the east and southeast by Iraq, in the south by Jordan, in the southwest by Israel and in the west by Lebanon and the Mediterranean Sea. Administratively the country is divided into 14 mohafazats (governorates), one of which is the capital Damascus.

- The country can be divided into four physiographic regions:
- the coastal region between the mountains and the sea;
- the mountains and the highlands extending from north to south parallel to the Mediterranean coast;
- the plains or interior, located east of the highlands and including the plains of Damascus, Homs, Hama, Aleppo, Hassakeh and Dara;
- the Badiah and the desert plains in the southeastern part of the country, bordering Jordan and Iraq.

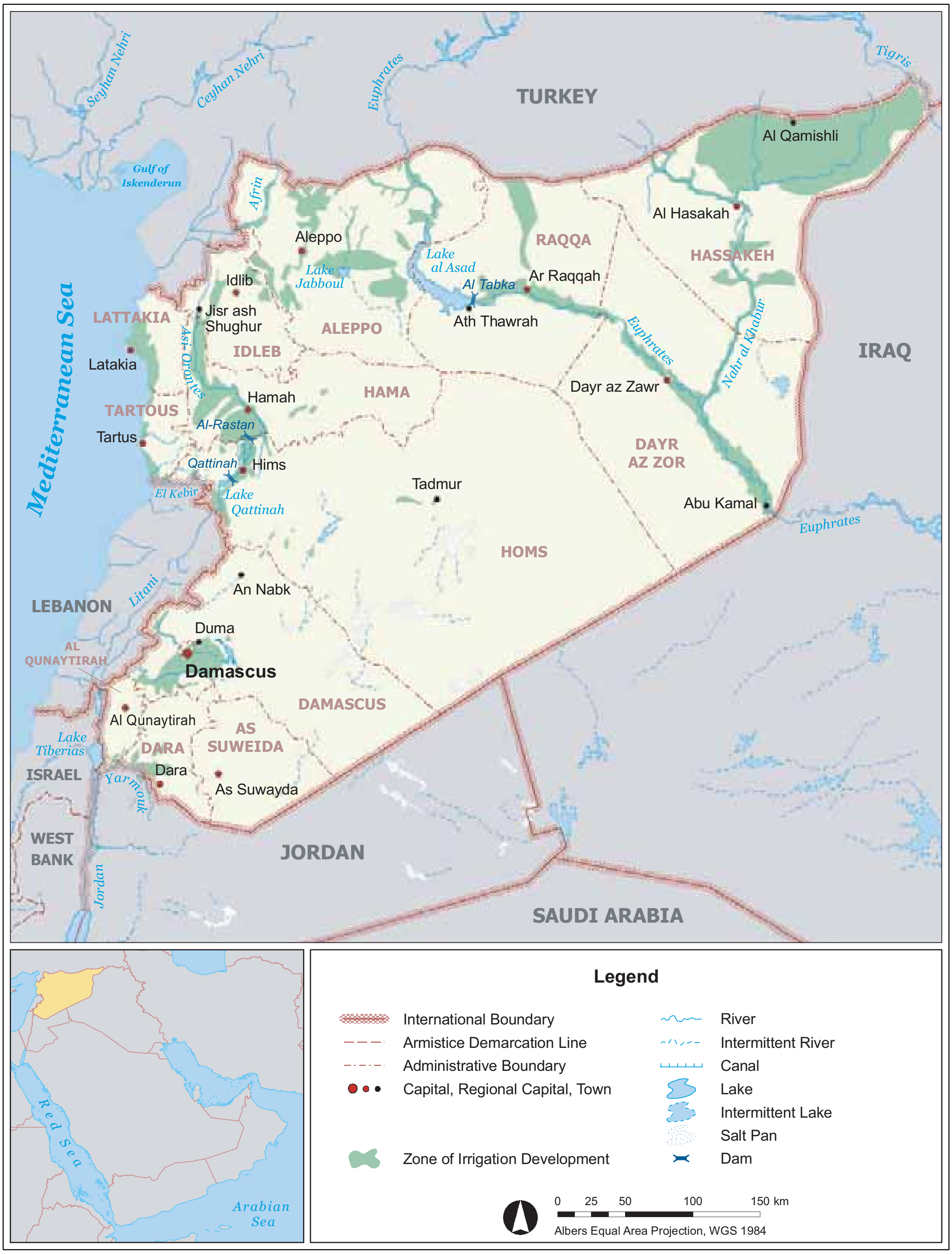
In 2005, total cultivable land was estimated at 5.91 million ha, or 32 percent of the total area of the country and the cultivated land was 5.74 million ha (Table 1). Of the 5.53 million ha of cultivated land in 2004, temporarily fallow land represented 0.80 million ha and the effective cultivated land 4.73 million ha, of which over 30 percent was irrigated. Hassakeh, Aleppo and Raqqa are the main agricultural mohafazats accounting for 28, 21 and 12 percent respectively of the effective cultivated land in the country. The private sector owns 54 percent of the effective cultivated area, cooperatives 45 percent and the public sector less than 0.5 percent (CBS, 2006).

Climate

The Syrian Arab Republic's climate is Mediterranean with a continental influence: cool rainy winters and warm dry summers, with relatively short spring and autumn seasons. Large parts of the Syrian Arab Republic are exposed to high variability in daily temperature. The maximum difference in daily temperature can be as high as 32 °C in the interior and about 13 °C in the coastal region. Total annual precipitation ranges from 100 to 150 mm in the northwest, 150 to 200 mm from the south towards the central and east-central areas, 300 to 600 mm in the plains and along the foothills in the west, and 800 to 1 000 mm along the coast, increasing to 1 400 mm in the mountains. The average annual rainfall in the country is 252 mm.

Population

Total population is just over 19 million (2005), of which almost 50 percent is rural (Table 1). The average annual demographic growth rate was estimated at 2.5 percent



SYRIAN ARAB REPUBLIC **FAO - AQUASTAT, 2008**

Disclaimer

The designations employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of the Food and Agriculture Organization of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2005	18 518 000	ha
Cultivated area (arable land and area under permanent crops)	2005	5 742 000	ha
• as % of the total area of the country	2005	31.0	%
• arable land (annual crops + temp. fallow + temp. meadows)	2005	4 873 000	ha
• area under permanent crops	2005	869 000	ha
Population			
Total population	2005	19 043 000	inhabitants
• of which rural	2005	49.7	%
Population density	2005	102.8	inhabitants/km^2
Economically active population	2005	6 548 000	inhabitants
• as % of total population	2005	34.4	%
• female	2005	28.7	%
• male	2005	71.3	%
Population economically active in agriculture	2005	1 690 000	inhabitants
• as % of total economically active population	2005	25.8	%
• female	2005	66.1	%
• male	2005	33.9	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2007	38 080	million US$/yr
• value added in agriculture (% of GDP)	2007	20	%
• GDP per capita	2005	1 480	US$/yr
Human Development Index (highest = 1)	2005	0.724	
Access to improved drinking water sources			
Total population	2006	89	%
Urban population	2006	95	%
Rural population	2006	83	%

during the period 2000–2005. The average population density is about 103 inhabitants/km^2.

In 2006, 92 percent of the population had access to improved sanitation (96 and 88 percent in urban and rural areas respectively) and 89 percent had access to improved water sources (95 and 83 percent in urban and rural areas respectively).

ECONOMY, AGRICULTURE AND FOOD SECURITY

In 2007 the Gross Domestic Product (GDP) was US$38.1 billion, and agriculture accounted for 20 percent of the GDP (Table 1). The economically active population is about 6.55 million of which 71 percent is male and 29 percent female. In agriculture, 1.69 million inhabitants are economically active of which 34 percent is male and 66 percent female.

The Syrian Arab Republic can be divided into five main agricultural regions, namely Southern, Central, Coastal, Northern and Eastern:

- The Southern region covers about 15.7 percent of the total area of the country. It includes Damascus, Dara, Suweida, and Al-Qunaytirah. It is famous for its fruit production, especially apricots, apples and grapes, but it also produces crops such as chickpeas and tomatoes, in addition to raising cattle. Between 1998 and 1999, the region's contribution to national production was 36 percent for chickpeas, 51 percent for apples, 31 percent for grapes, and 62 percent for apricots.
- The Central region accounts for about 27.6 percent of the total area and produces mainly sugar beets, dried onion, potato and almonds. Between 1998 and 1999, the region's contribution to the national production was 57 percent for sugar beets, 53 percent for dried onions, 31 percent for potatoes, and 14 percent for irrigated wheat.

- The Coastal region on the Mediterranean Sea includes the cities of Lattakia and Tartous. Although this region is relatively small (2.3 percent of the total area), it contributes significantly to national agricultural production, with 98 percent of citrus, 42 percent of olives, 55 percent of tomatoes and 56 percent of tobacco.
- The Northern region covers 12.6 percent of the country's total area and includes the cities of Aleppo and Idleb. Its main contributions to national agricultural production are lentils with 55 percent, chickpeas 51 percent, olives 56 percent, and pistachios 69 percent. Local farmers breed about 20 percent of the total sheep population of the Syrian Arab Republic.
- The Eastern region is the largest in the country, covering 41.8 percent of the total area, concentrating the national cereals and cotton production. In order to enhance productivity through irrigation many networks have been built in this region, especially on the Euphrates and Al Khabour rivers. In addition many wells have been constructed. Farms tend to specialize in irrigated wheat which contributes 64 percent to the national production, while rainfed wheat contributes 38 percent, cotton 63 percent, and lentils 29 percent.

Self-sufficiency has been achieved for some crops, such as wheat, legumes (chickpeas and lentils), cotton, vegetables (potatoes and tomatoes), and fruit (citrus and olive). There have even been cases of surplus production. However, domestic production of crops for sugar, vegetable oils (with the exception of olive oil), and of some kinds of red meat, and dairy products (cheese, butter and dried milk) is not sufficient to meet domestic demand. Moreover, maize imports for chicken feed have increased (NAPC, 2003).

WATER RESOURCES AND USE

Water resources

It is estimated that water resources generated from rain falling within the country amount to about 7.1 km^3/year (Table 2). Internal renewable surface water resources are estimated at 4.3 km^3/year and groundwater recharge at 4.8 km^3/year, of which 2 km^3/year discharge into rivers as spring water (overlap between surface water and groundwater).

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	252	mm/yr
	-	46.67	10^9 m^3/yr
Internal renewable water resources (long-term average)	-	7.132	10^9 m^3/yr
Total actual renewable water resources	-	16.797	10^9 m^3/yr
Dependency ratio	-	72.29	%
Total actual renewable water resources per inhabitant	2005	882	m^3/yr
Total dam capacity	2007	19 654	10^6 m^3
Water withdrawal:			
Total water withdrawal	2003	16 690	10^6 m^3/yr
- irrigation + livestock	2003	14 669	10^6 m^3/yr
- municipalities	2003	1 426	10^6 m^3/yr
- industry	2003	595	10^6 m^3/yr
• per inhabitant	2003	921	m^3/yr
Surface water and groundwater withdrawal	2003	13 894	10^6 m^3/yr
• as % of total actual renewable water resources	2003	82.7	%
Non-conventional sources of water:			
Produced wastewater	2002	1 364	10^6 m^3/yr
Treated wastewater	2002	550	10^6 m^3/yr
Reused treated wastewater	2002	550	10^6 m^3/yr
Desalinated water produced		-	10^6 m^3/yr
Reused agricultural drainage water	2004	2 246	10^6 m^3/yr

Seven main hydrographic basins can be identified: Al Jazeera, Aleppo (Quaick and Al Jabbool sub-basins), Al Badia (Palmyra, Khanaser, Al Zelf, Wadi el Miah, Al Rassafa, Al Talf and Assabe'biar sub-basins), Horan or Al Yarmook, Damascus, Asi-Orontes and Al Sahel. Rainfall and snowfall represent the major water supply for the basins, except for the Al Jazeera and Asi-Orontes, the main sources of which are located in the neighbouring countries. There are 16 main rivers and tributaries in the country, of which 6 are main international rivers:

- the Euphrates (Al Furat), which is the Syrian Arab Republic's the largest river. It comes from Turkey and flows to Iraq. Its total length is 2 330 km, 680 km of which are in the Syrian Arab Republic;
- the Afrin in the northwestern part of the country, which comes from Turkey, crosses the Syrian Arab Republic and flows back to Turkey;
- the Asi-Orontes in the western part of the country, coming from Lebanon and flowing into Turkey;
- the Yarmouk in the southwestern part of the country with sources in the Syrian Arab Republic and Jordan and which forms the border between these two countries before flowing into the Jordan river;
- the El-Kabir with sources in the Syrian Arab Republic and Lebanon and which forms the border between them before flowing to the sea;
- the Tigris, which forms the border between the Syrian Arab Republic and Turkey in the extreme northeastern part.

Total actual renewable water resources are estimated at 16.797 km^3/year. The natural average surface runoff to the Syrian Arab Republic from international rivers is estimated at 28.515 km^3/year. The actual external renewable surface water resources are 17.335 km^3/year, which includes 15.750 km^3 of water entering with the Euphrates, as unilaterally proposed by Turkey, 0.335 km^3 of water entering with the Asi-Orontes, as agreed with Lebanon, and 1.250 km^3/year from the Tigris. The Tigris has a total mean annual flow of 18 km^3, but since it only borders the country over a short distance in the east, very little can be available for the Syrian Arab Republic and a figure of 1.250 km^3/year is given (Abed Rabboh, 2007). Total actual groundwater inflow has been estimated at 1.33 km^3/year, of which 1.20 km^3 from Turkey and 0.13 km^3 from Lebanon (Dan springs). Groundwater outflow to Israel and Jordan is estimated at 0.25 and 0.09 km^3/year respectively.

The main groundwater aquifers are those of Anti-Lebanon and the Alouite Mountains. Folding and faulting of the geological layers has resulted in the mingling of the subaquifer systems. There are a number of springs discharging from this aquifer system, such as the Ari-Eyh, Barada, Anjar-Chamsine and Ras El-Ain. Recharge to the system occurs from intense precipitation in the mountainous regions which infiltrates through the fractures and fissures of the karstified surface layer. Water quality ranges from 175 to 900 ppm. Another significant aquifer system is that of the Damascus plain aquifers extending from the Anti-Lebanon Mountains in the west to the volcanic formations in the south and east of the country. This system is composed of gravel and conglomerates with some clay, and is represented by riverbeds and alluvial fan deposits with a thickness of up to 400 metres. Groundwater quality ranges from 500 to more than 5 000 ppm. The major carbonate Haramoun mountain aquifer is located between Lebanon and the Syrian Arab Republic. The main discharging springs are those of the Banias and Dan tributaries of the Jordan River basin. Groundwater quality is estimated at 250 ppm. Other aquifers with limited potential are located in the desert areas. These consist of marl and chalky limestone of the Paleogene age. Recharge occurs mainly from flood flow. Water quality ranges from 500 to 5 000 ppm depending on the source of recharge (ESCWA, 2001).

There are 166 dams in the Syrian Arab Republic with a total storage capacity of 19.7 km^3 (Table 3). The largest dam is the Al Tabka dam, located near Ar Raqqah on

TABLE 3
Main dams in Syria (MLAE, 2007)

Basin	Number of dams	Total storage capacity (million m^3)
Yarmouk	42	245
Barada and Awaj	-	-
Coastal	21	602
Orontes	49	1 492
Al Badia	37	69
Euphrates and Allepo	4	16 146
Tigris and Khabour	12	1 045
Total	**165**	**19 599**

FIGURE 1
Water withdrawal by sector
Total 16.69 km^3 in 2003

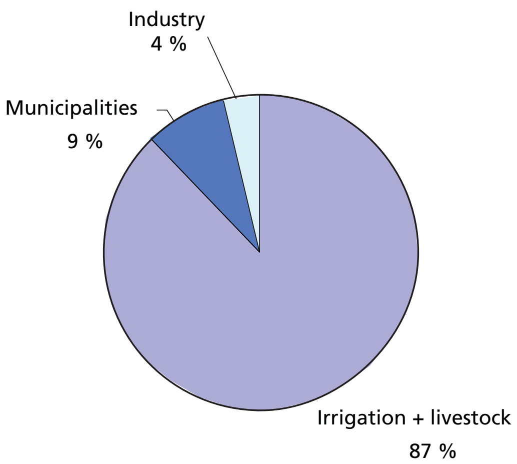
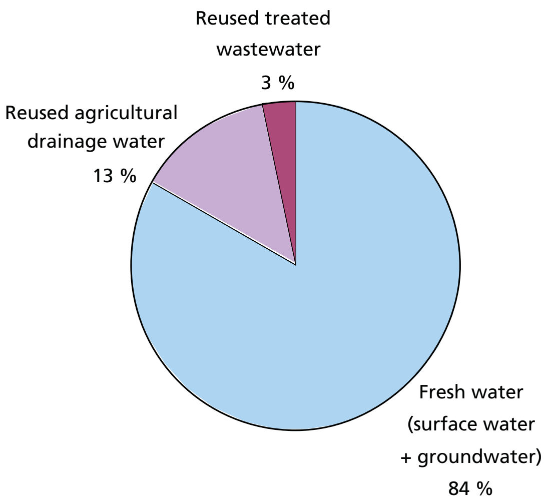


FIGURE 2
Water withdrawal by source
Total: 16.690 km^3 in 2003



the Euphrates and forming the Al Assad Lake with a storage capacity of 14.1 km^3 and a surface area of 674 km^2. Medium-size dams include the Al Rastan (228 million m^3), the Qattinah (200 million m^3), the Mouhardeh (67 million m^3) and the Taldo (15 million m^3). The majority of these dams are located near Hims and Hamah in the western part of the country.

In 2002, total wastewater produced in the Syrian Arab Republic was 1 364 million m^3. The treatment of municipal wastewater was carried out mainly in the towns of Damascus, Aleppo, Hims and Salamieh and it reached 550 million m^3 in 2002. All treated wastewater is reused. The reused treated wastewater was 330 million m^3 in 1993, meaning an increase of 49 percent since 1993. The production of desalinated water in the Syrian Arab Republic is marginal. The installed gross desalination capacity (design capacity) is 8 183 m^3/day, which is less than 3 million m^3/year (Wangnick Consulting, 2002).

Water use

Total annual water withdrawal in the Syrian Arab Republic was estimated at 16.69 km^3/year in 2003, 87.9 percent of which was for agricultural purposes (Table 2, Figure 1 and Figure 2). Compared to 1993, the total water withdrawal increased by almost 31 percent. Agricultural water withdrawal followed the same trend but municipal and industrial withdrawal increased by 39 and 89 percent respectively.

In 1999, the Euphrates and Asi-Orontes basins accounted for about 50 and 20 percent of the water withdrawal respectively (Salman, 2004).

International water issues

An agreement was signed in 1955 between the Syrian Arab Republic and Jordan regarding the allocation of the water of the Yarmouk River, and was further revised in 1987. A recent agreement between Lebanon and the Syrian Arab Republic on the Asi-Orontes River has led to a share of 80 million m^3/year for Lebanon and the remaining 335 million m^3 for the Syrian Arab Republic.

In 1973, the Syrian Arab Republic constructed the Tabqa Dam, which was filled in 1975. The filling of this dam and the Turkish Keban dam caused a sharp decrease in downstream flow and the quantity of water entering Iraq fell by 25 percent (El Fadel *et al*, 2002). As a consequence Iraq and the Syrian Arab Republic exchanged mutually hostile accusations and came dangerously close to a military confrontation (Akanda *et al*, 2007). Iraq threatened to bomb the dam. Both countries moved troops towards their common border. Saudi Arabia and possibly the Soviet Union mediated. Eventually the threat of war died down, after the Syrian Arab Republic released more water from the dam to Iraq. Although the terms of the agreement were never made public, Iraqi officials have privately stated that the Syrian Arab Republic agreed to take only 40 percent of the river's water, leaving the remainder for Iraq (Kaya, 1998).

In 1983, Turkey, Iraq and the Syrian Arab Republic established the Joint Technical Committee for Regional Waters, the aim of which was to deal with all water issues among the Euphrates-Tigris basin riparians and to ensure that the procedural principles of consultation and notification were followed as required by international law. However, this group disintegrated after 1993 without making any progress (Akanda *et al*, 2007).

In 1987, an informal agreement between Turkey and the Syrian Arab Republic guaranteed the latter a minimum flow of the Euphrates River of 500 m^3/sec throughout the year (15.75 km^3/year). The Syrian Arab Republic has since then accused Turkey of violating this agreement a number of times. According to an agreement between the Syrian Arab Republic and Iraq signed in 1990, the Syrian Arab Republic agrees to share the Euphrates water with Iraq on a 58 percent (Iraq) and 42 percent (the Syrian Arab Republic) basis, which corresponds to a flow of 9 km^3/year at the border with Iraq when using the figure of 15.75 km^3/year from Turkey (FAO, 2004).

The construction of the Ataturk Dam, one of the Southeastern Anatolia projects (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 timely informed that river flow would be interrupted for a period of one month, due to technical necessities" (Kaya, 1998). Turkey returned to previous flow sharing agreements after the dam became operational, but the conflicts were never fully resolved as downstream demands had increased in the meantime (Akanda *et al*, 2007).

As shown above, a number of crises have occurred in the Euphrates-Tigris basin because of a lack of communication, conflicting approaches, unilateral development, and inefficient water management practices. The Arab countries have long accused Turkey of violating international water laws with regard to the Euphrates and the Tigris rivers. Iraq and the Syrian Arab Republic consider these rivers as international, and thus claim a share of their waters. Turkey, in contrast, refuses to concede the international character of these two rivers and only speaks of the rational utilization of transboundary waters. According to Turkey, the Euphrates only becomes an international river after it joins the Tigris in lower Iraq to form the Shatt al-Arab, which then serves as the border between Iraq and the Islamic Republic of Iran until it reaches the Persian Gulf only 193 km further downstream. Furthermore, Turkey is the only country in the Euphrates basin to have voted against the United Nations Convention on the Law of Non-navigational Uses of International Watercourses. According to

TABLE 4
Irrigation and drainage

Irrigation potential		**-**	**ha**
Irrigation:			
1. Full or partial control irrigation: equipped area	2004	1 439 100	ha
- surface irrigation	2004	1 251 400	ha
- sprinkler irrigation	2004	130 200	ha
- localized irrigation	2004	57 500	ha
• % of area irrigated from surface water		-	%
• % of area irrigated from groundwater	2004	60.1	%
• % of area irrigated from mixed surface water and groundwater	2004	39.9	%
• % 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)	**2004**	**1 439 100**	**ha**
• as % of cultivated area	2004	26	%
• % of total area equipped for irrigation actually irrigated		-	%
• average increase per year over the last 11 years	1993-2004	3.2	%
• 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**	**1 439 100**	**ha**
• as % of cultivated area	2004	26	%
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	2000	1 334 265	ha
• Annual crops: total	2000	1 214 050	ha
- Wheat	2000	694 469	ha
- Sugar beet	2000	27 474	ha
- Pulses	2000	7 271	ha
- Vegetables	2000	87 508	ha
- Cotton	2000	270 290	ha
- Fodder	2000	100 974	ha
- Other annual crops	2000	26 064	ha
• Permanent crops: total	2000	120 215	ha
- Olive	2000	28 994	ha
- Citrus	2000	27 338	ha
- Other perennial crops	2000	63 883	ha
Irrigated cropping intensity (on full/partial control area actually irrigated)	2000	105	%
Drainage - Environment			
Total drained area	1993	273 000	ha
- part of the area equipped for irrigation drained	1993	273 000	ha
- other drained area (non-irrigated)	1993	0	ha
• Drained area as % of cultivated area		-	%
Flood-protected areas		-	ha
Area salinized by irrigation	1989	60 000	ha
Population affected by water-related diseases		-	inhabitants

Turkey, if signed, the law would give “a veto right” to the lower riparians over Turkey’s development plans. Consequently, Turkey maintains that the Convention does not apply to them and is thus not legally binding (Akanda *et al*, 2007).

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

In 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 average, shall be 1.25 km^3 with a drainage capacity proportional to the relative surface area 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 that will consist of 18 water experts from each country to work towards the solution of water-related problems among the three countries. This institute will conduct its studies at the facilities of the Ataturk Dam, the biggest dam in Turkey, and plans to develop projects for the fair and effective use of transboundary water resources. Several talks have been held between the Syrian Arab Republic and Turkey, during which the two countries have decided to jointly construct a dam on the Asi-Orontes River, which originates in the Syrian Arab Republic and flows to the Mediterranean Sea from Turkey's Hatay province (Yavuz, 2008).

The Golan Heights control the main water sources of the State of Israel. Israel's only lake and its main source of fresh water, supplying the country with a third of its water, is fed from the Golan Heights. The Golan Heights were conquered by Israel in 1967 and have been under Israeli law, jurisdiction, and administration since 1981, which however has not been recognized by the United Nations Security Council.

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

Estimates of irrigation potential, based solely on soil resources, lead to a figure of around 5.9 million ha, which is roughly equal to the cultivable area. Considering the water resources available, irrigation potential depends on how the Syrian Arab Republic reaches agreements with neighbouring countries on the sharing of river waters in the future.

In 2004, the total area equipped for irrigation was estimated at 1 439 100 ha (Table 4). Irrigated areas are not distributed evenly across the country and most are concentrated in the mohafazat of Hassakeh (33.1 percent), Raqqa (13.6 percent), Aleppo (13.1 percent), Hama (10.6 percent) and Dayr-az-Zor (10.1 percent) (CBS, 2006). Surface irrigation is the prevailing irrigation system in the Syrian Arab Republic covering 87 percent of the irrigated area. Basin irrigation is the predominant technique used in surface irrigation and most of the irrigated wheat and barley is irrigated by this method. Irrigation field efficiency is reported to be in general below 60 percent. Furthermore, the construction of ridges for the basins implies a loss of productive land which could be assessed at between 5 and 10 percent further reducing the productivity of the land. Cotton and vegetables are irrigated by furrows but because the land is rarely levelled the efficiency of

FIGURE 3
Source of irrigation water
Total: 1 439 100 ha in 2004

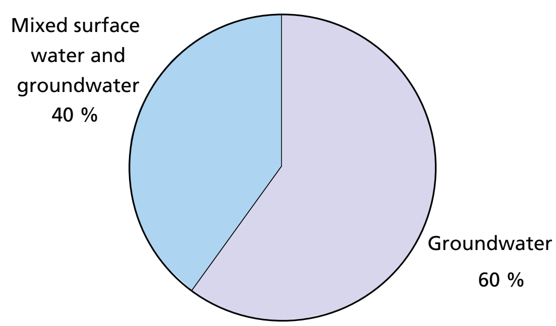
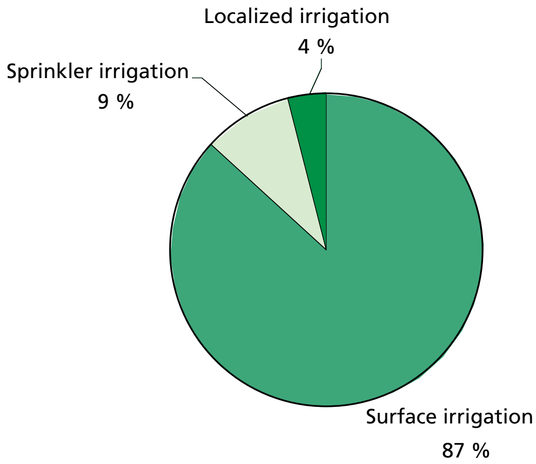


FIGURE 4
Irrigation techniques
Total: 1 439 100 ha in 2004



such a technique is also low (Varela-Ortega and Sagardoy, 2001).

In 2004, 864 700 ha (60.1 percent of the total irrigated area) were irrigated from groundwater (Figure 3), the remaining 574 400 ha by mixed surface water and groundwater, of which 340 200 ha were government projects. Recycled irrigation drainage water was estimated in 2004 at 2 246 million m^3 (Ministry of Local Administration and Environment, 2007).

In 2003, the agricultural sector withdrew 14 669 million m^3/year to irrigate 1 361 200 ha, which means an average of 10 777 m^3/ha.

The sprinkler irrigation area increased from 30 000 ha in 1993 to 130 200 ha in 2004. While localized irrigation was practiced on only 2 000 ha in 1993, the figure rose to 57 500 ha in 2004 (Figure 4). Lands irrigated by these so-called modern irrigation systems (sprinkler and localized irrigation) are mainly situated in the mohafazat of Hama (26.9 percent), Idleb (18.9 percent) and Aleppo (12.5 percent) (CBS, 2006).

The size of the irrigated holdings is substantially smaller than the size of the rainfed holdings and varies distinctively across regions. At national level, the average farm size for all types of holdings is 9.2 ha and the average irrigated farm size is 3.6 ha. The average size of irrigated holdings varies greatly according to the mohafazat, it is 10.5 ha in Hassakeh, 8.9 ha in Raqqa and 5.4 ha in Aleppo but only 0.8 ha and 0.9 ha in Aa-Suweida and Tartous respectively (Varela-Ortega and Sagardoy, 2001).

Role of irrigation in agricultural production, economy and society

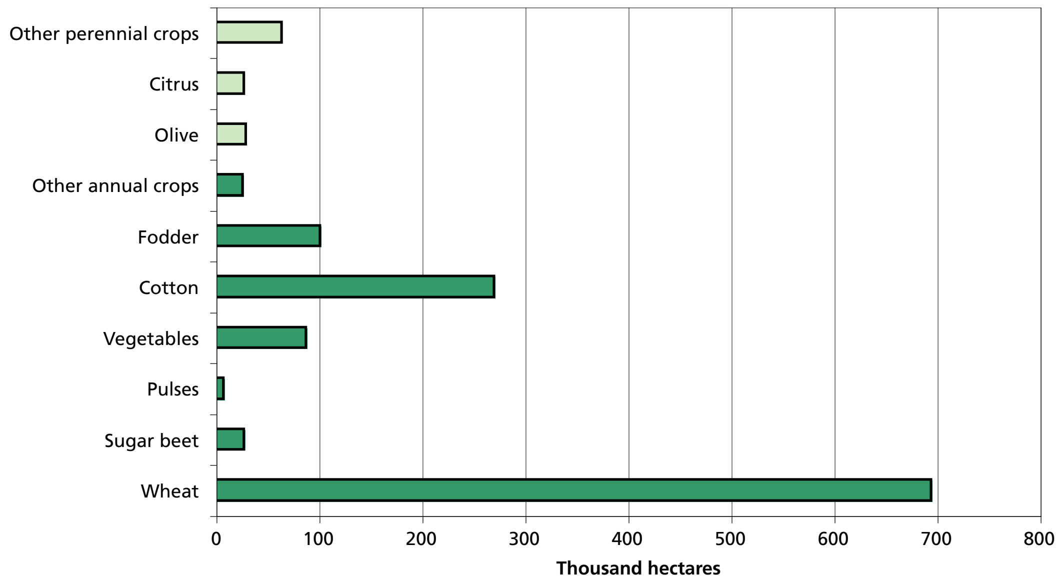
In 2000, the harvested irrigated crop area covered 1 334 265 ha while the rainfed area occupied 3 352 204 ha. Thus 28.5 percent of the harvested crop area was irrigated. Sugar beet and cotton were entirely irrigated just as almost all the citrus area (99.7 percent) was. About 75 percent of the area under vegetables and 41 percent of wheat were irrigated. Only 6.7 percent of fodder area, 6.1 percent of olives and 3.1 percent of pulses were irrigated. Irrigated barley and maize are mainly used as a fodder crop (Table 4 and Figure 5).

The performance of irrigated agriculture is high and the difference with rainfed yields is noticeable. Yields of wheat range between 3.4 and 3.5 tonnes/ha when irrigated and between 0.6 and 0.8 tonnes/ha when rainfed. Irrigated citrus trees produce on average 99 kg/tree while non irrigated citrus trees produce less than 20 kg/tree. Average yields of irrigated sugar beet and cotton are 42.8 and 4 tonnes/ha respectively (National Agricultural Policy Centre, 2003).

There is a wide variation in cropping patterns in the irrigated areas, depending on the water resources available and the agroclimatological conditions. Strategic crops such as wheat and cotton are concentrated in the northern and eastern parts of the country. More than 50 percent of the wheat and cotton produced comes from the Hassakeh governorate in the northeastern part of the country. The production of winter vegetables is centred in the coastal region, while summer vegetables are produced mainly in the internal plains, especially in the central and southern regions.

Unit costs for irrigation development have increased considerably in the last three decades and this is one of the reasons why since the 1970s attention has also been

FIGURE 5
Irrigated crops
Total harvested area: 1 334 265 ha in 2000 (cropping intensity on equipped area: 105%)



paid to drainage and irrigation rehabilitation, mainly in the Euphrates valley where irrigation through pumping from the river has developed rapidly since the 1950s. Appreciable progress has been made in restoring large irrigated areas which went out of cultivation due to waterlogging and salinity, especially in the lower and middle parts of the Euphrates valley. At present, the average cost of a drip system varies between US$1 000 and US$3 000/ha (US$1 000–1 400/ha for trees and US$2 400–3 000/ha for vegetables) and that of a sprinkler system ranges between US$2 000 and US$2 400/ha for fixed devices and US$400/ha for manual ones (World Bank, 2001).

Cost of irrigation development is around US$1 100–1 200/ha in one part of the Euphrates (Beer Hashem), in the Yarmouk and in the Coastal basins, but it is US$2 700/ha in the Tigris and Al-Kabour basins (Hassakeh). It even reaches US$3 500/ha in another part of the Euphrates basin (Maskeneh Gharb) (Varela-Ortega and Sagardoy, 2001).

Status and evolution of drainage systems

Drainage is mainly developed in the mohafazats bordering the Euphrates River. In Raqqa, for instance, 62 percent of the irrigated area is drained. About 24 percent of the total drained area is power drained. The drainage systems are generally mixed systems of surface and subsurface drainage. In 1989, 60 000 ha of irrigated land were estimated to be affected by salinization (Table 4). Some 5 000 ha in the Euphrates basin have been abandoned due to waterlogging and salinity problems. In new irrigation schemes open drainage systems have been installed on 90 percent of the irrigated land. Only a small area has been equipped with subsurface drains.

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

Institutions

The responsibility of dealing with water resources management lies with a number of ministries, which are all represented on the Council of General Commission for Water Resource Management:

- The Ministry of Irrigation (MOI) is the central institution for managing, developing and protecting the water resources, supervising the investments and the establishments in all water basins and drawing up strategic plans for executing the water policies to achieve sustainable development for water resources. The ministry is responsible for making available suitable water resources for all water using sectors, for controlling drilled wells and for licensing future wells.
- The Ministry of Agriculture and Agrarian Reform (MAAR) is the main consumer of water resources; it is responsible for the rational use of water for agricultural purposes, for minimizing water consumption and encouraging the use of modern irrigation techniques. The Council of Ministers agreed (2005) to establish a national monetary fund for modern irrigation projects.
- The Ministry of Housing and Construction (MHC) is responsible for supplying drinking water from surface and underground water resources by building, operating and investing in the water networks and water purification stations as well as building sewage-water networks and treatment plants and enhancing the efficiency of water and sewage networks.
- The Ministry of Local Administration and Environment (MLAE) is responsible for monitoring and controlling water quality through its laboratories and observatory networks, for issuing national standards for the protection of water resources and tracking the sources of pollution in order to implement Environmental Law.
- Each Ministry has local bodies (local directorates or local institutions) related to the central body of each Ministry and distributed over the 14 administrative units. In the case of the MOI there is the General Commission for Water Resources as a central body within the Ministry and in the case of the MLAE, there is the General Commission for Environmental Affairs (MLAE, 2007).

Water management

On-farm irrigation is under the jurisdiction of the Directorate of Irrigation and Water Use (DIWU) of the MAAR in terms of research, testing, piloting and demonstration programmes regarding on-farm irrigation techniques, scheduling, wastewater reuse and so on, although farmers are responsible for irrigation management at the field level. The MAAR has 13 irrigation and water use research stations in all basins in order to conduct research and to disseminate information on crop water requirements, optimized irrigation methods and so on, suitable for local conditions. The MAAR also provides farmers with technical support for the planning, design and maintenance of the on-farm irrigation systems (World Bank, 2001).

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 the Syrian Arab Republic. The objective of the programme is to strengthen participants' capacities for developing more effective and efficient projects to address pressing water issues in the region (FAO, 2008).

Finances

In the agricultural sector, the structure of the water tariff collected from farmers only covers a part of the cost for the irrigation water distribution network plus the costs of network operation and maintenance. The tariff is fixed at around US$70/ha, irrespective of the type of crops or the amount of exploited water. Apparently this does not provide any incentive for water conservation. So it is very important to shift to a volume based tariff for irrigation, in spite of the fact that till now there has been no strong policy for setting prices for irrigation water, and no legal regulation for invoicing the price of irrigation with a volume-related pricing system.

Beneficiaries from the public irrigation systems are subject to a fee which tries to recover some of the investments made. The fee to be paid is calculated by taking into consideration the development costs for an amortization period of 30 years but no interest is charged nor is it corrected by inflation. Therefore the amount charged is small, from US$40 to 140/ha. The payments to be made are regulated by several legislative decrees, and executive decisions have been issued in order to recover the cost of the irrigation projects.

Operation and maintenance (O&M) costs for the irrigation and drainage networks are charged with a flat fee of US$70/ha for permanent irrigation and US$12/ha for winter irrigation. These fees have been determined according to decision no. 5 of 21/11/1999 issued by the Prime Minister. As could be expected, the actual cost of operation and maintenance is considerably higher for pump irrigation (US$110/ha) than for gravity irrigation (less than US$35/ha). It has been reported that the percentage of payment of the established O&M fees is close to 90 percent which is very high by world standards (Varela-Ortega and Sagardoy, 2001).

Policies and legislation

Water is defined by Syrian law as a "public good" that is not treated according to market forces. The right to use surface water or groundwater is acquired through the issuance of water use licenses by the MOI. Whoever installs a pump on public surface water without having a license is subject to a nominal fine. The license can be withdrawn if users do not comply with license conditions or if they use the water for purposes other than those authorized. At present, licenses specify discharge, well numbers and a maximum depth of 150 metres. They are issued for periods of either 1–3 years or 10 years. A very strong law banning new wells has been in place for more than five years. This law allows the repair of problematic wells but prohibits new constructions. However, enforcement of this law is weak.

Over 140 laws dealing with water have been passed since 1924. Water use priorities have not, however, been set by any official legislation. There is, however, a widely accepted consensus among related ministries about priorities for water usage. Drinking water has the top priority followed by agricultural and industrial water. Prohibitions on well digging and groundwater pollution have been passed but there are no clear mechanisms for their enforcement (Salman, 2004).

ENVIRONMENT AND HEALTH

Monitoring activities show that near all major settlements groundwater and surface water are polluted by municipal and industrial waste where the concentrations of biochemical oxygen demand (BOD), suspended solids (SS) and ammonia exceed Syrian standards, and groundwater in the basin also contains extremely high concentrations of pathogens, nitrates and agrochemicals. This situation occurs in many areas (MLAE, 2007):

- Water pollution from sewage water is reported in the Barada River;
- An increase in the amount of nitrates and ammonia ions has been noted in some drinking wells in the Damascus countryside (Ghouta), over the permitted level. In 2005 this led to a stop in the investment of more than 200 wells for drinking;
- Uncontrolled discharge of industrial wastewater occurs on a large scale. The fertilizer and food processing industries contribute to the pollution load, but smaller and medium-sized industries such as tanneries also contribute and their impacts are even larger;
- Drainage water from irrigated agriculture, containing excessive nutrients, pesticides and sometimes (in the case of irrigation with untreated wastewater) pathogens, reaches the rivers and groundwater;

- In areas with heavy groundwater extraction, saltwater intrusion into the aquifer from the sea or other saline groundwater has occurred.

There is sufficient evidence to indicate that significant health impacts have been caused as a result of water pollution. The following cases have been reported:

- Almost 900 000 cases of waterborne diseases were reported in 1996, and a significant number went unreported;
- High rates of infantile diarrhoea, with fatality rates of up to 10 percent within some illegal housing areas not served by a drinking water network.

Compared to the period 1991–95, during the period 1995–2000 the rate of typhoid and hepatitis infections increased tenfold and that of diarrhoea doubled. Animals were also affected by several diseases, such as tapeworm and pulmonary tuberculosis and others, resulting from the use of untreated wastewater for fodder crop irrigation. The major factors favouring the development and dispersion of these diseases can be summarized as follows (DIWU, 2001):

- Scarcity of groundwater resources and the orientation toward the use of wastewater to meet the shortage;
- Lack of infrastructure especially that related to wastewater treatment and disposal, i.e. random disposal without treatment most of the time;
- Lack of health awareness and proper handling of polluted water;
- Non-existence or lack of adoption of regulations related to the protection of the environment and public health.

The cost of environmental degradation in the Syrian Arab Republic was estimated in 2004 by the Mediterranean Environmental Technical Assistance Program (METAP)/ World Bank to be 2.6–4.1 percent of GDP annually, based on the 2001 figures, with a mean estimate of around US$600 million/year. Estimated costs of damage are organized by environmental category. The cost of diarrhoea illness and mortality follows at an estimated 0.6–0.7 percent of GDP, caused by a lack of access to safe potable water and sanitation, and inadequate domestic, personal and food hygiene, while the total cost of water resource degradation, and inadequate potable water, sanitation and hygiene is estimated at 0.7–1.0 percent of GDP (MLAE, 2007).

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

Irrigation development to a large extent depends on how the Syrian Arab Republic reaches agreements with neighbouring countries on the sharing of river waters (Turkey, Lebanon, Jordan and Iraq). Identifying and implementing policies, programs, projects and techniques to improve water use efficiency and to control surface water and groundwater exploitation better are the important challenges facing Syrian policy-makers.

The main issues that the irrigation and drainage sector in the Syrian Arab Republic is facing are the legacy of over-investment in project development and the lack of an "exit strategy" to maintain the financial sustainability of this development, including clear economic incentives and an effective institutional framework. Reform of pricing and subsidies, management transfer and organizational restructuring are the key elements among others within the overall institutional reform that will encompass these issues and prioritize actions in order to achieve a sustainable improvement of this sector.

Government irrigation tariff policies do not provide any incentives to farmers to optimize water use and invest in modernized on-farm irrigation systems. For the public surface water irrigation schemes in particular, farmers do not have any incentives to save water since the operation and maintenance charge is a flat fee unrelated to water consumption and determined by the field size alone. For the individual groundwater irrigation systems, farmers have access to cheap credit to finance their initial capital investments and pay for subsidized energy with no charge for water.

Although there have been several attempts, particularly since 2000, to restructure the water sector in the Syrian Arab Republic, they have been somewhat superficial and have made no fundamental changes to its monumental structure which has a dominant "centralization" view. At present, the capacity of government organizations to support water management (as opposed to water development) appears limited and their services are weak and fragmented. Subsector agencies plan and implement their programmes without attempting to sequence and coordinate with each other which has led to incomplete improvements and reduced farmer benefits. In addition, the government policy to modernize irrigation systems at farm level requires the involvement of the Ministry of Agriculture and Agrarian Reform and the engagement of other agencies, which in reality seems incoherent and not applied properly. It is therefore important to emphasize the need for an overall organizational restructuring in the water sector that considers the possibility of decentralizing the decision-making authority, more involvement of private sector agriculture, greater involvement of users and strong quality control of activities. Such a restructuring can only be effective if it is embedded into an integrated set of measures that create the synergy necessary to achieve the anticipated objectives for sustainable water development in the country, and if it is backed by effective enforcement which in turn requires substantial support activities (education and outreach) to close the "perception gap" (Salman, 2004).

MAIN SOURCES OF INFORMATION

Abed Rabboh, Reem. 2007. *Water demand management in Syria*. Presented at the workshop on "Water demand management in the Mediterranean, progress and policies". Zaragossa 19–21 March 2007.

Akanda, A., Freeman, S. and Placht, M. 2007. The Tigris-Euphrates River Basin: *Mediating a Path Towards Regional Water Stability*

CBS (Central Bureau of Statistics). 2006. *Statistical abstract 2005*. Damascus.

DIWU (Directorate of Irrigation and Water Use). 1993. *Water requirements for the agricultural plan 1993–94*. Damascus.

DIWU. 2003. Syria country paper. In: *Proceedings-Expert consultation for launching the regional network on wastewater reuse in the Near East*.

Economic and Social Commission for Western Asia (ESCWA). 2001. *Implications of groundwater rehabilitation on water resources protection and conservation: artificial recharge and water quality improvement in the ESCWA Region*.

El Fadel, M., El Sayegh, Y., Abou Ibrahim, A., Jamali, D. and El Fadl, K. 2002. *The Euphrates-Tigris Basin: A Case Study in Surface Water Conflict Resolution*

ESCWA/FAO/ Ministry of Agriculture and Agrarian Reform (MAAR). 1995. *Evaluation of agricultural policies in the Syrian Arab Republic (policy analysis matrix approach)*. Damascus, Syria.

ESCWA/FAO/MAAR. 1995. *National Farm Data Handbook 1994*. United Nations, New York.

FAO. 1993. *Irrigation sub-sector review*. Mission Report. Rome, Italy.

FAO. 2002. *Bilateral agreement between Syria and Iraq concerning the installation of a Syrian pump station on the Tigris River for irrigation purposes*. http://faolex.fao.org/waterlex/

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

Kaya, I. 1998. *The Euphrates-Tigris basin: An overview and opportunities for cooperation under international law*

Ministry of Agriculture and Agrarian Reform (MAAR). 1993. *Annual plan for agricultural production 1993–94*. Damascus, Syria.

Ministry of Agriculture and Agrarian Reform (MAAR). 1993. *Balance of land utilization for 1993*.

MLAE (Ministry of Local Administration and Environment). 2007. *Water demand management in Syria*. Prepared by Abed Rabboh, R. Submitted to Blue Plan, UNEP/MAP. Third regional workshop on: Water and sustainable development in the Mediterranean - Water demand management, progress and policies. Zaragoza, Spain, March 2007.

National Agriculture Policy Center (NAPC). 2003. *The state of food and agriculture in the Syrian Arab Republic 2002*. FAO Project GCP/SYR/006/ITA.

Salman, Maher. 2004. *Institutional reform for irrigation and drainage in Syria: diagnosis of key elements*.

Soumi, George. 1993. *Management and development of water resources and their use rationalization*. Report to the Technical Conference of the Arab Agricultural Engineers Federation in Tunis.

UNDP/FAO. 1994. *Improved management of water resources for agricultural use (phase II)*. SYR/90/001. Damascus, Syria.

Varela-Ortega, C. and Sagardoy, J.A. 2001. *The Utilization of Water Resources for Agriculture: Analysis of the Current Regime and Policy*. Assistance in Institutional Strengthening and Agricultural Policy - Syria. FAO GCP/SYR/006/ITA.

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

World Bank. 2001. *Syrian Arab Republic: Irrigation Sector Report*. Report 22602.

Yavuz, Ercan. 2008. *Turkey, Iraq, Syria to initiate water talks*. Todays Zaman 12/03/2008