United Arab Emirates

GEOGRAPHY, CLIMATE AND POPULATION

Geography

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

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

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

Climate

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

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

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TABLE 1
Basic statistics and population

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

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

Population

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

TABLE 2
Mainland area and farms by emirates

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

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

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

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

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

ECONOMY, AGRICULTURE AND FOOD SECURITY

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

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

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

In the UAE, traditional knowledge and traditions are very important. While creating a modern country, the government aims to conserve the heritage of the past. Today's UAE residents come from different Arabian groups, some of which had a traditional nomadic lifestyle, breeding camels and goats; most of them were settled in the Liwa Oasis to work in simple agriculture and palm plantations. In the coastal area, groups used to work in fishing and pearl hunting. In the Al Ain Oasis, other groups work in agriculture, especially in date plantations using underground water and aflaj irrigation. In the northern emirates where, relatively, there is more rainfall, people can work in

agriculture all year round. In the Hajjar Mountains of Al Fujayrah, terrace farming is practised, while in Dubai, Shariqah & Galfar (Ras Al Khaymah) people are trading with boats and modern ships (MOEW, 2006).

WATER RESOURCES AND USE

Water resources

The total annual renewable water resources are about 150 million m^3, but there are no perennial streams (Table 4). Groundwater resources occur in the upper clastic and lower carbonate formations located in the Bajada region in the eastern part of the country. The aquifers consist of alluvial fan deposits along the base of the Oman and Ras Al Khaymah mountains extending over a large area. The upper aquifer is composed of gravel sand and silt, the lower aquifer of limestone, dolomite and marl. Both aquifers range in thickness from 200 to 800 metres. In addition, the Dammam and Umm er Radhuma formations extend into the western desert areas, with thicknesses ranging from 500 to 1 000 metres. Groundwater quality in the two aquifer systems, particularly in the Bajada region, ranges from 600 to 2 000 ppm. The Dammam and Umm er Radhuma aquifers contain highly saline water (ESCWA, 2001). Average annual groundwater recharge may be estimated at about 120 million m^3, most of which comes from infiltration from the river beds.

To increase the groundwater recharge, a number of dams have been built at various locations in the country. In 2003, there were 114 dams and embankments of various dimensions with a total storage capacity of 118 million m^3, which is an increase of almost 48 percent compared to 1995, but total water stored was only 12.3 million m^3. While most of these dams are basically built for recharging purposes, they also provide protection against damage caused by flash floods.

The first desalination plant was installed in Abu Dhabi in 1976 with a total capacity of 250 m^3/day. Because of a rapid increase in municipal and industrial water demand more plants were installed, particularly in Abu Dhabi and Dubai. In 2002, the total installed gross desalination capacity (design capacity) in the United Arab Emirates was 4 725 346 m^3/day or 1 725 million m^3/year (Wangnick Consulting, 2002). In 2005, total

TABLE 4
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	78	mm/yr
	-	6.521	10^9 m^3/yr
Internal renewable water resources (long-term average)	-	0.15	10^9 m^3/yr
Total actual renewable water resources	-	0.15	10^9 m^3/yr
Dependency ratio	-	0	%
Total actual renewable water resources per inhabitant	2005	48.29	m^3/yr
Total dam capacity	2006	118	10^6 m^3
Water withdrawal			
Total water withdrawal	2005	3 998	10^6 m^3/yr
- irrigation + livestock	2005	3 312	10^6 m^3/yr
- municipalities	2005	617	10^6 m^3/yr
- industry	2005	69	10^6 m^3/yr
• per inhabitant	2005	889.2	m^3/yr
Surface water and groundwater withdrawal	2005	2 800	10^6 m^3/yr
• as % of total actual renewable water resources	2005	1 867	%
Non-conventional sources of water			
Produced wastewater	1995	500	10^6 m^3/yr
Treated wastewater	2006	289	10^6 m^3/yr
Reused treated wastewater	2005	248	10^6 m^3/yr
Desalinated water produced	2005	950	10^6 m^3/yr
Reused agricultural drainage water	-	-	10^6 m^3/yr

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

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

Water use

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

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

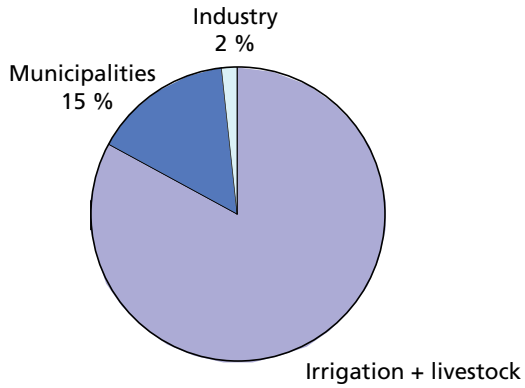
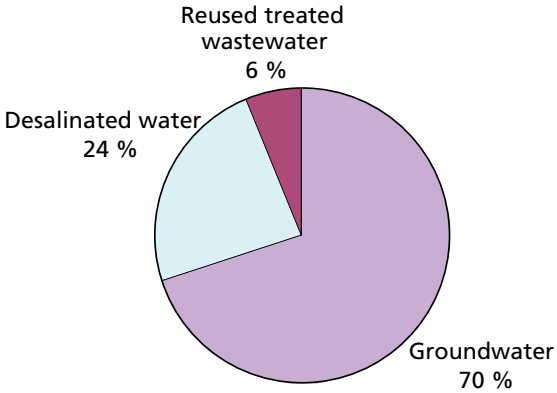


FIGURE 2
Water withdrawal by source
Total: 3 998 km³ in 2005



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

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

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

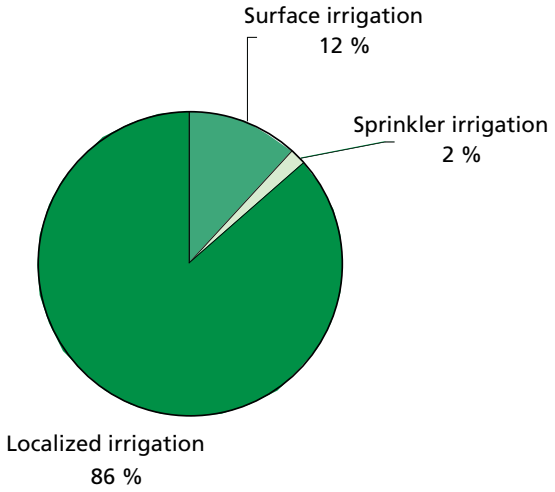
TABLE 5
Irrigation and drainage

Irrigation potential			**-**	**ha**
Irrigation				
1. Full or partial control irrigation: equipped area		2003	226 600	ha
- surface irrigation		2003	27 100	ha
- sprinkler irrigation		2003	4 000	ha
- localized irrigation		2003	195 500	ha
• % of area irrigated from surface water		2003	0	%
• % of area irrigated from groundwater		2003	100	%
• % of area irrigated from mixed surface water and groundwater			0	%
• % of area irrigated from non-conventional sources of water			-	%
• area equipped for full or partial control irrigation actually irrigated			-	ha
- as % of full/partial control area equipped			-	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)			-	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)		2003	226 600	ha
• as % of cultivated area		2003	88.9	%
• % of total area equipped for irrigation actually irrigated			-	%
• average increase per year over the last 10 years		1993-2003	13	%
• power irrigated area as % of total area equipped			-	%
4. Non-equipped cultivated wetlands and inland valley bottoms			-	ha
5. Non-equipped flood recession cropping area			-	ha
Total water-managed area (1+2+3+4+5)		2003	226 600	ha
• as % of cultivated area		2003	88.9	%
Full or partial control irrigation schemes	**Criteria**			
Small-scale schemes	< ha		-	ha
Medium-scale schemes			-	ha
large-scale schemes	> ha		-	ha
Total number of households in irrigation		2003	38 548	
Irrigated crops in full or partial control irrigation schemes				
Total irrigated grain production (wheat and barley)		2003	15	metric tons
• as % of total grain production		2003	100	%
Harvested crops				
Total harvested irrigated cropped area		2003	228 521	ha
• Annual crops: total		2003	38 307	ha
- Wheat		2003	6	ha
- Vegetables (including potatoes, beans...)		2003	8 083	ha
- Other annual crops (mainly green fodder)		2003	30 218	ha
• Permanent crops: total		2003	190 214	ha
- Palm tree		2003	185 330	ha
- Alfalfa		2003	2 801	
- Other perennial crops (citrus, mango)		2003	2 083	ha
Irrigated cropping intensity (on full/partial control irrigation equipped area)		2003	101	%
Drainage – Environment				
Total drained area			-	ha
- part of the area equipped for irrigation drained			-	ha
- other drained area (non-irrigated)			-	ha
• drained area as % of cultivated area			-	%
Flood-protected areas			-	ha
Area salinized by irrigation			-	ha
Population affected by water-related diseases			-	inhabitants

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

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

FIGURE 3
Irrigation techniques
Total: 226 600 ha in 2003



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

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

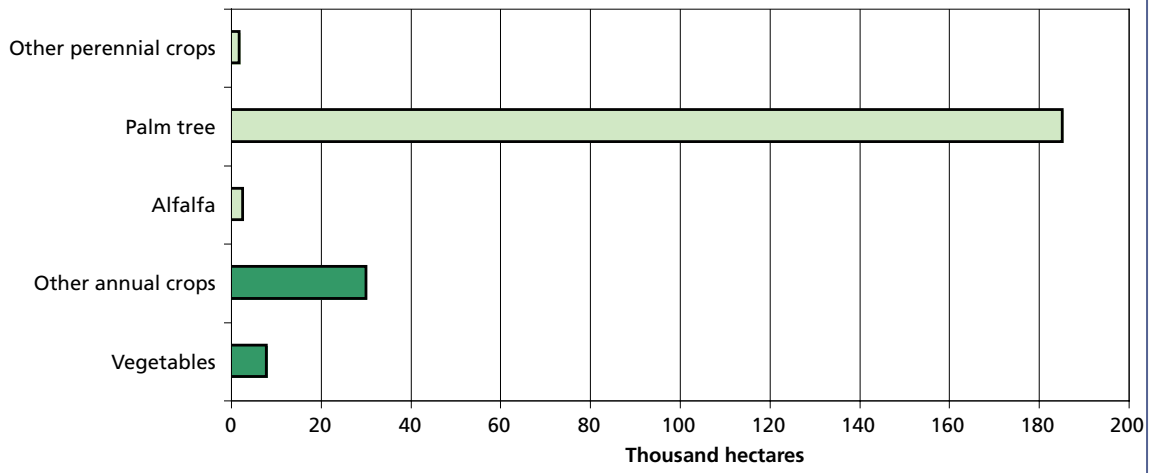
Apart from the government's experimental farms, nurseries, afforestation schemes and public gardens, all the agricultural land is owned and developed by private owners. In 2003, 61 percent of the farm holdings (23 421 units) owned modern irrigation systems (Table 6). More than 86 percent of the farms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

Role of irrigation in agricultural production, economy and society

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

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

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



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

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

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

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

Institutions

There are four main institutions involved in water resources management:

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

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

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

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

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

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

Water management

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

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

Finances

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

ENVIRONMENT AND HEALTH

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

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

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

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

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

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

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

Provision of suitable baseline data;

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

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

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

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

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