Qatar

GEOGRAPHY, CLIMATE AND POPULATION

Geography

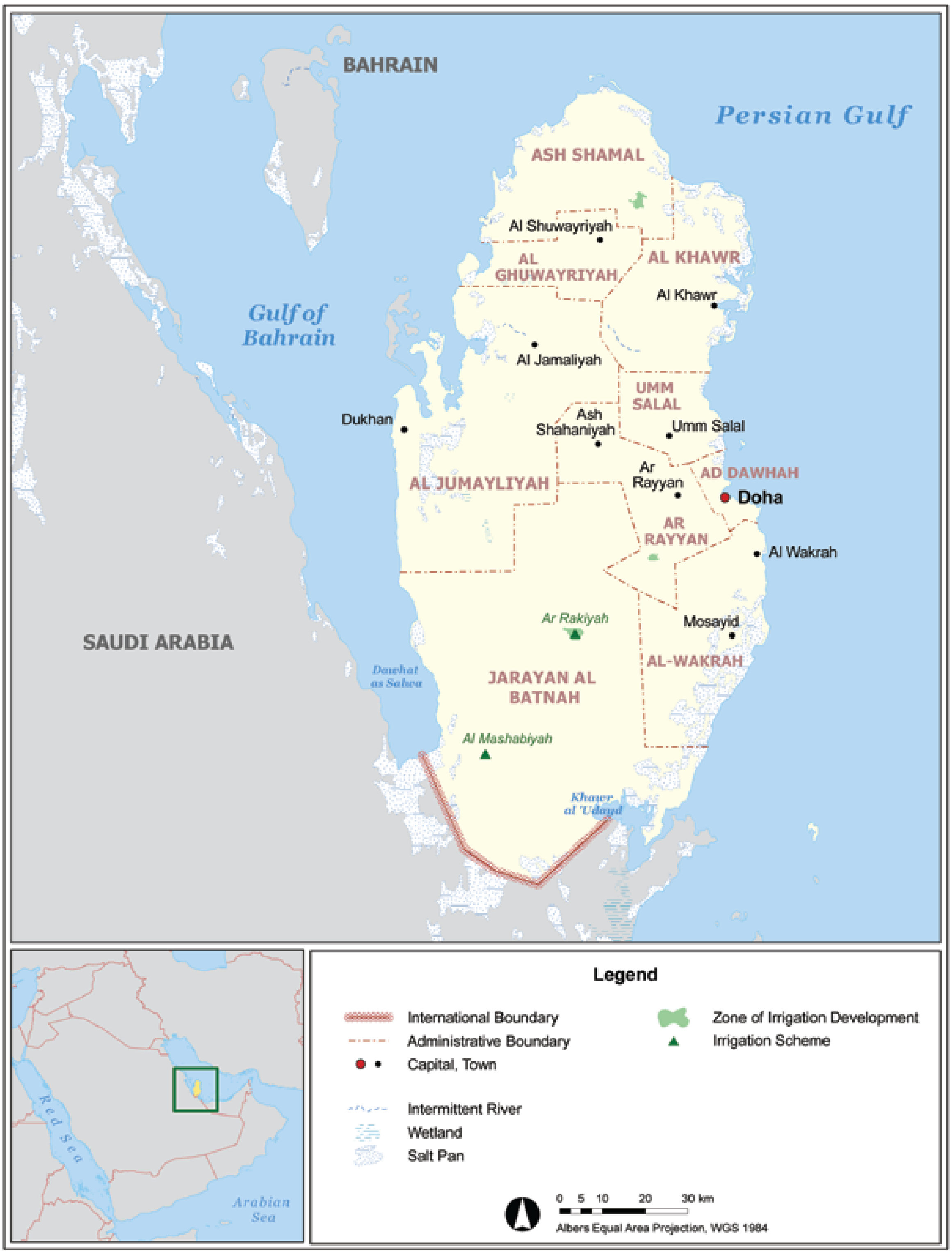
Qatar is a small peninsula in the Persian Gulf covering an area of approximately 11 000 km^2 including a number of small offshore islands. Its maximum length is about 180 km along the north-south axis, while the east-west width is 85 km at its widest point. It is bounded by the Persian Gulf on all sides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

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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

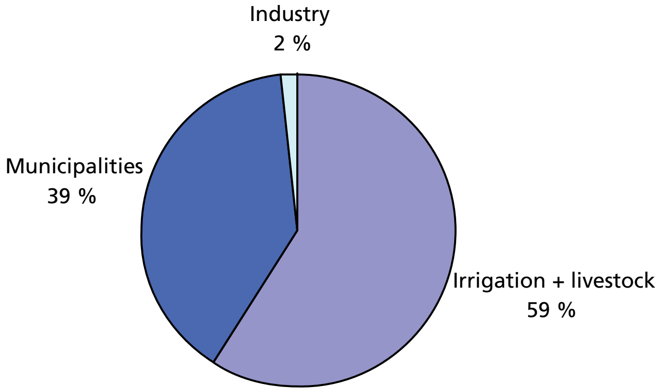


FIGURE 2
Water withdrawal by source
Total: 0.444 km^3 in 2005

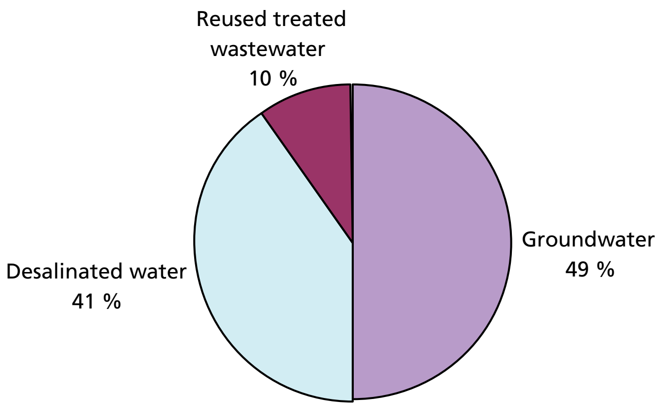


TABLE 3
Water withdrawals by different sectors in Qatar (2005)

	Agriculture		Domestic		Industry		Total	
	million m^3/ year	%	million m^3/ year	%	million m^3/ year	%	million m^3/ 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

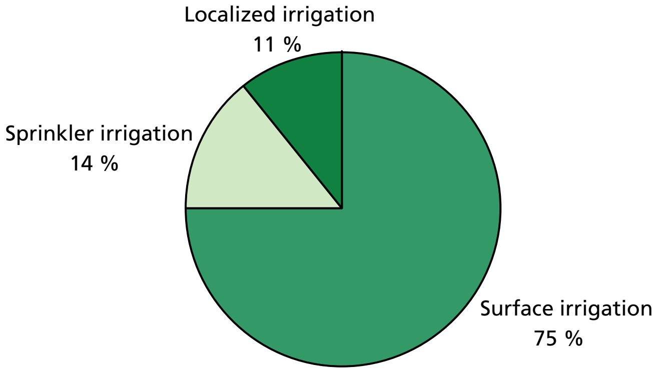


TABLE 4
Irrigation and drainage

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

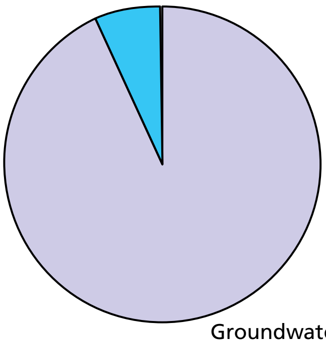
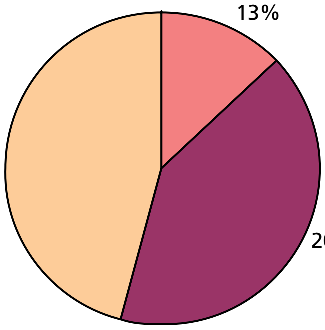


FIGURE 5
Type of irrigation schemes
Total: 12 935 ha in 2001



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).

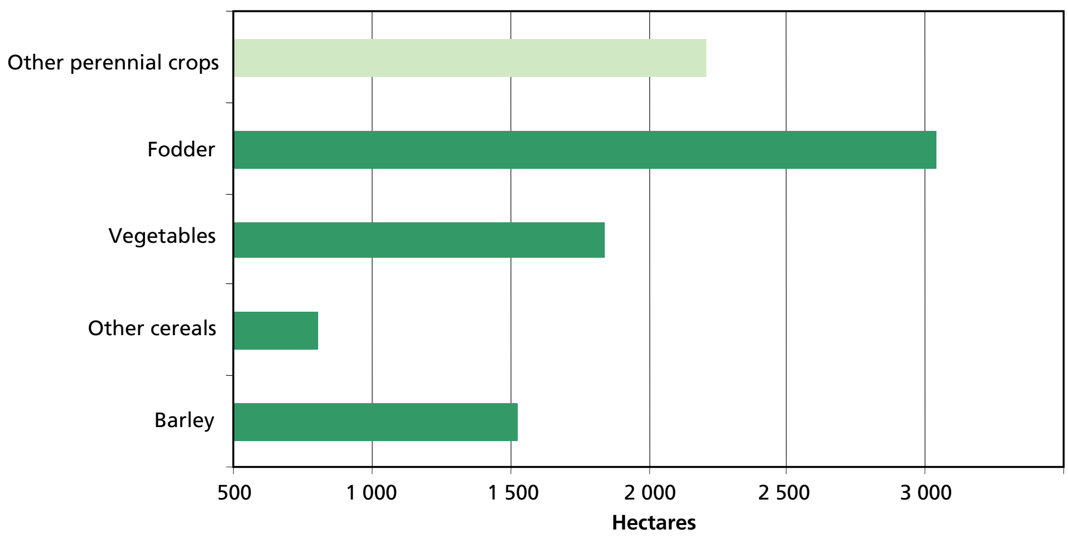
Small schemes (< 20 ha) cover 13 percent of the total equipped area for irrigation, medium size schemes (20-100 ha) 41 percent and large schemes (> 100 ha) 46 percent (Figure 5). All agricultural land in Qatar is owned by Qatari nationals, but farming is not the primary occupation of these landowners. 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.

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