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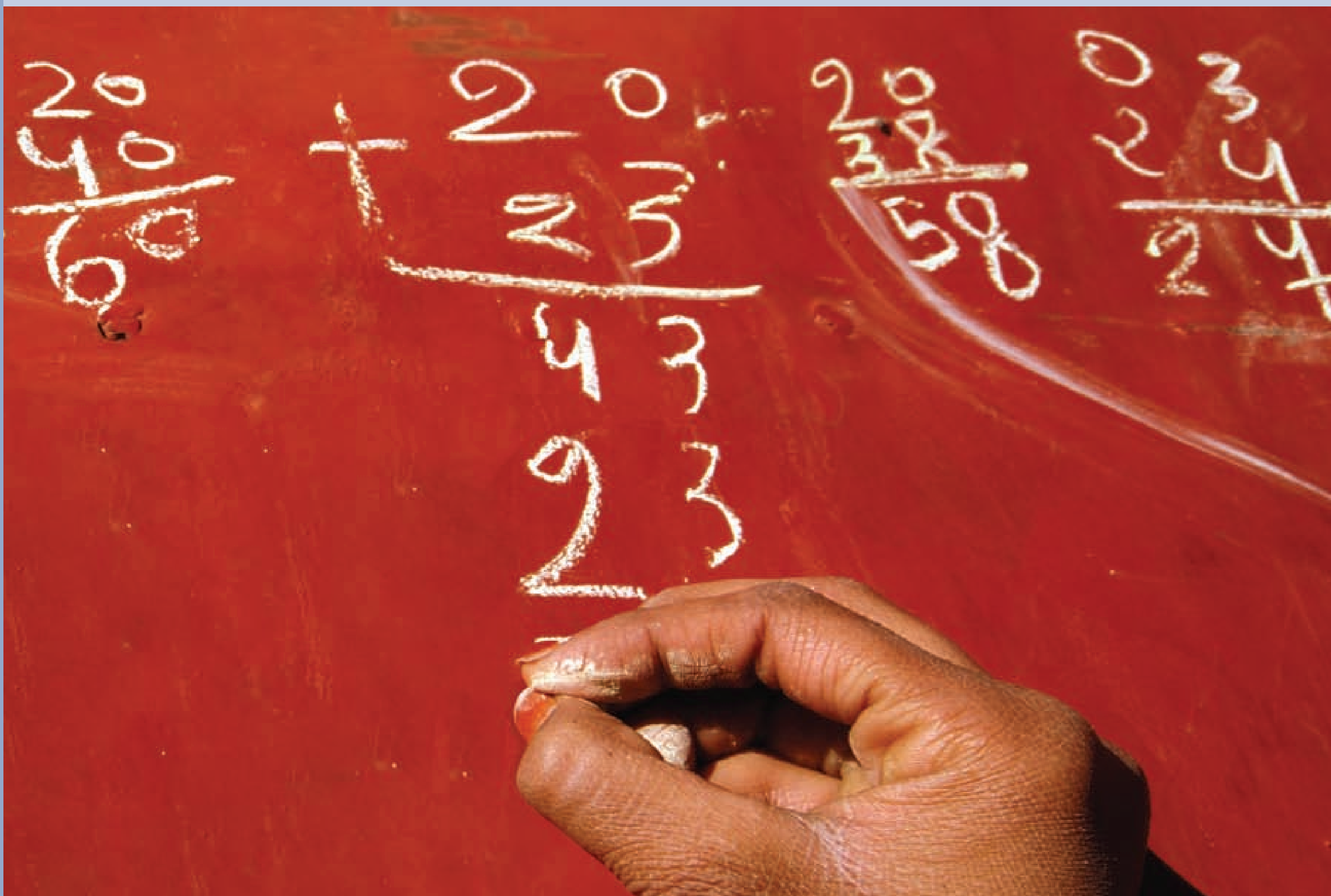
Irrigation in the Middle East region in figures

AQUASTAT Survey – 2008



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Irrigation in the Middle East region in figures – AQUASTAT Survey – 2008

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Irrigation in the Middle East region in figures

AQUASTAT Survey – 2008

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34

Edited by
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FAO Land and Water Division

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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Foreword

Eradication of extreme hunger and poverty and ensuring environmental sustainability are two of the eight Millennium Development Goals (MDG 1 and MDG 7) and the primary focus of FAO. Attainment of these goals is highly linked to water for agriculture and therefore reliable information for indicators linked to these goals is of utmost importance.

The MDG water indicator 7.5, for which FAO's Water Unit is responsible, is the proportion of renewable freshwater resources withdrawn for human use, including agricultural, municipal and industrial uses. This indicator reflects the overall anthropogenic pressure on freshwater resources. Physical water scarcity is taken to occur when more than 75 percent of renewable surface and groundwater are diverted for these uses. At this point, the indicator assumes that water resources development has exceeded the limit of the freshwater system to meet both socio-economic and environmental requirements.

In the Middle East region 12 out of the 18 countries already face physical water scarcity according to this 75 percent criterion. The Arabian Peninsula stands out, with withdrawal values exceeding 100 percent in all countries except Oman. Under these circumstances there is reliance upon withdrawals from non-renewable aquifers (fossil groundwater) and non-conventional sources of water (such as desalination or wastewater reuse) making up the balance.

In view of the unprecedented levels of demand on the already stressed systems of the Middle East region, the need for systematic information on water, its quality and its use cannot be overstated. Further, given that almost 85 percent of the water withdrawal in the region is used for irrigation, accurate and reliable information on agricultural water use is of critical importance. Also, given the number of joint initiatives on transboundary river basins and aquifers in the region, the need for this information to be compiled at basin or aquifer scale is all too evident.

This AQUASTAT report presents the most recent information available on water availability and its use in the 18 countries and territories in the Middle East region, with an emphasis on agricultural water use and management. It contains the relevant tables and maps, and a regional synopsis emphasizing the subregional characteristics of this large and diverse region. It also analyses the changes that have occurred since the first survey in 1997. Finally it gives a more detailed description of four transboundary river basins in the region, highlighting the different levels of cooperation and the agreements between countries located in the same river basin: the Euphrates–Tigris River Basin, the Kura–Araks River Basin, the Asi–Orontes River Basin and the Jordan River Basin.

We hope that this publication will contribute not just to a better understanding of irrigation conditions in the Middle East region but will also inform cross sectoral decision-making related to water development and management.

Alexander Müller
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Natural Resources Management
and Environment Department

Parviz Koohafkan
Director
Land and Water Division

Units

Length

1 km = 1 000 m = 1 x 103 m
1 mile = 1.56 km = 1 560 m

Area

1 acre = 4 047 m^2 = 0.4047 ha = 4.047 x 10^{-4} x 1 000 ha
1 are = 100 m^2 = 0.01 ha = 1 x 10^{-5} x 1 000 ha
1 feddan = 4 200 m^2 = 0.42 ha = 4.2 x 10^{-4} x 1 000 ha
1 ha = 10 000 m^2
1 km^2 = 1 000 000 m^2 = 100 ha = 1 x 10^{-1} x 1 000 ha
1 m^2 = 0.0001 ha = 1 x 10^{-7} x 1 000 ha

Volume

1 dm^3 = 1 litre = 0.001 m^3 = 1 x 10^{-12} km^3
1 hm^3 = 1 million m^3 = 1 000 000 m^3 = 1 x 10^{-3} km^3
1 km^3 = 1 billion m^3 = 1 000 million m^3 = 10^9 m^3
1 m^3 = 10^{-9} km^3
1 UK gallon = 4.546 dm^3 = 0.004546 m^3 = 4.546 x 10^{-12} km^3
1 US gallon = 3.785 dm^3 = 0.003785 m^3 = 3.785 x 10^{-12} km^3

Power-energy

1 GW = 1 x 10^3 MW = 1 x 10^6 kW = 1 x 10^9 W
1 GWh = 1 x 10^3 MWh = 1 x 10^6 kMh
US$1 = 1 United States Dollar
1 ºC = 1 degree centigrade

The information presented in this publication is collected from a variety of sources. It reflects FAO's best estimates, based on the most accurate and up-to-date information available at the date of printing.

List of abbreviations

ATP	Accelerated Transfer Program (Turkey)
AU	American University
CIA	United States Central Intelligence Agency
CILSS	Interstate Committee for Drought Control in the Sahel
DSI	General Directorate of State Hydraulic Works (Turkey)
ERWR	External renewable water resources
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GAP	Southeastern Anatolia Project (Turkey)
GLOWA	Global Change and the Hydrological Cycle
GDRS	General Directorate of Rural Services (Turkey)
GDP	Gross Domestic Product
HDI	Human Development Index
IBK	Industrial Bank of Kuwait
ICID	International Commission on Irrigation and Drainage
ICOLD	International Commission on Large Dams
IPTRID	International Programme for Technology and Research in Irrigation and Drainage
IRWR	Internal renewable water resources
IVB	Inland valley bottoms
JMP	Joint Monitoring Programme for Water Supply & Sanitation
MDG	Millennium Development Goal
NIC	National Intelligence Council
OECD	Organisation for Economic Cooperation and Development
O&M	Operation and Maintenance
OSU	Oregon State University
PPP	Purchasing Power Parity
SPC	State Planning Commission in the Syrian Arab Republic
TARWR	Total actual renewable water resources
TNO	Netherlands Organisation for Applied Scientific Research
TRWR	Total renewable water resources
UNDG	United Nations Development Group
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNESCO-IHE	Institute for Water Education

UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
WDI	World Development Indicators
WHO	World Health Organization
WHYMAP	World-wide Hydrogeological Mapping and Assessment Programme

Section I

Presentation of the survey

Introduction

It is in FAO's mandate, as stated in Article 1 of its constitution, to "collect, analyse, interpret and disseminate information related to nutrition, food and agriculture". Within this framework FAO launched in 1993 a programme known as AQUASTAT, its global information system on water and agriculture (http://www.fao.org/nr/aquastat). AQUASTAT collects, analyses and disseminates data and information, by country, on water recourses and water use, with emphasis on agriculture, which is targeted at users in international institutions, national governments and development agencies. Its goal is to support agricultural and rural development through sustainable use of water and land by providing the most accurate information presented in a consistent and standard way and more specifically:

- up-to-date and reliable data by country
- methodologies and definitions for information on the water resources and irrigation sector
- systematic descriptions on the state of agricultural water management by country
- predictions of future agricultural water use and irrigation developments
- in-depth analysis through diverse thematic studies
- contribution to major international publications
- answers to requests from governments, research institutions, universities, non-governmental organizations and individuals.

At the time of launch, priority was given to Africa, which initiated the AQUASTAT publication series (FAO, 1995). The survey continued with the Near East (FAO, 1997a), the countries of the former Soviet Union (FAO, 1997b), South and East Asia (FAO, 1999), Latin America and the Caribbean (FAO, 2000). In 2005, the African continent was updated (FAO, 2005).

Ten years after the first publication on the Near East region, it appeared necessary to update the data and to identify the main changes in water use and irrigation that had occurred there. However, the countries forming the region in this publication are not to the same as the ones in the previous publication. While in the first publication the composition of the Near East region was determined by the countries covered by FAO's Regional Office for the Near East, it was judged more logical to follow in AQUASTAT the regional distribution given in FAO's Water Report 23 "Review of world water resources by country" (2003). In that report the world was divided into ten large regions as shown in Figure 7. It was also decided to call the region "Middle East" rather than "Near East", since Near East is considered to be a subregion of the Middle East.

To the two objectives of the previous publication (FAO, 1997a) a third has been added in this new survey of the Middle East region:

- to provide for every country the most accurate status of rural water resources management, with a special focus on irrigation, by featuring major characteristics, trends, constraints and prospective changes in irrigation and in water resources;
- to support regional analyses by providing systematic, up-to-date and reliable information on the status of water resources and of agricultural water management that can serve as a tool for regional planning and predictive studies;
- to prepare a series of chronological data in order to highlight the major changes that have occurred in the last decade on national and regional scales.

To obtain the most reliable information possible, the survey is organized as follows:

1. Review of literature and existing information at country and sub-country level.
2. Collection of information by country using a detailed questionnaire filled in by national consultants, international consultants, or the AQUASTAT team at FAO.
3. Compilation and critical analysis of the information collected using data-processing software developed for this survey, and selection of the most reliable information.
4. Preparation of country profiles and submission to national authorities responsible for water resources or water management for verification, correction and approval.
5. Preparation of the final profile, the tables and the figures presenting the information by country.
6. Updating of the on-line database.
7. Preparation of the general regional analysis, the figures and the regional tables.

Where possible, AQUASTAT has made use of national capacity and competence. While collecting the information by country, preference was given to national experts as they have a better knowledge of their own country and easier access to national or so-called 'grey' documents, which are not available outside the country. The choice of the countries for which a national consultant was recruited depended on several factors, namely: the importance of irrigation in the country; the availability of an expert; the scarcity of data observed during the previous survey; and the funds available. For about half of the countries concerned, a national consultant assisted the AQUASTAT team.

Country profiles

Country profiles are prepared in English, which is the FAO official language in the Middle East region. They describe the state of water resources and water use in the respective countries, as well as the state of agricultural water management. The aims are to describe the particularities of each country and the problems met in the development of the water resources and, in particular, irrigation. They summarize the irrigation trends in the country and the prospects for water management in agriculture as described in the literature. The country profiles have been standardized and organized in sections according to the following model:

- Geography, climate and population
- Economy, agriculture and food security
- Water resources and water use
- Irrigation and drainage development
- Water management, policies and legislation related to water use in agriculture
- Environment and health
- Prospects of agricultural water management
- References and additional information

Standardized tables are used for each country. A hyphen (-) indicates that no information is available. As most information is available only for a limited number of years, the tables present the most recent reliable information and indicate the year to which it refers. In the AQUASTAT database, however, all available information is accessible.

The information in the country profiles is much more detailed than that in the first AQUASTAT survey of 1997. In order to establish a more complete picture of the agricultural water sector in each country, it addresses issues related to water and to irrigation that were not previously included. Some issues have been added in response to user demand.

Data collection, processing and reliability

The main sources of information were:

- National policies, and water resources and irrigation master plans
- National reports, yearbooks and statistics
- Reports from FAO and other projects
- International surveys
- Results and publications from national and international research centres
- The internet.

Furthermore, the following sources systematically provide certain data:

- FAOSTAT (http://faostat.fao.org/). This is the only source used for variables of area (total, arable land and permanent crops) and population (total, rural, urban, female, male, and economically active). An exception has been made for those countries where all the cultivated area is irrigated and where there is a difference between the AQUASTAT data related to area of irrigation and the FAOSTAT data related to cultivated area (arable land and permanent crops). In that case the data obtained by AQUASTAT through this survey are retained. FAOSTAT data on areas are provided every year by the countries through the FAO representations.
- World Development Indicators (http://www.worldbank.org/data/). This is the World Bank's premier annual compilation of data on development. This source provides the data on gross domestic product (GDP).
- The World Health Organization (WHO) and the United Nations Children's Fund (UNICEF). These organizations provide access to data on improved water sources under their Joint Monitoring Programme for Water Supply & Sanitation (JMP) (www.wssinfo.org/).
- The United Nations Development Programme (UNDP). The UNDP provides the Human Development Index (HDI) (http://hdr.undp.org/statistics/data/).

In total, more than 50 variables have been selected and these are presented in the national tables attached to the respective profiles. They are ordered in categories corresponding to the various sections of the profiles: characteristics of the country and population; water resources and use; and irrigation and drainage. A detailed description of each variable is given in the glossary in the next chapter. Additional tables have been added to the country profiles where information is available, especially in order to specify regional or river basin data.

In most cases, a critical analysis of the information is required in order to ensure the general coherence of information collected for a given country. Where several sources result in divergent or contradictory information, preference is given to information collected at national or sub-national levels rather than at regional or world levels. Moreover, except in the case of evident errors, official sources are privileged. As regards shared water resources, the comparison of information between countries has made it possible to verify and complete the data concerning the flows of transboundary rivers and to ensure coherence at a river basin level. This information has been added more in detail in the country water balance sheets, which are available at http://www.fao.org/nr/water/aquastat/water_res/index.stm.

In spite of these precautions, the accuracy, reliability and frequency with which information is collected vary considerably according to the region, the country and the category of information. These considerations are discussed in the profiles.

The regional analysis tables show the period 1997–2007 as the period between the two surveys. The AQUASTAT team justifies this choice by virtue of the slow evolution of data for different years for each country. However, should more precision be required, the summary tables and the on-line database specify the exact year for the items of national data.

Glossary of terms used in this study

The following definitions have been used for the variables presented in the country profiles, the tables and the database.

Access to improved drinking water sources (%)

Percentage of the total population using improved water sources. An "improved" source is one that is likely to provide "safe" water, such as a household connection, a borehole, etc. Current information does not yet allow us to establish a relationship between access to safe water and access to improved sources, but WHO and UNICEF are examining this relationship. Figures are provided by WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation website (http://www.wssinfo.org/)

Actually irrigated area as percent of the total area equipped (%)

Percent of area equipped for irrigation that is actually irrigated in any given year, expressed in percentage. Irrigated land that is cultivated more than once a year is counted only once.

Agricultural drainage water (km^3/year)

This is water withdrawn for agriculture but not consumed and returned. It does not go through special treatment and therefore should be distinguished from reused wastewater. It can be reused further downstream for irrigation, for example.

Annual crops (ha)

Area of land under temporary (annual) crops, which are crops with a growing season lasting between several months and about one year and which need to be re-sown or replanted after each harvest, such as cereals and vegetables.

Arable land (ha)

Land under temporary crops (double-cropped areas are counted only once), temporary meadows for mowing or pasture, land under market and kitchen gardens and land temporarily fallow (less than five years). The abandoned land resulting from shifting cultivation is not included. Data for arable land is not meant to indicate the amount of land that is potentially cultivable.

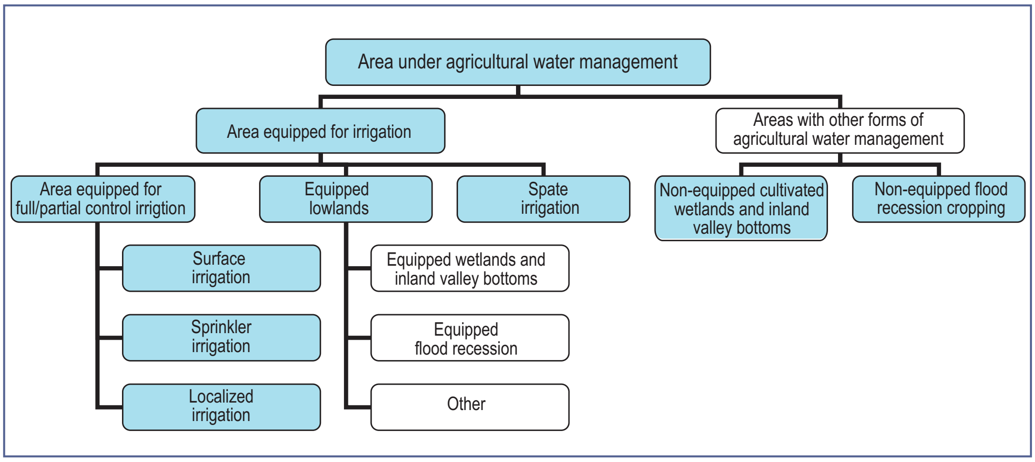
Area of the country (ha)

Total area of the country, including area under inland water bodies. Possible variations in the data may be due to updating and revisions of the country data and not necessarily to any change of area.

Area equipped for irrigation: total (ha)

Area equipped to provide water (via irrigation) to crops. It includes areas equipped for full/partial control irrigation, equipped lowland areas, pastures, and areas equipped for spate irrigation.

Area under agricultural water management (ha)
Sum of total area equipped for irrigation and areas with other forms of agricultural water management (non-equipped flood recession cropping area and non-equipped cultivated wetlands and inland valley bottoms). The classification adopted by AQUASTAT is presented in the following diagram. The blue ones are available in the AQUASTAT database and an explanation of each of them is given in this glossary.



Average annual increase of the area equipped for irrigation (%)
This increase is calculated with the following formula: new area = $(1+i)^n$ x old area, where "n" is the number of years in the period considered between the two AQUASTAT surveys and "i" is the average annual increase. The percentage is equal to (100 x i).

Cropping intensity: irrigated area (%)
The number of times the same area is cropped in one year (referring to area equipped for full/partial control irrigation). If available, the area effectively irrigated is used for the calculation of cropping intensity. If not available, the equipped area is used. The calculation only refers to irrigated crops. This means that in a country with one or two wet seasons only the crops grown under irrigation are taken into consideration. The crops grown on the full/partial control equipped area during the wet season without irrigation (but using the residual soil humidity) are not included in the irrigated crop area when calculating cropping intensity.

Cultivable area (ha)
Area of land potentially fit for cultivation. This term may or may not include part or all of the forests and rangeland. Assumptions made in assessing cultivable land vary from country to country. In this survey, national figures have been used whenever available, despite possible large discrepancies in computation methods.

Cultivated area (ha)
The sum of the arable land area and the area under permanent crops.

Dam capacity (km^3)
Total cumulative storage capacity of all large dams. According to ICOLD (International Commission on Large Dams), a large dam is a dam with a height of 15 m or more from the foundation. If dams are 5-15 metres high and have a reservoir volume of more than three million m^3, they are also classified as large dams. However, each country has its own definition of large dams and if information on other dams in a country is available it is also included. The value indicates the theoretical initial capacity, which does not

change with time. The current or actual dam capacity is the state of the dams at a given time that can be decreased by silting. Detailed information on African dams can be found in the AQUASTAT geo-referenced database on African dams on http://www.fao.org/ag/agl/aglw/aquastat/damsafrica/index.stm.

Dependency ratio (%)

Indicator expressing the percent of total renewable water resources originating outside the country. This indicator may theoretically vary between 0 percent and 100 percent. A country with a dependency ratio equal to 0 percent does not receive any water from neighbouring countries. A country with a dependency ratio equal to 100 percent receives all its renewable water from upstream countries, without producing any of its own. This indicator does not consider the possible allocation of water to downstream countries.

Depletion of renewable groundwater resources: rate (km^3/year)

Annual amount of water withdrawn from renewable aquifers which is not replenished (average overexploitation of aquifers). When the action is continuous, it is a form of overdraft of rechargeable aquifers or mining. Over a long period of time, there is a risk of depleting the aquifer when the abstraction exceeds the recharge.

Desalinated water produced (million m^3/year)

Water produced annually by desalination of brackish or salt water. It is estimated annually on the basis of the total capacity of water desalination installations.

Drained area in area equipped for irrigation (ha)

Irrigated area where drainage is used as an instrument to control salinity, pounding and waterlogging. This refers mainly to the area equipped for surface irrigation and to the equipped wetland and inland valley bottoms (the first part). Areas equipped for sprinkler irrigation and for localized irrigation do not really need a complete drainage system, except perhaps some small structures to evacuate the water in case of heavy rainfall. Flood recession cropping areas (the second part) are not considered as being drained. A distinction can be made between areas drained with surface drains (a system of drainage measures, such as natural or human-made drains meant to divert excess surface water away from an agricultural area in order to prevent inundation) and the area drained with subsurface drains (a human-made system that induces excess water and dissolved substances to flow through the soil to open wells, moles, pipe drains and/or open drains, from where it can be evacuated for final disposal).

Drained area in non-irrigated area (ha)

Area cultivated and not irrigated, where drainage is used to remove excess water from the land surface and/or the upper soil layer to make humid/wet land more productive. A distinction should be made between drainage in humid countries and drainage in semi-arid countries. In humid countries, it refers mainly to the areas which normally are flooded and where flood mitigation has taken place. A distinction could be made between ‘pumped’ drainage, ‘gravity’ drainage and ‘tidal’ drainage. In semi-arid countries, it refers to the area cultivated and not irrigated where drainage is used to remove excess water from the land surface and/or upper soil layer to make humid/wet land more productive.

Drained area: total (ha)

Sum of the drained portions of area equipped for irrigation and non-irrigated land area.

Exploitable water resources: regular renewable groundwater (km^3/year)
Average groundwater flow that is available 90 percent of the time, and economically/environmentally viable to extract.

Exploitable water resources: regular renewable surface water (km^3/year)
Annual average quantity of surface water that is available 90 percent of the time. In practice, it is equivalent to the low water flow of a river. It is the resource that is offered for withdrawal or diversion with a regular flow.

Exploitable water resources: irregular renewable surface water (km^3/year)
Irregular surface water resources are equivalent to the variable component of water resources (e.g. floods). It includes the seasonal and inter-annual variations, i.e. seasonal flow or flow during wet years. It is the flow that needs to be regulated.

Exploitable water resources: total (km^3/year)
Exploitable water resources (also called manageable water resources or water development potential) are considered to be available for development, taking into consideration factors such as: the economic and environmental feasibility of storing floodwater behind dams, extracting groundwater, the physical possibility of storing water that naturally flows out to the sea, and minimum flow requirements (navigation, environmental services, aquatic life, etc). Methods to assess exploitable water resources vary from country to country.

Flood-protected area (ha)
Area of land protected by flood control structures.

Flood recession cropping area: non-equipped but cultivated (ha)
Areas along rivers where cultivation occurs in the areas exposed as floods recede and where nothing is undertaken to retain the receding water. The special case of floating rice is included in this category.

Fossil groundwater: abstraction (km^3/year for a given period)
Annual amount abstracted from deep aquifers with a very low rate of renewal (less than 1 percent per year) so considered to be non-renewable or “fossil”.

Full/partial control irrigation: area equipped for localized irrigation (ha)
Localized irrigation is a system where the water is distributed under low pressure through a piped network, in a pre-determined pattern, and applied as a small discharge to each plant or adjacent to it. There are three main categories: drip irrigation (where drip emitters are used to apply water slowly to the soil surface), spray or micro-sprinkler irrigation (where water is sprayed to the soil near individual plants or trees) and bubbler irrigation (where a small stream is applied to flood small basins or the soil adjacent to individual trees).
The following other terms are also sometimes used to refer to localized irrigation: micro-irrigation, trickle irrigation, daily flow irrigation, drop-irrigation, sip irrigation, diurnal irrigation.

Full/partial control irrigation: area equipped for sprinkler irrigation (ha)
A sprinkler irrigation system consists of a pipe network, through which water moves under pressure before being delivered to the crop via sprinkler nozzles. The system basically simulates rainfall in that water is applied through overhead spraying. These systems are also known as overhead irrigation systems.

Full/partial control irrigation: area equipped for surface irrigation (ha)

Surface irrigation systems are based on the principle of moving water over the land by simple gravity in order to moisten the soil. They can be subdivided into furrow, borderstrip and basin irrigation (including submersion irrigation of rice). Manual irrigation using buckets or watering cans is also included. Surface irrigation does NOT refer to the method of transporting the water from the source up to the field, which may be done by gravity or by pumping.

Full/partial control irrigation: total area equipped (ha)

This is the sum of surface irrigation, sprinkler irrigation and localized irrigation. The text uses indifferently the expressions "full control" and "full/partial control".

Full/partial control irrigation: area equipped irrigated from groundwater (ha)

Portion of the full control irrigation area that is irrigated from wells (shallow wells and deep tube wells) or springs.

Full/partial control irrigation: area equipped irrigated from surface water (ha)

Portion of the full control irrigation area that is irrigated from rivers or lakes (reservoirs, pumping or diversion).

Full/partial control irrigation: area equipped irrigated from mixed and other sources of water (ha)

Portion of the full/partial control irrigation area that is irrigated from mixed surface water and groundwater or from non-conventional sources of water such as agricultural drainage water, treated wastewater or desalinated water.

Full/partial control irrigation schemes (ha)

Areas of irrigation schemes, usually classified as large, medium, and small schemes. Criteria used in this classification are given in the tables.

Gross Domestic Product (GDP)

GDP at purchaser's prices is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in current United States dollars (US$). Dollar figures for GDP are converted from domestic currencies using single year official exchange rates. For a few countries where the official exchange rate does not reflect the rate effectively applied to actual foreign exchange transactions, an alternative conversion factor is used. Figures provided by the World Development Indicators (WDI), the World Bank's premier annual compilation of data about development (http://devdata.worldbank.org/data-query/).

Harvested irrigated crop area (ha)

Total harvested irrigated crop area. It refers to the crops grown under full control irrigation. Areas under double irrigated cropping (same area cultivated and irrigated twice a year) are counted twice. Therefore the total area may be larger than the full/partial control equipped area, which gives an indication of the cropping intensity. The total is only given if information on all irrigated crops in the country is available.

Households in irrigation

Total number of households living directly on earnings from fully or partially controlled irrigation schemes.

Human Development Index (HDI)

This is a summary measure of human development. It measures the average achievements in a country in three basic dimensions of human development: (1) a long and healthy life, as measured by life expectancy at birth; (2) knowledge, as measured by the adult literacy rate (with two-thirds weight) and the combined primary, secondary and tertiary gross enrolment ratio (with one-third weight); (3) a decent standard of living, as measured by GDP per capita (Purchasing Power Parity or PPP US$). Figures provided by UNDP (http://hdr.undp.org/en/statistics/indices/hdi/).

Irrigated grain production: total (t)

The total quantity of cereals harvested annually in the irrigated area. Several harvests per year on the same area are counted several times.

Irrigation: total area (ha)

See *Area equipped for irrigation: total (ha).*

Irrigation potential (ha)

Area of land which is potentially irrigable. Country/regional studies assess this value according to different methods. For example, some consider only land resources, others consider land resources plus water availability, others include economical aspects in their assessments (such as distance and/or difference in elevation between the suitable land and the available water) or environmental aspects, etc. If available, this information is given in the individual country profiles. The figure includes the area already under agricultural water management.

Lowland areas: area equipped for irrigation (ha)

The land equipped for irrigation in lowland areas includes:

i. cultivated wetland and inland valley bottoms (IVB) that have been equipped with water control structures for irrigation and drainage (intake, canals, etc.);
ii. areas along rivers where cultivation occurs making use of structures built to retain receding flood water;
iii. developed mangroves and equipped delta areas.

Permanent crops (ha)

Crops are divided into temporary and permanent crops. Permanent crops are sown or planted once and then occupy the land for some years and do not need to be replanted after each annual harvest, such as cocoa, coffee and rubber. This category includes flowering shrubs, fruit trees, nut trees and vines, but excludes trees grown for wood or timber.

Precipitation in depth: average (mm/year)

Long-term average (over space and time) of annual endogenous precipitation (produced in the country) in depth.

Precipitation in volume: average (km³/year)

Long-term average (over space and time) of annual endogenous precipitation (produced in the country) in volume.

Population: economically active population (inhabitants)

The number of all employed and unemployed persons (including those seeking work for the first time). It covers employers; self-employed workers; salaried employees; wage earners; unpaid workers assisting in a family or farm or business operation; members of producers' cooperatives; and members of the armed forces. The economically active population is also called the labour force.

Population: economically active population in agriculture (inhabitants)

Part of the economically active population engaged in or seeking work in agriculture, hunting, fishing or forestry (agricultural labour force). The economically active population refers to the number of all employed and unemployed persons (including those seeking work for the first time). It covers employers, self-employed workers, salaried employees, wage earners, unpaid workers assisting in a family or farm or business operation, members of producers' cooperatives, and members of the armed forces. The economically active population is also called the labour force.

Population: total (inhabitants)

According to the FAO definition, the total population usually refers to the present-in-area (de facto) population, which includes all persons physically present within the present geographical boundaries of countries at the mid-point of the reference period.

Population: urban, rural (inhabitants)

Usually the urban area is defined and the remainder of the total population is defined as rural. In practice, the criteria adopted for distinguishing between urban and rural areas vary from country to country. However, these criteria can be roughly divided into three major groups: classification of localities of a certain size as urban; classification of administrative centres of minor civil divisions as urban; and classification of centres of minor civil divisions on a chosen criterion which may include type of local government, number of inhabitants or proportion of population engaged in agriculture. Thus, the urban and rural population estimates in this domain are based on the varying national definitions of urban areas.

Population affected by water-related diseases (inhabitants)

Three types of water-related diseases exist:

i. water-borne diseases are those diseases that arise from infected water and are transmitted when the water is used for drinking or cooking (for example cholera, typhoid);
ii. water-based diseases are those in which water provides the habitant for host organisms of parasites ingested (for example shistomasomiasis or bilharzia);
iii. water-related insect vector diseases are those in which insect vectors rely on water as habitat but transmission is not through direct contact with water (for example malaria, onchocerciasis or river blindness, elephantiasis).

Power irrigated area as percentage of total area equipped for irrigated (%)

Percent of irrigation area where pumps are used for water supply from the source to the scheme, expressed in percentage. It includes also areas where water is drained out with human- or animal-driven water lifting devices.

Renewable water resources: internal (km^3/year)

Internal Renewable Water Resources (IRWR): long-term average annual flow of rivers and recharge of aquifers generated from endogenous precipitation. Double counting of surface water and groundwater resources is avoided by deducting the overlap from the sum of the surface water and groundwater resources.

Renewable water resources: external (km³/year)

External Renewable Water Resources (ERWR) are that part of the country's renewable water resources that are not generated within the country. They include inflows from upstream countries (groundwater and surface water), and part of the water of border lakes or rivers.

Renewable water resources: total natural (km³/year)

Total Natural Renewable Water Resources (TRWR_natural): the long-term average sum of internal renewable water resources (IRWR) and external natural renewable water resources (ERWR_natural). It corresponds to the maximum theoretical yearly amount of water actually available for a country at a given moment.

Renewable water resources: total actual (km³/year)

Total Actual Renewable Water Resources (TRWR_actual): the sum of internal renewable water resources (IRWR) and external actual renewable water resources (ERWR_actual). It corresponds to the maximum theoretical yearly amount of water actually available for a country at a given moment.

Return flow

That part of the water used for agricultural, domestic or industrial purposes which is returned to rivers or aquifers after use.

Safe yield of water systems (million m³)

Amount of water (in general, the long term average amount) which can be withdrawn from the groundwater basin or surface water system without causing undesirable results. This concept concerns mostly groundwater (flow extractable without over exploitation). For the rivers, it is more common to speak of reserved flow (reservation constraint for the environment).

Salinized area by irrigation (ha)

Irrigated area affected by salinization, including formerly irrigated land abandoned because of declining productivity caused by salinization. It does not include naturally saline areas. In general, each country has its own definition of salinized area.

Soil and water conservation

A combination of in-situ water conservation and soil conservation measures. Soil conservation measures comprise any set of measures intended to control or prevent soil erosion or to maintain fertility. Water conservation includes the usage of berms or bunds to slow or stop the migration of surface water.

Spate irrigation: equipped area for irrigation (ha)

Spate irrigation, also sometimes referred to as floodwater harvesting, is a method of informal irrigation using the floodwaters of a normally dry water course or riverbed (wadi). These systems are in general characterized by a very large catchment upstream (2 005 000 ha) with a ratio of "catchment area: cultivated area" = between 100:1 10 000:1. There are two types of spate irrigation:

1. floodwater harvesting within streambeds, where turbulent channel flow is collected and spread through the wadi where the crops are planted; cross-wadi dams are constructed with stones, earth, or both, often reinforced with gabions;
2. floodwater diversion, where the floods or spates from the seasonal rivers are diverted into adjacent embanked fields for direct application. A stone or

concrete structure raises the water level within the wadi to be diverted to the nearby cropping areas.

Temporary crops (ha)

See *Annual crops.*

Wastewater: produced volume (km^3/year)

Annual quantity of wastewater generated in the country, in other words, the quantity of water that has been polluted by adding waste. The origin can be domestic use (used water from bathing, sanitation, cooking, etc.) or industrial wastewater routed to the wastewater treatment plant. It does not include agricultural drainage water, which is the water withdrawn for agriculture but not consumed and returned to the system.

Wastewater: treated volume (km^3/year)

Quantity of generated wastewater that is treated in a given year and discharged from treatment plants (effluent). Wastewater treatment is the process to render wastewater fit to meet applicable environmental standards for discharge. Three broad phases of traditional treatment can be distinguished: primary, secondary and tertiary treatment. Discharge standards vary significantly from country to country, and therefore so do the phases of treatment. For the purpose of calculating the total amount of treated wastewater, volumes and loads reported should be shown only under the “highest” type of treatment to which it is subjected.

Wastewater: treated reused (million m^3/year)

Quantity of treated wastewater which is reused in a given year. Wastewater treatment is the process to render wastewater fit to meet applicable environmental standards for recycling or reuse.

Water harvesting area (ha)

Areas where rainwater is collected and either directly applied to the cropped area and stored in the soil profile for immediate uptake by the crop (runoff irrigation) or stored in a water reservoir for future productive use (for example used for supplementary irrigation). Rainwater harvesting includes:

i. roof water harvesting is mainly used for domestic purposes and sometimes as water supply for family gardens;
ii. micro-catchment water harvesting is characterized by a relatively small catchment area C (< 1 000 m^2) and cropping area CA (< 100 m^2) with ratio C:CA = 1:1 to 10:1. The farmer usually has control over both the catchment area and the target area. These systems are used for the irrigation of a single tree, fodder shrubs or annual crops. The construction is mainly manual. Examples are pits, semi-circular bunds, Negarim micro-catchment, eyebrow terrace, contour bench terrace, etc.;
iii. macro-catchment water harvesting collects water that flows over the ground as turbulent runoff and channel flow.

These systems are characterized by a large catchment area C (‘external’ catchment area of 1 000 m^2 200 ha), located outside the cultivated area CA, with a ratio C:CA = 10:1 to 100:1. The systems are mainly implemented for the production of annual crops. The construction is manual or mechanized. Examples are trapezoidal bunds, large semi-circular bunds, stone bunds, etc.

Water managed area (ha)

See *Area under agricultural water management.*

Water withdrawal for agriculture (million m^3/year)

Annual quantity of water withdrawn for irrigation and livestock purposes. It includes renewable freshwater resources as well as potential over-abstraction of renewable groundwater or withdrawal of fossil groundwater, use of agricultural drainage water, desalinated water and treated wastewater. It includes water withdrawn for irrigation purposes and for livestock watering, although depending on the country this last category sometimes is included in domestic water withdrawal. As far as the water withdrawn for irrigation is concerned, the value far exceeds the consumptive use of irrigation because of water lost in distribution from its source to the crops. The term “water requirement ratio” (sometimes also called “irrigation efficiency”) is used to indicate the ratio between the net irrigation water requirements or crop water requirements, which is the volume of water needed to compensate for the deficit between potential evapotranspiration and effective precipitation over the growing period of the crop, and the amount of water withdrawn for irrigation including the losses. In the specific case of paddy rice irrigation, additional water is needed for flooding to facilitate land preparation and for plant protection. In that case, irrigation water requirements are the sum of rainfall deficit and the water needed to flood paddy fields. At scheme level, water requirement ratio values can vary from less than 20 percent to more than 95 percent. As far as livestock watering is concerned, the ratio between net consumptive use and water withdrawn is estimated at between 60 percent and 90 percent. By default, livestock water use is accounted for in agricultural water use. However, some countries include it in domestic water withdrawal.

Water withdrawal for livestock (million m^3/year)

Some countries include this in domestic water withdrawal, others in agricultural water withdrawal.

Water withdrawal for municipal or domestic use (million m^3/year)

Annual quantity of water withdrawn for municipal or domestic purposes. It includes renewable freshwater resources as well as potential over-abstraction of renewable groundwater or withdrawal of fossil groundwater and the potential use of desalinated water or treated wastewater. It is usually computed as the total water withdrawn by the public distribution network. It can include that part of the industries which is connected to the domestic network. The ratio between the net consumption and the water withdrawn can vary from 5 to 15 percent in urban areas and from 10 to 50 percent in rural areas.

Water withdrawal for industry (million m^3/year)

Annual quantity of water withdrawn for industrial uses. It includes renewable water resources as well as potential over-abstraction of renewable groundwater or withdrawal of fossil groundwater and potential use of desalinated water or treated wastewater. Usually, this sector refers to self-supplied industries not connected to any distribution network. The ratio between net consumption and withdrawal is estimated at less than 5 percent.

Water withdrawal: total (million m^3/year)

Annual quantity of freshwater withdrawn for agricultural, industrial and domestic purposes. It includes renewable freshwater resources as well as potential over-abstraction of renewable groundwater or withdrawal of fossil groundwater and eventual use of desalinated water or treated wastewater. It does not include other categories of water use, such as for cooling of power plants, mining, recreation, navigation, fisheries, etc., which are sectors that are characterized by a very low net consumption rate.

Waterlogged area by irrigation (ha)

Part of the land that is waterlogged because of irrigation. Waterlogging is the state of land in which the water table is located at or near the surface, resulting in a decline in crop yields. Irrigation can contribute to the raising of the level of the aquifers. The non-saturated area of soils can become too small and the soils are over-saturated with water. If recharge to groundwater is greater than natural drainage, there is a need for additional drainage to avoid waterlogging.

Waterlogged area not irrigated (ha)

Part of the land in non-irrigated cultivated areas that is waterlogged. Waterlogging is the state of land in which the water table is located at or near the surface resulting in a decline of crop yields.

Wetlands and inland valley bottoms

Wetland and inland valley bottoms (IVB) that have not been equipped with water control structures but are used for cropping. They are often found in Africa. They will have limited (mostly traditional) arrangements to regulate water and control drainage.

Section II

Regional analysis

Composition of the Middle East region

The Middle East region has been grouped into four subregions, based on geographical and climatic homogeneity, which has a direct influence on irrigation. These subregions (Figure 8) and the countries and territories they include are:

- **Arabian Peninsula**: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates, Yemen.
- **Caucasus**: Armenia, Azerbaijan, Georgia.
- **Islamic Republic of Iran.**
- **Near East**: Iraq, Israel, Jordan, Lebanon, Occupied Palestinian Territory, Syrian Arab Republic, Turkey.

The Arabian Peninsula and the Caucasus are identical to the subregions with these names in the previous reports, *Irrigation in the Near East Region in figures* (FAO, 1997) and *Irrigation in the countries of the Former Soviet Union in figures* (FAO, 1997) respectively, which allows for comparison with the earlier data. The Islamic Republic of Iran is considered separately because it has not a clear geographical, climatic or hydrologic homogeneity with any of the other three subregions. The Near East subregion in this report is similar but not identical to the Middle East subregion included in the previous report *Irrigation in the Near East Region in figures* (FAO, 1997): Cyprus and Malta have been removed from this subregion, while Israel and the Occupied Palestinian Territory (including the West Bank and Gaza Strip) have been added.

This regional overview presents distinguishing features arising from the new data collected on a national scale for issues addressed in the country profiles. The interest of this new survey lies in the updating of data and in the trends during the last ten years.

Geography, climate and population

The total area of the Middle East region is 6.56 million km², or almost 5 percent of the world's emerged landmass (Table 1, Table 42, Table 52). Out of the total of 18 countries, the three largest (Saudi Arabia, Islamic Republic of Iran and Turkey, in decreasing order) represent 71 percent of this territory, while the smallest seven (Bahrain, Occupied Palestinian Territory, Lebanon, Qatar, Kuwait, Israel and Armenia) constitute barely 1.5 percent. The cultivated area is estimated at 64 million ha, or 39 percent of the cultivable land in the region. This percentage is lowest in the Arabian Peninsula, where the cultivated area is only 5 percent of the cultivable land and where cultivation almost entirely depends on irrigation, whereas in the Near East subregion the cultivated area represents 84 percent of the cultivable area (Table 1).

Average annual rainfall, estimated at 238 mm for the region, varies from less than 100 mm in parts of the Arabian Peninsula to over 1 000 mm in Georgia in the Caucasus (Figure 9).

Total population was estimated at 283 million inhabitants in 2005, representing about 4.4 percent of the world's population (Table 2, Table 43, Table 52). Turkey and the Islamic Republic of Iran are the most populous countries, containing together over half of the population of the Middle East region (Table 43 and Figure 1). The part of the population living in rural areas in the region (34 percent) is below the world average (51 percent), due to the low rural population in most of the countries of the region, especially in the Arabian Peninsula. In Bahrain, Israel, Kuwait, Lebanon, Qatar, Saudi Arabia and the United Arab Emirates, rural population accounts for less than 15 percent of the total. In the most populated countries, Turkey and the Islamic Republic of Iran, rural population represents one-third of the total population, in the Caucasus and the Syrian Arab Republic it is almost half and in Yemen almost three-

TABLE 1
Regional distribution of cultivable and cultivated areas

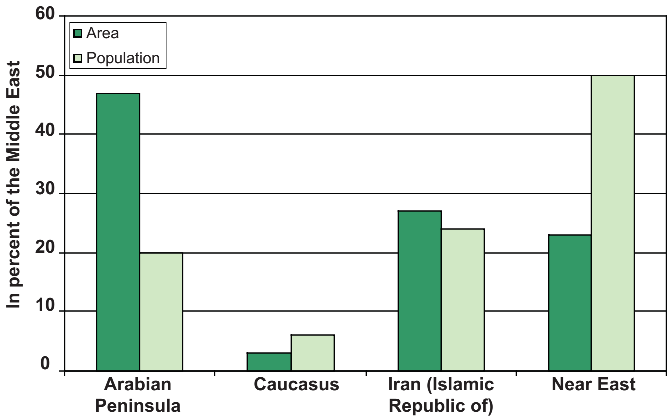
Subregion	Total area (ha)	Cultivable areas (ha)	Cultivated areas (around 2005)	
			Area (ha)	In % of cultivable areas (%)
Arabian Peninsula	310 029 000	58 967 029	2 733 849	5
Caucasus	18 610 000	8 697 733	3 685 700	42
Iran (Islamic Republic of)	174 515 000	51 000 000	18 107 000	36
Near East	153 303 000	47 304 400	39 570 000	84
Total region	**656 457 000**	**165 969 162**	**64 096 549**	**39**

TABLE 2
Regional distribution of area and of population

Subregion	Area		Population 2005					
	km²	% of Middle East	Population (millions)	% of Middle East	% living in rural areas	Population density (inhab./km²)	Economically active population as % of total	% economically active population in agriculture
Arabian Peninsula	3 100 290	47	56.8	20	35	18	38	19
Caucasus	186 100	3	15.9	6	47	85	39	25
Iran (Islamic Republic of)	1 745 150	27	69.5	24	32	40	40	24
Near East	1 533 030	23	140.8	50	33	92	41	31
Total region	**6 564 570**	**100**	**283.0**	**100**	**34**	**43**	**40**	**27**

FIGURE 1

Regional distribution of areas and population



quarters. The average population density of 43 inhabitants/km² conceals wide variations (Figure 10). The four most densely populated countries are Bahrain, Occupied Palestinian Territory, Lebanon and Israel, with 1 024, 615, 344 and 324 inhabitants/km², respectively (Table 43). On the other hand, most countries of the Arabian Peninsula are not very densely populated (18 inhabitants/km² on average), especially Oman and Saudi Arabia, which only have 8 and 11 inhabitants/km² respectively. In 2006, almost 10 percent of the total population of the Middle East region had no access to safe drinking water. In the same year, average life expectancy was 71 years.

ARABIAN PENINSULA

The Arabian Peninsula, consisting of Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates and Yemen, covers an area of about 3.1 million km², or 47 percent of the Middle East region (Table 2). Saudi Arabia covers almost 70 percent of the area of this subregion. Each of the countries in the Arabian Peninsula has access to the sea. Out of a total cultivable area of 59 million ha, only 2.7 million ha are cultivated, or 5 percent of the potential. The main reason for this low percentage is lack of water for irrigation. The subregion is bordered to the north by Jordan and Iraq, to the east by the Persian Gulf and the Gulf of Oman, to the south by the Arabian Sea and the Gulf of Aden, and to the west by the Red Sea and Egypt. The climate is dry with very limited water resources. Annual average precipitation in the region reaches only 117 mm, ranging from 62 mm in Oman to 121 mm in Kuwait and 167 in Yemen, which allows no cultivation without irrigation in all countries except in Yemen where rainfed production is possible in the highlands.

The population of the Arabian Peninsula was 57 million in 2005, of which 80 percent lives in Saudi Arabia and Yemen (Table 43). About 35 percent of the population lives in rural areas (Table 2). The average population density in the subregion, 18 inhabitants/km², is lower than the average density of the Middle East region as a whole, which is 43 inhabitants/km². The population is concentrated mainly on the coasts, where density can reach 1 024 inhabitants/km², as in Bahrain, while the desert is practically uninhabited (Figure 10). The overall annual population growth of 3.2 percent in the period 1995–2005 and 3.9 percent in the previous decade (1985–1995) is extremely high, mostly because of immigrant labourers.

CAUCASUS

The Caucasus covers three countries, Armenia, Azerbaijan and Georgia, and is located in the north of the Middle East region, between the Black Sea in the west and the Caspian Sea in the east. It is situated at the southern foothills of the Greater Caucasus mountain range, which is considered the boundary between Europe and Asia. The highest peak in the region stands at about 5 000 m above sea level. Large areas around the Black Sea, the Caspian Sea and the river deltas are lowlands. The total area of the Caucasus is 0.2 million km², or only 3 percent of the total area of the Middle East region (Table 2). Azerbaijan, bordering the Caspian Sea, represents about 50 percent of this territory (Table 42). Georgia, bordering the Black Sea, represents about 34 percent. Armenia, finally, covers only 16 percent and is landlocked. The cultivable area is 8.7 million ha, 50 percent of which is in Azerbaijan, and in 2005 about 3.7 million ha was cultivated, or almost 42 percent of the cultivable area. The climate varies from typical dry continental, with average summer temperatures up to 27 ºC, to warm, humid, subtropical in the northwest near the Black Sea coast, with average temperature of 22 ºC in summer and 5 ºC in winter. Average annual precipitation is 702 mm, varying from 200 mm in the Ararat valley in central Armenia to 1 700 mm in western Georgia. In the southern and eastern parts of this region irrigation is necessary, but drainage is also required in larges areas to reduce irrigation-induced salinization.

In 2005 about 16 million people lived in the Caucasus, which is equal to a density of 85 inhabitants/km^2 (Table 2). National average densities range from 64 inhabitants/km^2 in Georgia, to 101 inhabitants/km^2 in Armenia (Table 43). About 47 percent of this population is rural. Population in this subregion decreased by almost 0.1 percent per year in the period 1995–2005, Armenia accounting for 0.7 percent per year of the decrease, and Georgia for 1.2 percent. Only in Azerbaijan has the population increased in the last ten years, with a yearly growth rate of 0.8 percent.

ISLAMIC REPUBLIC OF IRAN

The Islamic Republic of Iran, located at the eastern part of the Middle East region, covers an area of 1.74 million km^2, which represents almost 27 percent of total area of the region. It is almost nine times the area of the Caucasus subregion and slightly less than the area of the entire Arabian Peninsula. It is bordered to the north by the Caucasus, the Caspian Sea and Turkmenistan, to the east by Afghanistan and Pakistan, to the south by the Gulf of Oman and the Persian Gulf, and to the west by Iraq and Turkey. The cultivable area is 51 million ha, of which about one-third was cultivated in 2005. Annual precipitation is 228 mm, varying from less than 50 mm in the desert to 2 275 mm near the Caspian Sea in the north.

Almost one-quarter of the total population of the Middle East region lives in the Islamic Republic of Iran, which has a density of almost 40 inhabitants/km^2. Almost one-third of the population is rural. Annual population growth was only 1.1 percent in the period 1995–2005.

NEAR EAST

The Near East subregion comprises seven countries and territories: Iraq, Israel, Jordan, Lebanon, Occupied Palestinian Territory, Syrian Arab Republic and Turkey. The total area is 1.5 million km^2, representing 23 percent of the total area of the Middle East (Table 2 and Table 42). Of the total cultivable area of 47 million ha, about 40 million ha were cultivated in 2005, which is 84 percent of the potential. The subregion is bordered to the north by the Black Sea and the Caucasus, to the east by the Islamic Republic of Iran, to the south by Kuwait and Saudi Arabia and to the west by Egypt and the Mediterranean Sea. The annual average precipitation is 440 mm, varying from 94 mm in Jordan to 823 mm in Lebanon.

The population in the Near East subregion was 141 million inhabitants in 2005, of which 52 percent live in Turkey (Table 43). Average density was estimated at 92 inhabitants/km^2, ranging from 64 inhabitants/km^2 in Jordan to 615 inhabitants/km^2 in the Occupied Palestinian Territory (Table 43). About one-third of the population is rural. Annual population growth ranges from barely 1.2 percent in Lebanon to 3.5 percent in the Occupied Palestinian Territory, with a regional average of 2.1 percent in the period 1995–2005.

Economy, agriculture and food security

The economy of the Middle East region is dominated by oil and in the Arabian Peninsula countries the gross domestic product (GDP) per capita is among the highest values of the world. On the other hand, conflicts between some of the countries have a negative effect on the stability of the region. The sum of national GDPs in 2007 amounted to US$1 978 470 million, which is 3.6 percent of world GDP. It corresponds to a GDP of about US$5 160/inhabitant, ranging from US$800/inhabitant in Yemen to more than US$52 000/inhabitant in Qatar. As far as the Human Development Index (HDI) is concerned (range = 0–1), the countries rank between the 23rd and the 108th place out of a total of 177 countries, except for Yemen which holds the 153rd place with a HDI of 0.508. Israel, with 0.932, has the highest HDI in the region. The HDI for Iraq is unknown.

In 2006, the added value of the primary sector (agriculture) contributed 6.3 percent to the GDP of the Middle East region. It ranged from 0.4 percent in Kuwait (2000) and 0.9 percent in Bahrain (2002), to 18.3 percent in the Syrian Arab Republic and 19.6 percent in Armenia. In most countries less than 25 percent of the economically active population is engaged in the farming sector (Table 2 and Table 43). Oman (32 percent), Turkey (43 percent) and Yemen (45 percent) are exceptions. Most Arabian Peninsula countries have less agriculture and more industries, especially oil, and services. In the Caucasus countries, since the end of the Soviet era a transformation process has occurred, with transition towards a market economy. In Armenia and Azerbaijan industry is the main sector, followed by services and agriculture, while in Georgia services is the most important sector, followed by industry and agriculture. The Near East is the subregion with more economically active people involved in agriculture. Turkey is responsible for this higher percentage of active agricultural workers. The cultivated area per person economically active in agriculture varies from a low 0.2 ha/person in Oman and 0.4 ha/person in Yemen and Qatar to over 6 ha/person in Israel and more than 9 ha/person in Iraq and Lebanon, giving an average for the region of 2.1 ha/person.

Water resources

One of the problems encountered during this update is the confusion between "water resources" and "water supply sources" when information is provided. This report concentrates on "water resources" rather than "water supply sources":

Water resources are natural potential; they are *state variables* indicating the state of the resources, with conjunctural variations, that are renewable and stable (except in the case of climate change) or non-renewable.

Water supply sources give information on the origin of water withdrawn or produced for use. They are *decision variables*, with an underlying evolution, that are subject to an inventory, coherent with statistics on "water use", with the reference date to be specified.

RENEWABLE WATER RESOURCES

The volume of annual precipitation in the Middle East region is estimated at about 1 564 km^3, equal to a regional average of 238 mm/year, but with significant disparities between countries (Table 3 and Figure 9). The driest country is Oman with 62 mm/year on average, followed by the other countries of the Arabian Peninsula, which is the driest subregion in the Middle East with an average of 117 mm/year. Jordan in the Near East subregion also has a low average annual precipitation, below 100 mm, while Lebanon is the rainiest country with 823 mm, followed by Turkey with 643 mm. The Caucasus countries receive an average precipitation of 702 mm/year with Georgia having about 1 065 mm. Average annual precipitation in the Islamic Republic of Iran is 228 mm.

While the Middle East region covers 4.9 percent of the total area of the world and contains 4.4 percent of its population, its water resources, which total 484 km^3, are only about 1.1 percent of the total renewable water resources of the world (Table 52 and Figure 11). Moreover, large differences exist between the 19 countries and territories, as shown in Table 44.

Turkey accounts for 47 percent of Middle East region's resources on only 12 percent of the region's area, following the Islamic Republic of Iran, which accounts for 27 percent (Figure 2). On the other hand, the Arabian Peninsula is the most disadvantaged subregion with only 1 percent of the renewable water resources for an area equivalent to 47 percent of the Middle East. Kuwait has no internal renewable water resources. In the Arabian Peninsular, with the exception of land serviced by spate irrigation, all irrigated production is reliant upon groundwater pumping and associated 'quanats'.

TABLE 3
Regional distribution of the water resources

Subregion	Annual precipitation		Annual internal renewable water resources		
	Height	Volume	Volume	% of the Middle East	Per inhabitant (2005)
	(mm)	(million m^3)	(million m^3)	(%)	(m^3)
Arabian Peninsula	117	362 041	6 110	1	108
Caucasus	702	130 582	73 104	15	4 597
Iran (Islamic Republic of)	228	397 894	128 500	27	1 849
Near East	439	673 531	276 376	57	1 964
Total Region	**238**	**1 564 048**	**484 090**	**100**	**1 711**

FIGURE 2
Regional distribution of area and water resources

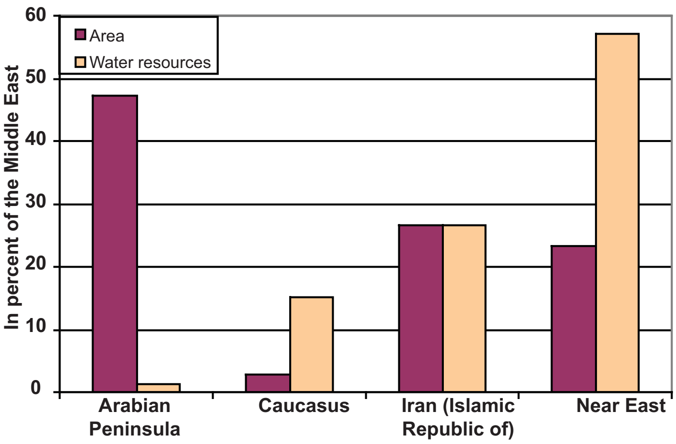


TABLE 4
Countries and territories with water resources of less than 500 m³/inhabitant per year

Country	Internal renewable water resources/ inhabitant/year		Total renewable water resources/ inhabitant/year	
	1995	2005	1995	2005
	(m³)			
Bahrain	7	6	206	160
Israel	140	112	331	265
Jordan	124	120	161	164
Kuwait	0	0	11	7
Occupied Palestinian Territory	310	219	320	226
Qatar	93	69	96	71
Saudi Arabia	134	98	134	98
Syrian Arab Republic	477	375	1 791	882
United Arab Emirates	79	33	79	33
Yemen	283	100	283	100

For the region as a whole, the renewable shallow groundwater circulation associated with alluvial deposits in wadis channels and extensive alluvial fans are important sources of water for potable water supply, stock watering and localized irrigation. The resources of these localized aquifer systems are dependant on indirect recharge from intermittent flows in watercourses. Other sources of renewable groundwater are also obtained from where outcrops of permeable limestones and sandstones accept direct recharge from rainfall. The distinction between direct and indirect recharge processes is important to make in any water resource accounting at basin or aquifer system level. Indirect recharge processes tend to dominate so that the frequency, magnitude and duration of runoff events are important indicators of groundwater resource recharge.

Due to population growth, there has been a decrease in average annual internal renewable water resources (IRWR) per inhabitant since the previous AQUASTAT survey. In 2005, the average per habitant IRWR was 1 717 m³ for the region, ranging from 0 m³ in Kuwait to 6 m³ in Bahrain and to 12 993 m³ for Georgia (Table 44). The distribution of total actual renewable water resources (TARWR) is different because of transboundary river basins, with values ranging from 7 m³ per inhabitant in Kuwait and 33 m³ in the United Arab Emirates to 14 155 m³ in Georgia (Figure 12).

Table 4 presents the IRWR and TARWR for ten countries and territories where resources per inhabitant are very limited. With respect to IRWR, their resources are lower than the cut-off point of 500 m³/inhabitant per year, considered to be the threshold for absolute water scarcity. With respect to TARWR, all except the Syrian Arab Republic remain below this threshold: Saudi Arabia, United Arab Emirates and Yemen do not benefit from any outside contributions (dependency ratio of zero); Qatar and the Occupied Palestinian Territory benefit only slightly (ratio lower than 10 percent); and Bahrain, Israel, Jordan and Kuwait have a high dependency ratio despite low external renewable resources. Only the Syrian Arab Republic has a relatively high proportion of external renewable resources, although it is still in a situation of chronic water scarcity (threshold 1 000 m³/inhabitant per year).

TRANSBOUNDARY WATERS

The main transboundary rivers in the Middle East region are the Euphrates–Tigris flowing to the Persian Gulf, the Kura–Araks flowing to the Caspian Sea, the Asi–

TABLE 5
The four most important transboundary river basins in the Middle East region

Basin	Area		Countries included	Area of country in basin (km²)	As percentage of total area of basin %
	km²	% of the Middle East			
Euphrates-Tigris	879 790	13.4	Iraq	407 880	46.4
			Turkey	192 190	21.8
			Iran (Islamic Republic of)	166 240	18.9
			Syrian Arab Republic	96 420	11.0
			Saudi Arabia	16 840	1.9
			Jordan	220	0.03
Kura-Araks	190 250	2.9	Azerbaijan	60 020	31.5
			Iran (Islamic Republic of)	37 080	19.5
			Georgia	34 560	18.2
			Armenia	29 800	15.7
			Turkey	28 790	15.1
Asi-Orontes	24 660	0.4	Syrian Arab Republic	16 910	68.6
			Turkey	5 710	23.1
			Lebanon	2 040	8.3
Jordan	18 500	0.3	Jordan	7 470	40.4
			Israel	6 830	36.9
			Syrian Arab Republic	1 910	10.3
			Occupied Palestinian Territory	1 620	8.8
			Lebanon	670	3.6
Total	**1 113 200**	**17.0**			

Orontes flowing to the Mediterranean Sea and the Jordan flowing to the Dead Sea. These four transboundary river basins cover 17 percent of the total area of the Middle East region (Table 5 and Figure 13).

Some major aquifers in the region can also be considered transboundary, the most notable being the Disi aquifer which straddles Jordan and Saudi Arabia.

A more detailed description of these four transboundary basins is given in the chapter entitled *Description of four transboundary river basins.*

WATER RESOURCES IN ENDOREIC BASINS

Generated by both the dominant aridity of the climate and structural geological conditions, an endhoreic basin, also called closed or interior basin, is a basin which has no outflow to the sea. This is a major characteristic of the hydrography of the Middle East region. The endhoreism in the Middle East region is either structural, in the case of completely closed basins surrounded by a continuous watershed line (such as exist in the Islamic Republic of Iran and Turkey, or the basin of the Dead Sea), or functional, in the case where the basins are theoretically exoreic or open but where the local outflow never reaches the sea (such as exist in Saudi Arabia or the United Arab Emirates) (Figure 14).

By definition, in the water balance of an endhoreic basin the rainfall is equal to the evapotranspiration and final runoff is equal to zero. However, superficial runoff and recharge of aquifers take place in part of the basin and can offer locally exploitable water resources. Estimation of those resources is based on the distinction in each endhoreic basin between an upstream “producing” zone, where water courses and aquifers have a runoff that significantly increases from upstream to downstream, and a downstream “consuming” zone, where runoff decreases from upstream to downstream and which can coincide with an evaporation area or an interior lake, such as the Dead Sea or Lake Van in Turkey. Determining the exact border between these two zones is very difficult, because it can be unstable. It is a matter of determining for each water course the point where the average natural discharge is maximal and taking measurements there. But the real discharges are often influenced, which complicates the evaluation. “Consuming” zones with decreasing runoff can be included in exoreic basins (basins having an outflow

TABLE 6
Average potential runoff in endorheic basins in the Middle East region

Endorheic basin	Country		Average potential runoff km³/year
Dead Sea:			
Yarmouk–Jordan	Israel, Jordan. Lebanon, Occupied Palestinian Territory, Syrian Arab Republic		1.5
Other	Israel, Occupied Palestinian Territory		0.1
Akarcay	Turkey*	0.5	7.9
Burdur		0.5	
Konya		4.5	
Van		2.4	
Barada–Awaj	Syrian Arab Republic	1.0	2.15
Alep		0.8	
El Badia–Hamad		0.35	
Markasi	Islamic Republic of Iran*	48.3	65.0
Hamoon		3.0	
Sarakhs		5.7	
Oroomieh		8.0	
Arabian Desert	Saudi Arabia	0.5	1.3
	Jordan	0.07	
	Oman	0.5	
	Yemen	0.2	
Total (rounded)			**78**

* Caspian basin excluded

to the sea), in arid or semi-arid zones, such as happens for example in the Euphrates–Tigris basin.

Table 6 shows natural renewable water resources (i.e. total runoff) of the endhoreic basins in the Middle East region, although a uniform estimation approach is not guaranteed.

NON-RENEWABLE GROUNDWATER AQUIFERS IN THE MIDDLE EAST REGION

Deep aquifer systems with significant stores of freshwater provide important sources of supply to municipal and agriculture uses. However, these large systems generally experience low rates of recharge (less than 1/100 or 1/1 000 of their stock in an average year). In many instances these groundwater resources are referred to as "fossil aquifers" since the bulk of the storage was emplaced during much wetter climatic periods. Dating of these waters indicates emplacement occurring between one thousand to several tens of thousand years before the present. These resources are particularly precious in arid and semi-arid zones and have been progressively depleted as pumping technology and energy availability has evolved. Non-renewable water resources can be defined as an economically recoverable 'stock', such as oil or minerals.

The Middle East region contains one of the most important multi-layered aquifer systems centred on the Arabian Peninsula and extending over an area of around 1.5 million km², mainly in Saudi Arabia and continuing into Jordan in the northwest and the Gulf countries in the east (Figure 15). Khater (2003) identifies three main sub-systems: (i) the Cambrian-Triassic Western Arabia sandstone aquifer system comprising the Saq, Tabuk, Wajid and Minjur aquifers; (ii) the Cretaceous Central Arabia sandstone aquifer system comprising the Biyadh and Wasia sandstones; (iii) the Tertiary Eastern Arabia carbonate aquifer system comprising the Umm er Radhuma and Dammanm aquifers together with later Neogene sands and limestones. This huge multilayer sedimentary basin (with a thickness up to 4 500 m) comprises several aquifers one above the other, from Cambrian ("Saq") in Jordan and north-western Saudi Arabia to the superficial Neogene aquifers along the eastern margin of Arabian peninsular. The combined stock is estimated to be in the order of 2 000 km³ and the actual replenishment around 1 km³/year. However, water quality throughout the system is variable with salinities ranging from an average of 1 000 ppm in the Saq to 150 000 ppm in parts of the Biyadh system. The whole multi-layered system has been extensively exploited for several decades, particularly following the introduction of deep submersible pumps: approximately 380 km³ are estimated to have been extracted in 25 years (between 1975 and 2000).

DAMS

The total dam capacity in the Middle East region is 870 km³. Turkey, Iraq and the Syrian Arab Republic contain more than 93 percent of the total dam capacity, most of it in the Euphrates–Tigris Basin. Turkey' accounts for 651 km³ (75 percent of the Middle

East) and Iraq accounts for 140 km^3 (16 percent of the Middle East). The Caucasus countries have 3 percent of the total dam capacity, of which 82 percent is located in Azerbaijan. The Arabian Peninsula countries have a small dam capacity, representing 0.2 percent only (Table 7). Twelve dams in the Middle East region have a capacity over 5 km^3, most of them in the Euphrates–Tigris basin, except the Mingechevir dam located in Azerbaijan in the Kura Basin and the Hirfanli and Atinkaya dams located in Turkey in the Black Sea Basin. In total these twelve large dams account for 234 km^3, or 27 percent of the total dam capacity in the Middle East region. The dam with the largest capacity is the Samarra–Tharthar (73 km^3) in Iraq, followed by the Ataturk dam (49 km^3) and the Keban dam (31 km^3), both in Turkey (Table 8).

TABLE 7
Regional distribution of dams

Subregion	Dam capacity	
	km^3	% of the Middle East
Arabian Peninsula	1.5	0.2
Caucasus	26.4	3.0
Iran (Islamic Republic of)	31.6	3.6
Near East	810.8	93.2
Total region	**870.3**	**100.0**

NON-CONVENTIONAL SOURCES OF WATER

The water scarcity that prevails in the region has forced and will continue to force national economies to find alternative ways to satisfy the demand for water. The reuse of treated wastewater and water desalination take place mainly in dry countries seeking to increase their limited sources of water. Some oil-rich countries convert a significant amount of saline water from the sea or from poor-quality aquifers (brackish water) into drinking water. Similarly, wastewater treatment and reuse is becoming a common practice in the Middle East region. Countries such as Armenia and Georgia have not yet developed non-conventional sources of water because they have enough renewable water resources.

Total treated wastewater reused in the Middle East region is 2 663 million m^3 (Table 9). On a subregional scale, the Near East subregion accounts for 72 percent of the total reused treated wastewater, the Arabian Peninsula for 22 percent and the Caucasus for 6 percent. Country-wise, Turkey accounts for 38 percent of the total reused treated wastewater of the Middle East region, followed by the Syrian Arab Republic, Israel and United Arab Emirates with 21, 10 and 9 percent respectively. Saudi Arabia and Azerbaijan each represent 6 percent of the total.

The total use of desalinated water in the Middle East region is estimated to be 3 225 million m^3/year. On a subregional scale, the Arabian Peninsula accounts for 87.4 percent

TABLE 8
Dams in the Middle East region with a capacity larger than 5 km^3

Dam	River	Basin	Capacity (km^3)	Surface area (km^2)	Main use*	Country
Samarra–Tharthar	Tigris	Tigris	72.8	2 170	F	Iraq
Ataturk	Fırat	Euphrates	48.7	817	I, H	Turkey
Keban	Fırat	Euphrates	31.0	675	H	Turkey
Mingechevir	Kura	Kura	15.7	605	I, H, F	Azerbaijan
Mosul	Tigris	Tigris	12.5	326	I	Iraq
Al Tabka	Euphrates	Euphrates	11.2	-	-	Syrian Arab Republic
Karakaya	Firat	Euphrates	9.6	268	H	Turkey
Haditha	Euphrates	Euphrates	8.2	500	I, H	Iraq
Dokan	Lesser Zab	Tigris	6.8	270	I	Iraq
Hirfanlı	Kızılırmak	Black Sea	6.0	263	H, F	Turkey
Altınkaya	Kızılırmak	Black Sea	5.8	118	H	Turkey
Karkheh	Karkheh	Karkheh	5.6	166	I, H, F	Iran (Islamic Republic of)
Total			**233.9**	**6 178**		

* I = irrigation; H = Hydropower, W = water supply; F = Flood protection

TABLE 9
Regional distribution of non-conventional sources of water and their uses

Subregion	Wastewater			Desalinated water	Reused agricultural drainage water
	Produced	Treated	Reused treated		
	million m³/year				
Arabian Peninsula	2 119	1 290	594	2 820	-
Caucasus	5 243	259	161	0	-
Iran (Islamic Republic of)	3 080	130	-	200	-
Near East	4 976	2 624	1 908	205	3 911
Total region	**15 418**	**4 303**	**2 663**	**3 225**	**3 911**

of the total desalinated water and the Near East subregion and the Islamic Republic of Iran for 6.4 percent and 6.2 percent respectively. The Caucasus has not started to produce desalinated water because its renewable resources are not as limited as in the Arabian Peninsula and the Near East countries. In absolute terms, three countries (Saudi Arabia, the United Arab Emirates and Kuwait) are by far the largest users of desalinated water, accounting for 77 percent of the region's total. Saudi Arabia uses an annual 1 033 million m^3 and United Arab Emirates and Kuwait 950 and 420 million m^3 respectively (Table 46 and Figure 16). The Occupied Palestinian Territory has not developed these techniques because of lack of economic resources; however reused treated wastewater in the Gaza Strip amounts to 10 million m^3.

Only three countries, Iraq, Lebanon and the Syrian Arab Republic, provide data about reused agricultural drainage water, which amounts to 1 500 million m^3, 165 million m^3 and 2 246 million m^3 respectively.

Water withdrawal

WATER WITHDRAWAL BY SECTOR

Data on water withdrawal by sector refer to the gross quantity of water withdrawn annually for a given use. Table 45 presents the distribution of water withdrawal by country for the three large water-consuming sectors: agriculture (irrigation and livestock watering), water supply (domestic/municipal use) and industry. Although able to mobilize a significant portion of water, requirements for energy purposes (hydroelectricity), navigation, fishing, mining, environment and leisure activities have a low rate of net water consumption. For this reason, they are not included in the calculation of the regional withdrawals but they do appear in the country profiles where information is available.

For most countries, the methods used for calculation or the measurements for obtaining the values of withdrawals are not specified.

Total annual water withdrawal for the Middle East region is 271.5 km^3, which is around 7 percent of world withdrawals (Table 10 and Table 52). About 84 percent of inventoried withdrawals are by agriculture, which is higher than the value for global agricultural water withdrawal (70 percent). However, this figure varies by country. In the Syrian Arab Republic, Saudi Arabia, Oman, Yemen and the Islamic Republic of Iran, agricultural withdrawal accounts for more than 85 percent of the total water withdrawal, while in Bahrain, Occupied Palestinian Territory, Kuwait, Israel and Qatar it represents less than 60 percent. The Caucasus countries use 73 percent of their withdrawal for agriculture. The annual precipitation in this subregion allows rainfed agriculture, which is not feasible in dry countries, such as most of the Arabian Peninsula.

The Islamic Republic of Iran, Iraq and Turkey cover the highest withdrawals in the Middle East region, accounting for 34 percent, 24 percent and 15 percent respectively. Saudi Arabia is the country with the highest withdrawals in the Arabian Peninsula at 9 percent of the total withdrawals in the Middle East. These four countries have both the highest area under irrigation and the highest population. Azerbaijan accounts for 73 percent of the total withdrawal in the Caucasus (Table 45). Water withdrawal per inhabitant is 963 m^3/year, but this average conceals significant variations between countries. The figure ranges from 113 m^3/inhabitant in the Occupied Palestinian Territory to 1 452 m^3/inhabitant in Azerbaijan and 2 632 m^3/inhabitant in Iraq. In the Arabian Peninsula, Saudi Arabia and United Arab Emirates account for the highest annual per capita withdrawal with 963 and 889 m^3/inhabitant respectively (Figure 17).

TABLE 10
Regional distribution of water withdrawal by sector

Subregion	Annual withdrawal by sector									
	Agriculture		Municipalities			Industry		Total		
	million m^3	% of total	million m^3	% of total	m^3 per capita	million m^3	% of total	million m^3	% of Middle East	m^3 per capita
Arabian Peninsula	29 279	86	3 905	11	69	915	3	34 100	13	600
Caucasus	12 244	73	1 722	10	108	2 693	16	16 659	6	1 048
Iran (Islamic Republic of)	86 000	92	6 200	7	89	1 100	1	93 300	34	1 342
Near East	98 978	78	13 509	11	96	14 925	12	127 413	47	905
Total region	**226 501**	**84**	**25 337**	**9**	**90**	**19 633**	**7**	**271 472**	**100**	**963**

Municipal water withdrawal per inhabitant is 90 m³/year for the Middle East region as a whole, with variations between countries from 13 m³/inhabitant in Yemen to 51 m³/inhabitant in Jordan, 245 m³/inhabitant in Bahrain and 280 m³/inhabitant in Armenia. Industrial water withdrawal per inhabitant is 70 m³/year for the Middle East on average. However, this figure also varies considerably at country level. In seven countries it amounts to less than 10 m³/inhabitant per year, especially Yemen, where industrial water withdrawal is 3 m³/inhabitant per year, whereas in Azerbaijan and Iraq the figures are 280 and 337 m³/inhabitant per year respectively.

WATER WITHDRAWAL BY SOURCE

Data on water withdrawal by source refer to the gross quantity of water withdrawn annually from all the possible sources, which are divided into freshwater resources and non-conventional sources of water. Table 11 presents the distribution of water withdrawal by subregion, distinguishing between freshwater (surface water and groundwater), desalinated water, reused treated wastewater and reused agricultural drainage water.

For most countries, the methods used for calculation or the measurements for obtaining the values of the withdrawal by source are not specified. For the countries for which recent data were not available or were not reliable, estimations that take into account total water withdrawal by sector have been used, given that total water withdrawal by source and total water withdrawal by sector must be equal.

Total annual water withdrawal by source is 271.5 km³ for the Middle East region (Table 11). Freshwater accounts for 96.4 percent of total water withdrawal, reused agricultural drainage water for 1.4 percent, desalinated water for 1.2 percent and reused treated wastewater for 1.0 percent. Considering the 14 countries for which data on surface water and groundwater withdrawal is available, surface water withdrawal represents 48 percent of the freshwater withdrawal and groundwater 52 percent in the region. In the Arabian Peninsula, groundwater is the largest source of freshwater withdrawal, amounting to 84 percent of the total, while in the Caucasus countries surface water accounts for 87 percent of the total freshwater withdrawal. Turkey's surface water withdrawal represents 73 percent of the total freshwater withdrawal, whereas in Iran and Jordan groundwater withdrawal accounts for almost 60 percent (Table 46). The Arabian Peninsula countries are the most advanced regarding non-

TABLE 11
Regional distribution of water withdrawal by source

Subregion	Annual withdrawal by source										
	Freshwater*				Non-conventional source of water						Total water withdrawal
	Surface water	Ground-water	Total		Desalinated water		Reused treated wastewater		Reused** agricultural drainage water		
	million m³	million m³	million m³	% of total	million m³	% of total	million m³	% of total	million m³	% of total	million m³
Arabian Peninsula	2 087	28 718	30 701	90.0	2 805	8.2	594	1.8	-	0.0	34 100
Caucasus	14 021	1 867	16 498	99.0	0	0.0	161	1.0	-	0.0	16 659
Iran (Islamic Republic of)	40 000	53 100	93 100	99.8	200	0.2	-	0.0	-	0.0	93 300
Near East*/**	-	-	121 389	95.3	205	0.2	1 907	1.5	3 911	3.0	127 413
Total region	**-**	**-**	**261 688**	**96.4**	**3 210**	**1.2**	**2 663**	**1.0**	**3 911**	**1.4**	**271 472**

* In the Near East subregion the distribution between surface water and groundwater withdrawal is known only for three out of the seven countries: Jordan, Lebanon and Turkey, which respectively withdrew 294 million m³, 396 million m³ and 31 500 million m³ of surface water and 553 million m³, 700 million m³ and 10 500 million m³ of groundwater.

** Only three countries in the Middle East, all in the Near East subregion, provided data on reused agricultural drainage water: Iraq, Lebanon and the Syrian Arab Republic, which reported 1 500 million m³ , 165 million m³ and 2 246 million m³ respectively.

conventional sources of water: desalinated water represents 8 percent and reused treated wastewater 2 percent of the total water withdrawal. Saudi Arabia and United Arab Emirates account for 32 percent and 29 percent respectively of the use of desalinated water in the Middle East region. In the Caucasus countries there is no desalinated water and reused treated wastewater represents only 1 percent on average. Turkey, the Syrian Arab Republic and Israel register the largest reuse of treated wastewater in the Middle East region with 38, 21 and 10 percent respectively (Figure 16). In the Syrian Arab Republic reused agricultural drainage water amounts to 2 246 million m^3.

THE WATER INDICATOR OF THE MILLENNIUM DEVELOPMENT GOALS

The Millennium Development Goal (MDG) water indicator, which is the total freshwater withdrawal as a percentage of total renewable freshwater resources, reflects the overall anthropogenic pressure on freshwater resources. In many areas, water use is unsustainable: withdrawal exceeds recharge rates and the water bodies are overexploited. The depletion of water resources can have a negative impact on aquatic ecosystems and, at the same time, undermine the basis for socio-economic development.

When relating freshwater withdrawal to the renewable water resources in the Middle East region, the Arabian Peninsula stands out with values over 100 percent in all the countries, except Oman, indicating that more water is withdrawn than the quantity annually renewed on a long-term basis, thus depleting the freshwater resources and using fossil groundwater. At country level, Kuwait has by far the highest water indicator, 2 075 percent, meaning that large use is made of fossil groundwater (Table 12 and Table 46). The United Arab Emirates and Saudi Arabia follow, with 1 867 percent and 936 percent respectively. In contrast, freshwater withdrawal in Oman represents 84 percent of renewable water resources (Figure 18).

TABLE 12
MDG* Water Indicator by country

Country	Freshwater withdrawal	Total actual renewable freshwater resources	MDG Water Indicator
	Total	TARWR**	Total freshwater withdrawal as percentage of TARWR
	million m^3	million m^3	%
Armenia	2 827	7 769	36
Azerbaijan	12 050	34 675	35
Bahrain	239	116	206
Georgia	1 621	63 330	3
Iran	93 100	137 515	68
Iraq	64 493	75 610	85
Israel	1 552	1 780	87
Jordan	848	937	90
Kuwait	415	20	2 075
Lebanon	1 096	4 503	24
Occupied Palestinian Territory	408	837	49
Gaza Strip	123	71	173
West Bank	157	766	21
Oman	1 175	1 400	84
Qatar	221	58	381
Saudi Arabia	22 467	2 400	936
Syrian Arab Republic	13 894	16 797	83
Turkey	39 100	213 562	18
United Arab Emirates	2 800	150	1 867
Yemen	3 384	2 100	161

* MDG - Millennium Development Goals
** TARWR – Total Actual Renewable Water Resources

TABLE 13
Evaporation losses from artificial reservoirs

Country	(Large) Dam capacity (km^3)	Reservoir surface area (km^2)	Evaporation of open water body (mm/year)	Evaporation losses from reservoirs (km^3/year)
Armenia	1.4	112	620	0.07
Azerbaijan	21.5	979	690	0.68
Georgia	3.4	383	590	0.22
Iran	31.6	1 167	1 050	1.22
Iraq	118.5	4 359	1 410	6.15
Turkey	157.0	9 926	720	7.15
Total	**333.4**			**15.49**
Total region	**870.0**			

In other areas of the Middle East region the percentage of use of renewable water resources is lower, with total freshwater withdrawal amounting to less than 100 percent of renewable water resources in most of the countries. Only in the Gaza Strip does withdrawal reach 173 percent of the total renewable water resources. The countries in which water withdrawal represents the smallest proportion of total renewable water resources are Lebanon, Turkey and Georgia, with values of 24 percent, 18 percent and 3 percent respectively.

EVAPORATION LOSSES FROM ARTIFICIAL RESERVOIRS

For six countries information on surface areas of the reservoirs behind the dams is available: Armenia, Azerbaijan, Georgia, Iran, Iraq (partial) and Turkey. Using, for each of these countries, an estimate for evaporation from open water bodies, the total annual evaporation losses from these reservoirs amounts to about 15.5 km^3 (Table 13).

However, these data should be looked at with caution and a more in-depth study would be necessary to confirm and complete the information for the whole region. Once this information is available it should be added to the sectoral (agricultural, municipal and industrial) water withdrawal figures.

Irrigation and water management

IRRIGATION POTENTIAL

Methods used by countries to estimate their irrigation potential vary, with significant influence on the results. In computing water available for irrigation, some countries only consider renewable water resources, while others, especially arid countries, include the availability of fossil or non-conventional sources of water. For this reason, comparison between countries should be made with caution. In the case of transboundary rivers, calculation by the individual countries of their irrigation potential in the same river basin may lead to double counting of part of the shared water resources. It is therefore not possible to systematically add up country figures to obtain regional estimates of irrigation potential.

Already, as shown in the previous Chapter, many countries of the Middle East region rely for a considerable part on fossil groundwater and non-conventional sources of water, or are depleting their renewable freshwater resources. For those countries any extension of existing irrigation would require more fossil groundwater or non-conventional sources of water if no improvement in water use efficiency and productivity is made.

The largest irrigation potential is concentrated in the Islamic Republic of Iran, with 5.6 million ha, based only on renewable water resources (Table 48). The Syrian Arab Republic and United Arab Emirates estimate that their irrigation potential is lower than the area equipped for irrigation at present. The reason for this may be the increasing demand for water for domestic and industrial purposes, groundwater depletion already taking place, and failure to take into account the availability of non-conventional water. They are also among the countries that have developed non-conventional sources of water. For these two countries, and those countries without data, irrigation potential is estimated as the total area equipped for irrigation, in order to be able to calculate a regional average. The irrigation potential of the Middle East region is estimated at more than 38.4 million ha, of which 76 percent corresponds to the Islamic Republic of Iran, Turkey and Iraq. The Caucasus countries account for 12 percent of the total irrigation potential of the Middle East region, whereas the Arabian Peninsula countries represent barely 7 percent.

Arid countries, where no agriculture is possible without irrigation, tend to consider the cultivable area as the potential irrigation area, for the development of which they would certainly have to rely on the use of fossil groundwater and non-conventional sources of water.

TYPOLOGY OF IRRIGATION AND WATER MANAGEMENT

Depending on the subregions, irrigation is seen as a necessary technique without which agricultural production would be practically impossible in dry countries, or as a means to increase productivity and cropping intensity and to favour crop diversification in the most humid countries.

The total area where water other than direct rainfall is used for agricultural production has been named "area under water management". The term "irrigation" refers to areas equipped to supply water to crops. Table 47 and Table 48 present the distribution by country of these areas under water management, making a distinction between areas under irrigation, which is the sum of full/partial control irrigation areas, spate irrigation areas, and equipped lowlands (wetlands, inland valley bottoms and flood recession areas) and areas under other forms of water management, which are non-equipped lowlands (wetlands, inland valley bottoms and flood recession cropping areas). The distinction between irrigation and water management is sometimes difficult. In particular, the demarcation between equipped and non-equipped lowland areas is often vague, and for that reason only one figure for non-equipped flood recession cropping area has been provided in the region, by the Islamic Republic of Iran.

The total area equipped for irrigation covers more than 23.3 million ha in the Middle East region, but the geographical distribution is very uneven, both from subregion to subregion and from country to country (Table 14, Figure 19 and Figure 20). More than 71 percent of the area equipped for irrigation is concentrated in the Islamic Republic of Iran (35 percent), in Turkey (21 percent) and in Iraq (15 percent). Within the Arabian Peninsula, Saudi Arabia has the largest area equipped for irrigation, accounting for 7 percent of the total area of the Middle East region, followed by Yemen which represents 3 percent. Finally, the Caucasus countries have 9 percent of the area equipped for irrigation, which is a high value taking into account that their total area is only 3 percent of the Middle East region.

Spate irrigation is typical of dry countries. In this survey only a figure for Yemen has been provided, amounting to 217 541 ha (Table 15 and Table 47). Equipped lowlands are frequent in countries with more renewable freshwater resources, such as Georgia and Turkey, amounting to 31 500 ha and 13 000 ha respectively. However, the figure for Yemen also is 7 799 ha.

Full/partial control irrigation, which covers 23.1 million ha, is by far the most widespread form of irrigation in the Middle East region. It accounts for 98.9 percent of the area equipped for irrigation, of which 71 percent is concentrated in three countries (the Islamic Republic of Iran, Iraq and Turkey).

Irrigation is practiced on 36 percent of the total cultivated area of the region (Table 15 and Figure 21). This percentage is much higher in the Arabian Peninsula, 99 percent, because of the fact that it is only in Yemen that rainfed crops can be cultivated. In the other countries of the Arabian Peninsula farming would be impossible without irrigation.

TABLE 14
Regional distribution of areas under water management

Subregion	Area equipped for irrigation		Non-equipped cultivated lowlands	Total area under water management
	ha	% of Middle East	ha	ha
Arabian Peninsula	2 719 867	12	-	2 719 867
Caucasus	2 132 320	9	-	2 132 320
Iran (Islamic Republic of)	8 131 564	35	10 000	8 141 564
Near East	10 364 960	44	-	10 364 960
Total region	**23 348 711**	**100**	**10 000**	**23 358 711**

TABLE 15
Regional distribution of irrigated areas

Subregion	Equipped for full/partial control irrigation	Spate irrigation	Equipped lowlands	Total area equipped for irrigation		
				Area	% of Middle East	% of cultivated area
	(ha)	(ha)	(ha)	(ha)	(%)	(%)
Arabian Peninsula	2 494 527	217 541	7 799	2 719 867	12	99
Caucasus	2 100 820	-	31 500	2 132 320	9	58
Iran (Islamic Republic of)	8 131 564	-	-	8 131 564	35	45
Near East	10 351 960	-	13 000	10 364 960	44	26
Total region	**23 078 871**	**217 541**	**52 299**	**23 348 711**		
% of area equipped	**98.9**	**0.9**	**0.2**	**100**	**100**	**36**

TABLE 16
Regional distribution of full/partial control irrigation techniques

Subregion	Surface irrigation		Sprinkler irrigation		Localized irrigation		Total
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)
Arabian Peninsula	1 215 747	48.7	1 042 227	41.8	236 553	9.5	2 494 527
Caucasus	1 894 892	90.2	174 000	8.3	31 928	1.5	2 100 820
Iran (Islamic Republic of)	7 431 564	91.4	280 000	3.4	420 000	5.2	8 131 564
Near East	9 435 860	91.2	510 750	4.9	405 350	3.9	10 351 960
Total region	**19 978 063**	**86.6**	**2 006 977**	**8.7**	**1 093 831**	**4.7**	**23 078 871**

FULL/PARTIAL CONTROL IRRIGATION TECHNIQUES

Table 16 presents the subregional distribution of irrigation techniques used on areas under full/partial control irrigation. For countries where techniques were described in the previous publication and where no new data are available, this report uses the earlier values for the analysis in Table 16, and includes the difference between the total area of the previous survey and of the present survey under surface irrigation. Table 49, however, provides the exact data available by country and the year to which they refer. As shown in Table 16, surface irrigation, which accounts for 86 percent of the irrigation techniques, greatly exceeds pressurized irrigation techniques, which are sprinkler irrigation (9 percent) and localized irrigation (5 percent).

Pressurized irrigation techniques are concentrated mainly in the Arabian Peninsula where sprinkler and localized irrigation are practised on over half of the area. This region is dry but it also contains some of the most advanced countries in the use of these techniques. For example, localized irrigation in the United Arab Emirates represents 86 percent and sprinkler irrigation in Saudi Arabia represents 60 percent of the irrigation techniques in the country. However, in the Arabian Peninsula, surface irrigation also still is practised on almost half of the area. In fact in all countries, except Saudi Arabia and the United Arab Emirates, it is practised on more than three-quarters of the area and in Yemen it is almost the only technique used. In the Caucasus, the area under surface irrigation accounts for around 90 percent of the area equipped for full or partial control irrigation, sprinkler irrigation represents 8 percent and localized irrigation 2 percent. In Iraq almost the entire area is under surface irrigation, while in the Islamic Republic of Iran, the Syrian Arab Republic and Turkey surface irrigation accounts for around 90 percent of the irrigation techniques. In Jordan localized irrigation represents 81 percent, and in Lebanon sprinkler irrigation represents almost 30 percent and localized irrigation 9 percent of the irrigation techniques.

ORIGIN OF WATER IN FULL/PARTIAL CONTROL IRRIGATION

Table 17 presents available data concerning the origin of irrigation water in the areas under full/partial control irrigation: surface water, groundwater, mix of surface water and groundwater, and non-conventional sources of water. Data are available for all countries, except Israel. For the purpose of the analysis in Table 17, it was assumed that 50 percent of the area in Israel was irrigated with surface water and 50 percent with groundwater. Finally, for the earlier data, the percentages for each of the sources were retained and applied to the areas under full/partial control at present. Therefore, these values are in order of magnitude only and are not an exact reflection of the real situation. However, it seemed worth attempting to complete the data based on the field knowledge of the AQUASTAT team in order to form a more precise picture of the sources of water used for irrigation in the Middle East region. In Table 50, however, the exact information as available is given for all countries.

With respect to "other sources of water", Lebanon and the Syrian Arab Republic use a mix of surface water and groundwater, while Bahrain, Jordan, Kuwait, Qatar, Saudi Arabia and Turkey have started using non-conventional sources of water to

TABLE 17
Regional distribution of the origin of water used in full/partial control irrigation

Subregion	Surface water		Groundwater		Other sources				Total
	Area	% of total	Area	% of total	Mix of surface water and groundwater		Non-conventional sources of water		Area
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)
Arabian Peninsula	0	0.0	2 439 485	97.8	0	0.0	55 043	2.2	2 494 527
Caucasus	2 004 470	95.4	96 350	4.8	0	0.0	0	0.0	2 100 820
Iran (Islamic Republic of)	3 078 054	37.9	5 053 510	62.1	0	0.0	0	0.0	8 131 564
Near East	7 402 927	71.5	2 181 448	21.1	604 400	0.3	163 185	7.1	10 351 960
Total region	**12 485 451**	**54.1**	**9 770 793**	**42.4**	**604 400**	**0.1**	**218 228**	**3.4**	**23 078 871**

increase their resources (Tables 17 and 50). Kuwait accounts for the highest percentage of non-conventional sources, with 39 percent.

Surface water is the main source of water for irrigation in the Middle East region as a whole (54 percent), since countries such as Turkey and Iraq, which have large areas under irrigation, irrigate mainly with surface water (78 percent and 94 percent respectively), mainly coming from the Euphrates–Tigris Basin. In the Caucasus countries, surface water accounts on average for 94 percent of the area equipped for irrigation and comes mainly from the Kura–Araks Basin. In this subregion non-conventional sources of water are not used since it is not as dry as in the other subregions. In contrast, the Arabian Peninsula has no area irrigated by surface water and the Islamic Republic of Iran, Jordan and the Occupied Palestinian Territory feed their irrigation systems mainly with groundwater.

SCHEME SIZES

The definition of large schemes varies from one country to another. While certain countries, such as Bahrain, the Islamic Republic of Iran and Oman, consider a scheme of 50 ha to be large, other countries, such as Georgia, Jordan, Lebanon and Turkey use a minimum area of 1 000 ha for a scheme to be classified large. Azerbaijan even considers large schemes those over 20 000 ha. The Arabian Peninsula schemes are the smallest ones, since Qatar and Saudi Arabia consider a scheme of 100 ha and 200 ha respectively to be large (Table 18).

Rather than by its size, a scheme is often described by its type of management: small private farms, commercial farms, communal schemes or public schemes.

Table 18 shows the scheme sizes in several countries and the criteria used. If no recent information on scheme sizes is available, the information of the previous survey is used, as is the case for Azerbaijan, Bahrain, Saudi Arabia and Turkey.

TABLE 18
Scheme sizes in some countries

Country	Year	Criteria	Small	Medium	Large	Total area
		ha	ha	ha	ha	
Armenia	2006	200	55 697	-	217 863	273 560
Azerbaijan	1995	10 000–20 000	77 420	192 600	1 183 000	1 453 020
Bahrain	1994	50	2 885	-	280	3 215
Georgia	2007	500–1 000	103 770	90 350	207 170	401 290
Iran (Islamic Republic of)	2003	10–50	4 000 000	3 281 564	850 000	8 131 564
Jordan	2004	100–1 000	37 500	6 000	35 360	78 860
Lebanon	2000	100–1 000	24 400	22 070	43 530	90 000
Oman	2004	2 - 8	23 456	22 548	12 846	58 850
Qatar	2001	20–100	1 703	5 272	5 960	12 935
Saudi Arabia	1992	5–200	450 000	730 000	428 000	1 608 000
Turkey	1994	1 000	2 265 360	-	1 805 390	4 070 750

Cultivation in full/partial control irrigation schemes

LEVEL OF USE OF AREAS EQUIPPED FOR FULL/PARTIAL CONTROL IRRIGATION

It is difficult to calculate the areas actually irrigated for the Middle East region as a whole because information is missing for most of the countries in both AQUASTAT surveys. Where a country did not have new data, those of the previous survey are used. Given that data about actually irrigated areas are available for only 7 out of the 18 countries, Table 19 focuses on these countries.

Use rates vary considerably among those the countries providing such data. In Bahrain and Yemen the total area equipped for full or partial control irrigation is actually irrigated. Jordan has a rate exceeding 90 percent and Turkey a rate of 87 percent. Armenia and Saudi Arabia have use rates lower than 70 percent and Qatar even has a use rate of only 49 percent. In numerous cases, low rates are explained by deterioration of the infrastructure owing to a lack of maintenance (caused by a lack of experience or the use of non-adapted techniques) or political and economic reasons. Other causes are: inadequate management of technical means of production under irrigation, soil impoverishment, local instability and insecurity, and the reduction of public funds allocated to irrigation.

CROPPING INTENSITY

Cropping intensity, another indicator of the use of equipped areas, is calculated based on the area actually irrigated in full or partial control irrigation for the 7 countries for which that information is available. For the other 11 countries, it is estimated equal to the area equipped for full or partial control irrigation. Thus cropping intensity is probably underestimated because the area actually irrigated might be smaller than equipped area in several of these 11 countries. The calculation only refers to irrigated crops. This means that in a country with one or two wet seasons only the crops grown under irrigation are taken into consideration. The crops grown on the full/partial control equipped area during the wet season without irrigation (but using the residual soil humidity) are not included in the irrigated crop area when calculating cropping intensity.

National cropping intensity ranges from 31 percent in Georgia to 138 percent in Jordan (Table 51). In the Islamic Republic of Iran and the Arabian Peninsula cropping intensity is 106 and 105 percent respectively (Table 20). In the Near East and the Caucasus subregions it amounts to 87 and 85 percent respectively.

Table 21 shows the cropping intensity for those countries where the area effectively irrigated is available and therefore it is easier to evaluate the real situation. As shown, figures range from 100 percent, meaning that one crop per year is irrigated, to 138 percent in Jordan.

The calculation of cropping intensity is straightforward for dry countries because irrigation is indispensable for the growing of

TABLE 19
Distribution of actually irrigated areas in some countries

Country	Area equipped for full/partial control irrigation	Actually irrigated	
		Area	% of equipped areas
	(ha)	(ha)	(%)
Armenia	273 530	176 000	64
Bahrain	4 015	4 015	100
Jordan	78 860	72 009	91
Qatar	12 935	6 322	49
Saudi Arabia	1 730 767	1 191 351	69
Turkey	4 970 000	4 320 000	87
Yemen	454 310	454 310	100

TABLE 20
Cropping intensity over area actually irrigated

Subregion	Area equipped for full/partial control irrigation	Area actually irrigated in full/partial control irrigation	% of equipped areas	Harvested irrigated crop areas	Cropping intensity
	(ha)	(ha)	(%)	(ha)	(%)
	(1)	(2)	(3) = 100 * (2)/(1)	(4)	= 100 × (4)/(2)
Arabian Peninsula	2 494 527	1 948 498	78	2 055 644	105
Caucasus	2 100 820	2 003 290	95	1 693 581	85
Iran (Islamic Republic of)	8 131 564	8 131 564	100	8 592 544	106
Near East	10 351 960	9 691 182	94	8 386 858	87
Total region	**23 078 871**	**21 774 534**	**94**	**20 728 627**	**95**

TABLE 21
Cropping intensity over area actually irrigated in some countries

Country	Area equipped for full/ partial control irrigation	Area actually irrigated in full/ partial control irrigation	Harvested irrigated crop areas	Cropping intensity
	(ha)	(ha)	(ha)	(%)
	(1)	(2)	(3)	= 100 × (3)/(2)
Armenia	273 530	176 000	176 000	100
Bahrain	4 015	4 015	4 015	100
Jordan	78 860	72 009	99 029	138
Qatar	12 935	6 322	6 928	110
Saudi Arabia	1 730 767	1 191 351	1 204 958	101
Turkey	4 860 800	4 320 000	4 206 000	100
Yemen	454 310	454 310	527 038	116

crops in all seasons. However, the calculation is more problematic for countries with one or more wet seasons. For two crop cycles a year, only one is irrigated (during the dry season), the second uses soil moisture provided by the precipitation. Therefore, the cropping intensity (irrigated crops only) is 100 percent on the area considered, while the harvested area is double.

IRRIGATED CROPS IN FULL/PARTIAL CONTROL SCHEMES

Table 22 shows the subregional distribution of irrigated crops for those countries and territories that have provided such information. The equipped areas with several crop cycles a year are counted several times, which explains why the total is superior to the physically equipped areas or physically actually irrigated areas in some countries (Table 51). This also gives an idea of the cropping intensity under irrigation (see below). Georgia is included in the total irrigated crops area, but it is not in the distribution of each crop because there is no data available.

Cereals represent 44 percent of the harvested irrigated crop area, of which wheat constitutes 60 percent. The group of vegetables, roots and tubers, and pulses are the second most widespread crop, representing 16 percent. Irrigated fodder follows with 9 percent, and cotton represents 6 percent of the harvested irrigated crop area. Permanent crops account for 15 percent.

In the Arabian Peninsula, cereals and perennial crops are the dominant crops, representing 39 percent and 31 percent respectively, followed by fodder which accounts for 15 percent. The United Arab Emirates has the largest area of perennial crops (mainly dates) at 82 percent of the total irrigated crops area of the country. In Oman and Bahrain perennial crops represent 58 and 55 percent respectively. In the Caucasus countries, perennial crops only account for 10 percent on average, whereas cereals represent 55 percent and vegetables 12 percent. In the Islamic Republic of Iran, Turkey and Iraq, the countries with the largest irrigated crop area, cereals account for 48, 21 and 70 percent respectively. In the Islamic Republic of Iran and in Turkey,

TABLE 22
Regional distribution of irrigated crops under full/partial control irrigation

Subregion	Wheat	Barley	Maize	Rice	Cereals not specified	Vegetables, roots and tubers and pulses	Fodder	Cotton	Fruit trees	Annual crops not specified	Permanent crops not specified	Total
						(1 000 ha)						
Arabian Peninsula	532.79	36. 78	31.45	0.00	206.73	247.43	300.02	17.25	34.75	55.23	592.80	2 055.23
	(26%)	(2%)	(2%)	(0%)	(10%)	(12%)	(15%)	(1%)	(2%)	(3%)	(29%)	(100%)
Caucasus*	645.92	164.81	36.294	2.57	9.30	195.65	26.00	78.16	0.00	256.510	152.31	1 693.58
	(41%)	(11%)	(2%)	(0.2%)	(1%)	(12%)	(2%)	(5%)	(0%)	(16%)	(10%)	(100%)
Iran (Islamic Republic of)	2 634.11	607.49	275.94	628.11	0.07	1 111.03	878.18	143.23	216.24	1 044.14	1 054.03	8 592.55
	(31%)	(7%)	(3%)	(7%)	(0%)	(13%)	(10%)	(2%)	(3%)	(12%)	(12%)	(100%)
Near East	1 602.09	876.82	608.49	197.00	7.06	1 765.01	575.97	929.29	272.89	848.23	704.01	8 386.86
	(19%)	(10%)	(7%)	(2%)	(0%)	(21%)	(7%)	(11%)	(3%)	(10%)	(8%)	(100%)
Total region*	**5 414.90**	**1 685.89**	**952.18**	**827.68**	**223.16**	**3 319.12**	**1 780.18**	**1 167.93**	**523.87**	**2 204.11**	**2 503.15**	**20 728.22**
	(26%)	**(8%)**	**(5%)**	**(4%)**	**(1%)**	**(16%)**	**(9%)**	**(6%)**	**(3%)**	**(11%)**	**(12%)**	**(100%)**

* Georgia is not included in the distribution of crops because there is no available data, but it is included in the total for the region.

irrigated fodder represents around 10 percent. In the Islamic Republic of Iran, Turkey and Saudi Arabia it accounts for 49, 27 and 12 percent respectively of the total area under this crop in the Middle East.

The Islamic Republic of Iran has 76 percent of the area under rice in the Middle East, followed by Iraq with 15 percent. In Turkey vegetables (including roots and tubers) account for 23 percent. Turkey and the Islamic Republic of Iran have 35 percent and 34 percent respectively of the total area of vegetables (including roots and tuber crops) in the Middle East region. Turkey and the Islamic Republic of Iran represent 53 and 33 percent of the total area of pulses, followed Yemen, which accounts for 6 percent. Cotton is the main industrial crop and covers 6 percent of the total irrigated crop area in the Middle East region. Cotton cultivation is concentrated in Turkey (55 percent), the Syrian Arab Republic (23 percent), the Islamic Republic of Iran (12 percent) and Azerbaijan (7 percent) (Table 51). Other industrial crops are sugarcane, olives and bananas. Citrus is found mainly in the Islamic Republic of Iran (50 percent), Turkey (23 percent), Iraq (15 percent) and the Syrian Arab Republic (6 percent). In Lebanon, citrus accounts for 36 percent of the total irrigated crop area of the country.

Trends in the last ten years

During the previous survey the population of the Middle East region was 236 million, slightly more than 4.1 percent of the world's population. At present it is 283 million, or about 4.4 percent of the world's population. Population density has risen from 41 to 43 inhabitants/km². The annual rate of population growth over the last ten years is 1.8 percent, a sharp decrease from the 3.1 percent/year for 1984–1994. While ten years ago about 36 percent of the population in the Middle East region lived in a rural environment, at present it is 34 percent (Table 2 and Table 43). This indicates that there is low migration towards cities.

WATER WITHDRAWAL BY SECTOR

On a sectoral basis, the proportions of water withdrawal have changed only slightly: agricultural water withdrawal has decreased by 2 percent, while municipal and industrial withdrawals have increased by 1 percent each. However, total water withdrawal has grown by 29 percent over the last ten years (Table 23).

Between the two survey dates, withdrawal per inhabitant has also increased (by 72 m³). This growth is due to a per capita increase in the Islamic Republic of Iran and in the Near East subregion of 301 and 87 m³ respectively, while in the Arabian Peninsula Region and in the Caucasus subregion withdrawal per inhabitant has decreased by 22 and 380 m³ respectively.

Looking at the municipal sector, water withdrawal per capita has increased from 74 m³/year, or 203 litres/day, to 89 m³/year, or 316 litres/day. There is quite some variation between the subregions and countries. In the Arabian Peninsula subregion it has increased from 67 to 69 m³/year, while in the Near East subregion there has been an increase from 71 to 96 m³/year. However, in the Caucasus subregion it has decreased from 148 to 108 m³/year. Qatar and Iraq have the largest increases, from 120 to 214 m³/year and from 63 to 149 m³/year respectively, while the United Arab Emirates has the largest decrease, from 263 to 137 m³/year. Moreover, in Georgia, Azerbaijan and Lebanon water withdrawal per capita has decreased by 65, 38 and 16 m³/year respectively.

In agriculture, the annual water withdrawal per hectare of area equipped for irrigation seems to have increased from 8 650 m³ to 9 700 m³. The reason for this is not fully clear. It could be a result of data quality or changed cropping pattern. In the

TABLE 23
Trends in water withdrawal by sector

Subregion	Year	Annual water withdrawal by sector								
		Agriculture		Municipal		Industry		Total		
		km³	% of total	km³	% of total	km³	% of total	km³	% of Middle East	m³ per inhabitant
Arabian Peninsula	1997	21.2	87	2.6	11	0.5	2	24.3	12	622
	2007	29.3	86	3.9	11	0.9	3	34.1	13	600
Caucasus	1997	15.6	68	2.4	10	4.9	22	22.9	11	1 428
	2007	12.2	73	1.7	10	2.7	16	16.7	6	1 048
Iran (Islamic Republic of)	1997	64.2	92	4.4	6	1.5	2	70.0	33	1 041
	2007	86.0	92	6.2	7	1.1	1	93.3	34	1 342
Near East	1997	78.7	85	8.1	9	6.1	7	92.9	44	818
	2007	99.0	78	13.5	11	14.9	12	127.4	47	905
Total region	**1997**	**179.7**	**86**	**17.5**	**8**	**13.0**	**6**	**210.2**	**100**	**891**
	2007	**226.5**	**84**	**25.3**	**9**	**19.6**	**7**	**271.5**	**100**	**963**

Near East subregion it has gone from 8 678 m³ to 9 549 m³, in the Islamic Republic of Iran from 8 832 m³ to 10 576 m³ and in the Arabian Peninsula subregion from 9 487 m³ to 10 765 m³. However, in the Caucasus subregion it has decreased from 7 072 m³ to 5 742 m³. In Iraq it has increased from 11 172 m³ to 14 752 m³ while in the United Arab Emirates it has decreased from 21 115 m³ to 14 616 m³. These data should be used with caution since, as mentioned above, the reason for the general increase is not fully clear.

WATER WITHDRAWAL BY SOURCE

For the Middle East region as a whole, annual freshwater withdrawal has increased from 206 km³ to 262 km³, which represents an annual increase rate of 2.4 percent (Table 24). Desalinated water has doubled from 1.5 km³ to 3.2 km³, equal to an annual increase of 7.6 percent, and reused treated wastewater has increased in volume at an annual rate of 12 percent, from 2.4 to 6.6 km³. This shows the necessity of using non-conventional sources of water in the Middle East region. However, freshwater remains by far the most important source, accounting for 96 percent of the total and decreasing by only two points from 98 percent in 1997.

The countries with data on non-conventional sources of water are practically the same as in the previous survey, with all of them increasing the quantity of water withdrawn. In 2007 Iraq and Lebanon report using desalinated water, while in 1997 no data was available. In the same year Azerbaijan, Israel and Turkey report using treated wastewater, while in 1997 there was no data available. Iraq, Lebanon and the Syrian Arab Republic report using agricultural drainage water. On a subregional level, the Arabian Peninsula Region now desalinates 1 303 million m³ more than in 1997. In particular, the United Arab Emirates and Saudi Arabia have increased annual desalinated water use by 565 and 319 million m³ respectively. In the Caucasus, total withdrawal has decreased from last survey, mainly due to a decrease in the actually irrigated area. Reused treated wastewater accounts for 161 million m³ in this subregion compared with 0 in 1997. In the Near East subregion withdrawal has increased for both freshwater and non-conventional sources of water, especially reused treated wastewater and agricultural drainage water, which are up from 2 percent to 4.6 percent of the total withdrawals of this region. However, some caution is needed here. Reused agricultural drainage water is reported only in 2007 by Lebanon and the Syrian Arab

TABLE 24
Trends in water withdrawal by source

Subregion	Year	Annual withdrawal by source						Total water withdrawal
		Freshwater		Non-conventional sources of water				
		Total		Desalinated water		Reused treated wastewater and agricultural drainage water**		
		Million m³	% of total	Million m³	% of total	Million m³	% of total	Million m³
Arabian Peninsula	1997	22 390	92.0	1 517	6.2	436	1.8	24 343
	2007	30 701	90.0	2 805	8.2	594	1.8	34 100
Caucasus	1997	22 926	100.0	0	0.0	0	0.0	22 926
	2007	16 498	99.0	0	0.0	161	1.0	16 659
Iran (Islamic Republic of)	1997	70 031	100.0	3	0.0	0	0.0	70 034
	2007	93 100	99.8	200	0.2	0	0.0	93 300
Near East*	1997	90 917	97.9	28	0.0	1 922	2.1	92 867
	2007	121 389	95.3	205	0.2	5 818	4.6	127 413
Total region	**1997**	**206 264**	**98.2**	**1 548**	**0.7**	**2 359**	**1.1**	**210 170**
	2007	**261 688**	**96.4**	**3 210**	**1.2**	**6 574**	**2.4**	**271 472**

*In 2007 only three countries in the Near East subregion provided data for reused agricultural drainage water amounting to 3 911 million m³ in total (see Table 11 in Chapter 9), which represents 3 percent of the withdrawal in the Near East subregion and 1.4 percent in the Middle East region. In 1997 only Iraq provided this data (1 500 million m³).

*The Occupied Palestinian Territory is not included in figures for 1997 because there is no available data.

Republic. This does not mean that it was equal to 0 in the previous survey just that no data were available at that time.

AREAS UNDER IRRIGATION

Table 25 presents the trends in the area under irrigation during the last ten years. It should be taken into account that the information for some of the countries is for earlier years as new data was not provided (Table 47).

For the Middle East region, the increase in the equipped area is 12 percent, which is equal to an annual rate of 1.31 percent using a weighted year index. The weighted year index is calculated by allocating to the year for each country a weighting coefficient proportional to its area equipped for irrigation, therefore giving more importance to countries with the largest areas under irrigation.

The area under full or partial control irrigation has an annual rate of increase of 1.35 percent, which is a little higher than the annual rate for total irrigation. This is explained by the fact that the area of spate irrigation has not increased as much as the area of full or partial control irrigation and also because equipped lowlands area have decreased since 1997.

The Arabian Peninsula has an annual rate of increase of more than 2.2 percent. The rate for the United Arab Emirates is 13 percent, the largest increase in equipped areas in the Middle East region. However, this could also be explained by the reclassification of areas previously indicated as non-equipped, which have been counted as equipped areas this time because of better knowledge of the field situation. Other countries in the Arabian Peninsula, such as Kuwait, Bahrain and Yemen, have shown annual rates of increase of 4 percent, while the annual increase in Saudi Arabia and Qatar is close to zero. Oman has recorded a drop in the areas equipped for irrigation, with an annual rate of –0.4 percent.

The Caucasus is the only subregion where the area under irrigation has not increased. The rate of abandonment of full or partial control irrigation area has been almost 0.4 percent per year in this period (–0.7 percent in Georgia, –0.4 percent in Armenia and –0.2 percent in Azerbaijan). Reasons are civil strife, war, vandalism and theft, as well as problems associated with land reform, the transition to a market economy, and the loss of markets with traditional trading partners, high pumping costs, which all have contributed to the widespread deterioration of the irrigation conveyance systems.

In the Near East subregion the annual increase rate is 1.7 percent. The Syrian Arab Republic has an annual rate of increase of around 4 percent; while in Lebanon it is close

TABLE 25
Regional trends in the areas under irrigation

Subregion	Year	Irrigation (ha)				
		Full/partial control irrigation	Spate irrigation	Equipped lowlands	Total irrigation	Annual increase
		(1)	(2)	(3)	(4) = (1) + (2) + (3)	%
Arabian Peninsula	1997	2 139 887	98 320	-	2 238 207	2.2
	2007	2 494 527	217 541	7 799	2 719 867	
Caucasus	1997	2 176 467	-	31 500	2 207 967	–0.4
	2007	2 100 820	-	31 500	2 132 320	
Iran (Islamic Republic of)	1997	7 264 194		-	7 264 194	1.1
	2007	8 131 564	-	-	8 131 564	
Near East	1997	8 974 819	-	115 164	9 089 983	1.7
	2007	10 351 960	-	13 000	10 364 960	
Total region	**1997**	**20 555 237**	**98 320**	**146 664**	**20 800 351**	**1.3**
	2007	**23 078 871**	**217 541**	**52 299**	**23 348 711**	
Change		+2 523 634	+119 221	- 94 365	+2 548 360	

to zero. Jordan has shown a drop in areas equipped for irrigation, at an annual rate of –0.9 percent.

Spate irrigation has increased in area by 0.1 million ha (121 percent), all in Yemen, which is the only country in the region reporting information on spate irrigation. The area of equipped lowlands has decreased by 94 365 ha. This may be due to the fact that in Turkey this area was previously included in the category of equipped lowlands but is now considered to be equipped for full/partial control irrigation, probably due to improved infrastructure.

IRRIGATION TECHNIQUES

Table 26 presents the trends in irrigation techniques. To facilitate the comparison between 1997 and 2007, data has been estimated for Kuwait, Qatar and Saudi Arabia, taking into account either the previous survey or the current survey. Iraq, Israel and the Occupied Palestinian Territory are not included in the Near East subregional figures as data was not obtained for these countries in both the previous and the present survey. Therefore, it should be considered that the real area is larger than the total presented below, for every technique.

The area under surface irrigation, the most important technique, has increased by 1.4 million ha (9 percent). However, in all subregions except the Caucasus, the relative importance of surface irrigation has decreased. Sprinkler irrigation has increased by 0.3 million, which represents a growth rate of 18 percent for this technique. While its relative importance has become less in the Arabian Peninsula and the Caucasus, it has grown especially in the Islamic Republic of Iran and the Near East subregion. Localized irrigation, which is the technique that requires less water, has increased in area by 0.7 million ha, representing a growth rate of 424 percent during the ten years. Its relative importance has increased in all subregions. It is developing most, however, in the Arabian Peninsula, where the percentage compared with the other techniques has increased from 3.5 to 10 percent; the Islamic Republic of Iran and the Near East follow with increases from 0.6 to 5.2 percent and from 1.0 to 3.5 percent respectively. These regions include the driest countries in the world, but are also among the more developed regions, two factors favouring the adoption of these techniques.

IRRIGATED CROPS

The main change in the last ten years has been a decrease in wheat-growing areas and their proportion in the whole area under full/partial control irrigation. This reduction has occurred mainly because of the increase in other cereals, especially barley but also maize and rice. Irrigated cereals as a percentage of total irrigated crops have decreased

TABLE 26
Regional trends in the irrigation techniques on the full/partial control irrigation areas

Subregion	Year	Surface irrigation		Sprinkler irrigation		Localized irrigation		Total
		(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)
Arabian Peninsula	1997	1 027 876	48.0	1 037 281	48.5	75 145	3.5	2 140 302
	2007	1 097 000	46.0	1 042 227	44.0	236 553	10.0	2 369 480
Caucasus	1997	1 926 249	88.5	247 400	11.4	2 818	0.1	2 176 467
	2007	1 922 210	90.3	174 000	8.2	31 928	1.5	2 128 138
Iran (Islamic Republic of)	1997	7 173 494	98.8	47 200	0.6	43 500	0.6	7 264 194
	2007	7 431 564	91.4	280 000	3.4	420 000	5.2	8 131 564
Near East*	1997	4 861 584	92.9	320 549	6.1	53 686	1.0	5 235 819
	2007	5 894 860	89.6	454 500	6.9	228 600	3.5	6 577 960
Total region*	**1997**	**14 989 203**	**89.1**	**1 652 430**	**9.8**	**175 149**	**1.1**	**16 816 782**
	2007	**16 339 334**	**85.0**	**1 950 727**	**10.2**	**917 081**	**4.8**	**19 207 141**
Change		+1 350 131	+9	+298 297	+18	+741932	+424	+2 390 359

* Iraq, Israel and the Occupied Palestinian Territory are not included

from 60 percent in 1997 to 44 percent in 2007. The area under permanent crops has increased from 6 to 15 percent, indicating that a higher percentage of irrigated area is dedicated to these crops. The area under vegetables and cotton has also increased, while the area under fodder has decreased from 11 percent to 9 percent. These statistics must be considered with caution as Israel and the Occupied Palestinian Territory were not included in the previous survey and therefore old data are not available.

USE RATE OF AREAS EQUIPPED FOR IRRIGATION

Amongst the five countries for which information is available, i.e. Armenia, Bahrain, Qatar, Saudi Arabia and Turkey, three have seen their rate of use for equipped areas improve in the last ten years, in two it has decreased, and in one it has remained the same. Areas actually irrigated in Armenia have increased from 60 percent of equipped areas in 1995 to 64 percent in 2006, while there has been a small decrease in equipped areas. The same holds for Turkey, where areas have increased from 74 to 87 percent between 1994 and 2006. Conversely, two countries have experienced a reduction in the use of their irrigation systems. In Qatar, the area actually irrigated has declined from 66 percent in 1993 to 47 percent in 2004, for almost the same equipped areas. In Saudi Arabia the use rate has fallen from 100 percent to 69 percent between 1992 and 1999, for a slight increase in equipped area. In Bahrain, the area actually irrigated represented 100 percent of the equipped areas in 1994 and in 2000. While a more extensive use of equipped areas in the first two countries can be explained by the rehabilitation of degraded schemes, it is often the degradation of equipment that justifies the abandonment of equipped areas in the latter group of countries.

Legislative and institutional framework of water management

In 14 out of the 18 countries of the Middle East region for which information is given, water management is generally based on a water code, on a specific water law or on several water laws. Armenia and Azerbaijan have a Water Code, signed in 2002 and 1997 respectively. A specific Water Law has been enacted in Georgia (1997), the Islamic Republic of Iran (1982), Israel (1959), Lebanon (2000), Occupied Palestinian Territory (1996) and Yemen (2002). In six other countries (Iraq, Jordan, Oman, Qatar, Saudi Arabia and the Syrian Arab Republic) certain aspects of water management such as pollution, drilling, irrigation or water rights are regulated, but these specific arrangements are not grouped in a water code. In Iraq a law on irrigation was enacted in 1995. In Jordan, laws and regulations are imposed to enable the authorities and other bodies to perform their duties in respect of water. In Oman, several decrees concerning water and irrigation have been enacted, and in Qatar a decree was issued to govern drilling of wells and use of groundwater. In Saudi Arabia various water laws are under revision and reformulation, although there are still grey areas of overlapping responsibilities regarding irrigation and the control and implementation of water reuse for irrigation. In the Syrian Arab Republic, over 140 laws that address water have been passed since 1924. No information is available for Bahrain, Kuwait, Turkey and the United Arab Emirates; however, these countries have institutions responsible for water management or water supply.

The national institutions responsible for the management and planning of irrigation development are, for a large majority of the Middle East countries (12 out of 18), departments or divisions within the Ministry of Agriculture. In Azerbaijan irrigation management depends on the State Committee of Amelioration and Water Management, in Jordan on the Ministry of Water and Irrigation and in Kuwait on the Public Authority for Agricultural Affairs and Fish Resources. In the Syrian Arab Republic there is a Ministry of Irrigation, and in Turkey the General Directorate of State Hydraulic Works (DSI) and the General Directorate of Rural Services (GDRS) are responsible for irrigation and drainage development activities.

The management and conservation of water resources are generally the responsibility of a different ministry (environment, nature protection, natural resources, energy or water resources), although in Israel it falls to the Water Commission (part of the Ministry of National Infrastructures), in the Occupied Palestinian Territory to the Palestinian Water Authority, in Qatar to the Permanent Water Resources Committee, in the Syrian Arab Republic to the Council of General Commission for Water Resource Management, and in the United Arab Emirates to the General Water Resources Authority. Municipal water supply and wastewater treatment depend in some countries on another ministry again (such as territorial administration, health, public works or housing and construction).

The management of the irrigation systems is generally performed jointly by the State, as regards the primary infrastructure or public systems, and by user associations or independent users for the secondary and tertiary infrastructure or private systems. There are countries where water user associations do not exist, such as Lebanon. In the Caucasian countries, after the Soviet period there was a disengagement of the State from the irrigation sector and subsequent creation of user associations that are now in place or in the pipeline. In Turkey, the General Directorate of State Hydraulic

Works began an Accelerated Transfer Program (ATP) in 1993, transferring irrigation systems management to users. In most of the countries surface water and groundwater are state property and the right to use either is acquired through licences. In many countries landowners have priority for water taken from a well on their land. There are exceptions such as Bahrain, where groundwater is property of the landowners.

Water tarification is used in Armenia, Azerbaijan, Israel, the Islamic Republic of Iran, Lebanon, the Syrian Arab Republic and Turkey. In Israel, urban users pay much higher rates for water than farmers, and irrigation water is subsidized, though the subsidy has declined since 1987. In the United Arab Emirates water used for agriculture is free of charge while water for municipal use, which is mostly desalinated water, is subsidized by the State. Charges on wastewater discharge exist in Azerbaijan. The government of Bahrain is planning an appropriate pricing system for excess water utilization. In Armenia, the State budget finances about 50 percent of the annually assessed operation and maintenance (O&M) requirements of the water services for irrigation. In Jordan, the funds for the public irrigation schemes and dams come from international loans and the national budget, while in the private sector irrigation projects, investors and owners pay for the full cost of construction and for the rehabilitation and the annual running O&M cost. In Kuwait, the Industrial Bank of Kuwait (IBK) is responsible for administering the "agriculture and fisheries credit portfolio", which is a fund for soft loans for investment in agriculture and fisheries. Finally, in the United Arab Emirates 50 percent of the costs of the infrastructures such as bubbler, drip and sprinkler irrigation are subsidized by the government.

Most countries are making considerable technical, policy and institutional progress within the water sector. The region manages sophisticated irrigation and drainage systems, and has spearheaded advances in desalination technology. Governments in some cities have shifted from direct provision of water supply services to regulation of services provided by independent or privately owned utilities. In some countries, farmers have begun managing irrigation infrastructure and water allocations. Some countries have established agencies to plan and manage water at the level of the river basin. To implement the new policies, most governments have established ministries that manage water resources and staffed them with well-trained and dedicated professionals. However, these efforts have not led to the expected improvements in water outcomes for several reasons. One issue is that cropping choices are a key determinant of water use in agriculture and they are affected far more by the price the farmer can get for those crops than by the price of irrigation services (World Bank, 2007).

Environment and health

In the Middle East region, surface water and groundwater quality is commonly affected by agricultural, industrial and municipal wastewater. Also, the quality of groundwater has drastically deteriorated due to over-pumping and subsequent salinization. In the Caucasus countries the largest source of pollution is municipal wastewater, which pollutes rivers downstream of large cities with organic matter, suspended solids, surfactants, etc, followed by industrial and agricultural wastewater discharges. In the Near East subregion, water quality of rivers, such as the Euphrates and Tigris, is affected by return flow from irrigation projects and municipal and industrial wastewater. Groundwater quality is decreasing because of overexploitation of aquifers and leaching of fertilizers and pesticides. Deterioration of the quality of irrigation water is increasing owing to the use of treated wastewater, particularly in drought years. In the Arabian Peninsula, groundwater availability may be further reduced due to groundwater salinization in coastal areas and groundwater pollution in urban areas and areas of intensive agriculture.

The overexploitation of aquifers (when water withdrawal exceeds water recharge) and the subsequent lowering in their levels is a problem in all the countries of the Arabian Peninsula and in the Near East, such as Israel, Jordan and the Occupied Palestinian Territory. This overexploitation is at the origin of seawater intrusion and/or the upward diffusion of deeper saline water in at least Bahrain, Gaza Strip, Israel, Oman and Qatar, which leads to a deterioration of groundwater quality. Using saline groundwater for irrigation may increase soil salinity. The use of fossil water, which is water from aquifers whose rate of renewal is very slow and which are therefore considered non-renewable, will cause depletion of the aquifers in the long term.

Scarcity of water resources, severe climatic conditions, pollution of groundwater, unsuitable cropping patterns and incorrect cultural practices 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. Consecutive accumulation of salts year after year degrades the soils and renders them unproductive, this being regarded as the main reason for the abandonment of farms.

Arid areas are sensitive to salinization problems because the volume of rainwater dissolving the salts generated by the soil is low. By extracting water from the soil, evaporation and evapotranspiration tend to increase salt concentrations. Direct evaporation from the soil surface causes a rapid accumulation of salt in the top layers. When significant amounts of water are provided by irrigation with no adequate provision for leaching of salts, the soils rapidly become salty and unproductive. Water storage in the reservoirs, where evaporation is intense, tends to increase the salt concentration of the stored water. For all these reasons, the Middle East is a region subject to salinization, a problem that has been recognized for a long time. However, assessment of salinization at national level is a difficult enterprise and very little information on the subject could be found during the survey. Furthermore, no commonly agreed methods exist to assess the degree of irrigation-induced salinization. New figures on areas salinized by irrigation were available for only 5 of the 19 countries and territories, and for that reason figures from last survey for 6 more countries have been used (Table 27). In the near future, more information on salinization will probably become available and strategies to improve the situation should be defined, as this has been recognized as a priority by most of the Middle East countries. Considering the 11 countries which have reported figures,

TABLE 27
Salinization in irrigation areas in some countries

Country	Salinization		
	Year	ha	% of equipped area
Armenia	2006	20 415	7
Azerbaijan	2003	635 800	45
Bahrain	1994	1 065	34
Georgia	2002	113 560	26
Iran (Islamic republic of)	1993	2 100 000	29
Israel	1993	27 820	14
Jordan	1989	2 280	4
Kuwait	1994	4 080	86
Lebanon	2001	1 000	1
Syrian Arab Republic	1989	60 000	6
Turkey	2004	1 519 000	30

TABLE 28
Drainage in irrigation areas in some countries

Country	Drainage		
	Year	ha	% of equipped area
Armenia	2006	34 457	13
Azerbaijan	2003	608 336	43
Bahrain	1994	1 300	41
Georgia	1996	31 800	7
Iran (Islamic republic of)	2002	1 508 000	19
Israel	1987	100 000	52
Jordan	2005	10 506	13
Kuwait	1994	2	0
Lebanon	2001	3 000	3
Oman	2006	0	0
Saudi Arabia	2007	10 850	1
Syrian Arab Republic	1993	273 000	27
Turkey	2006	340 890	7

around 28 percent of the irrigated areas is under salinization on average. The situation is of particular concern in Kuwait, where the area salinized by irrigation exceeds 85 percent of the total equipped area for irrigation. In Azerbaijan, salinization affects 45 percent of the equipped area and in Bahrain, Turkey, and the Islamic Republic of Iran around 30 percent. In Lebanon or Jordan on the other hand the figures are only 1 and 4 percent respectively.

One of the measures needed to prevent irrigation-induced waterlogging and salinization in arid and semi-arid regions is the installation of drainage facilities. Drainage, in combination with adequate irrigation scheduling, allows for the leaching of excess salts from the plant root zone. Figures on drained areas are available for 13 of the 19 countries of which 5 are from the previous survey, since no new information could be obtained (Table 28). About 16 percent of the area equipped for irrigation in these countries has been provided with drainage facilities, varying from 0 percent in Kuwait and Oman to over 50 percent in Israel.

Only 7 out of the 19 countries of the Middle East region have reported information about water-related diseases for this survey, although these diseases are also represented in other countries of the region. The major factors favouring the development and dispersion of these diseases are as follows:

- the orientation towards the use of wastewater to meet water shortage
- lack of infrastructure, especially related to wastewater treatment and disposal
- lack of health awareness and proper handling of polluted water
- non-existence of regulations related to the protection of the environment and public health.

In Armenia, more than 1 600 persons were affected with water-related diseases in 2006 and more than 1 100 malaria cases were reported by 1998 although, owing to epidemic control interventions, the number of autochthonous malaria cases has decreased, dropping to 8 in 2003. In Georgia, the poor quality of water has resulted in several outbreaks of infectious intestinal diseases and epidemics. In Iran, water-related diseases are prevalent in some irrigated areas where the water is also used for domestic purposes, although the extent is unknown. In Jordan, contaminated water is a source of many human infections causing diarrhoea and other diseases, to which children are more exposed than adults. In Lebanon, water-related diseases, especially diarrhoea, are one of the leading causes of mortality and morbidity among children under five. In addition, health problems resulting from exposure to water pollutants often result in health care expenditures and absence from work. Typhoid and hepatitis due to water quality result in a larger number of sick persons. In the Syrian Arab Republic, 900 000 cases of waterborne diseases caused by water pollution were reported in 1996. There are also high rates of infantile diarrhoea and typhoid and hepatitis infections have increased. Animals are also attacked by several diseases, such as tapeworm and pulmonary tuberculosis and others, resulting from the use of untreated wastewater for fodder crop irrigation. In Turkey, the two major water-related diseases connected with irrigation and water resources development are schistosomiasis (bilharzias) and malaria. Schistosomiasis occurs sporadically, but the implementation of the large-scale projects within the Southeastern Anatolia Project (GAP) may eventually lead to epidemics. Malaria has long been a significant health problem in the country and is still common in areas of irrigation and water resources development.

Prospects for agricultural water management

Countries in the Middle East region consider water and irrigation management a key factor in the use and conservation of their water resources. In the near future, agricultural water management in the countries of the Middle East region for which information is available will take into consideration the following: control of groundwater abstraction in order to reduce overexploitation, use of non-conventional sources of water, improvement of the irrigation infrastructure and drainage network, rehabilitation and construction of dams, improvement of the water quality in irrigation, increasing water use efficiency and recovery of the expenses for water supply service. In some countries, in order to release the State budget from high expenditures related to water resources management, it has been considered necessary to involve the private sector. Developing water user associations is considered a priority in some countries.

In countries such as Iraq, Jordan and the Syrian Arab Republic, water will be a limiting factor over the next years. Iraq expects that between 2020 and 2030 a situation may arise in which there will be a shortage in the Tigris and Euphrates owing to the increasing demand in the riparian countries. Since water shortages are forecast to occur with the development of irrigation, solutions have to be found for an integrated basin-level planning of water resources development. Jordan expects that within the next years all its available water resources will be developed. The available renewable water will never be enough to meet the escalating water demand. Water deficit will have to be met by extracting groundwater at rates not exceeding the safe yields, desalination of brackish and saline water and seawater, rationing of the water demand and improving the country's water management. The Syrian Arab Republic estimates that its irrigation potential is lower than the area equipped for irrigation at present.

According to available information, the current use of non-conventional sources of water (desalination and/or reuse of treated wastewater) concerns 16 out of the 18 countries of the Middle East region. Only Armenia and Georgia do not use these sources of water as their resources are not as low as in other countries of the Middle East. Non-conventional sources of water are expected to develop considerably in the future to mitigate the lack of available resources in most of the Middle East countries. Bahrain, Israel, Jordan, Kuwait, Qatar and United Arab Emirates include in their respective prospects for water management the increase of desalinated water and treated wastewater in the near future. The Islamic Republic of Iran, Lebanon, Occupied Palestinian Territory, Saudi Arabia, and Turkey include principally the development of reused treated wastewater. For Armenia, Azerbaijan, Georgia, Iraq and Yemen only, no information is available regarding an increase of non-conventional sources of water in the near future. Groundwater recharge with advanced wastewater treatment technologies could also be an option which is being taken into consideration in some countries, such as Kuwait and Qatar. However, there is a lack of experimental data on groundwater recharge, so that efforts should be focused in this direction.

Increasing water use efficiency will be possible by adopting efficient localized farm irrigation methods and irrigation scheduling. Increasing the net benefit per unit of land and water could be possible by reducing the growth of crops with high water requirements. In the Caucasian countries and in Turkey, donors and international financial institutions have developed projects dealing with the rehabilitation of irrigation and drainage. In Qatar interest-free loans will be provided to farmers to promote modernizing irrigation systems with a repayment period of several years.

The determination of relevant prices, which should recover the expenses for water supply service, is said to be one of the principles of effective water resources management. In Israel, increasing water tariffs is also a solution to reduce water demand for municipal gardening, home gardening, the domestic sector and the agricultural sector. Qatar is looking at the possibility of introducing a pricing system for water consumption with penalties for extravagant water use and incentives for water saving.

Information regarding specific water plans for the near future is available for some countries. In Armenia, the sub-programme on irrigated agriculture of the Millennium Goal programme aims to find a solution to the existing problems of irrigation systems. In Lebanon, the Water Plan 2000–2010 defines the strategy to satisfy Lebanon's future water needs. In Oman, 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 Saudi Arabia, a Future Plan of Agriculture has been developed which calls for reducing water demand through a policy of diversification of agricultural production, taking into account the comparative advantages of each region of the country. In Turkey, irrigation investment in the GAP which will finish at the end of 2010 comprises 910 000 ha in the Euphrates River Basin and 540 000 ha in the Tigris River Basin planned for irrigation. In Yemen, specific objectives of the second Five-Year Plan are the optimal exploitation of available water resources, improving the means and techniques for water resources recovery and for feeding aquifers, and protecting water resources from pollution.

Although they already exist in some countries, water transfers are not included in any water plan presented for the future or in major prospects for water management in the Middle East region.

Regarding transboundary river basins, riparian countries need to prepare joint water management plans for each basin in order to avoid lack of communication, conflicting approaches, unilateral development, and inefficient water management practices which cause international crisis in these countries. In that direction, in 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. The institute will conduct its studies at the facilities of the Ataturk Dam, the largest dam in Turkey, and plans to develop projects for the fair and effective use of transboundary water resources.

Water professionals across the Middle East region recognize the need to focus more on integrated management of water resources and on regulation rather that provision of services. The region has seen major advances, but on the whole, progress towards better management has been slow. A series of technical and policy changes to the water sector in most Middle East countries is needed if they are to accelerate on water policy and avoid the economic and social hardships that might otherwise occur. The changes include planning that integrates water quality and quantity and considers the entire water system; promotion of demand management; tariff reform for water supply, sanitation and irrigation; strengthening of government agencies; decentralizing responsibility for delivering water services to financially autonomous utilities; and stronger enforcement of environmental regulations. The water sectors of the region will need to tackle three types of scarcity – scarcity of physical resources, scarcity of organization capacity and scarcity of accountability for achieving sustainable outcomes – in order to reduce the region's water management problems so that water can achieve its potential contribution to growth and employment (World Bank, 2007).

Description of four transboundary river basins

EUPHRATES–TIGRIS RIVER BASIN

Geography, climate and population

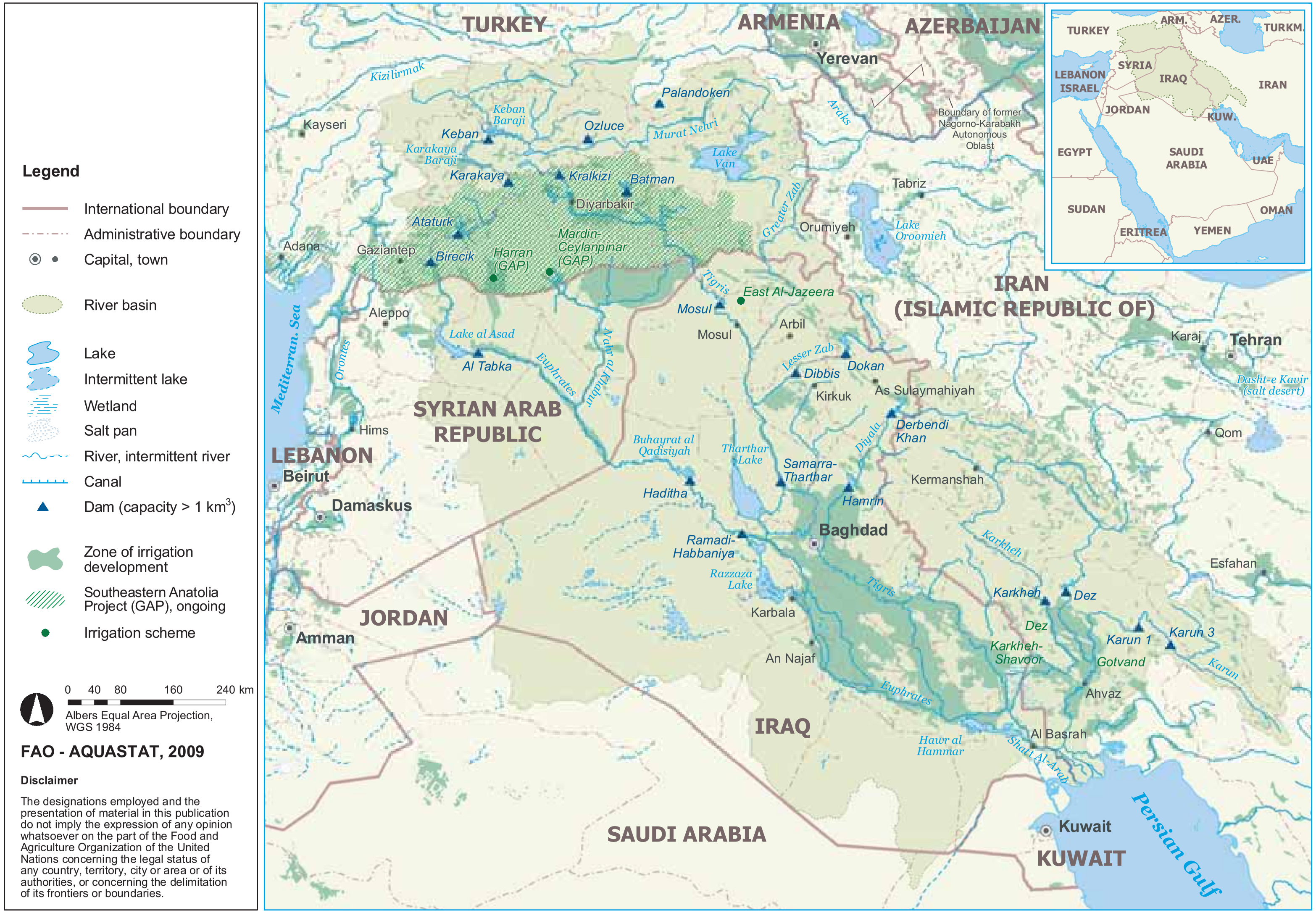
The Euphrates–Tigris River Basin is a transboundary basin with a total area of 879 790 km² distributed between Iraq (46 percent), Turkey (22 percent), the Islamic Republic of Iran (19 percent), the Syrian Arab Republic (11 percent), Saudi Arabia (1.9 percent) and Jordan (0.03 percent) (Lehner *et al*, 2008) (Table 29 and Figure 3). The Islamic Republic of Iran is riparian only to the Tigris, and Jordan and Saudi Arabia are riparian only to the Euphrates. Both the Euphrates and the Tigris rise in the mountains of eastern Turkey and the basin has high mountains to the north and west and extensive lowlands to the south and east. Two-thirds of their courses go through the highlands of eastern Anatolia in Turkey and the valleys of the Syrian and Iraqi plateaus before descending into the arid plain of Mesopotamia (Kibaroglu, 2002). The Euphrates and Tigris join near Qurna (Iraq) in a combined flow called Shatt Al-Arab, which empties into the Persian Gulf. However, more upstream within Iraq both rivers are also connected through the construction of several canals.

Most of the Euphrates–Tigris River Basin has a sub-tropical Mediterranean climate with wet winters and dry summers. In the mountainous headwater areas freezing temperatures prevail in winter and much of the precipitation falls in the form of snow. As the snow melts in spring the rivers rise, augmented by seasonal rainfall which reaches its maximum between March and May. In southeastern Turkey as well as in the north of the Syrian Arab Republic and Iraq the climate is characterized by rainy winters and dry warm summers. Average annual precipitation in the Euphrates–Tigris River Basin is estimated at 335 mm, although it varies all along the basin area (New *et al*, 2002). In the Mesopotamian Plain the annual rainfall is rarely above 200 mm, while it reaches 1 045 mm in other places in the basin. The summer season is exceedingly hot and dry with midday temperatures approaching 50 ºC and with daytime relative humidity as low as 15 percent. These climatic conditions demonstrate that both the Euphrates and the Tigris flow through arid and semi-arid regions within the Syrian Arab Republic and Iraq, since 60 percent of the Syrian territory receives less than 250 mm/year of precipitation and 70 percent of Iraq receives on average 400 mm/year (Kibaroglu, 2002). The annual average temperature of the entire Euphrates–Tigris River Basin is 18 ºC. The average temperature of the basin in January is 5 ºC, though it can decrease to -11 ºC in the coldest places in the basin. In July, the average temperature

TABLE 29
Country areas in the Euphrates-Tigris River Basin

Basin	Area		Countries included	Area of country in basin (km²)	As % of total area of the basin	As % of total are of the country
	km²	% of the Middle East				
Euphrates–Tigris	879 790	13	Iraq	407 880	46.4	93.1
			Turkey	192 190	21.8	24.5
			Iran (Islamic Republic of)	166 240	18.9	9.5
			Syrian Arab Republic	96 420	11.0	52.1
			Saudi Arabia	16 840	1.9	0.8
			Jordan	220	0.03	0.2

FIGURE 3
Euphrates-Tigris river basin



of the Euphrates–Tigris River Basin reaches 31 ºC, although in the hottest places it can increase to 37 ºC (New *et al, 2002).*

Water resources

The Euphrates originates in the eastern highlands of Turkey, between Lake Van and the Black Sea, and is formed by two major tributaries, the Murat and the Karasu. It enters the Syrian territory at Karkamis, downstream from the Turkish town of Birecik. It is the joined by its major tributaries, the Balik and Khabur, which also originate in Turkey, and flows southeast across the Syrian plateaus before entering the Iraqi territory near Qusaybah. Of the Euphrates Basin 28 percent lies in Turkey, 17 percent in the Syrian Arab Republic, 40 percent in Iraq, 15 percent in Saudi Arabia, and just 0.03 percent in Jordan. The Saudi Arabian stretch of the Euphrates dries in summer; there are no perennial rivers. The Euphrates river is 3 000 km long, divided between Turkey (1 230 km), the Syrian Arab Republic (710 km), and Iraq (1 060 km), whereas 62 percent of the catchment area that produces inputs into the river is situated in Turkey and 38 percent in the Syrian Arab Republic. It is estimated that Turkey contributes 89 percent of the annual flow and the Syrian Arab Republic 11 percent. The remaining riparian countries contribute very little water.

The Tigris, also originating in eastern Turkey, flows through the country until the border city of Cizre. From there it forms the border between Turkey and the Syrian Arab Republic over a short distance and then crosses into Iraq at Faysh Khabur. The Tigris river is 1 850 km long, with 400 km in Turkey, 32 km on the border between Turkey and the Syrian Arab Republic and 1 418 km in Iraq. Of the Tigris Basin 12 percent lies in Turkey, 0.2 percent in the Syrian Arab Republic, 54 percent in Iraq and 34 percent in the Islamic Republic of Iran. Turkey provides 51 percent, Iraq 39 percent, and the Islamic Republic of Iran 10 percent of the annual water volume of the Tigris, but because of unfavourable geographic and climatic conditions the latter cannot use the water of the Tigris for agriculture or hydropower (Kaya, 1998). Within Iraq, several tributaries flow into the river coming from the Zagros Mountains in the east, thus all on its left bank. From upstream to downstream there are:

- the Greater Zab, which originates in Turkey. It generates 13.18 km^3/year at its confluence with the Tigris; 62 percent of the total area of this river basin of 25 810 km^2 is in Iraq;
- the Lesser Zab, which originates in the Islamic Republic of Iran and which is equipped with the Dokan Dam (6.8 km^3). The river basin of 21 475 km^2 (of which 74 percent is in Iraqi territory) generates about 7.17 km^3/year, of which 5.07 km^3 of annual safe yield after construction of the Dokan Dam;
- the Al-Adhaim or Nahr Al Uzaym, which drains about 13 000 km^2 entirely in Iraq. It generates about 0.79 km^3/year at its confluence with the Tigris. It is an intermittent stream subject to flash floods;
- the Diyala, which originates in the Islamic Republic of Iran and which drains about 31 896 km^2, of which 75 percent in Iraqi territory. It is equipped with the Derbendi Khan Dam and generates about 5.74 km^3/year at its confluence with the Tigris;
- the Nahr at Tib, Dewarege (Doveyrich) and Shehabi rivers, draining together more than 8 000 km^2. They originate in Iranian territory, and together bring into the Tigris about 1 km^3/year of highly saline waters;
- the Karkheh, the main course of which is mainly in the Islamic Republic of Iran and which, from a drainage area of 46 000 km^2, brings about 6.3 km^3 yearly into Iraq, namely into the Hawr Al Hawiza during the flood season, and into the Tigris River during the dry season

The Shatt Al-Arab is the river formed by the confluence downstream of the Euphrates and the Tigris and it flows into the Persian Gulf after a course of only

190 km. The Karun River, originating in Iranian territory, has a mean annual flow of 24.7 km³ and flows into the Shatt Al-Arab just before it reaches the sea, bringing a large amount of freshwater.

The average annual discharge of the Euphrates and Tigris rivers together is difficult to determine due to the large yearly fluctuation. According to the records for 1938–1980, there have been years when 68 km³ were observed in the two rivers in the mid–1960s, and years when the amount was over 84 km³ in the mid–1970s. On the other hand, there was the critical drought year with less than 30 km³ at the beginning of the 1960s. Such variation in annual discharge makes it difficult to develop an adequate water allocation plan for competing water demand from each sector as well as fair sharing of water among neighbouring countries (UNDG, 2005). The annual flow of the Euphrates River Basin from Turkey to the Syrian Arab Republic is 28.1 km³, of which 26.9 km³ corresponds to the Euphrates main river, and 30.0 km³ from the Syrian Arab Republic to Iraq. The annual flow of the Tigris River Basin from Turkey to Iraq is 21.3 km³. The Tigris borders the Syrian Arab Republic only over a short distance in the east and therefore very little annul flow, estimated at 1.25 km³/year, can be available for the Syrians (Abed Rabboh, 2007). The annual flow of the tributaries of the Tigris from Iran to Iraq is 10 km³.

Turkey finds itself in a strategically strong position as the only country in the Euphrates–Tigris River Basin to enjoy abundant surface water and groundwater resources. The Syrian Arab Republic depends heavily on the water of the Euphrates. Iraq is also reliant upon the Euphrates, but uses the Tigris River as well as an alternative source of water (Hohendinger, 2006).

Groundwater aquifers in Iraq consist of extensive alluvial deposits of the Tigris and Euphrates and are composed of Mesopotamian-clastic and carbonate formations. The alluvial aquifers have limited potential because of poor water quality. The alluvial aquifers contain large volume reservoirs: and annual recharge is estimated at 620 million m³ from direct infiltration of rainfall and surface water runoff.

Water quality

Downstream riparian countries complain about the quality of the water. Turkey's use of water has so far been limited mainly to hydropower generation and irrigation. While the former use is considered non-consumptive and not directly linked to water quality, the return flow from irrigation causes water pollution, which in turn affects potential downstream uses. Equally important are natural causes of environmental concern in the sense that some residual characteristics common to both rivers exacerbate the damaging effects of human pollution. Notable natural causes are the high rate of evaporation, sharp climatic variations, the accumulation of salts and sediments, poor drainage and low soil quality in the lower reaches of the Tigris and Euphrates (Erdem, after 2002).

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

The deterioration of water quality and the heavy pollution from many sources are becoming serious threats to the Euphrates–Tigris River Basin. A problem is that there is no effective water monitoring network, making it difficult to address water quality and pollution, as the sources of pollution cannot be precisely identified. Hence, the rehabilitation and reconstruction of the water monitoring network is urgently needed for water security.

Water-related development in the basin

The Euphrates and Tigris were the cradle of the early Mesopotamian civilizations and irrigation made it possible for the local people to develop agriculture. This resulted in the development of great ancient civilizations, where water played an important role. Mesopotamia, the land between the Euphrates and the Tigris, remained the centre of many different civilizations and gave life to millions of inhabitants up to modern times (AU, 1997). Unfortunately, as is usually the case, the seasonal distribution of the availability of water does not coincide with the irrigation requirements of the basin. The typical low water season in the Euphrates occurs from July to December, reaching its lowest point in August and September when water is most needed to irrigate the region's winter crops (Akanda *et al*, 2007). In the area close to the two river systems, rainfed farming is possible, although supplementary irrigation would raise yield and allow several cropping seasons. In the Mesopotamian Plain, however, the evaporative demand is very high and crops require intensive irrigation because of low annual rainfall and hot and dry summers. The total area equipped for irrigation in the Euphrates–Tigris River Basin is estimated to be around 6.5–7 million ha, of which Iraq accounts for approximately 53 percent, the Islamic Republic of Iran for 18 percent, Turkey for 15 percent and the Syrian Arab Republic for 14 percent. Agricultural water withdrawal is approximately 68 km^3.

Iraq was the first riparian country to develop engineering projects in the basin. The Al Hindiya and Ramadi-Habbaniya dams on the Euphrates were constructed in 1914 and in 1951 respectively, both for flood control and irrigation (Kaya, 1998). By the mid–1960s, the development of irrigated agriculture in Iraq far surpassed the development in the Syrian Arab Republic and Turkey. During this period, Iraq was irrigating over five times as much land in the river basin as the Syrian Arab Republic and nearly ten times as much as Turkey. To continue its efforts to use the water of these rivers efficiently and to provide irrigation water for the land between the Euphrates and the Tigris rivers, Iraq began constructing in the 1960s a 565 km long canal, the Third River (also called Saddam River), between the Euphrates and Tigris, which was completed in 1992. In the late 1970s, as part of the effort to prevent flood damage, Iraq built another canal to divert excess water from the Tigris into Lake Thartar. Since then, Iraq has built other similar canals linking Lake Thartar to the Euphrates and again connecting the lake with the Tigris. Iraq has also built dams on the Euphrates and Tigris to produce hydropower, such as the Haditha Dam completed in 1985 (Korkutan, 2001). In 1991 a large irrigation project, the North Al-Jazeera irrigation project, was launched in order to serve approximately 60 000 ha by using a linear-move sprinkler irrigation system with water stored by the Mosul Dam. Another irrigation project, the East Al-Jazeera irrigation project, involved the installation of irrigation networks on more than 70 000 ha of previously rainfed land near Mosul. These projects were part of a scheme to irrigate 250 000 ha in the Al-Jazeera plain.

The Syrian Arab Republic began exploiting the water of the Euphrates for irrigation and hydropower in the early 1960s. The Tabqa Dam was built on the Euphrates in 1973, mainly with the help of the then Soviet Union. The purpose of this major dam was to meet the Syrian Arab Republic's water and energy needs. The Bath Dam, completed in 1986, was the second Syrian dam on the Euphrates river. However, the hydropower capacity of the Bath Dam was not of the same scale as the Tabqa Dam.

The Bath Dam had a limited capacity for electricity generation and provided relatively little water for irrigation. The Tishreen Dam, the third Syrian dam on the Euphrates, mainly designed for hydropower, is still under construction. Since the Tigris river forms the border with Turkey, the Syrian Arab Republic could not build reservoirs to store or divert the water of this river without the cooperation of its neighbour on the other bank (Korkutan, 2001).

Turkey began constructing its first dam on the Euphrates River, the Keban Dam near Keban Strait, in the mid–1960s and finished the project in 1973. The second dam on the Euphrates was the Karakaya Dam, completed in 1988. This was the first dam built as part of the implementation of the Southeastern Anatolia Project (GAP). Like the Keban Dam, the purpose of the Karakaya Dam was to produce hydropower. The third dam on the Euphrates River was the Ataturk Dam, the most important in the GAP Project, completed in 1992. It was designed to store water for large-scale irrigation as well as for the generation of hydropower (Korkutan, 2001).

Table 30 shows the large dams in the Euphrates–Tigris River Basin, i.e. dams with a height of more than 15 metres or with a height of 5–15 metres and a reservoir capacity larger than 3 million m^3 according to the International Commission on Large Dams (ICOLD).

Transboundary water issues

During the 20th century various bilateral attempts at cooperation were made within the Euphrates–Tigris Basin. In 1920 the French and British governments, as the mandatory powers in Mesopotamia, signed a treaty regarding utilization of the water of the Euphrates and Tigris. The Turco–French Protocol, signed in 1930, committed the Turkish and French governments to coordinate any plans to use the water of the Euphrates. The principle of mutual cooperation over water development was extended in a Protocol annexed to the 1946 Treaty of Friendship and Good Neighbourly Relations between Turkey and Iraq. The agreement encompassed both rivers and their tributaries, and both countries agreed that the control and management of the Euphrates and Tigris rivers depended to a large extent on the regulation of flow in the Turkish source areas. At that time Turkey and Iraq agreed to share related data and consult with each other in order to accommodate both countries' interests. The 1946 Treaty mandated a committee to implement these agreements. However, none of this occurred because of different conflicts among the riparian countries (Kaya, 1998).

As the population of the region progressively increases, the demand for agricultural products increases and hence also the number of water supply projects. In 1973, Turkey constructed the Keban Dam in the Euphrates River Basin. The Syrian Arab Republic soon followed suit with the Tabqa Dam, also completed in 1973 and filled in 1975. The filling of these dams caused a sharp decrease in downstream flow and the quantity of water entering Iraq fell by 25 percent, causing tension between the countries (El Fadel *et al.*, 2002). The tension eased when 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 1976, Turkey pledged to release 350 m^3/s from the Euphrates downstream and later in the same year increased the minimum flow to 450 m^3/s, also in an effort to reduce tensions.

In 1977, Turkey announced plans for the region's largest water development project ever, the Southeastern Anatolia Project (GAP), which included 22 dams and 19 hydropower projects to be built on the Euphrates–Tigris. This project is intended to provide irrigation, hydropower, and socio-economic development in Turkey. The Syrian Arab Republic and Iraq fear that the project will lead to reduced river flows and leave little water for use in their countries' agricultural and energy projects (Akanda *et*

TABLE 30
Large dams in the Euphrates-Tigris River Basin

Country	Name	Nearest city	River	Year	Height (m)	Capacity (million m³)	Main use *
Turkey							
	Keban	Elazig	Firat	1975	210	31 000	H, F
	Karakaya	Diyarbakir	Firat	1987	173	9 580	H
	Ataturk	Sanliurfa	Firat	1992	169	48 700	I, H
	Ozluce	Bingol	Peri	2000	144	1 075	H
	Kralkizi	Diyarbakir	Maden	1997	126	1 919	H
	Kuzgun	Erzurum	SerCeme	1996	110	312	I, H
	Dicle	Diyarbakir	Dicle	1997	87	595	I, H, W
	Batman	Batman	Batman	1999	85	1 175	I, H, F
	Erzincan	Erzincan	Goyne	1997	81	8	I
	Zernek	Van	Hosap	1988	80	104	I, H
	Kockopru	Van	Zilan	1992	74	86	I, H, F
	Kayalikoy	Kirklareli	Kaya	1986	72	150	I
	Demirdoven	Erzurum	Timar	1996	67	34	I
	Tercan	Erzincan	Tuzla	1988	65	178	I, H
	Birecik	Sanliurfa	Firat	2000	63	1 220	I, H
	Sarimehmet	Van	Karasu	1991	62	134	I
	Sultansuyu	Malatya	Sultansuyu	1992	60	53	I
	Mursal	Sivas	Nih	1992	59	15	I, H
	Surgu	Malatya	Surgu	1969	55	71	I
	Polat	Malatya	Findik	1990	54	12	I
	Goksu	Diyarbakir	Goksu	1991	52	62	I
	Kayacik	Karaburun		2002	50	117	I
	Hancagiz	Gaziantep	Nizip	1989	45	100	I
	Camgazi	Adiyaman	Doyran	1999	45	56	I
	Medik	Malatya	Tohma	1975	43	22	I
	Hacihidir	sanliurfa	sehir	1989	42	68	I
	K. Kalecik	Elazig	Kalecik	1974	39	13	I
	Gayt	Bingol	Gayt	1998	36	23	I
	Devegecidi	Diyarbakir	DevegeCidi	1972	33	202	I
	Dumluca	Mardin	Bugur	1991	30	22	I
	Karkamis	Kahramanmaras	Firat	2000	29	157	H
	Cip	Elazig	Cip	1965	23	7	I
	Palandoken	Erzurum	GedikCayiri	1997	19	1 558	I
	Porsuk	Erzurum	Masat	1994	17	770	I
					Total	**99 598**	
Syrian Arab Republic							
	Al Tabka	At Thawrah	Euphrates	-	-	11 200	
					Total	**11 200**	
Iraq							
	Mosul	Mosul	Tigris	1983	131	12 500	I
	Derbendi Khan	Ba'qubah	Diyola river	1962	128	3 000	I
	Dokan		Lesser Zab	1961	116	6 800	I
	Haditha	Haditha	Euphrates	1984	57	8 200	I, H
	Hamrin	Ba'qubah	Diyola river	1980	40	4 000	
	Dibbis		Lesser Zab	1965	15	3 000	I
	Samarra - Tharthar	Samarra	Tigris	1954	-	72 800	F
					Total	**110 300**	
Iran (Islamic Republic of)							
	Karoun 3	Eizeh	Karoun	2004	205	2 970	I, H
	Dez	Andimeshk	Dez	1962	203	2 856	I, H, W
	Karoun 1	Masjedsoleyman	Karoun	1976	200	3 139	I, H
	Masjedsoleyman	Masjedsoleyman	Karoun	2001	177	230	I, H
	Gavoshan	Kamyaran	Gaveh roud	-	136	550	I, H, W
	Karkheh	Andimeshk	Karkheh	2001	127	5 575	I, H, F
	Vahdat	Sanandaj	Gheshlagh	-	80	224	I, H, W
	Eilam	Eilam	Baraftab & Chaviz	-	65	71	I, W
	Guilangharb	Guilangharb	Guilangharb	-	51	17	I
	Shahghasem	Yasouj	Parikedoun	1996	49	9	I
	Hana	Samirom	Hana	1996	36	48	I
	Bane	Bane	Banechay	-	20	4	W
	Chaghakhor	Boldaji	Aghbolagh	1992	13	42	I
	Zarivar	Marivan	Zarivar	-	11	97	I
					Total	**15 832**	
					TOTAL	**236 930**	

* I = irrigation; H = Hydropower, W = Water Supply; F = Flood protection

al, 2007). The construction of the Ataturk Dam in Turkey, one of the GAP projects, was completed in 1992.

In 1983, Turkey, Iraq and the Syrian Arab Republic established the Joint Technical Committee for Regional Waters to deal with all water issues among the Euphrates–Tigris Basin riparian countries 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 any progress (Akanda *et al*, 2007).

In 1984, Turkey proposed a "Three-staged plan for optimal, equitable and reasonable utilization of the transboundary watercourses of the Euphrates–Tigris Basin". This plan, which conforms to the principle of equitable utilization, proposes that the riparian countries jointly conduct and complete inventory studies and evaluation of water and land resources. This plan would promote objective data-gathering in the basin. After evaluation of all the data the proposed projects could be compared, based on their economic and social merits, and those deemed more beneficial could be implemented. The plan considers the basin to be a whole system, underlining the interdependence of its elements, as required by the UN Watercourses Convention (Kaya, 1998). For its part, the Syrian Arab Republic has proposed the following formula for water allocation: each riparian country will notify the other riparian countries of its demands on each river separately; the capacities of both rivers in each riparian country shall be calculated and, if the total demand exceeds the total supply of a given river (as is sure to be the case), the exceeding amount will be deducted proportionally from the demand of each riparian country (El Fadel *et al*, 2002).

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).

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 using the figure of 15.75 km^3/year from Turkey (FAO, 2004b).

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, but is limited because it only involves Turkey and the Syrian Arab Republic (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 in the average, will be 1.25 km^3, with a drainage capacity proportional to the aimed surface of 150 000 ha (FAO, 2002)

In April 2008, Turkey, the Syrian Arab Republic and Iraq decided to cooperate on water issues by establishing a water institute that will consist of 18 water experts from each country to work towards solving water-related problems among the three countries. This institute will conduct its studies at the facilities of the Ataturk Dam, the dam with the largest reservoir capacity in Turkey, and plans to develop projects for the fair and effective use of transboundary water resources (Yavuz, 2008).

Table 31 lists the main historical events in the Euphrates–Tigris River Basin.

KURA–ARAKS RIVER BASIN

Geography, climate and population

The Kura-Araks River Basin is a transboundary basin with a total area of about 190 110 km^2 of which 65 percent is located in the South Caucasus countries:

TABLE 31
Chronology of major events in the Euphrates-Tigris River Basin

Year	Plans/projects/treaties/conflicts	Countries involved	Main aspects
1914	Al Hindiya dam on the Euphrates	Iraq	For flood control and irrigation purposes
1920	Treaty regarding utilization of the waters of the Euphrates and the Tigris rivers	France and Great Britain	
1930	Turco-French Protocol	Turkey and France	Coordinates any plans to use the waters of the Euphrates.
1946	Treaty of Friendship and Good Neighbourly Relations	Turkey and Iraq	Extended the principle of mutual cooperation over water development in both rivers. Sharing of related data.
1951	Ramadi Habbaniya dam on the Euphrates	Iraq	For flood control and irrigation purposes.
1960s	Start of the construction of the "Third River"	Iraq	565 km canal between the Euphrates and the Tigris (completed in 1992).
1970s	Construction of several canals	Iraq	Linking Lake Thartar to the Euphrates, and connecting the lake with the Tigris.
1973	The Kevan dam	Turkey	First dam on the Euphrates for Turkey. Construction started in the 1960s. For hydropower purposes.
1973	The Tabqa dam	Syrian Arab Republic (with the help of the USSR)	First dam on the Euphrates for the Syrian Arab Republic, to meet water and energy needs.
1975	Filling of the Tabqa dam conflict	Syrian Arab Republic and Iraq (Saudi Arabia and possibly USSR mediated)	Major sources of conflict between Syrians and Iraqis addressed. Finally the Syrian Arab Republic released more water from the dam to Iraq.
1976	Release of 350 m^3/s from the Euphrates downstream	Turkey	Prevented tension between the Syrian Arab Republic and Iraq, regarding the filling of the Tabqa Dam.
1977	Southeastern Anatolia Project (GAP)	Turkey	Turkey announced plans for GAP, which included 22 dams and 19 hydropower installations on the Euphrates-Tigris.
1983	Establishment of Joint Technical Committee for Regional Waters	Turkey, Iraq, and the Syrian Arab Republic	Dealing with water issues between the basin riparian countries, to ensure principles of consultation and notification as required by international law. This group disintegrated after 1993 without any progress having been made.
1984	Turkey proposes a "Three-staged plan"	Turkey (indirectly Syrian Arab Republic and Iraq)	For optimal, equitable and reasonable utilization of the transboundary watercourses of the Euphrates-Tigris basin. Conforms to the principle of equitable utilization.
1985	The Haditha dam	Iraq	Dam on the Euphrates river to produce hydropower.
1986	The Bath dam	Syrian Arab Republic	Second dam on the Euphrates for the Syrian Arab Republic. Small-scale electric generation and small amount of water for irrigation.
1987	Informal agreement guaranteed 500 m^3/s of the Euphrates from Turkey to the Syrian Arab republic	Turkey and the Syrian Arab Republic	The Syrian Arab Republic has accused Turkey of violating this agreement a number of times.
1988	The Karakaya dam	Turkey	Second dam on the Euphrates. First dam built under the GAP. For production of hydropower.
1990	Agreement between the Syrian Arab Republic and Iraq to share the Euphrates water	Syrian Arab Republic and Iraq	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. Corresponds to a flow of 9 km^3/year.
1992	Completion of the Ataturk dam	Turkey	Third dam on the Euphrates for Turkey, the most important one under the GAP project. For irrigation and hydropower. The filling of the dam, shutting off the river flow for a month, causes conflict with Syrians and Iraqis.
2001	Joint Communiqué	GOLD (Syrian Arab Republic), and GAP-RDA (Turkey)	Supporting training, technology exchange, study missions, and joint projects.
2002	Bilateral Agreement concerning the installation of a Syrian pump station on the Tigris river	Syrian Arab Republic and Iraq	For irrigation purposes.
2008	Cooperation on water issues by establishing a water institute	Turkey, the Syrian Arab Republic and Iraq	18 water experts from each country to work toward the resolution of water-related problems.

FIGURE 4
Kura-Araks river basin

TABLE 32
Country areas in the Kura-Araks River Basin

Basin	Area		Countries included	Area of country in basin (km²)	As % of total area of the basin	As % of total area of the country
	km²	% of the Middle East				
Kura-Araks	190 250	2.90	Azerbaijan	60 020	31.5	69.3
			Iran (Islamic Republic of)	37 080	19.5	2.1
			Georgia	34 560	18.2	49.6
			Armenia	29 800	15.7	100.0
			Turkey	28 790	15.1	3.7

31.5 percent in Azerbaijan, 18.2 percent in Georgia and 15.7 percent in Armenia. The remaining part is distributed between the Islamic Republic of Iran (19.5 percent of the basin) and Turkey (15.1 percent) (Lehner *et al*, 2008) (Table 32 and Figure 4). The Kura-Araks River Basin is situated south of the Caucasus Mountains. Its borders are northeastern Turkey, central and eastern Georgia, and the northwestern part of the Islamic Republic of Iran. It contains all the territory of Armenia and more than two-thirds of Azerbaijan. The Kura River rises in Georgia and the Araks River in Turkey and both join in Azerbaijan about 150 km before its mouth at the Caspian Sea.

The geographical location of the South Caucasus at the border where the humid Mediterranean and dry continental air masses meet, the complex mountainous relief and other factors have conditioned the diversity of climate zones across the region, from everlasting snow caps and glaciers to warm humid subtropical forests and humid semi-desert steppes. Average annual precipitation in the basin is estimated at 565 mm, although it varies all along the basin territory. The annual average temperature of the entire Kura–Araks River Basin is estimated at 9 ºC. Average temperature in January is -4 ºC although it can drop to -13 ºC in the coldest places of the basin. In July, average temperature reaches 22 ºC, although in the hottest places it can increase to 28 ºC (New *et al*, 2002). The climate of Armenia, which is entirely located in the basin, is highland continental: hot summers and cold winters. Average annual temperature is 5.5 °C. Summer in Armenia is moderate, with the average temperature for July at 16.7 °C, and in the Ararat Valley it varies in the range of 24–26 °C. Winters are quite cold, with an average temperature of -6.7 °C. Total annual precipitation in Armenia is 592 mm. The driest regions are the Ararat Valley and the Meghri region, where the annual precipitation is 200–250 mm. The maximum precipitation, observed in high mountainous areas, is more than 1 000 mm annually. Azerbaijan is situated at the northern extremity of the subtropical zone and two-thirds of the country is located in the Kura–Araks River Basin. Its climatic diversity is caused by the complicated geographical location and landscape, the proximity of the Caspian Sea, the effect of the sun's radiation, and air masses of different origin. The climate in Azerbaijan is continental. Arid weather with average summer temperatures above 22 °C is observed in the lowlands. In the mountain regions, temperatures may be below 0 °C in winter. Humid tropical weather is observed in the coastal zone near the Caspian Sea, mainly in the Lankaran lowlands in the southeast. The average precipitation is estimated at 447 mm/year. Almost half of Georgia, the eastern part, is located in the Kura–Araks River Basin, which has a subtropical dry climate with relatively cold winters and arid, hot summers. The average precipitation varies between 500 and 1 100 mm/year. About 80 percent of the rainfall occurs from March to October, while the longest dry period is about 50–60 days. Drought years are common. There is a need for irrigation in the areas where precipitation is less than 800 mm/year. Average temperatures vary between –1 °C in January and 22 °C in July.

Finally, as far as Turkey and the Islamic Republic of Iran are concerned, while a considerable part of the basin, 15 and 19 percent, respectively, is located in these countries, only a small part of each country, 4 and 2 percent respectively, is located in the Kura–Araks River Basin.

Average population densities are 128 persons/km^2 in Armenia, 93 persons/km^2 in Azerbaijan, and 78 persons/km^2 in Georgia. There are three cities with an excess of 1 million inhabitants in the South Caucasus: Baku (Azerbaijan), Tbilisi (Georgia), and Yerevan (Armenia) (Ewing, 3003).

A majority of the population of the Caucasus still lives below the poverty line. Gross Domestic Product (GDP) has decreased roughly by 50 percent since 1991, poverty levels have reached 60–80 percent, and unemployment has skyrocketed. Even though all three countries have shown signs of macroeconomic recovery and progress in the implementation of structural reforms, there has been emigration from the region to the Russian Federation, Turkey, the Persian Gulf, and the West (Vener, 2006).

Water resources

The Kura River, with a total length of 1 515 km, rises in Georgia and flows into Azerbaijan before entering the Caspian Sea. It has an average discharge of 0.575 km^3/year. Two of its tributaries rise in Turkey: the Mtkvari, with an inflow from Turkey estimated at 0.91 km^3/year, and the Potskhovi, with an inflow estimated at 0.25 km^3/year. The inflow of the Debet River, a southern tributary of the Kura River, is estimated at 0.89 km^3/year from Armenia to Georgia. The annual flow from Georgia to Azerbaijan of the Kura Basin is 11.9 km^3 and the annual flow of the Agstay from Armenia to Azerbaijan is about 0.35 km^3.

The Araks River originates in Turkey and after 300 km forms part of the international border between Armenia and Turkey, then for a very short distance between Azerbaijan and Turkey, between Armenia and the Islamic Republic of Iran, and between Azerbaijan and the Islamic Republic of Iran. The Araks River is about 1 072 km long and it has an average discharge of 0.21 km^3/year (Berrin and Campana, 2008). The total annual flow from Armenia to Azerbaijan through the Araks River and its tributaries (Arpa, Vorotan, and Vokhchi) is estimated at about 5.62 km^3, and from the Islamic Republic of Iran is estimated at 7.5 km^3. The Araks River joins the Kura River in Azerbaijan about 150 km before its mouth at the Caspian Sea.

With respect to storm water and sewage effluent discharges, the Kura–Araks River Basin receives 100 percent of Armenia's, 60 percent of Georgia's, and 50 percent of Azerbaijan's deficit (Berrin and Campana, 2008).

The South Caucasus countries are faced with water quantity and quality problems. In general terms, Georgia has a lot of water, Armenia has some shortages due to poor management, and Azerbaijan has a lack of water; moreover, its groundwater is of poor quality. In Georgia, the main use of the Kura–Araks water is agriculture. In Armenia it is agriculture and industry whereas in Georgia drinking water is withdrawn from a large fresh groundwater stock. In Azerbaijan, the Kura–Araks water is the primary source of freshwater, and 70 percent of drinking water comes from these rivers. In general, water is used for municipal, industrial, irrigation, fishery, recreation, and transportation purposes. The main water use is agriculture, followed by industry and households uses (Berrin and Campana, 2008).

Water quality

During the Soviet era and also in the post-Soviet period, large volumes of effluents were discharged into surface water bodies by the municipal, industrial and agriculture sectors, causing pollution of both surface water and groundwater. The largest source of pollution is municipal wastewater, which pollutes the rivers downstream of large cities with organic matter, suspended solids, surfactants, etc. Industrial wastewater discharges also are high, polluting surface water with heavy metals, oil products, phenols and other hazardous substances. In Georgia, for example, large industrial facilities producing manganese, ammonia, machinery, etc. together with arsenic, copper and gold mining and processing plants, oil refineries and power plants pollute the river bodies of the Black Sea and the Caspian Sea basins with heavy metals, oil products, phenols and other toxic substances. In Armenia and Azerbaijan, different industries also have discharged high loads of pollutants into the Kura and Araks rivers and their tributaries (UNEP, 2002). Agricultural return flows also contribute to the Kura–Araks pollution with pesticides such as DDT (Berrin and Campana, 2008). On its way through Turkey and the Islamic Republic of Iran, there is also a large populated area with an advanced industry, which increases the pollution in the Kura–Arak rivers.

Water-related development in the basin

The total area equipped for irrigation in the Kura–Araks River Basin is estimated at between 2 and 2.5 million ha, of which Azerbaijan accounts for approximately 45 percent, the Islamic Republic of Iran 21 percent, Georgia 14 percent, Armenia 11 percent and Turkey 8 percent. Agricultural water withdrawal is about 19 km^3.

During the Soviet era, the Caucasus was an important agricultural region that supported the entire USSR. Soviet agriculture was highly inefficient and suffered from poorly equipped infrastructure. At present, agriculture remains the main sector in the region, employing a significant amount of the population. In the Soviet period, from the 1970s to 1980s, industry in the Caucasus was well developed. The major industrial sectors were oil and gas, chemicals and machinery, ferrous and non-ferrous metals, cement, fertilizer, light manufacturing, and food processing. This rapid industrial development resulted in increased environmental pressures. After the USSR was dismantled, industrial production declined sharply because of the energy crisis and the dissolution of economic ties among the former Soviet Republics. Recently, some signs of industrial revival have appeared. However, the growth rate is still insignificant (Vener, 2006).

The main Kura and Araks rivers have only two reservoirs but the tributaries have more than 130 major reservoirs. Table 33 shows the large dams in the Kura–Araks River Basin, i.e. dams with a height of more than 15 metres or with a height of 5–15 metres and a reservoir capacity greater than 3 million m^3 according to the International Commission on Large Dams (ICOLD).

Transboundary water issues

During the Soviet era, water resources management of the basin was contingent upon the policy that the USSR was implementing at the time. In the 1960s and 1970s, surface water quality standards for a broad spectrum of substances were established. Domestic sewage was required to enter wastewater treatment facilities and undergo both mechanical and biological treatment. Meanwhile, no standards, guidelines or management practices existed for controlling diffused source pollution. Until 1991, there were no taxes on water pollution. Only water use fees were employed, introduced in 1982. In essence, they served more to finance state water protection programmes rather than to give an incentive to water users to conserve a resource. Legal requirements, existing laws, regulations and standards were frequently ignored or violated, because of their strictness and unfeasibility (UNEP, 2002). In the Soviet period the USSR signed an agreement with Turkey concerning the use of the Araks River, according to which the water of this transboundary river is divided equally between the countries. According to another agreement signed between the USSR and the Islamic Republic of Iran, the water of the Araks River is divided equally between them.

When Armenia, Azerbaijan and Georgia became independent states, the three countries had neither water resources management regulations nor water codes. However, each country has adopted water codes within the last 15 years: Armenia in 1992 and revised in 2002 according to the European Union Water Framework Directives

TABLE 33
Large dams in the Kura-Araks River Basin

Country	Name	Nearest City	River	Year	Height (m)	Capacity (million m³)	Main use*
Armenia	Spandaryan	Sistan	Vorotan	1989	83	257	I, H, O
	Azat	Artashat	Azat	1976	76	70	I, H, O
	Her-her	Vayk	Arpa	1993	74	26	I, H
	Tolors	Sistan	Sisian	1975	69	96	I, H
	Akhuryan	Maralik	Akhuryan	1981	59	525	I
	Aparan	Aparan	Qasakh	1966	52	91	I
	Kechut	Jermuk	Arpa	1981	50	25	I, O
	Hakhum	Berd (Ijevan)	Hakhum	1985	45	12	I
	Shamb	Sistan	Vorotan	1970	41	14	H
	Tavush	Berd	Tavush	1973	37	5	I
	Karnut	Gyumri	Akhuryan	1973	35	25	I
					Total	**1 146**	
Azerbaijan	Sarsang	Terter	Terter	1976	125	565	I, F, H
	Mingechevir	Mingechevir	Kura	1953	80	15 730	I, W, F, H, N, R
	Shamkir	Shamkir	Kura	1983	70	2 677	I, W, F, H
	Agstafachay	Kazax	Agstafachay	1969	53	120	I, F
	Araz	Nakhchivan	Araz	1971	40	1 350	I, W, F, H
	Xachinchay	Agdam	Xachinchay	1964	38	23	I, F
	Ayrichay	Sheki	Ayrichay	1986	23	81	I, F
					Total	**20 546**	
Georgia	Jinvali	Dusheti	Pshavis Aragvi	1985	102	520	I, W, H
	Sioni	pianeti	Iori	1963	85	325	I, H
	Dalis Mta	Dedoplistskaro	Iori	0	38	180	I
	Tblisi-Samgori	Tbilisi	Iori	1956	15	308	I, W, R
					Total	**1 333**	
Iran (Islamic Republic of)	Sabalan	Meshkin shahr	Ghare Sou	2006	89	105	I, W
	Makou	Makou	Zangmar	0	78	150	I, W, H
	Satarkhan	Ahar	Ahar Chay	1998	78	135	I, W
	Yamchi	Ardebil	Balkhli Chay	2004	67	82	I, W
	Zenouz	Zenouz	Zenouz Chay	2004	60	6	I
	Aras	Jolfa	Aras	0	42	1 350	I, H
	Arasbaran	Kalibar	Silinchay	2003	34	25	I
	Ghourichay	Ardebil	Ghourichay	1996	33	20	I
	Shourabil	Ardebil	Balkhli	2001	10	14	I
					Total	**1 887**	
Turkey	Arpacay	Kars	ArpaCay	1983	59	525	
	Catoren	Eskisehir	Harami	1987	45	47	
	Beyler	Kastamonu	Incesu	1994	42	25	
	Patnos	Agri	Gevi	1992	38	33	
					Total	**630**	
					TOTAL	**25 542**	

* I = irrigation; H = Hydropower, W = Water Supply; F = Flood protection; N = Navigation; R = Recreation

(EU-WFD), and Georgia and Azerbaijan in 1997. Nevertheless, there is no uniform control or management system for the rivers and, in the post-Soviet period, no water quality monitoring by the riparian countries. While the three countries are willing to cooperate on water-related issues since they recognize their dependency on the basin, whose waters they must share, they have not resolved their political, economic, and social issues. Currently no water treaties exist among the three countries, a condition directly related to the difficult political situation in the region.

In 1997, an agreement on environmental protection was signed between the governments of Georgia and Azerbaijan. In 1998, a similar agreement was signed between Georgia and Armenia. According to both agreements, the governments will cooperate in creating specifically protected areas within the transboundary ecosystems.

Azerbaijan and the Islamic Republic of Iran have an agreement on the protection of the Araks River (UNECE, 2004).

In 2002, the Republic of Armenia Commission on Transboundary Water Resources was established, chaired by the Head of the Water Resources Management Agency. This

TABLE 34
Chronology of major events in the Kura-Araks River Basin

Year	Plans/projects/treaties/conflicts	Countries involved	Main aspects
Soviet period	Agreement concerning the use of the water of the Araks river	USSR and Turkey	The water of the Araks river is divided equally between them.
Soviet period	Agreement concerning the use of the water of the Araks river	USSR and the Islamic Republic of Iran	The water of the Araks river is divided equally between them.
1960s–1970s	Surface water quality standards	USSR	Surface water quality standards for a broad spectrum of substances was established.
1982	Water use fees	USSR	
1992	Water code in Armenia	Armenia	In 2002 the code was revised according to the European Union Water Framework Directives.
1997	Water code in Azerbaijan	Azerbaijan	
1997	Water code in Georgia	Georgia	
1997	Agreement on environmental protection	Georgia and Azerbaijan	Cooperation in creating specifically protected areas within the transboundary ecosystems.
1998	Agreement on environmental protection	Georgia and Armenia	Cooperation in creating specifically protected areas within the transboundary ecosystems.
1999–2001	Integrated water resources management plan for Armenia	Armenia	The World Bank funded the development of this plan.
2000–2002	South Caucasus water management project	South Caucasus countries	Strengthening the cooperation among water-related agencies and integrating water resources management.
2000–2006	Joint river management programme on monitoring and assessment of water quality on transboundary rivers	South Caucasus countries	Prevention, control and reduction of trans-boundary pollution impact.
2002–2007	South Caucasus river monitoring project	South Caucasus countries	Established social and technical infrastructure for international, cooperative, transboundary river water quality and quantity monitoring, data sharing and watershed management system.
2002	Republic of Armenia commission on transboundary water resources was established	Armenia	This commission together with corresponding commissions in neighbouring countries resolved the issues related to transboundary water resources use and protection.
2005-2006	Reducing transboundary degradation in the Kura-Araks river basin project	South Caucasus countries, the Islamic Republic of Iran	To ensure that the quality and quantity of the water throughout the Kura-Araks river system meets the short and long-term needs of the ecosystem and the communities relying upon the ecosystem.
2004–2008	Caucasus-Georgia strategic plan	Georgia	Support for the South Caucasus regional water management programme as a principal component of its regional conflict prevention and confidence-building objectives.

commission, together with corresponding commissions of neighbouring countries, deals with issues related to transboundary water resources use and protection.

Table 34 shows the main historical events in the Kura–Araks River Basin.

ASI-ORONTES RIVER BASIN

Geography, climate and population

The Asi-Orontes River Basin is a transboundary basin with a total area of about 24 660 km^2 of which 69 percent is located in the Syrian Arab Republic, 23 percent in Turkey and 8 percent in Lebanon (Lehner *et al*, 2008) (Table 35 and Figure 5). The Asi-Orontes is the only river in the region flowing in northern direction, draining from western Asia to the Levant coastline of the Mediterranean Sea. The river rises in the mountains of Lebanon and flows 40 km in Lebanon to continue into the Syrian Arab Republic for about 325 km before arriving in Turkey for its last reach of 88 km to the Mediterranean Sea (UNESCO-IHE, 2002). The river rises in the great springs of

FIGURE 5
Asi-Orontes river basin

TABLE 35
Country areas in the Asi-Orontes River Basin

Basin	Area		Countries included	Area of country in basin (km^2)	As % of total area of the basin	As % of total area of the country
	km^2	% of the Middle East				
Asi-Orontes	24 660	0.38	Syrian Arab Republic	16 910	68.6	9.1
			Turkey	5 710	23.1	0.7
			Lebanon	2 040	8.3	19.6

Labweh on the east side of the Bekaa Valley and it runs in a northern direction, parallel with the coast, falling 600 m through a rocky gorge. Leaving this, it expands into the Qattinah Lake, having been dammed back in antiquity. The valley now widens out into the rich district of Hama, below which lie the broad meadow-lands of Amykes, containing the sites of ancient Apamea. This central Asi–Orontes valley ends at the rocky barrier of Jisr al-Hadid, where the river is diverted to the west and the plain of Antioch opens. Two large tributaries from the north, the Afrin and Karasu, reach it here through the former Lake of Antioch or Lake Amik, which is now drained through the artificial Nahr al-Kowsit channel. Passing north of the modern Antakya (ancient Antioch) the Asi–Orontes plunges southwest into a gorge and falls 50 m in 16 km to the sea just south of the little port of Samandagi.

The average annual precipitation in the basin is estimated at 644 mm, although it varies all along the basin area. Annual average temperature of the entire Asi–Orontes River Basin is estimated at 16 °C. Average temperature in the basin in January is 6 °C, although it can drop to –1 °C in the coldest places of the basin. In August, the average temperature reaches 25 °C, rising to 28 °C in the hottest places (New *et al*, 2002). In the Lebanese part of the Asi–Orontes Basin, the climate is semi-arid to arid, with annual rainfall below 400 mm (Estephan *et al*, 2008). In the Syrian part, the western mountains receive precipitation ranging from 600 to 1 500 mm, while in the eastern parts of the basin it is much lower, ranging from 400 to 600 mm (FAO, 2006). The Turkish part of the basin is a transition zone between the Mediterranean and Eastern Anatolian climatic zones. While a southeastern climate prevails in the eastern part of this basin, the western parts is dominated by a Mediterranean climate.

Water resources

The Asi–Orontes River and its tributaries collect the runoff from the highlands and plateau areas situated on both sides of the rift valley. The average annual flow of the river is estimated at 2 400 million m^3, but the surface water amount in the basin has been re-estimated at 1 110 million m^3 (FAO, 2006). The Al-Azraq spring is a very important tributary to the Asi–Orontes with an annual flow of more than 400 million m^3. There are several bid springs: Al Ghab, Al Rouj, and Al Zarka (FAO, 2006).

The annual flow from Lebanon to the Syrian Arab Republic is 415 million m^3, of which an informal agreement between these two countries attributes 80 million m^3 to Lebanon and the rest to the Syrian Arab Republic. The natural annual flow from the Syrian Arab Republic to Turkey is estimated at 1 200 million m^3, while the actual flow amounts to 12 million m^3.

The intensive use of groundwater by agriculture in the last decade has resulted in depletion of the water storage in the aquifers, lowering of the groundwater table and considerable reduction of the spring yield. The average annual discharge of 26 springs in Al Ghab valley dropped from 18.5 m^3/s in the period 1965–71 to 9.7 m^3/s in 1992–93 and declined steadily to 4.2 m^3/s in 1995–96. The amount of groundwater in the Syrian part of the Asi–Orontes Basin is estimated at 1 607 million m^3; most of it flows as springs (1 134 million m^3) and the rest (473 million m^3) is stored into aquifers and withdrawn from wells for irrigation and water supply.

Water quality

Water quality is good in the headwaters, while due to anthropogenic inputs associated with agricultural, urban, and industrial activities it deteriorates in the middle section of the river.

Water-related development in the basin

The total area equipped for irrigation in the Asi–Orontes River Basin is estimated at 300 000–350 000 ha, of which approximately 58 percent in the Syrian Arab Republic, 36 percent in Turkey, and 6 percent in Lebanon. Agricultural water withdrawal is approximately 2.8 km^3.

The Asi–Orontes Basin is an important agricultural area, contributing to the regional economy.

In the Lebanese Bekaa valley, the most important crops are fruits, vegetables, field crops, and forests and rangeland. However, poor management of natural resources and poor integration of production systems produce low farm income and unsustainable farming (Estephan *et al*, 2008). To obtain water for irrigation, two water regulators have been placed in Lebanon on the Asi–Orontes (El-Fadel *et al*, 2002).

In the Syrian part of the basin the total area irrigated increased from 155 300 ha in 1989 to around 215 000 ha in 2008. The expansion of irrigation using groundwater has been most intensive in the Al Ghab valley and the Mohafazat of Idleb. In the Al Ghab region, the areas irrigated with groundwater have increased and the areas irrigated with surface water have decreased. The annual amount of groundwater used for water supply, irrigation and industry is more than 1 607 million m^3, while the annual renewable amount in aquifers is less than 473 million m^3, meaning an over-abstraction of 1 134 million m^3 (FAO, 2006).

In the Syrian Arab Republic, regulation of the Asi–Orontes River flow to increase its irrigation capacity began with the reconstruction of the ancient Qattinah Dam in 1937, completed in 1976, and the construction of the dams at Rastan and Mhardeh on the main river stream in 1960, the first large dams built in the Syrian Arab Republic. These reservoirs control about 12 600 km^2 of the Asi–Orontes drainage basin upstream of Mhardeh. The total capacity of the three reservoirs (495 million m^3) represents about 45 percent of the estimated average annual flow yield. Until 2002 the dams built in the Syrian part of the basin numbered 41, with total a reservoir capacity of 741 million m^3, all built on tributaries of the Asi–Orontes River. Among the dams with large reservoir capacity is the Zeyzoun Dam (71 million m^3) which had been damaged in 2002. The Zeita Dam, one of the most recently built dams, will have a total capacity of 80 million m^3 (SPC, 2009).

In Turkey, the Lake of Antioch or Lake Amik was a large freshwater lake in the Asi–Orontes River Basin in Hatay Province which is now drained through the artificial channel Nahr al-Kowsit. Sedimentary analysis suggests that Lake Amik was formed, in its final state, in the past 3 000 years by episodic floods and silting up of the outlet to the Asi–Orontes. This dramatic increase in the lake's area displaced many settlements; the lake became an important source of fish and shellfish for the surrounding area and the city of Antioch. The lake was drained during a period from the 1940s–1970s. The most important dams located on the Turkish side of the basin are the Karamanli Dam and the Yarseli Dam. Table 36 shows the large dams in the Asi–Orontes River Basin, i.e. dams with a height of more than 15 metres or with a height of 5–15 metres and a reservoir capacity greater than 3 million m^3 according to the International Commission on Large Dams (ICOLD).

Transboundary water issues

Mainly non-navigable and of relatively little use for irrigation, the Asi–Orontes derives its historical importance from the convenience of its valley for traffic from

TABLE 36

Large dams in the Asi-Orontes River Basin

Country	Name	Nearest city	River	Year	Height (m)	Capacity (million m^3)	Main use*
Syrian Arab Republic	Al Rastan	Hims	Asi-Orontes	1960	67	228	I
	Qattinah	Hims	Asi-Orontes	1976	7	200	I
	Mhardeh	Hamah	Asi-Orontes	1960	41	67	I
	Zeyzoun	Hamah	-	1995	43	71	I
	Kastoun	Hamah	-	1992	20	27	I
Turkey	Karamanli (Hatay)	Hatay	Bulanik	1985	35	2 000	I
	Yarseli	Hatay	BeyazCay	1989	42	55	I
					Total	**2 648**	

* I = irrigation; H = Hydropower, W = Water Supply; F = Flood protection; R = recreation; N = Navigation; O = Other

TABLE 37

Chronology of major events in the Asi-Orontes River Basin

Year	Plans/projects/treaties/conflicts	Countries involved	Main aspects
1937	Reconstruction of the Qattinah dam	Syrian Arab Republic	Reconstruction of the ancient Qattinah dam, completed in 1976.
1939	French colonization of the Syrian Arab Republic	Syrian Arab Republic, Turkey, France	The Asi-Orontes terminates in Hatay (Alexandretta) province, which is Syrian land given to Turkey by France in 1939 during the French colonization of the Syrian Arab Republic.
1940s–1970s	Lake Amik drained	Turkey	Lake Amik was drained in the period running from the 1940s to the 1970s.
1950s	Ghab Valley Project	Syrian Arab Republic, Turkey, Lebanon	The Syrian Arab Republic applied for World Bank loans to build its Ghab Valley Project. Turkey requested that the project be revised. Later, the Syrian Arab Republic withdrew its requests for the loans it had negotiated.
1994	Agreement on water quantity	Lebanon, Syrian Arab Republic	Bilateral agreement, concerning the division of the water of the Asi-Orontes river between the Syrian Arab Republic and Lebanon.
2002	Floods	Syrian Arab Republic, Turkey	El Zeyzoun dam, located near the city of Hama in the Syrian Arab Republic, suddenly released about 70 million m^3. 22 Syrians lost their lives and the flood damaged some villages in the Syrian Arab Republic and cultivated land in Turkey.
2009	Agreement to develop the "Asi Friendship dam"	Syrian Arab Republic, Turkey	Turkey and the Syrian Arab Republic have agreed in principle to develop the "Asi Friendship Dam," to be built on the Asi-Orontes River on the border between the Syrian Arab Republic and Turkey.

north to south; roads from the north and northeast, converging at Antioch, follow the course of the stream up to Hims, where they built the Al-Rastan Dam, before forking to Damascus and to the Syrian Arab Republic and the south. The Asi–Orontes has long been a boundary marker. For the Egyptians it marked the northern extremity of *Amurru*, east of Phoenicia. For the Crusaders in the 12th century, the Asi–Orontes River became the permanent boundary between the Principality of Antioch and that of Aleppo.

The Syrian Arab Republic has been using 90 percent of the total flow, which reaches an annual average of 1 200 million m^3 at the Turkish-Syrian border. Out of this total capacity, only a meagre 12 million m^3 enter Turkey after heavy use by the Syrian Arab Republic.

In August 1994, the Lebanese and Syrian governments reached a water-sharing agreement on the Asi–Orontes River, according to which Lebanon receives 80 million m^3/year and the remaining 335 million m^3 are for the Syrian Arab Republic if the river's flow inside Lebanon is 400 million m³ or more during that given year. If this figure falls below 400 m³, Lebanon's share is adjusted downwards, relative to the reduction in flow. Wells in the river's catchments area that were already operational before the agreement are allowed to remain operational, but no new wells are permitted.

In 2009 Turkey and the Syrian Arab Republic have agreed in principle to develop the "Asi Friendship Dam", to be built on the Asi–Orontes River on the border between the Syrian Arab Republic and Turkey. The dam is expected to be approximately 15 m high with a capacity of 110 million m³. Of that total, 40 million m³ will be used to prevent flooding and the rest for energy production and irrigation. The idea to build a shared dam on the Asi–Orontes River has been discussed over the years between Turkey and the Syrian Arab Republic, but political differences between the countries held them back until now.

Table 37 shows the main historical events in the Asi–Orontes River Basin.

JORDAN RIVER BASIN

Geography, climate and population

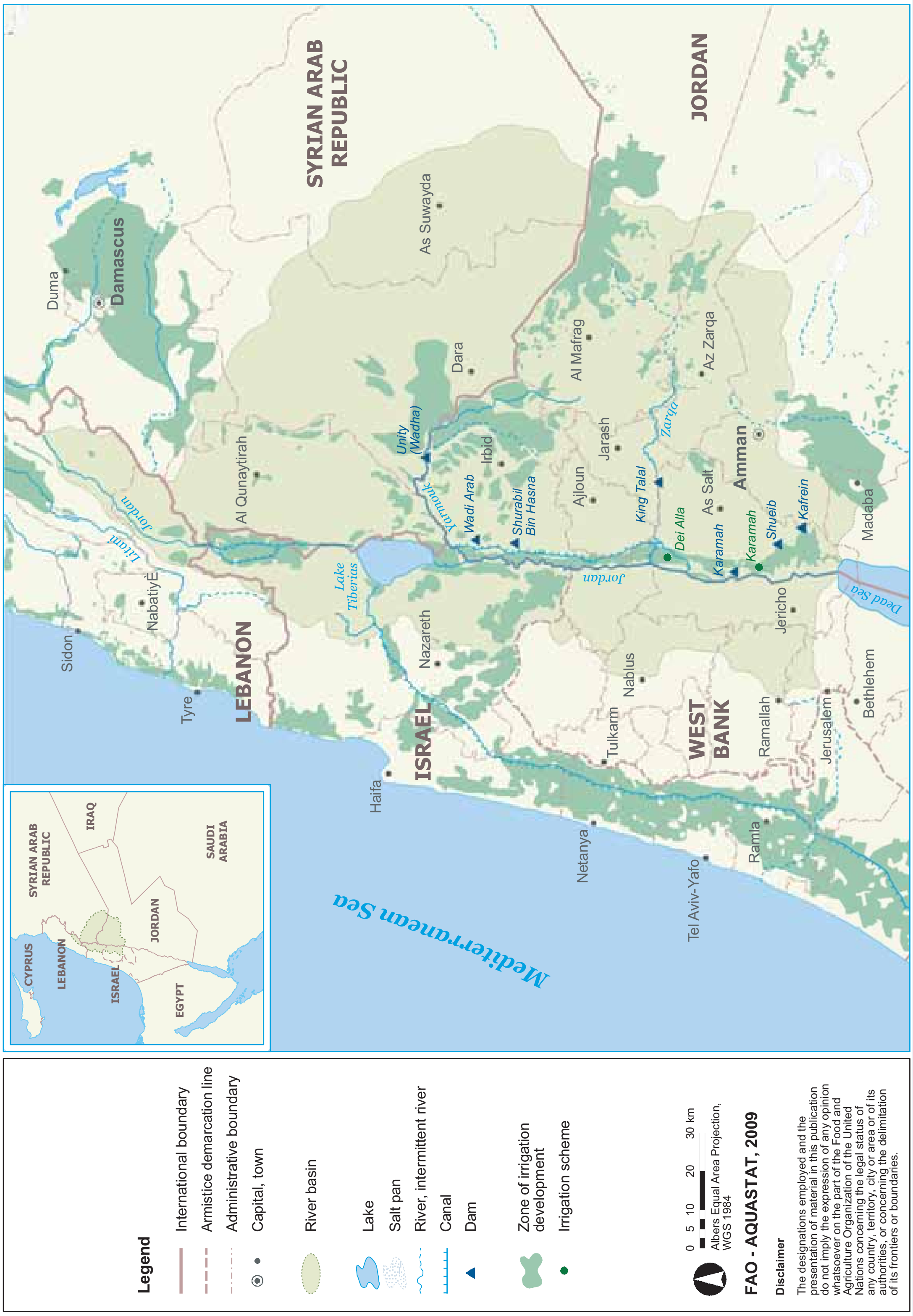
The Jordan River Basin is a transboundary basin with a total area of about 18 500 km² of which 40 percent is located in Jordan, 37 percent in Israel, 10 percent in the Syrian Arab Republic, 9 percent in the West Bank, and 4 percent in Lebanon (Lehner *et al*, 2008) (Table 38 and Figure 6). The headwater of the 250 km long Jordan River originates from three rivers, the Dan, the Banias and the Hasbani, which merge at a point 5 km south of the northern Israeli border then flow south through the Hula Valley to join Lake Tiberias. With the outflow of the Jordan River from Lake Tiberias, the Lower Jordan River receives the water from its main tributary, the Yarmouk River. The Yarmouk River originates in Jordan, then forms the border between Jordan and the Syrian Arab Republic and then between Jordan and Israel, before flowing into the Lower Jordan River. The river then continues flowing south, forming the border between Israel and the West Bank to the west and Jordan to the east and finally ends in the Dead Sea (Green Cross Denmark, 2006).

Ecosystems in the region are extremely diverse, ranging from sub-humid Mediterranean environments to arid climates across very small distances. Climate projections for the eastern Mediterranean indicate future aridification (GLOWA, 2007). The average annual precipitation in the basin is estimated at 380 mm, although it varies all along the basin area (New *et al*, 2002). The Upper Basin, north of Lake Tiberias, has an annual precipitation of up to 1 400 mm, while the Lower Jordan Basin has an average annual precipitation rate of 100 mm only at its southern end. The largest part of the fertile land in the basin is located in Jordan and the West Bank, along the eastern and western banks of the Jordan River and the side wadis, in an area with annual rainfall of less than 350 mm. Other portions of the catchment area in the Syrian Arab Republic and Israel enjoy higher annual rainfall, more than 500 mm per year (Venot *et al*, 2006). The average annual temperature of the entire Jordan River Basin is around 18 °C. The average temperature of the Jordan River Basin in January is 9 °C,

TABLE 38
Country areas in the Jordan River Basin

Basin	Area		Countries or territories included	Area of country in basin (km²)	As % of total area of the basin	As % of total area of the country
	km²	% of the Middle East				
Jordan	18 500	0.28	Jordan	7 470	40.4	8.4
			Israel	6 830	36.9	32.9
			Syrian Arab Republic	1 910	10.3	1.0
			West Bank	1 620	8.8	28.7
			Lebanon	670	3.6	6.4

FIGURE 6
Jordan river basin



although it can drop to 5 °C in the coldest places. In August, the average temperature of the Jordan River Basin reaches 26 °C, rising to 30 °C in the hottest places (New *et al*, 2002).

Water resources

The Upper Jordan River Basin, north of Lake Tiberias, contributes the vast majority of the water while the Lower Jordan River Basin, which represents 40 percent of the entire Jordan River Basin, makes a much smaller contribution (Venot *et al*, 2006). The Yarmouk River, which is the main water course in this latter part of the Valley, joins the Jordan River in an area partly occupied by Israel. During the summer, most side streams dry up completely and capturing the winter floodwaters is one of the most critical aspects of water resources management in the Jordan River Basin. If these waters are not diverted or stored, they flow directly to the Dead Sea (Green Cross Italy, 2006).

The total natural discharge of the basin is subject to extreme seasonal and annual variations. In February, for example, the river may carry as much as 40 percent of its total annual flow, but in each of the summer and autumn months, when water is most needed, it carries only 3–4 percent of its annual discharge. In drought periods like 1987–91 the water discharge of the Jordan River Basin can be reduced by up to 40 percent over the whole year (Libiszewski, 1995). The annual flow entering Israel corresponding to the Jordan Basin includes 138 million m^3 from Lebanon (Hasbani River), 125 million m^3 from the Syrian Arab Republic and 20 million m^3 from the West Bank. The natural annual flow of the Yarmouk River from the Syrian Arab Republic to Jordan is estimated at 400 million m^3. However, the total actual flow at present is much lower as a result of the drought and upstream Syrian development works done in the 1980s. The Yarmouk River is the main source of water for the King Abdullah Canal (KAC), the backbone of development in the Jordan Valley. A main tributary of the Jordan River in Jordan, controlled by the King Talal Dam and also feeding the KAC, is the Zarqa River. There are also 6–10 small rivers, called "Side Wadis", going from the mountains in Jordan to the Jordan Valley.

Surface water accounts for 35 percent of the existing water resources in the basin, groundwater aquifers account for 56 percent of the resources, while reused wastewater and other non-conventional sources of water represent around 9 percent. The surface water of the Jordan River Basin is the main surface water resource available for relatively stable use in the region. It is the major source of water for Israel and Jordan and also supports the many aquifers in both countries, extending the reliance on the river (Green Cross Italy, 2006). The three main aquifers in the system are west of the Jordan River and are central to the water supply of Israel, Jordan and the Occupied Palestinian Territories: the western (or mountain) aquifer, the northeastern aquifer, and the eastern aquifer.

The region has one of the lowest per capita water resources worldwide, well below the typical absolute water scarcity threshold of 500 m^3/year per capita, except for Lebanon (Table 39). Moreover, water demand continues to increase rapidly due to high population growth rates and economic development (GLOWA, 2007).

TABLE 39
Internal and total actual renewable water resources per capita in 2006 in m^3/year

Country or Territory	Internal renewable water resources	Total actual renewable water resources
Israel	110	261
Jordan	119	164
Lebanon	1 184	1 110
Occupied Palestinian Territory	209	215
Syrian Arab Republic	367	865

Water quality

Due to the continuous drop in water levels in Lake Tiberias since 1996, in 2001 regulations in Israel lowered the minimum "red line" from 213 m below sea level to minus 215.5 m. The risks associated with reduced water levels are enormous: ecosystem instability and deterioration of water quality, damage to nature and landscape assets, receding shorelines and adverse impacts on tourism and recreation. Salinity in the lake has been alleviated by diverting several major saline inputs at the northwest shore of the lake into a "salt water canal" leading to the southern Jordan River. This canal removes about 70 000 tonnes of salt (and 20 million m^3 of water) from the lake each year. The salt water canal is also used to remove treated sewage from Tiberias and other local authorities along the western shoreline away from Lake Tiberias and into the Lower Jordan River. In the catchment area, a concerted effort has been made to lower the nutrient load by changing agricultural and irrigation practices, by cutting back the acreage of commercial fishponds and by introducing new management techniques. Sewage treatment plants have been improved and a new drainage network that recycles most of the polluted water within the watershed has been constructed. Around the lake, public and private beaches and recreation areas with appropriate sanitary facilities have been developed. Pollution and sewage from settlements and fishponds near the shores are treated and diverted from the lake.

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

Water-related development in the basin

The total area equipped for irrigation in the Jordan River Basin is estimated at 100 000–150 000 ha, of which approximately 32 percent in Jordan, 31 percent in Israel, 30 percent in the Syrian Arab Republic, 5 percent in the West Bank, and 2 percent in Lebanon. Agricultural water withdrawal is approximately1.2 km^3.

In Jordan, intensive irrigation projects have been implemented since 1958, when the Government decided to divert part of the Yarmouk River water and constructed the East Ghor Canal (later named King Abdullah Canal or KAC). The King Talal Dam on the Zarqa River also diverts the water into the KAC. The canal was 70 km long in 1961 and was extended three times between 1969 and 1987 to reach a total length of 110.5 km. The construction of dams on the side wadis and the diversion of the flows from other wadis have allowed the development of irrigation over a large area. At the same time, wells have been drilled in the Jordan Valley to abstract groundwater, not only for domestic purposes but also for irrigation. Irrigation projects from surface water resources are mainly located in the Jordan River Valley (JRV) and the side wadis linked with the Jordan River Basin. Irrigation schemes in the JRV have been constructed, rehabilitated, operated and maintained by the government. In the first projects in the north, concrete-lined canals were constructed equipped with all irrigation structures to convey and distribute irrigation water on volumetric basis. Additional irrigation schemes were constructed during the 1970s and 1980s following the extension of the KAC, and through the construction of dams, and diversion of side wadis springs and streams. From the 1990s onwards the open canal irrigation schemes were converted to pressurized irrigation systems.

Israel has constructed the Cross Israel Water Carrier, which starts at the northern end of Lake Tiberias and diverts water via massive pipelines across the Jezreel Valley and south along the coastal plain, terminating in Beersheba. Across Israel, the government has built smaller pipelines radiating out over the farmland to bring water for irrigation. The entire system, completed in 1964, forms a water grid, easily controlled and measured.

TABLE 40
Large dams in the Jordan River Basin

Country	Name	Nearest city	River	Year	Height (m)	Capacity (million m³)	Main use*
Jordan	King Talal	Jarash	Zarqa River	1987	108	75	I, F, H, N
	Karamah	Al-Balqa (J)	Wadi Al Mallaha	1998	45	53	I, F, R
	Wadi Arab	Irbid	Wadi Arab	1986	84	20	I, W, F, N, R
	Shurabil Bin Hasna	Irbid	Wadi Ziglab	1967	48	4	I, W, F
	Kafrein	Al-Balqa	Wadi Kafrein	1997	37	9	I, F, R, O
	Shueib	Al-Balqa	Wadi Shueib	1969	32	2	I, F, O
Jordan and Syrian Arab Republic	Wadha (Unity)	Irbid (J) Dara (S)	Yarmouk River	2007	87	110	I, W, F, O H
					Total	273	

* I = irrigation; H = Hydropower, W = Water Supply; F = Flood protection; R = recreation; N = Navigation; O = Other

In the West Bank, localized irrigation systems are used to irrigate vegetables. A small percentage of vegetables is still irrigated by traditional methods, as well as the majority of citrus trees. Farmers usually use plastic lined pools to store their shares of fresh spring water and mix them with brackish well water. Then water is pumped and applied through trickle irrigation systems. From nearly all wells water is pumped into steel pipes which convey the water to the irrigation systems directly in the farms. As the pumping costs are high, the cost per unit water is high and thus farmers need to improve distribution and conveyance efficiency through the use of pipes.

In the Syrian Arab Republic surface irrigation is the prevailing irrigation system. Basin irrigation is the predominant technique used in surface irrigation and most of the irrigated wheat and barley are irrigated by this method. Irrigation field efficiency is reportedly to be in general below 60 percent.

Table 40 shows the large dams in the Jordan River Basin, i.e. dams with a height of more than 15 metres or with a height of 5–15 metres and a reservoir capacity larger than 3 million m³ according to the International Commission on Large Dams (ICOLD).

Transboundary water issues

While the idea of developing a water sharing strategy for the whole basin was recognized as early as 1913, when the Franjieh Plan was proposed, and 1955, when the Johnston Plan was devised, not one single plan has been completely adhered to. The Franjieh Plan was intended for the irrigation of the Jordan Valley, to generate hydropower and to transfer Yarmouk River flow (100 million m³) to Lake Tiberias (Sofer *et al.*, 1999). The Johnston Plan called for the allocation of 55 percent of available water in the basin to Jordan, 36 percent to Israel, and 9 percent to the Syrian Arab Republic and Lebanon. However, it was never signed by the countries involved.

In 1951, Jordan announced its plan to divert part of the Yarmouk River via the East Ghor Canal to irrigate the East Ghor area of the Jordan Valley. In response, Israel began the construction of its National Water Carrier (NWC) in 1953. In 1964, the NWC opened and began diverting water from the Jordan River Valley. This diversion led to the Arab Summit of 1964, where a plan was devised to begin diverting the headwater of the Jordan River to the Syrian Arab Republic and Jordan. From 1965 to 1967 Israel attacked these construction projects in the Syrian Arab Republic and along with other factors this conflict escalated into the Six Day War in 1967 when Israel completely destroyed the Syrian diversion project and took control of the Golan Heights, the West Bank, and the Gaza Strip. This gave Israel control of the Jordan River's headwater and of significant groundwater resources. The most recent direct water-related conflict occurred in 1969 when Israel attacked Jordan's East Ghor Canal due to suspicions that Jordan was diverting excess amounts of water (Green Cross Italy, 2006). Later on, Israel and Jordan acquiesced to the apportionment contained in the non-ratified 1955 Johnston Plan for sharing the Jordan River Basin's water (Milich and Varady, 1998). In 1978, Israel invaded Lebanon, giving Israel temporary control of the Wazzani spring/stream feeding the Jordan River (Attili *et al.*, after 2003).

Inter-Arab conflicts have also often arisen, but have only been small-scale low-level conflicts. The terms of the 1987 agreement between the Syrian Arab Republic and Jordan defined the Syrian share of the Yarmouk and limited the Syrian Arab Republic to building 25 dams with a holding capacity of 156 million m^3. To date, the Syrian Arab Republic has built 37 dams on the four recharge wadis of the Yarmouk River with a total holding capacity of 211 million m^3 (i.e. 55 million m^3 in violation of the agreement). The Syrian Arab Republic's continuous well drilling in the Yarmouk Basin negatively impacts the base flow in the river, reducing it by approximately 30 percent (Green Cross Italy, 2006). The Wadha (Unity) Dam on the Yarmouk River was included in the agreement, with a height of 100 m and a storage capacity of 225 million m^3. Jordan would receive 75 percent of the water stored and the Syrian Arab Republic would receive all of the hydropower generated. In 2003 the height of the dam was reduced to 87 m and the storage capacity became 110 million m^3. The dam was completed in 2007.

Since the start of the Peace Process in the early 1990s, bilateral agreements and common principles have been signed between Israel and Jordan and Israel and the Palestinian Authority, but no multilateral plan or agreement has been negotiated and even the bilateral ones have been put under pressure and frequently violated in times of natural or political crisis.

In July 1994, Israel and Jordan signed The Washington Declaration and negotiated the Treaty of Peace, signed in October 1994. The treaty spells out allocations for both the Yarmouk and Jordan rivers and calls for joint efforts to prevent water pollution. This peace treaty established the Israel–Jordan Joint Water Committee (IJJWC), comprised of three members from each country. The Committee was tasked to seek experts and advisors as required, and form specialized subcommittees with technical tasks assigned. The two countries undertook to exchange relevant data on water resources through the IJJWC and also agreed to cooperate in developing plans for purposes of increasing water supplies and improving water use efficiency. It also specified the volumes of water to be used, stored, and transferred by and to each country during a "summer" and a "winter" season (Milich and Varady, 1998). Jordan is entitled to store 20 million m^3 of the Upper Jordan winter flow on the Israeli side (in Lake Tiberias) and get it back during the summer months. Jordan can build a dam on the Yarmouk downstream of the diversion point of Yarmouk water to the KAC. Jordan can also build a dam of 20 million m^3 capacity on the Jordan River and on its reach south of Lake Tiberias on the border between Jordan and Israel. Because Israel is to provide only 50 million m^3/year of additional water to Jordan, insufficient to allow the Jordanians to cover their annual deficit, the two countries have agreed to cooperate in finding sources to supply Jordan with an additional quantity of 50 million m^3/year of water of drinkable standards, within one year from the entry into force of the treaty. To protect the shared water of the Jordan and Yarmouk rivers against any pollution or harm, each country is to jointly monitor the quality of water along their boundary, building monitoring stations to be operated under the guidance of the IJJWC. Israel and Jordan are each to prohibit the disposal of municipal and industrial wastewater into the Yarmouk or Jordan River before treatment to standards allowing unrestricted agricultural use (Milich and Varady, 1998).

Interpretation of several terms of the treaty has at times had an uneven history. On the positive side is the June 1995 completion of a pipeline making the physical connection between the Jordan River immediately south of its exit from Lake Tiberias and the King Abdullah Canal in Jordan. Moreover, the provision of the additional

50 million m^3/year that Israel promised to Jordan went ahead on schedule. However, the article which calls for cooperation so that Jordan acquires 50 million m^3 more per year led to a "mini crisis" between the two countries in May 1997. At the heart of the dispute was Jordan's demand for an immediate transfer of 50 million m^3, which was to have been obtained by the construction of two internationally financed dams in Jordan. However, neither Jordan nor Israel was successful in obtaining the necessary financing. Finally, Israel agreed to supply Jordan with 25 million m^3 of water per year for three years as an interim solution, until the desalination plant is erected.

Recent dialogue and peace treaties have lead to increased cooperation regarding the development of future water resources projects. For instance, the 1994 and 1997 Israel–Jordan agreements led to discussions on the possibility of building a canal from the Red Sea to the Dead Sea to produce desalinated water with hydropower. It should be mentioned, however, that in their fervour to reach an accord, apparently both the Jordanians and the Israelis negotiated without coordinating their moves with the relevant ministries. Therefore, important issues remain open or vague and conflicts have arisen as a result. For example, in 1999, due to drought Israel decided to reduce the quantity of water piped to Jordan by 60 percent, which caused a sharp response from that country. Disputes of such nature are not unexpected in the future. However, the peace agreements have had the benefit of restricting such conflicts to political rather than military solutions. The fact that the Joint Water Commission for Israel and the Palestinian Authority have continued to meet to discuss critical issues even during the current period of hostilities illustrates the progress that has already been made (Green Cross Italy, 2006).

More than 30 years of Israeli occupation of the West Bank and Gaza Strip have been accompanied with a series of laws and practices targeting Palestinian land and water resources. In 1993, the "Declaration of Principles on Interim Self-Government Arrangements" was signed between Palestinians and Israelis, which called for Palestinian autonomy and the removal of Israeli military forces from Gaza and Jericho. Among other issues, this bilateral agreement called for the creation of a Palestinian Water Administration Authority and cooperation in the field of water, including a Water Development Programme prepared by experts from both sides, which will also specify the mode of cooperation in the management of water resources in the Occupied Palestinian Territory. Between 1993 and 1995, Israeli and Palestinian representatives negotiated to broaden the provisional agreement to encompass the greater West Bank territory. In September, 1995, the "Israeli-Palestinian Interim Agreement on the West Bank and the Gaza Strip", commonly referred to as "Oslo II", was signed. The question of water rights was one of the most difficult to negotiate, with a final agreement postponed for inclusion in the negotiations regarding final status arrangements. However tremendous compromise was achieved between the two sides: Israel recognized the Palestinian water rights – during the interim period a quantity of 70–80 million m^3 should be made available to the Palestinians – and a Joint Water Committee was established to manage cooperatively West Bank water and to develop new supplies. This Committee also supervises joint patrols to investigate illegal water withdrawals. No territory whatsoever was identified as being necessary for Israeli annexation due to access to water resources (Wolf, 1996). In 2003, the Roadmap for Peace, developed by the United States, in cooperation with the Russian Federation, the European Union, and the United Nations (the Quartet), was presented to Israel and the Palestinian Authority to seek a final and comprehensive settlement of the Israel–Palestinian conflict.

The basis for Israeli–Syrian negotiations is the premise of an exchange of the Golan Heights for peace (Wolf, 1996). In 1967 Israel seized the Golan Heights from the Syrian Arab Republic during the six-day war. The Golan Heights control the main water sources of Israel. Israel's only lake and its main source of freshwater, supplying the country with a third of its water, is fed from the Golan Heights. Conquered in 1967, they have been under Israeli law, jurisdiction, and administration since 1981, which, however, has not been recognized by the United Nations Security Council. The crux of the territorial dispute is the question of which boundaries Israel would withdraw to; the boundaries between Israel and the Syrian Arab Republic have included the international boundary between the British and French mandates from 1923, the Armistice Line from 1949 and the cease fire lines from 1967 and 1974. The Syrian position has been to insist on a return to the borders of 1967, while Israel refers to the boundaries of 1923. The only distinction between the two lines is the inclusion or exclusion of the three small areas with access to the Jordan and Yarmouk rivers (Wolf, 1996). In 2008, negotiations between Israel and the Syrian Arab Republic started with the objective to solve the conflict of the Golan Heights.

In 2002, the water resources of the Hasbani Basin became a source of mounting tensions between Lebanon and Israel, when Lebanon announced the construction of a new pumping station at the Wazzani springs. The springs feed the Hasbani River, which rises in the south of Lebanon and crosses the frontier ('Blue Line') to feed the Jordan River and subsequently the Sea of Galilee, which is used as Israel's main reservoir. The pumping station was completed in October 2002. Its purpose was to provide drinking and irrigation water to some 60 villages on the Lebanese side of the Blue Line. The Israelis complained about the lack of prior consultation whereas the Lebanese contended that the project was consistent with the 1955 Johnston Plan on the water resources of the region.

In 2004 and 2005 Jordan got only around 119 and 92 million m^3/year from the Yarmouk River and from Lake Tiberias respectively. This is only around 10 percent of the total flow of the Upper Jordan and Yarmouk rivers. It is also much less than the water share from these two basins proposed by the Johnston plan through his negotiations in 1950s.

In 2007, Jordan and the Syrian Arab Republic agreed to expedite the implementation of agreements signed between the two countries, especially with regards to shared water in the Yarmouk River Basin. They also agreed to continue a study on the Yarmouk River Basin based on previous studies. Currently, the Joint Jordanian–Syrian Higher Committee is discussing how to make use of the Yarmouk River Basin water and how to protect Yarmouk water against depletion. Talks will also include preparations for winter and storage at the Wadha (Unity) Dam in the Yarmouk River.

Table 41 shows the main historical events in the Jordan River Basin.

TABLE 41
Chronology of major events in the Jordan River Basin

Year	Plans/projects /treaties/conflicts	Countries & territories involved	Main aspects
1913	Franjieh Plan	Ottoman Commission	Irrigation of the Jordan Valley, transferring Yarmouk River flows to Lake Tiberias, generating electricity.
1951	Jordan announced Plan	Jordan	Jordan Plan to divert part of the Yarmouk river via the East Ghor canal.
1953	Israel began construction of the National Water Carrier (NWC)	Israel	Resulting in military skirmishes between Israel and the Syrian Arab Republic.
1955	Johnston Plan	USA. Riparian countries	Allocation of water: 55% for Jordan, 36% for Israel, 9% each to the Syrian Arab Republic and Lebanon. Not signed because Arab riparian countries insisted the USA was not impartial.
1964	The NWC opened and began diverting water from the Jordan River Valley	Israel	This diversion led to the Arab Summit of 1964.
1964	Arab Summit	Arab League	A plan was devised to begin diverting the headwaters of the Jordan River to the Syrian Arab Republic and Jordan.
1965–1967	Israel attacked construction projects in the Syrian Arab Republic	Israel, Syrian Arab Republic	This conflict, along with other factors escalated in the Six Day War in 1967.
1967	Six Day War	Egypt, Israel, Jordan, Syrian Arab Republic, Occupied Palestinian Territory	Israel destroyed the Syrian diversion project and took control of the Golan Heights, the West Bank and the Gaza Strip. Palestinian irrigation pumps on the Jordan River were destroyed or confiscated after the Six Day War and Palestinians were not allowed to use Jordan River water. Israel introduced quotas on existing Palestinian irrigation wells and did not allow any new ones.
1969	Israel attacked Jordan's East Ghor Canal	Israel and Jordan	Because of suspicions that Jordan was diverting excess amounts of water. Later on, Israel and Jordan acquiesced to the apportionment contained in the non-ratified Johnston Plan.
1978	Israel's invasion of Lebanon	Israel and Lebanon	Giving Israel temporary control of the Wazzani spring/stream feeding the Jordan.
1987	Syrian Arab Republic and Jordan agreement	Syrian Arab Republic and Jordan	Defined the Syrian share of the Yarmouk and limited the Syrian Arab Republic to 25 dams with a capacity of 156 million m^3. The Wadha (Unity) Dam was included.
1993	Declaration of Principles on Interim Self-Government Arrangements	Israel, Occupied Palestinian Territory	Called for Palestinian autonomy. Creation of the Palestinian Water Administration Authority. Water Development Programme.
1994	Washington Declaration and Treaty of Peace	Israel and Jordan	Israel and Jordan signed The Washington Declaration, ending the state of belligerency and negotiated the Treaty of Peace. Allocations for Yarmouk and Jordan rivers and efforts to prevent water pollution.
1995	Israeli-Palestinian Interim Agreement on the West Bank and the Gaza Strip (Oslo II)	Israel, the West Bank, and the Gaza Strip	Israel recognized Palestinian water rights (during the interim period a quantity of 70–80 million m^3 to be made available to the Palestinians). A Joint Water Committee was established to cooperatively manage West Bank water and to develop new supplies.
1996	Israel tries to begin talks on water resources with the Syrians	Israel and Syrian Arab Republic	Syrian Arab Republic refuses because of the conflict concerning the Golan Heights.
1999	Israel reduces the quantity of water piped to Jordan by 60 percent	Israel and Jordan	Due to drought. This reduction caused a sharp response from Jordan.
2002	The Wazzani Conflict	Israel, Lebanon	Lebanon announced the construction of a new pumping station at the Wazzani springs causing tension between Israel and Lebanon.
2003	Roadmap for Peace	Israel, Occupied Palestinian Territory, The Quarter	Purpose: to end of the Israel-Palestinian conflict.
2007	Jordan and Syrian Arab Republic agreements	Jordan and Syrian Arab Republic	Implementation of agreements signed between the two countries, especially with regard to shared water in the Yarmouk river basin.
2008	Negotiations between Israel and the Syrian Arab Republic	Israel and Syrian Arab Republic	Negotiations are taking place in order to resolve the the Golan Heights conflict.

Main sources of general information

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Summary tables

EXPLANATORY NOTES

Table 42 – Land use and irrigation potential

- The cultivable area for Israel, the Occupied Palestinian Territories and the United Arab Emirates was estimated as cultivated area. For Qatar it was estimated as the irrigation potential.
- The cultivated areas for Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates do not correspond to the FAOSTAT values because there is no rainfed cultivation, thus cultivated land is equal to the total water managed area or, if known, the actually irrigated area (Qatar and Saudi Arabia).
- The cultivated area for Yemen corresponds to the value provided by the national consultant because the FAOSTAT value is smaller than the total harvested irrigated crops area.
- The cultivated area does not correspond to the year indicated in the column for Bahrain (2000), Kuwait (2003), Occupied Palestinian Territory (1998), Qatar (2004), United Arab Emirates (2003) and Yemen (2004).
- The irrigation potential area for Israel, Oman, Saudi Arabia, the Syrian Arab Republic, the United Arab Emirates and Yemen was estimated as equipped area, since there was no data available.
- Figures on irrigation potential cannot be totalled due to possible double-counting of shared water resources.

Table 46 – Water withdrawals by source

- Freshwater (Surface water + groundwater) for Iraq, Israel, the Occupied Palestinian Territory and the Syrian Arab Republic are unknown, however total freshwater has been estimated taking into account water withdrawal by sector.
- Turkey's surface water and groundwater refers to 2000 while total freshwater refers to 2003, and Azerbaijan surface water and groundwater refers to 2004 while total freshwater refers to 2005.

Table 49 – Full/partial control irrigation techniques

- There is no data available for Iraq, Israel and the Occupied Palestinian Territory, thus these countries are not included in the totals.

Table 50 – Origin of full/partial control irrigation water

- For Azerbaijan, Kuwait and Turkey surface water area + groundwater area + other sources of water area is not equal to the full/partial control irrigation area in Table 47 because it refers to different years.

Table 51 – Harvested irrigated crops on full/partial control areas

- For Kuwait, Oman, Saudi Arabia, the Syrian Arab Republic and Turkey, the harvested irrigated crops area, equipped area actually irrigated, or equipped full/partial control irrigation area which are used for the calculation of cropping intensity refer to the same year (2003, 2004, 1999, 2000 and 2004 respectively).

TABLE 42
Land use and irrigation potential

Country	Total area		Cultivable area		Cultivated area (2005)		Irrigation potential	
	area	per inhabitant	area	per inhabitant	area	per inhabitant	area	in % of cultivable area
Unit	ha	ha/inhab	ha	ha/inhab	ha	ha/inhab	ha	%
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)=100x(7)/(3)
Armenia	2 980 000	0.99	1 391 400	0.46	555 000	0.18	666 000	48
Azerbaijan	8 660 000	1.03	4 318 860	0.51	2 064 700	0.25	3 200 000	74
Bahrain	71 000	0.10	4 230	0.01	4 235	0.01	4 230	100
Georgia	6 970 000	1.56	2 987 473	0.67	1 066 000	0.24	725 000	24
Iran (Islamic Republic of)	174 515 000	2.51	51 000 000	0.73	18 107 000	0.26	15 000 000	29
Iraq	43 832 000	1.52	11 480 000	0.40	6 010 000	0.21	5 554 000	48
Israel	2 077 000	0.31	392 000	0.06	392 000	0.06	225 000	57
Jordan	8 878 000	1.56	886 400	0.16	270 000	0.05	85 000	10
Kuwait	1 782 000	0.66	154 000	0.06	7 050	0.00	25 000	16
Lebanon	1 040 000	0.29	360 000	0.10	328 000	0.09	177 500	49
Occupied Palestinian Territory	602 000	0.16	222 000	0.06	222 000	0.06	80 000	36
Gaza Strip	36 500	0.03	-	-	18 309	0.02	-	-
West Bank	565 500	0.25	-	-	166 702	0.10	-	-
Oman	30 950 000	12.06	2 200 000	0.86	58 850	0.02	58 850	3
Qatar	1 100 000	1.35	52 128	0.06	6 322	0.01	52 128	100
Saudi Arabia	214 969 000	8.75	52 684 000	2.14	1 213 586	0.05	1 730 767	3
Syrian Arab Republic	18 518 000	0.97	5 910 000	0.31	5 742 000	0.30	1 439 100	24
Turkey	78 356 000	1.07	28 054 000	0.38	26 606 000	0.36	8 500 000	30
United Arab Emirates	8 360 000	1.86	254 918	0.06	254 918	0.06	226 600	89
Yemen	52 797 000	2.52	3 617 753	0.17	1 188 888	0.06	679 650	19
Total region	**656 457 000**	**2.32**	-	-	**64 096 549**	-	-	-

TABLE 43
Population characteristics

Country	Population		Population density	Human Development Index (2005)	Part of economically active population		Part of economically active population in agriculture	
	(2005)				Total	in % of total population	Total	in % of economically active population
Unit	inhabitants	% rural	inhabitants per km²		inhabitants	%	inhabitants	%
Armenia	3 016 000	36	101	0.775	1 522000	51	162 000	11
Azerbaijan	8 411 000	50	97	0.746	3 980 000	47	982 000	25
Bahrain	727 000	10	1 024	0.866	353 000	49	3 000	1
Georgia	4 474 000	49	64	0.754	2 287 000	51	395 000	17
Iran (Islamic Republic of)	69 515 000	32	40	0.759	27 594 000	39	6 689 000	24
Iraq	28 807 000	33	66		8 189 000	28	651 000	8
Israel	6 725 000	8	324	0.932	2 947 000	44	64 000	2
Jordan	5 703 000	21	64	0.773	1 975 000	35	194 000	10
Kuwait	2 687 000	4	151	0.891	1 469 000	55	15 000	1
Lebanon	3 577 000	12	344	0.772	1 337 000	37	35 000	3
Occupied Palestinian Territory	3 702 000	28	615	0.731	1 066 000	29	108 000	10
Gaza Strip	1 400 000	5	3 836	-	-	-	-	-
West Bank	2 302 000	47	407	-	-	-	-	-
Oman	2 567 000	21	8	0.814	977 000	38	317 000	32
Qatar	813 000	8	74	0.875	486 000	60	15 000	1
Saudi Arabia	24 573 000	12	11	0.812	8 694 000	35	600 000	7
Syrian Arab Republic	19 043 000	50	103	0.724	6 548 000	34	1 690 000	26
Turkey	73 193 000	33	93	0.775	35 190 000	48	14 994 000	43
United Arab Emirates	4 496 000	15	54	0.868	2 666 000	59	103 000	4
Yemen	20 975 000	74	40	0.508	6 820 000	33	3 091 000	45
Total region	**283 004 000**	**34**	**43**	**-**	**112 578 000**	**40**	**30 108 000**	**27**

TABLE 44
Renewable water resources

Country	Average annual precipitation		Annual renewable water resources				Dependency ratio
			Internal (IRWR)		Total (TRWR)		
	height	volume	volume	per inhabitant (2005)	volume	per inhabitant (2005)	
Unit	mm	million m³	million m³	m³/inhab	million m³	m³/inhab	%
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Armenia	592	17 642	6 859	2 274	7 769	2 576	11.7
Azerbaijan	447	38 710	8 115	965	34 675	4 123	76.6
Bahrain	83	59	4	6	116	160	96.6
Georgia	1 065	74 231	58 130	12 993	63 330	14 155	8.2
Iran (Islamic Republic of)	228	397 894	128 500	1 849	137 515	1 978	6.6
Iraq	216	94 677	35 200	1 222	75 610	2 625	53.4
Israel	435	9 035	750	112	1 780	265	57.9
Jordan	94	8 345	682	120	937	164	27.2
Kuwait	121	2 156	0	0	20	7	100.0
Lebanon	823	8 559	4 800	1 342	4 503	1 259	0.8
Occupied Palestinian Territory	402	2 420	812	219	837	222	3.0
Gaza Strip	300	110	46	33	71	51	35.2
West Bank	**409**	**2 313**	**766**	**333**	**766**	**333**	**0.0**
Oman	62	19 189	1 400	545	1 400	545	0.0
Qatar	80	880	56	69	58	71	3.5
Saudi Arabia	114	245 065	2 400	98	2 400	98	0.0
Syrian Arab Republic	252	46 665	7 132	375	16 797	882	72.4
Turkey	643	503 829	227 000	3 101	213 562	2 918	1.0
United Arab Emirates	78	6 521	150	33	150	33	0.0
Yemen	167	88 171	2 100	100	2 100	100	0.0
Total region	**238**	**1 564 048**	**484 090**	**1 711**	-	-	-

TABLE 45
Water withdrawals by sector

Country	Year	Annual water withdrawal							
		Agriculture		Municipalities		Industries		Total	
		volume	% of total	volume	% of total	volume	% of total	volume	per inhabitant
Unit		million m³	%	million m³	%	million m³	%	million m³	m³/inhab
		(1)	(2)= 100x(1)/(7)	(3)	(4)= 100x(3)/(7)	(5)	(6)= 100x(5)/(7)	(7)= (1)+(3)+(5)	(10)
Armenia	2006	1 859	66	843	30	125	4	2 827	937
Azerbaijan	2005	9 330	76	521	4	2 360	19	12 211	1 452
Bahrain	2003	159	45	178	50	20	6	357	506
Georgia	2005	1 055	65	358	22	208	13	1 621	362
Iran (Islamic Republic of)	2004	86 000	92	6 200	7	1 100	1	93 300	1 356
Iraq	2000	52 000	79	4 300	7	9 700	15	66 000	2 632
Israel	2004	1 129	58	712	36	113	6	1 954	296
Jordan	2005	611	65	291	31	38	4	941	165
Kuwait	2002	492	54	401	44	21	2	913	375
Lebanon	2005	780	60	380	29	150	11	1 310	366
Occupied Palestinian Territory	2005	189	45	200	48	29	7	418	113
Gaza Strip	2000	85	64	42	32	6	5	133	128
West Bank	2000	89	57	59	38	9	5	157	92
Oman	2003	1 168	88	134	10	19	1	1 321	526
Qatar	2005	262	59	174	39	8	2	444	546
Saudi Arabia	2006	20 826	88	2 130	9	710	3	23 666	963
Syrian Arab Republic	2003	14 669	88	1 426	9	595	4	16 690	921
Turkey	2003	29 600	74	6 200	15	4 300	11	40 100	563
United Arab Emirates	2005	3 312	83	617	15	69	2	3 998	889
Yemen	2000	3 060	90	272	8	68	2	3 400	187
Total region		**226 501**	**83**	**25 337**	**9**	**19 633**	**7**	**271 472**	**963**

TABLE 46
Water withdrawals by source

Country	Year	Freshwater							Other sources of water									Total withdrawal by source	
		Surface water		Groundwater		Total			Desalinated water			Reused treated wastewater			Reused agricultural drainage water			Year	Volume
		Volume	% of total	Volume	% of total	Volume	% of total	MDG Water Indicator	Year	Volume	% of total	Year	Volume	% of total	Year	Volume	% of total		
Unit		million m^3	%	million m^3	%	million m^3	%	%		million m^3	%		million m^3	%		million m^3	%		million m^3
Armenia	2006	2 216	78	611	22	2 827	100	36			0.0	1994	0.1	0.0				2006	2 827
Azerbaijan	2004	10 733	93	707	6	12 050	99	35			0.0	2005	161	1.3				2005	12 211
Bahrain	2003	0	0	239	67	239	67	206	2003	102	28.7	2005	16	4.6				2003	357
Georgia	2005	1 072	66	549	34	1 621	100	3	-		0.0		0	0.0				2005	1 621
Iran (Islamic Republic of)	2004	40 000	43	53 100	57	93 100	100	68	2004	200	0.2			0.0				2004	93 300
Iraq	2000	-	-	-	-	64 493	98	85	1997	7	0.0			0.0	1997	1 500	2.3	2000	66 000
Israel	2004	-	-	-	-	1 552	79	87	2007	140	1.3	2002	262	13.4				2004	1 954
Jordan	2005	294	31	553	59	848	90	91	2005	10	1.0	2005	84	8.9				2005	941
Kuwait	2002	0	0	415	45	415	45	2 075	2002	420	46.0	2002	78	8.5				2002	913
Lebanon	2005	396	30	700	53	1 096	84	24	2006	47	3.6	2006	2	0.2	2001	165	12.6	2005	1 310
Occupied Palestinian Territory	2005	-	-	-	-	408	98	49	-		0.0	1998	10	2.4				2005	418
Gaza Strip	2000			123	92	123	92	173	-		0.0	1998	10	7.5				2000	133
West Bank	2000			157	100	157	100	21	-		0.0							2000	157
Oman	2003	0	0	1 175	89	1 175	89	84	2006	109	8.0	2006	37	2.7				2003	1 321
Qatar	2005	0	0	221	50	221	50	381	2005	180	40.5	2005	43	9.7				2005	444
Saudi Arabia	2006	1 100	5	21 367	90	22 467	95	936	2006	1 033	4.4	2006	166	0.7				2006	23 666
Syrian Arab Republic	2003		-		-	13 894	83	83	-		0.0	2002	550	3.3	2004	2 246	13.5	2003	16 690
Turkey	2000	31 500	73	10 500	24	39 100	98	18	1990	1	0.0	2006	1000	2.5				2003	40 100
United Arab Emirates	2005	0	0	2 800	70	2 800	70	1 867	2005	950	23.8	2005	248	6.2				2005	3 998
Yemen	2000	987	29	2 397	71	3 384	100	161	2000	10	0.3	2000	6	0.2				2000	3 400
Total region		**88 297**		**95 614**		**261 688**	**96**	**-**	**-**	**3 210**	**1.2**		**2662.8**	**0.98**		**3 911**	**1.4**		**271 472**

TABLE 47
Area under irrigation

Country	Year	Full/partial control irrigation	Spate irrigation	Equipped lowlands	Total equipped for irrigation	% of cultivated area	Part of equipped actually irrigated	Annual increase rate
Unit		ha	ha	ha	ha	%	%	%
		(1)	(2)	(3)	(4)=(1)+(2)+(3)	(5)	(6)	(7)
Armenia	2006	273 530	-	-	273 530	49.3	64.0	-0.4
Azerbaijan	2003	1 426 000	-	-	1 426 000	69.1	-	-0.2
Bahrain	2000	4 015	-	-	4 015	94.8	100.0	4.0
Georgia	2007	401 290	-	31 500	432 790	40.6	-	-0.7
Iran (Islamic Republic of)	2003	8 131 564	-	-	8 131 564	46.0	-	1.1
Iraq	1990	3 525 000	-	-	3 525 000	59.0	97.0	-
Israel	2004	225 000	-	-	225 000	57.0	-	2.1
Jordan	2004	78 860	-	-	78 860	26.8	91.0	-0.9
Kuwait	2003	7 050	-	-	7 050	100.0	-	4.4
Lebanon	2000	90 000	-	-	90 000	27.1	-	0.4
Occupied Palestinian Territory	2003	24 000	-	-	24 000	11.0	-	-
Gaza Strip	2003	11 400	-	-	11 400	-	-	-
West Bank	2003	12 600	-	-	12 600	-	-	-
Oman	2005	58 850	-	-	58 850	100.0	-	-0.4
Qatar	2001	12 935	-	-	12 935	200.0	47.0	0.4
Saudi Arabia	2000	1 730 767	-	-	1 730 767	143.0	69.0	0.9
Syrian Arab Republic	2004	1 439 100	-	-	1 439 100	26.0	-	3.2
Turkey	2006	4 970 000	-	13 000	4 983 000	19.0	87.0	1.3
United Arab Emirates	2003	226 600	-	-	226 600	88.9	-	13.0
Yemen	2004	454 310	217 541	7 799	679 650	57.2	67.0	3.5
Total region		**23 078 871**	**217 541**	**52 299**	**23 348 711**		**-**	**-**

TABLE 48
Water managed area

Country	Year	Area equipped for irrigation (table 43)	Non equipped cultivated wetlands and valley bottoms	Non equipped flood recession cropping area	Total water managed area	% of irrigation potential	% of cultivated area
Unit		ha	ha	ha	ha	%	%
		(1)	(2)	(3)	(4)=(1)+(2)+(3)	(5)	(6)
Armenia	2006	273 530	-	-	273 530	41	64
Azerbaijan	2003	1 426 000	-	-	1 426 000	45	69
Bahrain	2000	4 015	-	-	4 015	95	95
Georgia	2007	432 790	-	-	432 790	60	41
Iran (Islamic Republic of)	2003	8 131 564	-	10 000	8 141 564	54	46
Iraq	1990	3 525 000	-	-	3 525 000	63	59
Israel	2004	225 000	-	-	225 000	-	
Jordan	2004	78 860	-	-	78 860	93	27
Kuwait	2003	7 050	-	-	7 050	28	100
Lebanon	2000	90 000	-	-	90 000	51	27
Occupied Palestinian Territory	2003	24 000	-	-	24 000	30	11
Gaza Strip	2003	11 400	-	-	11 400	60	-
West Bank	2003	12 600	-	-	12 600	21	-
Oman	2005	58 850	-	-	58 850	-	100
Qatar	2001	12 935	-	-	12 935	25	200
Saudi Arabia	2000	1 730 767	-	-	1 730 767	-	143
Syrian Arab Republic	2004	1 439 100	-	-	1 439 100	-	26
Turkey	2006	4 983 000	-	-	4 983 000	57	19
United Arab Emirates	2003	226 600	-	-	226 600	-	89
Yemen	2004	679 650	-	-	679 650	-	57
Total region		**23 348 711**	**0**	**10 000**	**23 358 711**	**-**	

TABLE 49
Full/partial control irrigation techniques

Country	Year	F/p control – equipped	Year	Full/partial control irrigation – equipped area		
		Total**		Surface irrigation	Sprinkler irrigation	Localized irrigation
Unit		ha		ha	ha	ha
Armenia	2006	273 530	2006	247 530	25 000	1 000
Azerbaijan	2003	1 426 000	1995	1 301 700	149 000	2 618
Bahrain	2000	4 015	2000	3 390	160	465
Georgia	2007	401 290	2007	372 980	0	28 310
Iran (Islamic Republic of)	2003	8 131 564	2003	7 431 564	280 000	420 000
Iraq	1990	3 525 000	1994	-	-	8 000
Israel	2004	225 000	2004	-	-	168 750
Jordan	2004	78 860	2004	13 860	1 000	64 000
Kuwait	2003	7 050	1994	3 020	600	1 150
Lebanon	2000	90 000	2000	57 200	25 100	7 700
Occupied Palestinian Territory	2003	24 000	-	-	-	-
Gaza Strip	-	11 400	-	-	-	-
West Bank	-	12 600	-	-	-	-
Oman	2005	58 850	2004	46 658	6 654	5 538
Qatar	2001	12 935	2001	9 707	1 813	1 415
Saudi Arabia	2000	1 730 767	1992	547 000	1 029 000	32 000
Syrian Arab Republic	2004	1 439 100	2004	1 251 400	130 200	57 500
Turkey	2006	4 970 000	2006	4 572 400	298 200	99 400
United Arab Emirates	2003	226 600	2003	27 100	4 000	195 500
Yemen	2004	454 310	2004	453 825	0	485
Total region*		**23 078 871**		**16 339 334**	**1 950 727**	**917 081**

* Iraq, Israel and Occupied Palestinian Territory not included in the totals of the different techniques.
** For Azerbaijan, Iraq, Kuwait, Oman and Saudi Arabia, the year of the total area under full/partial control irrigation is different from the year for the different techniques.

TABLE 50
Origin of full/partial control irrigation water

Country	Year	Surface water		Groundwater		Mixed surface water and groundwater		Non - conventional sources of water	
		Area	% of f/p control area	Area	% of f/p control area	Area	% of f/p control area	Area	% of f/p control area
Unit		ha		ha		ha		ha	
Armenia	2006	246 180	90	27 350	10	-	-	-	-
Azerbaijan	1995	1 357 000	93	96 700	7	-	-	-	-
Bahrain	2003	-	0	3 614	90	-	-	402	10
Georgia	2007	401 290	100	-	0	-	-	-	0
Iran (Islamic Republic of)	2003	3 078 054	38	5 053 510	62	-	-	-	-
Iraq	1990	3 306 000	94	219 000	6	-	-	-	-
Israel		-	-	-	-	-	-	-	-
Jordan	2004	24 360	31	42 000	53	-	-	12 500	16
Kuwait	1994	-	0	2 910	61	-	-	1 860	39
Lebanon	2000	40 000	45	20 000	22	30 000	33	-	-
Occupied Palestinian Territory	2003	-	-	24 000	100	-	-	-	-
Gaza Strip	2003	-	-	11 400	100	-	-	-	-
West Bank	2003	-	-	12 600	100	-	-	-	-
Oman	2005	-	0	58 850	100	-	-	-	0
Qatar	2001	-	-	12 077	93	-	-	858	7
Saudi Arabia	2000	-	0	1 678 844	97	-	-	51 923	3
Syrian Arab Republic	2004	-	0	864 700	60	574 400	40	-	-
Turkey	2005	3 810 867	78	899 248	19	-	-	150 685	3
United Arab Emirates	2003	-	0	226 600	100	-	-	-	0
Yemen	2004	-	0	454 310	100	-	-	-	0
Total region		**12 263 751**	**54**	**9 683 713**	**43**	**604 400**	**2**	**218 228**	**1**

TABLE 51
Harvested irrigated crops on full/partial control areas

Country	Year	Equipped F/P control irrigation	Year	F/P equipped area actually irrigated	Year	Wheat	Barley	Maize	Rice	Other cereals	Vegetables including roots and tubers	Pulses	Fodder	Sugar cane	Cotton	Citrus	Bananas	Olives	Dates	Other annual crops	Other perennial crops	TOTAL	Cropping intensity (equipped area)	Cropping intensity (actually irrigated)
		ha		ha		ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	%	%
Armenia	2006	273 530	2006	176 000	2006	35 000	5 900	3 100			47 400	2 000	26 000							5 700	50 900	176 000	64	100
Azerbaijan	2003	1 426 000			2004	610 919	158 909	33 194	2 573	9 302	146 246				78 161					250 810	101 407	1 391 521	98	
Bahrain	2000	4 015	2000	4 015	2000						1 015		790								2 210	4 015	100	100
Georgia	2007	401 290			2006																	126 060	31	
Iran (Islamic Republic of)	2003	8 131 564			2003	2 634 106	607 485	275 941	628 105	65	951 315	159 716	878 181	63 385	143 233	213 348	2 889			980 752	1 054 033	8 592 554	106	
Iraq	1990	3 525 000			1998	717 000	785 000	60 000	126 000	7 000	252 000	26 000		3 000	19 000	72 000				76 000	285 000	2 428 000	69	
Israel	2004	225 000			2000						37 670									79 520	73 060	190 250	85	
Jordan	2004	78 860	2004	72 009	2004	1 676	684				34 429	927				6 638	1 900			6 193	46 582	99 029	126	138
Kuwait	2003	7 050			2006	290	1 263				4 420								1 589	390	103	8 055	106	
Lebanon	2000	90 000			2003	16 940	5 140	3 490		61	37 663	4 310				16 426	2 754			13 609	4 900	105 293	117	
Occupied Palestinian Territory	2001	20 073			1997						12 759					6 261	577			2 839	1 585	24 021	120	
Gaza Strip																								
West Bank																								
Oman	2004	58 850			2007	311	1 171			5 601	5 539		15 817	40		1 232	2 436		32 759		2 182	67 087	108	
Qatar	2001	12 935	2004	6 322	2004	10	1 027	93		204	1 345		2 544			140					1 565	6 928	54	110
Saudi Arabia	2000	1 730 767	1999	1 191 351	2006	490 272	22 091	12 123		150 093	127 831		207 298			10 848				2 216	190 815	1 213 587	70	101
Syrian Arab Republic	2004	1 439 100			2000	694 469					114 982	7 271	100 974		270 290	27 338		28 994		26 064	63 883	1 334 265	105	
Turkey	2006	4 970 000	2006	4 320 000	2004	172 000	86 000	545 000	71 000		977 000	260 000	475 000		640 000	110 000				641 000	229 000	4 206 000	85	100
United Arab Emirates	2003	226 600			2003	6					8 083		2 801						185 330	30 218	2 083	228 521	101	
Yemen	2004	454 310	2004	454 310	2004	41 903	11 223	19 234		50 835	72 364	26 832	70 772		17 246	11 252	8 837			22 375	174 165	527 038	116	116
Total region						**5 414 902**	**1 685 893**	**952 175**	**827 678**	**223 161**	**2 832 061**	**487 056**	**1 780 177**	**66 425**	**1 167 930**	**475 483**	**19 393**	**28 994**	**219 678**	**2 137 686**	**2 283 473**	**20 728 224**		

TABLE 52
Middle East compared to the world

Variable	Unit	Middle East	World	Middle East as % of the world
Total area 2005	1 000 ha	656 457	13 443 403	4.9
Cultivated area	1 000 ha	64 097	1 561 682	4.1
- in % of total area	%	10	12	-
- per inhabitant	ha	0.23	0.24	-
- per economic active person engaged in agriculture	ha	2.13	1.15	-
Total population 2005	inhabitants	283 004 000	6 464 750 000	4.4
Population growth 2004-2005	%/year	1.8	1.2	-
Population density	inhabitants/km²	43	48	-
Rural population as % of total population	%	34	51	-
Economically active population engaged in agriculture	%	27	21	-
Precipitation	km³/year	1 543	110 000	1.4
	mm/year	235	818	-
Internal renewable water resources	km³/ year	484	43 658	1.1
- per inhabitant	m³/year	1 711	6 753	-
Actual total renewable water resources	km³/ year	564	55 250	1.0
Total water withdrawal by sector	km³/year	271	3 871	7.0
- agricultural	km³/year	227	2 694	8.4
- in % of total water withdrawal	%	83	70	-
- domestic	km³/year	25	387	6.5
- in % of total water withdrawal	%	9	10	-
- industrial	km³/year	20	790	2.5
- in % of total water withdrawal	%	7	20	-
Total water withdrawal by source	km³/year	271	3 871	7.0
- total freshwater	km³/year	262	3 844	6.8
- in % of internal renewable water resources	%	54	9	-
- in % of total actual renewable water resources	%	46	7	-
- desalinated water	km³/year	3	6	54.0
- reused treated wastewater	km³/year	3	22	12.1
Irrigation	ha	23 348 711	280 375 100	8.3
- in % of cultivated area	%	36	18	-

Regional figures

EXPLANATORY NOTES

Figure 7 – Regional division of the world adopted by AQUASTAT

- This is the regional division as given in FAO. 2003. Review of world water resources by country. *Water Report 23*. FAO, Rome. 110 pp.

Figure 18 – Annual freshwater withdrawal as percentage of total actual renewable water resources

- Values over 100 percent indicate that more freshwater is withdrawn than the quantity annually renewed on a long-term basis, thus depleting the freshwater resources and using fossil groundwater. At country level, Kuwait has by far the highest value, 2 075 percent, meaning that large use is made of fossil groundwater. The United Arab Emirates and Saudi Arabia follow, with 1 867 percent and 936 percent respectively. For Qatar, Bahrain, Gaza Strip and Yemen, the values are 381 percent, 206 percent, 173 percent and 161 percent respectively.

FIGURE 7
Regional division of the world adopted by AQUASTAT

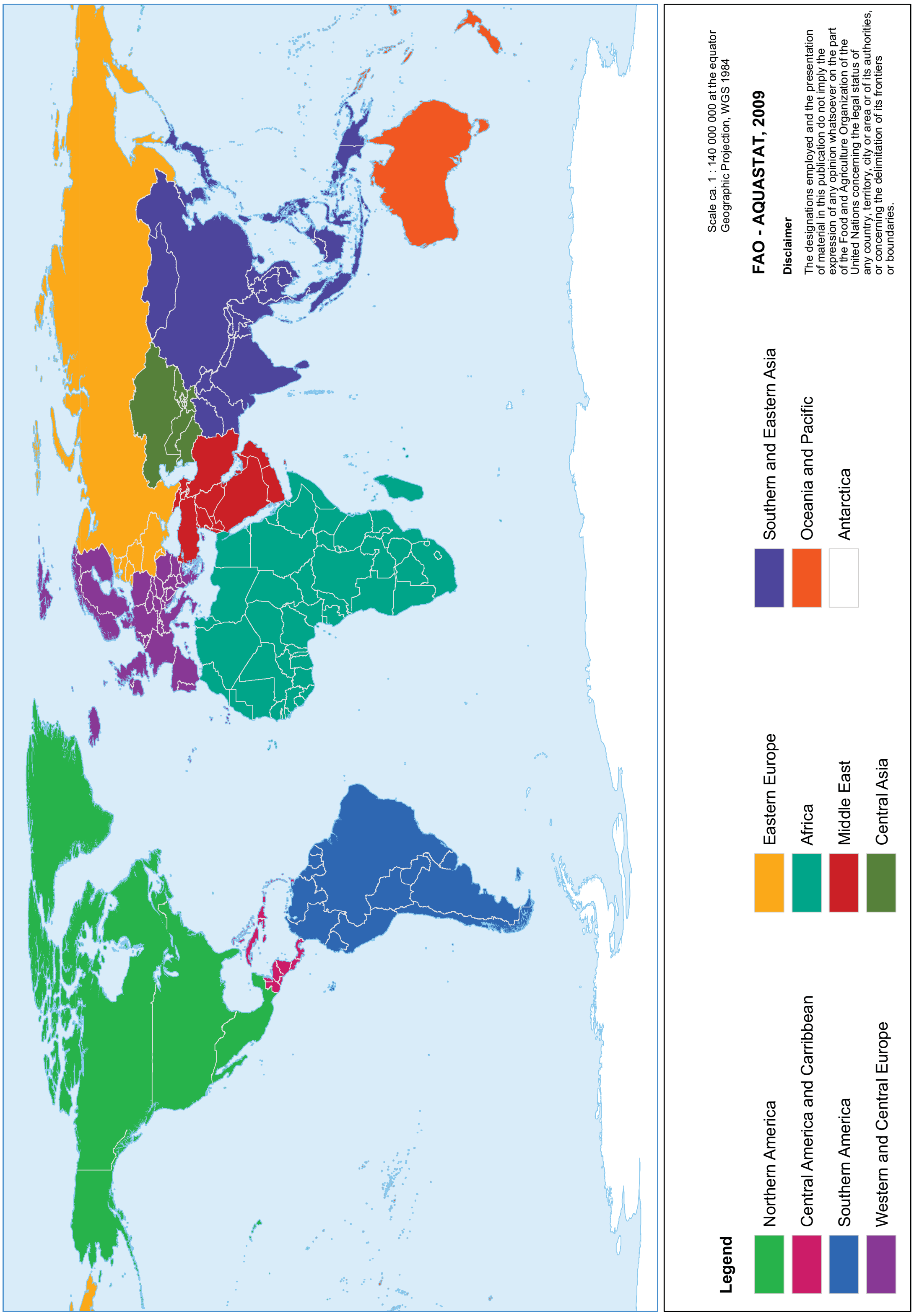

FIGURE 8
Regional division of the Middle East

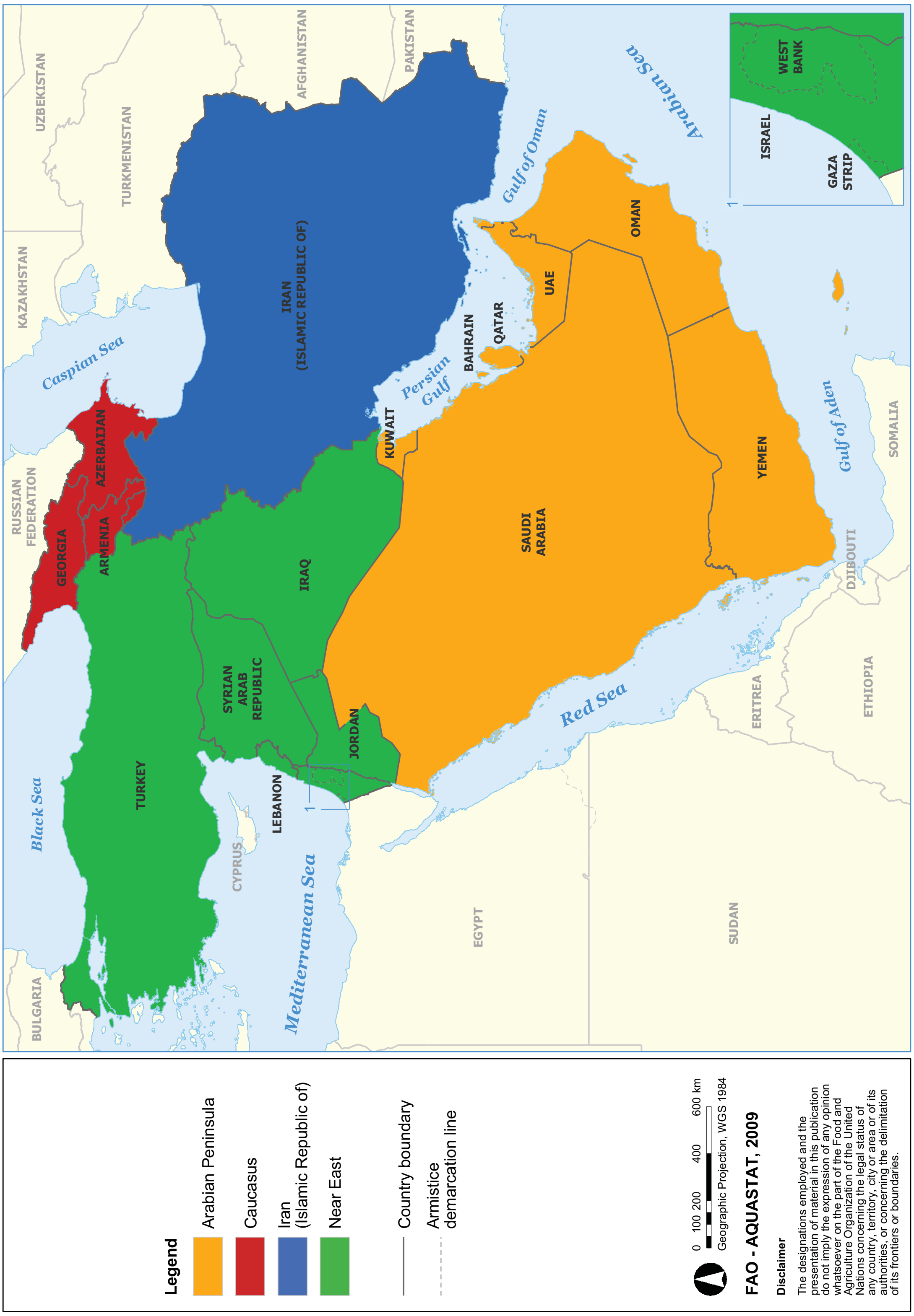

FIGURE 9
Average annual rainfall

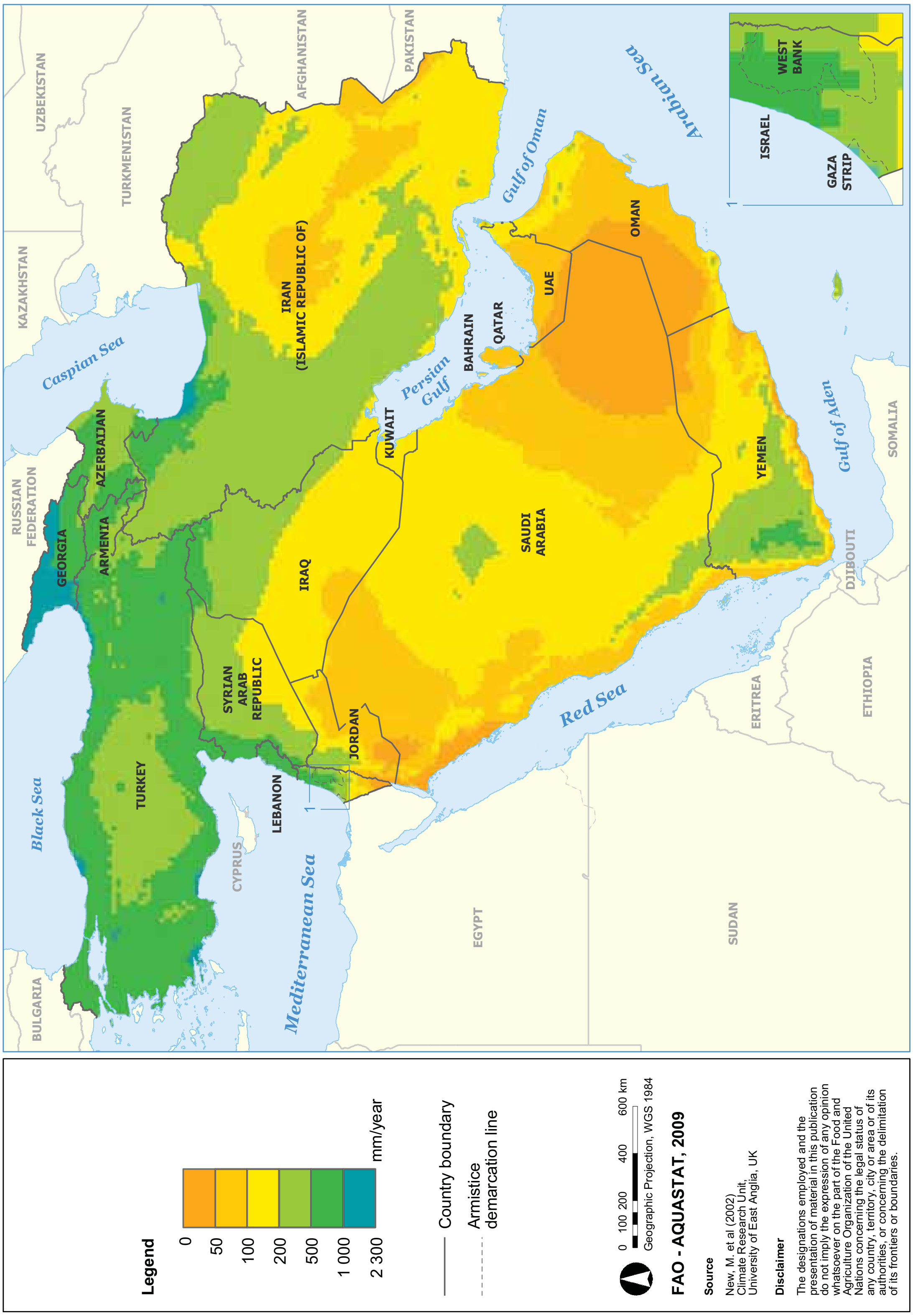

FIGURE 10
Population density

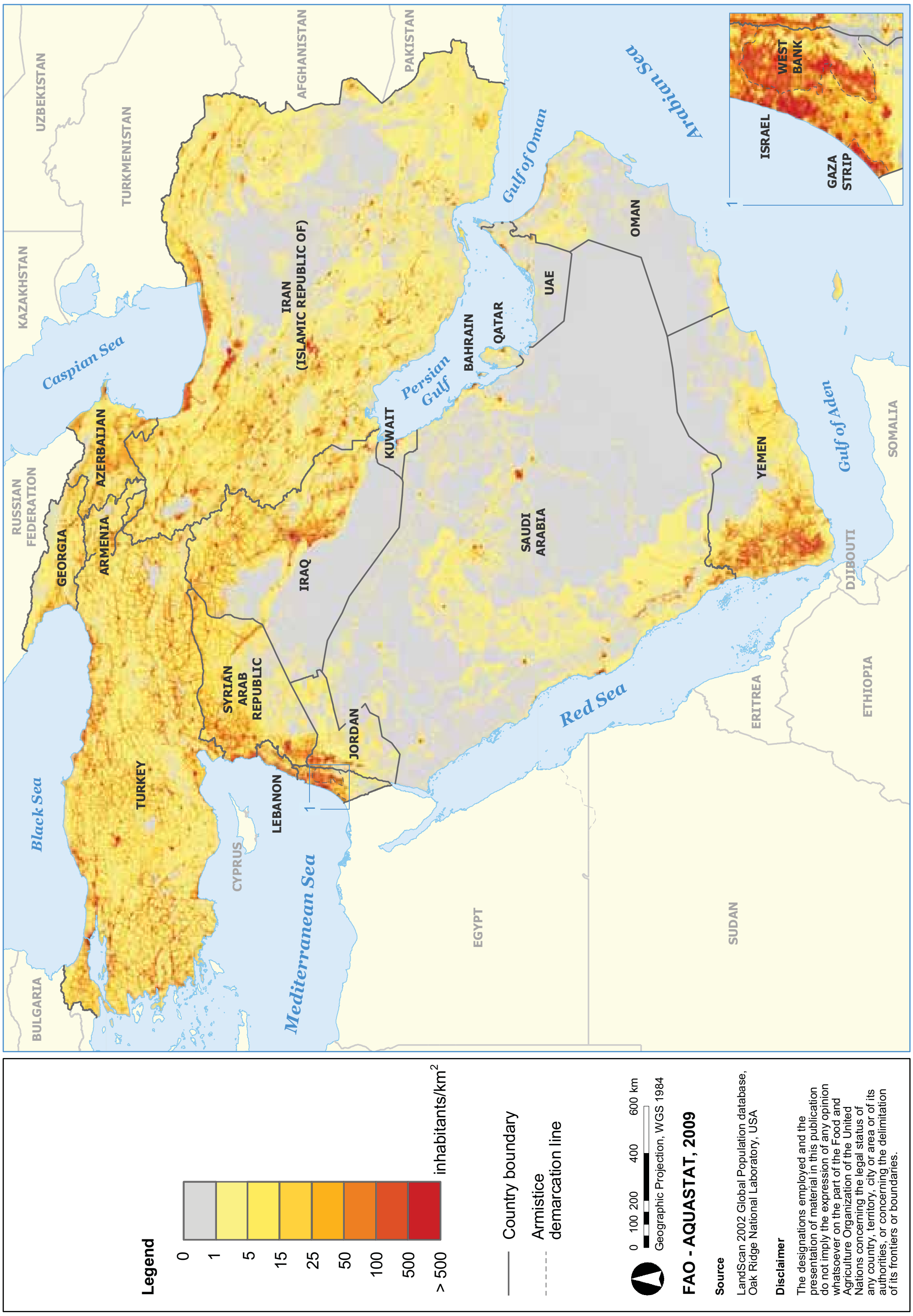

FIGURE 11
Internal renewable water resources

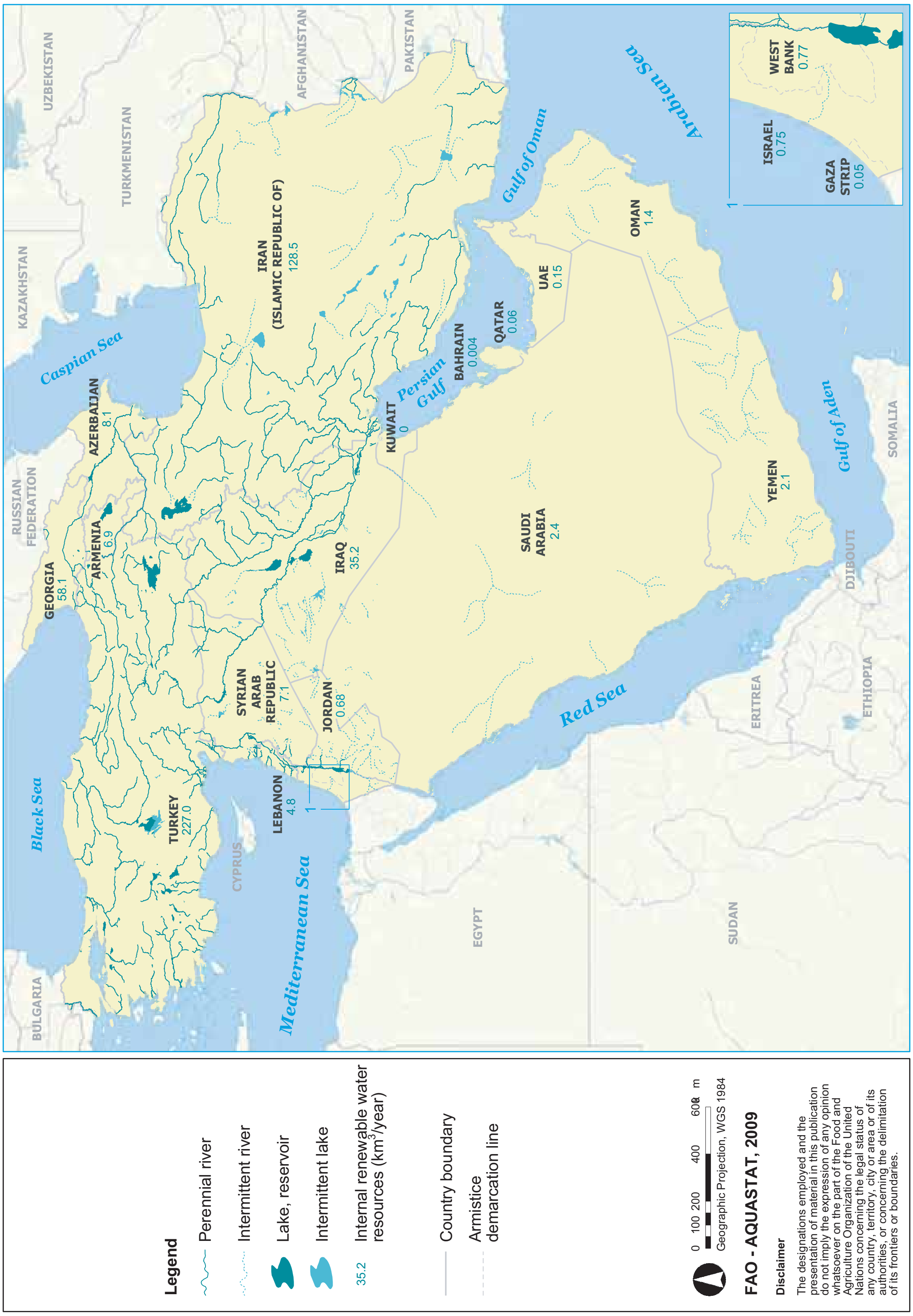

FIGURE 12
Total renewable water resources per inhabitant

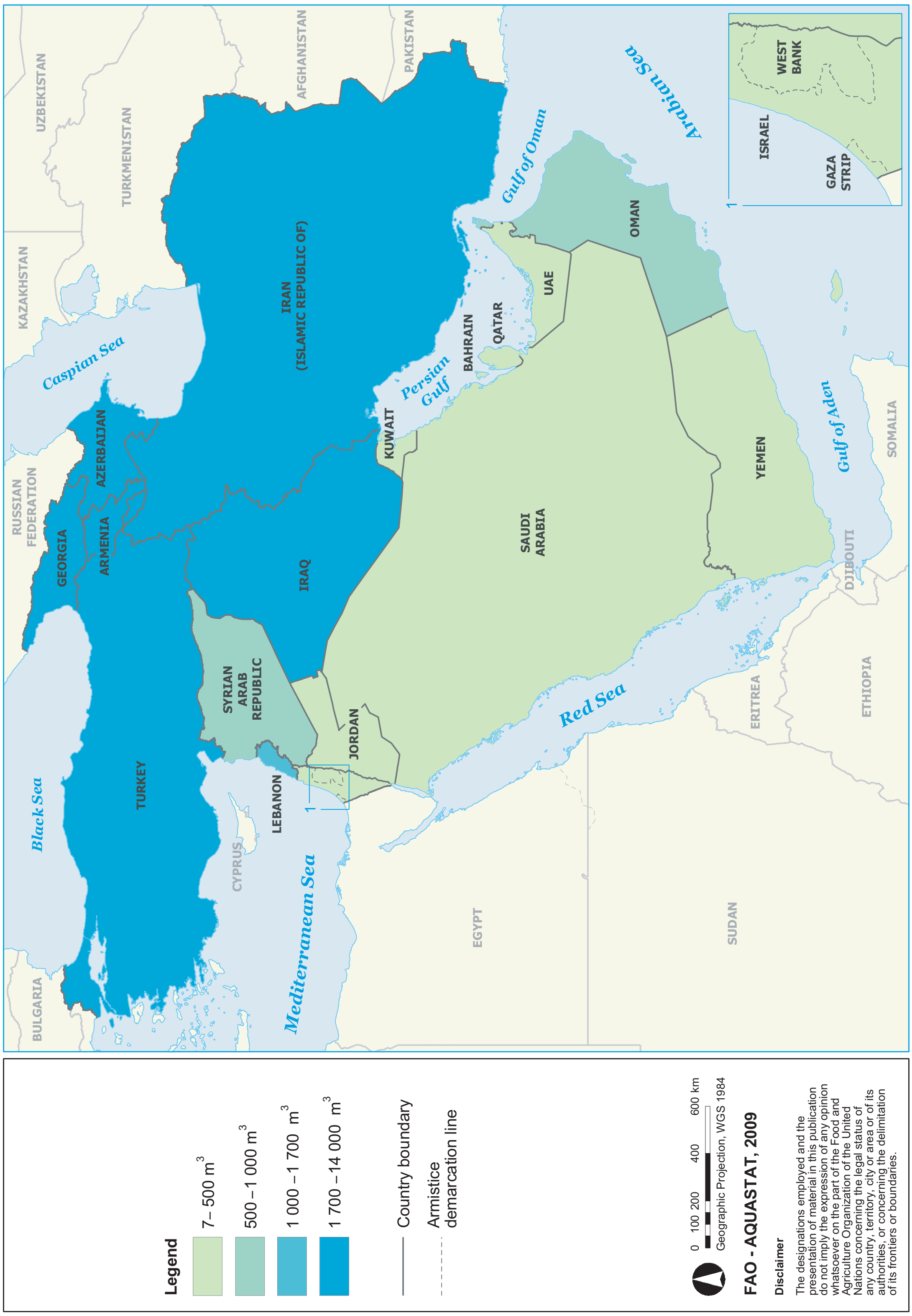

FIGURE 13
Transboundary river basins

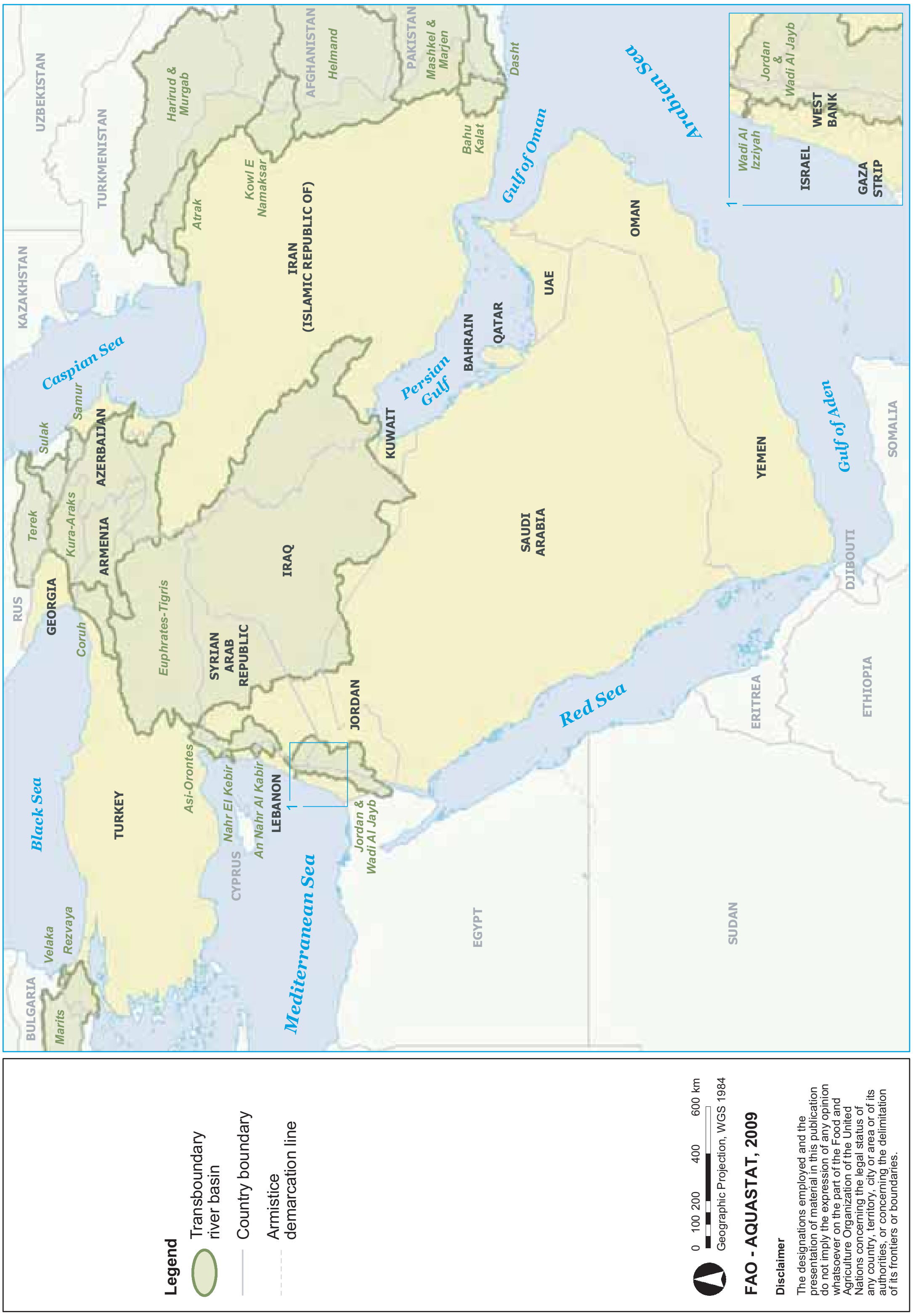

FIGURE 14
Endoreic basins

FIGURE 15

Non-renewable groundwater aquifers

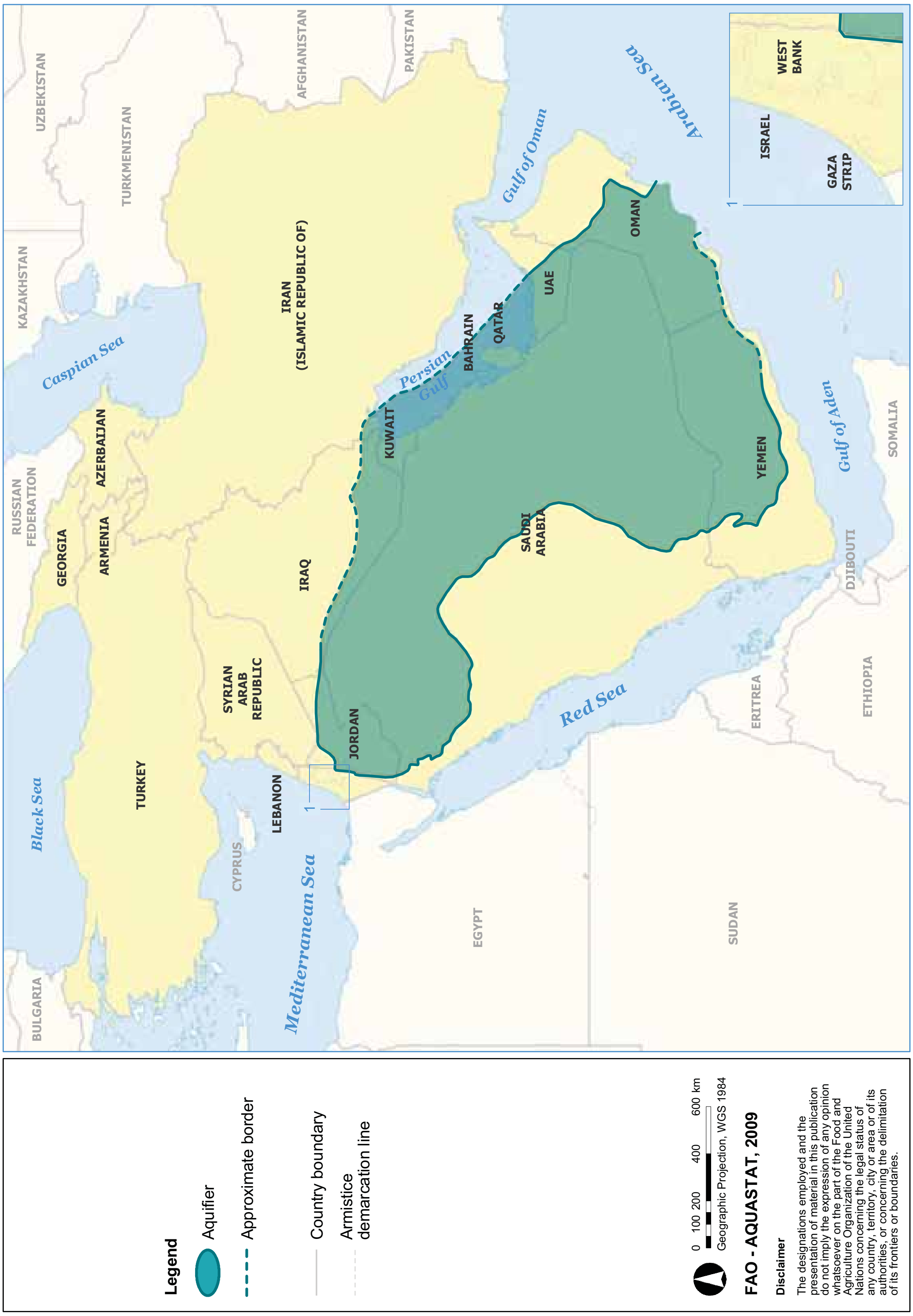

FIGURE 16
Non-conventional souces of water as percentage of total water withdrawals

Legend

- 0–1 %
- 1–10 %
- 10–20 %
- 20–55 %

Country boundary
Armistice demarcation line

0 100 200 400 600 km
Geographic Projection, WGS 1984

FAO - AQUASTAT, 2009

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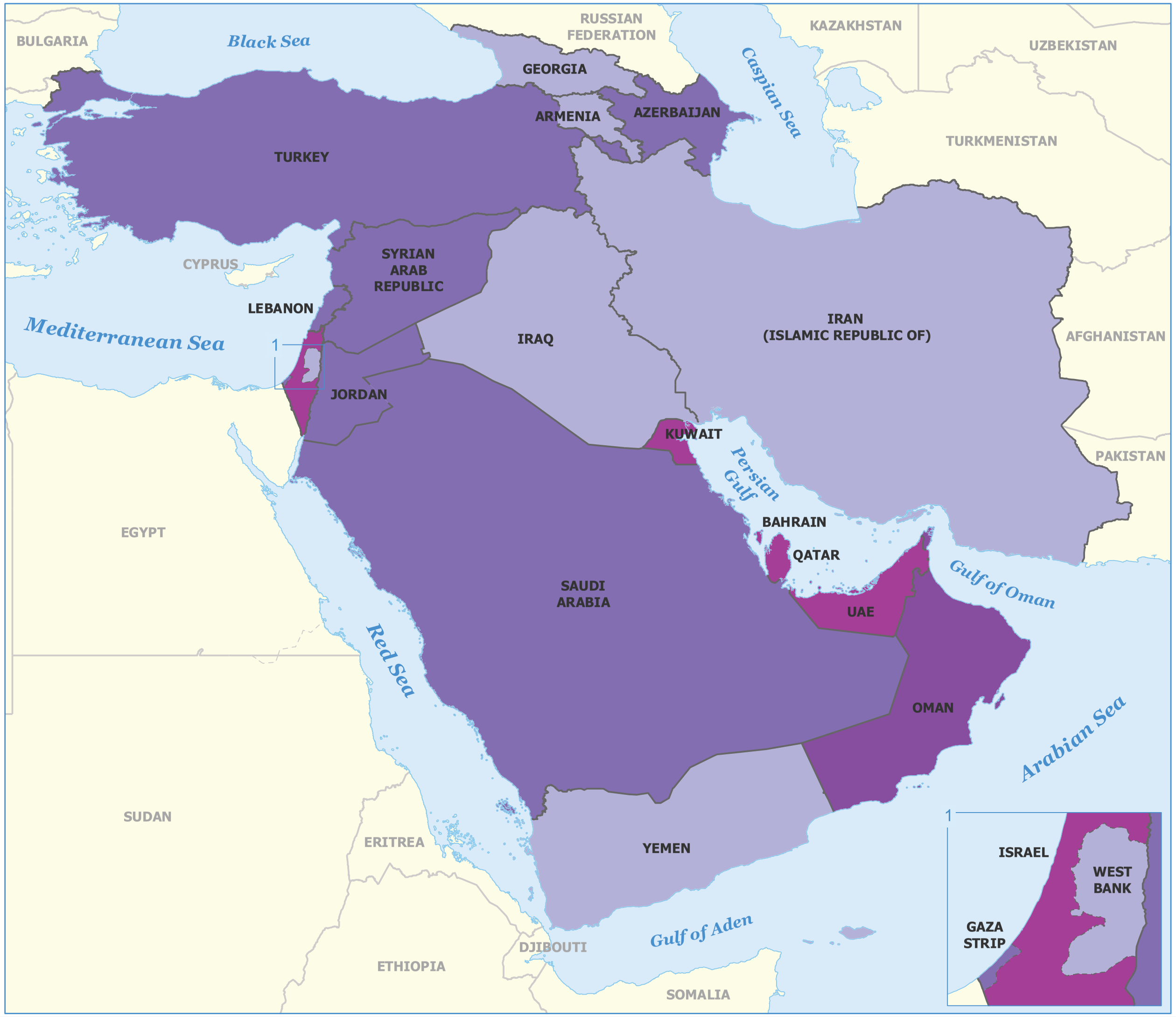

FIGURE 17
Annual water withdrawal per inhabitant

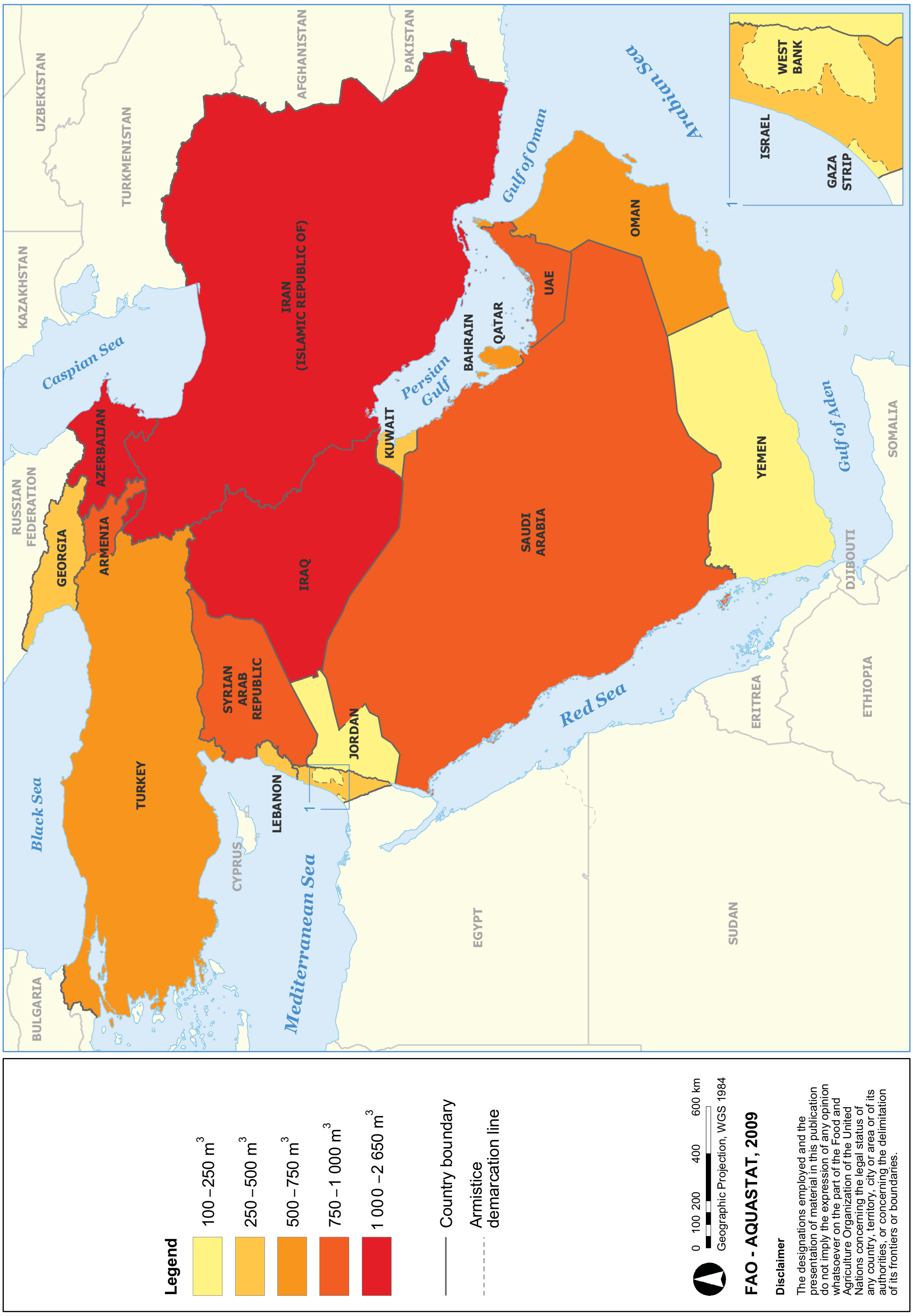

FIGURE 18

Annual freshwater withdrawal as a percentage of total actual renewable water resources

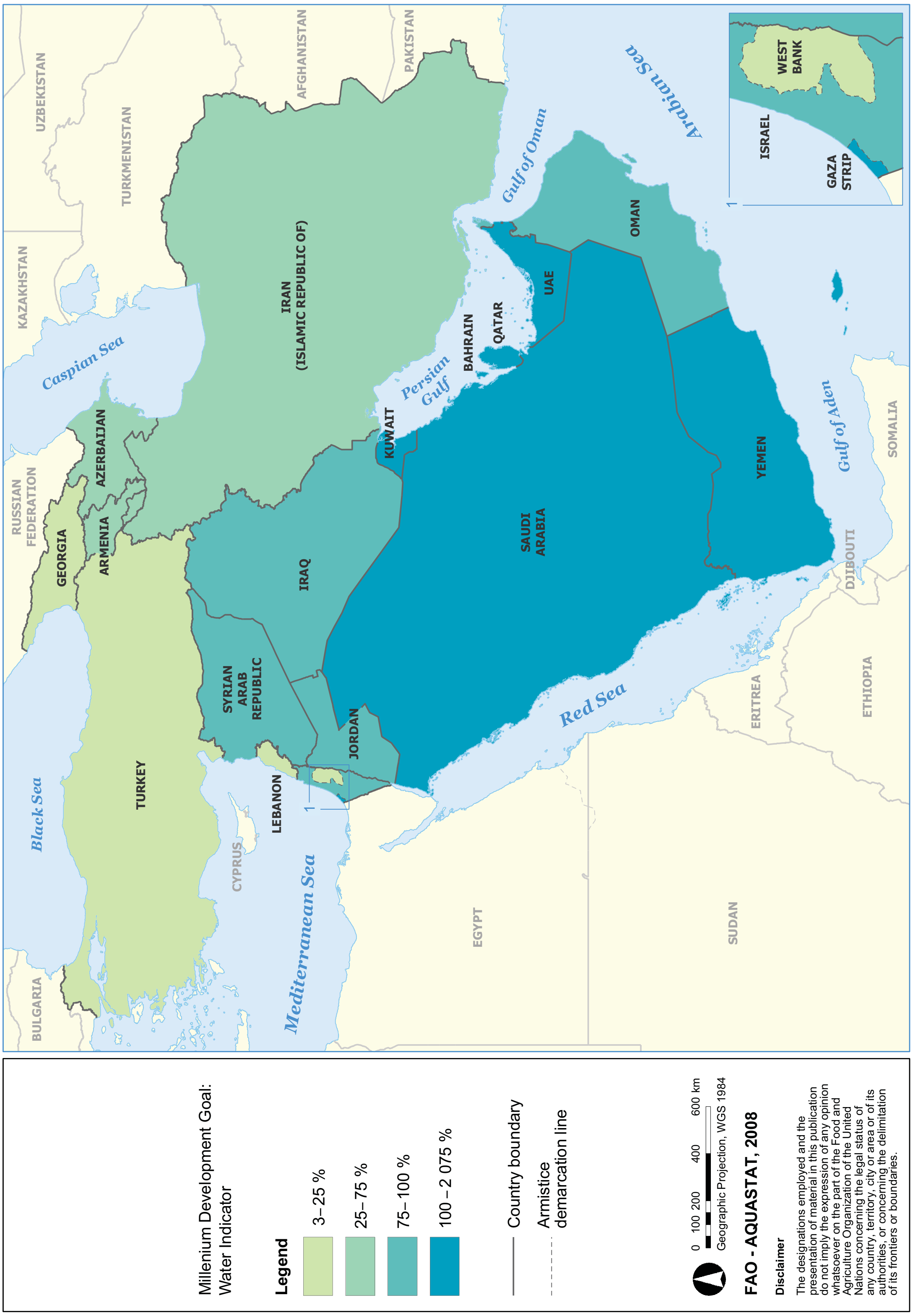

FIGURE 19
Area equipped for irrigation

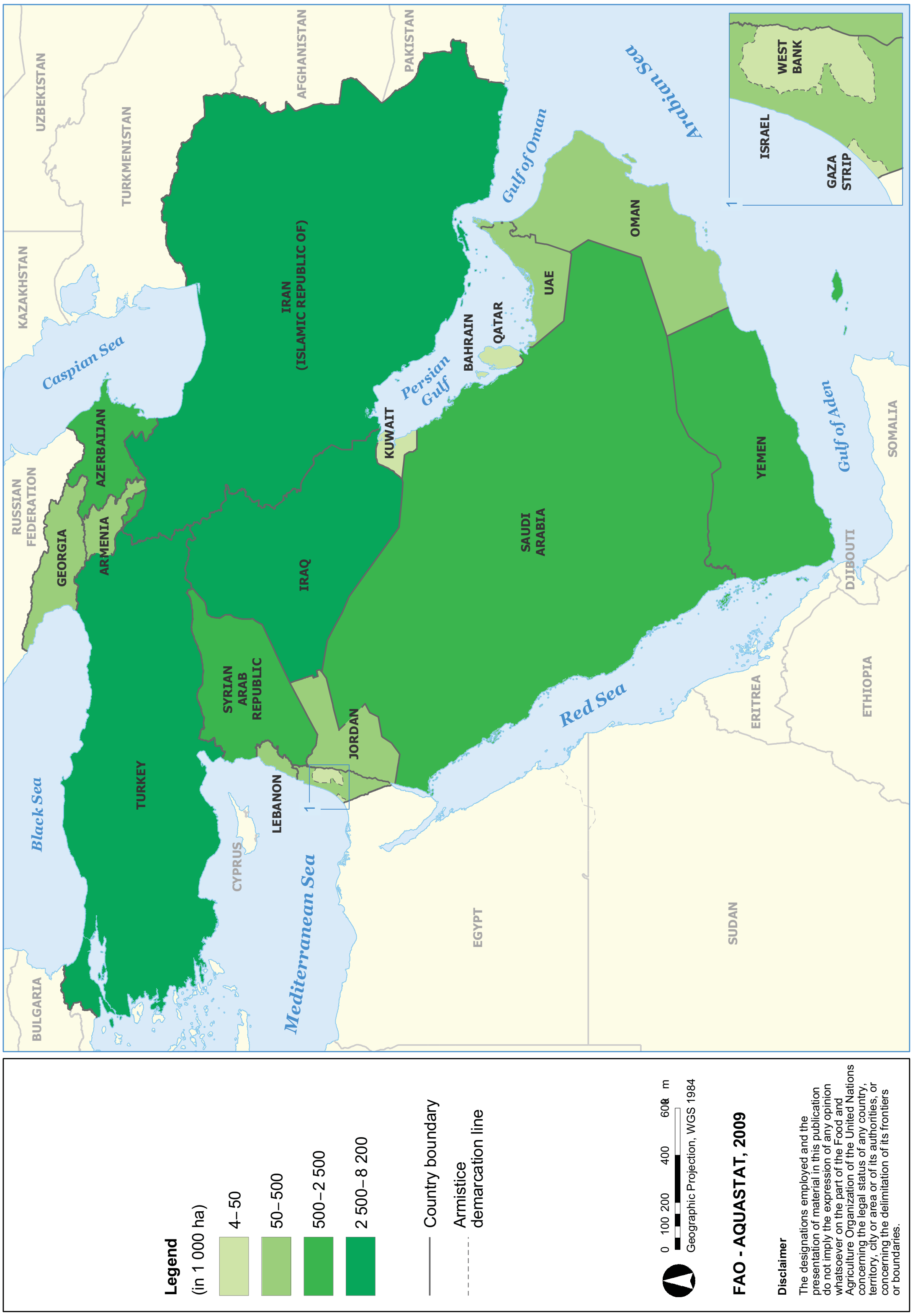

FIGURE 20

Area equipped for irrigation as percentage of country area

Legend

- 0–1 %
- 1–5 %
- 5–10 %
- 10–32 %
- 274 Total area equipped for irrigation (in 1000 ha)
- Country boundary
- Armistice demarcation line

0 100 200 400 600 km

Geographic Projection, WGS 1984

FAO - AQUASTAT, 2009

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FIGURE 21
Area equipped for irrigation as percentage of cultivated area

Legend

- 10–30 %
- 30–60 %
- 60–90 %
- > 90 %

Country boundary
Armistice demarcation line

0 100 200 400 600 km
Geographic Projection, WGS 1984

FAO - AQUASTAT, 2009

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Section III

Country profiles

Country profiles

EXPLANATORY NOTES

In this section country profiles for Armenia, Azerbaijan, Bahrain, Georgia, Iran (Islamic Republic of), Iraq, Israel, Jordan, Kuwait, Lebanon, Occupied Palestinian Territory, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Turkey, United Arab Emirates and Yemen have been designated as an extra to the publication with their exclusive assigned numbers to figures and tables, and including a detailed map for each country.

The main reason for this is that these profiles have also been included on the AQUASTAT country web page (http://www.fao.org/nr/water/aquastat/countries/index.stm), where each country profile can be downloaded as a stand-alone profile in PDF format.

Armenia

GEOGRAPHY, CLIMATE AND POPULATION

Geography

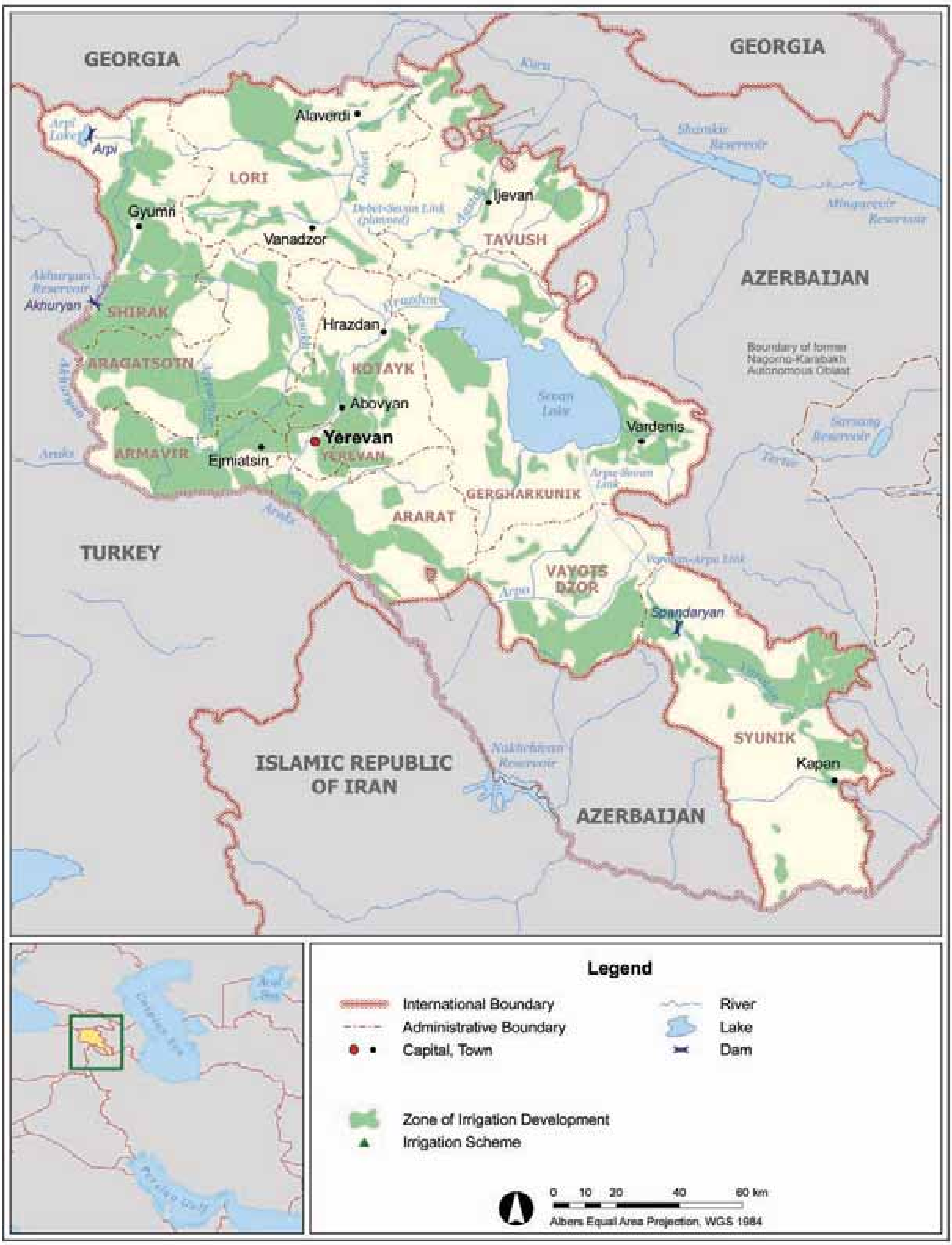
Armenia, with a total area of 29 800 km², is a landlocked country in the Caucasus region bordered in the north by Georgia, in the east by Azerbaijan, in the southeast by the Islamic Republic of Iran, and in the southwest and west by Turkey. Until 1995, the country was divided into 37 districts. It is now divided into ten marzes (provinces) plus Yerevan, the capital city.

Armenia is a mountainous country, with 77 percent of its territory located at 1 000 to 2 500 m above sea level and with an average altitude of 1 850 m. The highest point is 4 095 m (Mount Aragats) and 42 percent of the area is unusable for habitation (MNR, 2005). The country has a complex combination of uplands, plateaus, river valleys, depressions, and limited land, water and forest resources, with unfavourable engineering-geological conditions in most of the area (high seismicity, abundance of geodynamic processes). The landform in the centre and north of the country consists of rocky high mountain ranges separating narrow fertile valleys. Towards the south are the broad, flat and fertile Ararat valleys along the left bank of the Araks River forming the border with Turkey. To the west and north of Mount Aragat and around Lake Sevan in the east, the landform is generally rolling with rocky outcrops. In the southeast, a few small irregular-shaped valleys are surrounded by high mountain ranges. Pastures dominate at higher altitudes. The country is divided into two major river basins, the Araks Basin in the southwest and the Kura Basin in the northeast, which converge farther downstream in Azerbaijan. The low-lying areas, such as the Ararat plains, have rich, deep soils, but at higher elevations and on steep slopes, soils tend to be shallow.

Agriculture is greatly influenced by the topography, most of the cultivated land lying within an altitude range of 600–2 500 m. The predominant agricultural soils are generally fertile and deep. The cultivable area is estimated at almost 1.4 million ha, which is 47 percent of the total area of the country. In 2005, the cultivated area was estimated at 555 000 ha, of which 495 000 ha were under annual crops and 60 000 ha under permanent crops (Table 1).

Climate

Armenia has a highland continental climate: hot summers and cold winters. The geographical location of the country and its complex mountainous relief have conditioned the diversity of natural conditions across the country. There are six climate zones ranging from dry subtropical to rigorous high mountainous. The average annual temperature is 5.5 °C. Summer in Armenia is moderate, with an average temperature in July of around 16-17 °C, but ranging from 24 to 26 °C in the Ararat Valley. Winters are quite cold; the average winter temperature in Armenia is almost –7 °C. Total annual



ARMENIA **FAO - AQUASTAT, 2008**

TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2005	2 980 000	ha
Cultivated area (arable land and area under permanent crops)	2005	555 000	ha
• as % of the total area of the country	2005	18.6	%
• arable land (annual crops + temp. fallow + temp. meadows)	2005	495 000	ha
• area under permanent crops	2005	60 000	ha
Population			
Total population	2005	3 016 000	inhabitants
• of which rural	2005	35.9	%
Population density	2005	101.2	inhabitants/km^2
Economically active population	2005	1 522 000	inhabitants
• as % of total population	2005	50.5	%
• female	2005	51.9	%
• male	2005	48.1	%
Population economically active in agriculture	2005	162 000	inhabitants
• as % of total economically active population	2005	10.6	%
• female	2005	21	%
• male	2005	79	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2007	9 180	million US$/yr
• value added in agriculture (% of GDP)	2007	18	%
• GDP per capita	2005	1 626	US$/yr
Human Development Index (highest = 1)	2005	0.775	
Access to improved drinking water sources			
Total population	2006	98	%
Urban population	2006	99	%
Rural population	2006	96	%

precipitation is 592 mm. The driest regions are the Ararat Valley and the Meghri region, where the annual precipitation is 200–250 mm. The maximum precipitation is observed in high mountainous areas with more than 1 000 mm annually. The multiyear average for annual evaporation in Armenia is 10–11 million m^3, equal to about 350 mm over the entire country (UNDP, 2006).

Population

The total population is slightly more than 3 million (2005), of which about 36 percent is rural (Table 1). The population density is 101 inhabitants/km^2. The annual demographic growth rate was estimated at –2.1 percent for the period 2000–2005. In 2006, 91 percent of the population had access to improved sanitation (96 and 81 percent in urban and rural areas, respectively). Access to improved drinking-water sources reached 96 percent (99 and 96 percent for urban and rural population respectively). It is estimated that about half of the population in Armenia lives below the poverty line. The rural population is less vulnerable because of its capacity to provide for basic foodstuffs on a more or less stable basis. The poorest communities in Armenia reside in the mountainous regions and the very poor are principally concentrated in the earthquake zone, in border regions or in regions with a low level of economic activity (FAO and MOA, 2002) More than 90 percent of households have access to an improved/not shared toilet facility (NSS and MOH, 2006).

ECONOMY, AGRICULTURE AND FOOD SECURITY

During the Soviet era, Armenia experienced robust industrial and agricultural development despite its limited natural resources. It became one of the most industrialized republics, providing machinery, chemicals, electronics and software to Russia and other Soviet Republics. In return, Armenia received raw materials and energy.

In December 1988, a devastating earthquake struck Armenia, killing more than 25 000 people and destroying large areas of the industrial heartland. This was followed by the break-up of the Soviet Union in 1991 and the consequent loss of markets and largely subsidized energy. This further led to a rapid decline in industrial output and to high unemployment. By 1993 the Gross Domestic Product (GDP) had fallen by almost two-thirds. Since 1994, however, Armenia has been among the most reform-minded countries of the former Soviet Union. Factors that have contributed to economic growth include: reforms in the electricity sector; growth in exports in specific sectors, such as cut diamonds, metals, electricity, and processed food; housing construction, and a major programme of international assistance. However, the high levels of economic growth have not yet compensated for jobs lost because of downsizing or the closure of Soviet era enterprises (USAID, 2006).

In 2007, Armenia's GDP was US$9.2 billion and agriculture accounted for 18 percent (Table 1), down from a share of 41 percent in 1994. Industry on the contrary increased its contribution to GDP between 2000 and 2007 from 35 to 44 percent. Just over 50 percent of the population, 1.5 million people – of whom 21 percent is female - is economically active (2005): 162 000 people, or 11 percent of the labour force, are employed in agriculture whereas in 1994 agriculture employed 15 percent of all workers.

In 2003, crops accounted for 55.8 percent and stock breeding 44.2 percent of agriculture compared with 49.4 and 50.6 percent respectively in 1990. Since the beginning of the transition period the grain sowing areas have expanded by more than 20 percent and areas under cultivated potato by about 40 percent. However, the areas under forage plants have decreased by more than 3 times. In 2004, the main agricultural products were cereals, potatoes, vegetables, forage plants and fruit, especially grapes, given the long tradition of viticulture and wine-making. Agriculture has played a very important role in the economy of the country although it depends heavily on irrigation - half the total cultivated area is currently irrigated.

At present, in the agricultural food products sector, there is a free economy system regulated by the market which includes more than 338 000 farms. More than 98 percent of gross agricultural production comes from the private sector. The contribution of the agriculture and food sectors to the Armenia's international trade has changed considerably since the start of the transition: exports have shrunk while imports have surged. In recent years, there has been a visible and steady trend to sectoral development, but agriculture continues to be vulnerable, mainly because of the relative shortage of suitable land, the lack of sufficient water resources, the small size and detachment of farms formed as a result of land privatizations, the underdeveloped industrial market and social infrastructure, as well as because agriculture does not at present meet the requirements of a market economy.

An important objective of agricultural development is to ensure appropriate levels of food security for the urban and rural population. It is estimated that expenditure on food accounts for between 60 and 70 percent of households' total consumption. It can be as high as 85 percent for the poorest quintile, while it is 57 percent for the richest quintile. In view of the high share of food expenditure in total consumption, an adequate level of food security for the population requires that food is provided at affordable and stable prices. Given that farmgate prices of agricultural products are low and unfavourable to farmers' incomes, increasing food security for the population implies improving significantly the efficiency of the processing and marketing chains for agricultural products. This kind of improvement will be attained primarily through better organization of the markets, increased competition in processing and trade and increased safety of marketed products. Investments in market infrastructure need to be carefully assessed in order to avoid unnecessary costs that would increase retail food prices (FAO and MOA, 2002).

WATER RESOURCES AND USE

Water resources

The internal renewable surface water resources are estimated at 3.948 km³/year and the internal renewable groundwater resources at 4.311 km³/year. The overlap between surface water and groundwater is estimated at 1.400 km³/year. This gives a total of 6.859 km³ of annual internal renewable water resources (IRWR) (Table 2).

The rivers in Armenia are tributaries of the main rivers of the southern Caucasus, namely the Araks and the Kura. About 76 percent of the total territory is part of the Araks basin and 24 percent of the Kura basin (UNDP/GEF, 2006). Total outflow is equal to the IRWR. The outflow to Georgia through the Debet River is estimated at about 0.89 km³/year and the outflow to Azerbaijan through the Agstay River at about 0.35 km³/year; both these rivers are located in the Kura basin. The total outflow to Azerbaijan through the Araks and its tributaries (Arpa, Vorotan, Vokhchi) is estimated at about 5.62 km³/year. The Araks River forms the border between Turkey and Armenia and further downstream, between the Islamic Republic of Iran and Armenia, it flows into Azerbaijan, joining the Kura River about 150 km before its mouth at the Caspian Sea. The border flow of the Akhuryan (with Turkey) is estimated at 1.03 km³/year and the Araks at 0.79 km³/year. Half of the border flow is accounted for in Armenia's water balance, bringing the total actual renewable water resources to 7.769 km³/year.

The 14 sub-basins of the two main river basins (Kura and Araks) have been grouped into five basin management areas: Akhuryan, Northern, Sevan-Hrazdan, Ararat and Southern basins (USAID, 2006). About 9 500 rivers and streams with the total length of 23 000 km flow in Armenia. Out of that number 379 rivers are around 10–100 km long, and seven, namely the Akhuryan, Debet, Vorotan, Hrazdan, Aghstev, Arpa and Metsamor-Kasakh, are longer than 100 km. The annual distribution of river flow generated in the country by the 14 river basins and their characteristic features are presented in Table 3 (UNDP, 2006). Armenian rivers are typically of a mountainous nature with sharp seasonal variations, spring freshets and low water flow in summer.

Armenia has more than 100 small lakes, some of which regularly dry out in the dry season. The Sevan and Arpi lakes are the most important in terms of size and economic

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	592	mm/yr
	-	17.642	10^9 m³/yr
Internal renewable water resources (long-term average)	-	6.859	10^9 m³/yr
Total actual renewable water resources	-	7.769	10^9 m³/yr
Dependency ratio	-	11.71	%
Total actual renewable water resources per inhabitant	2005	2 576	m³/yr
Total dam capacity	2004	1 399	10^6 m³
Water withdrawal			
Total water withdrawal	2006	2 827	10^6 m³/yr
- irrigation + livestock	2006	1 859	10^6 m³/yr
- municipalities	2006	843	10^6 m³/yr
- industry	2006	125	10^6 m³/yr
• per inhabitant	2005	776.5	m³/yr
Surface water and groundwater withdrawal	2006	2 827	10^6 m³/yr
• as % of total actual renewable water resources	2006	36.4	%
Non-conventional sources of water			
Produced wastewater	2006	363	10^6 m³/yr
Treated wastewater	2006	89	10^6 m³/yr
Reused treated wastewater	1994	0.1	10^6 m³/yr
Desalinated water produced		-	10^6 m³/yr
Reused agricultural drainage water		-	10^6 m³/yr

TABLE 3
Characteristics of the main river basins in Armenia

N	River Basin	Area	Precipitation	Evaporation	Flow	Flow volume module	Reservoirs (2004)
		km²	million³ per year	million m³ per year	million m³ per year	million m³ per km²	In operation
I	Debet - within Armenia	3 895	2 726	1 457	1 203	0.309	1
II	Aghstay - within Armenia	2 480	1 569	979	445	0.205	5
III	Small tributaries of Kura - within Armenia	810	510	354	199	0.106	4
IV	Akhuryan - within Armenia	2 784	1 653	972	392	0.140	8
V	Kasakh	1 480	979	486	329	0.222	6
VI	Metsamor, without Kasakh	2 240	not available	not available	711	0.317	25
VII	Hrazdan	2 565	1 572	876	733	0.286	7
VIII	Lake Sevan Basin	4 750	not available	not available	265	0.056	4
IX	Azat	952	607	306	232	0.244	2
X	Vedi	998	573	340	110	0.111	1
XI	Arpa - within Armenia	2 306	1 643	768	764	0.331	11
XII	Vorotan – within Armenia	2 476	1 828	811	725	0.293	7
XIII	Voghji - within Armenia	1 341	1 097	448	502	0.374	2
XIV	Meghri	664	470	241	166	0.250	-

importance. The Hrazdan and Akhuryan rivers originate from these two lakes, the largest of which is Lake Sevan, located in the centre of the country. It lies at 1 900 m above sea level, which makes it a strategic source of energy and irrigation water. The level of the lake, originally with a surface area of about 1 414 km² and 58 km³ of stored water, has fallen since the 1930s due to the lake's increasing use for irrigation and domestic water supply. By 1972, its level had fallen by almost 19 m and its surface area had been reduced to 1 250 km². At present, it covers an area of about 1 200 km², has a volume of approximately 34 km³, and plays a central and important hydrological role in the country. It serves the densely populated Hrazdan river basin and the Ararat Valley where Yerevan, the capital, is situated. Through its regulated surface outflow into the Hrazdan River, the lake's water provides a substantial amount of hydropower and irrigation to croplands in the Ararat Valley. The lake is also an important recreational, natural habitat and cultural resource for the Armenian population (MNP, 2005). Since 1960, two inter-basin transfer schemes were implemented to restore the ecology of the lake and its storage capacity as a strategic water reserve for multipurpose use. A 48 km tunnel was built from 1963 to 1982 to divert some 250 million m³ of water annually from the Arpa River to Lake Sevan. A similar project, to divert 165 million m³ of water annually from the upper Vorotan River to the Arpa River through a 22 km tunnel, was completed in 2004. In the last few years, the lake's level has risen by about 2.7 m as a result of favourable meteorological conditions and improved management. Electricity generation at the Sevan-Hrazdan Cascade is currently tied to irrigation releases. During the last few years, irrigation releases have ranged from 120 to 150 million m³. The second most important lake is Lake Arpi. It is located in the western part of the Ashotsk depression at an altitude of 2 020 m above sea level. With the construction of a dam to solve irrigation problems, the lake became a reservoir.

Most of the reservoirs were constructed during the Soviet period. In 2004, some 83 reservoirs were operating in Armenia and total capacity was estimated at 1 399 million m^3, of which approximately 1 350 million m^3 was stored in reservoirs with a capacity of over 5 million m^3 each. Most of the water is used for irrigation. Some reservoirs are used for hydropower, recreation, fisheries and environmental protection. In 1995, about 145 million m^3 was used for municipal and industrial purposes. The largest reservoir is on the Akhuryan River, which forms the border with Turkey. It has a storage capacity of 525 million m^3, is shared with Turkey, and provides water for the irrigation of about 30 000 ha in Armenia. In contrast, many small off-channel reservoirs in the southwest of Aragats (Talish, Talin, Kakavadzor, Bazmaberd, Katnakhpyur), which accumulate spring tide waters, have a capacity of only 10 000–50 000 m^3 (UNDP, 2006).

Water use

Since the mid-1980s, there has been a decrease in the total water withdrawal, mainly due to a decrease in agricultural and industrial water withdrawal. In fact, the reduction in water use has been accompanied by a remarkable improvement in surface water quality. In 2006, the total water withdrawal for agricultural, municipal and industrial purposes was 2 827 million m^3, of which about 66 percent for agricultural purposes, 30 percent for municipal use and 4 percent for industrial purposes (Table 2 and Figure 1). Agricultural water withdrawal mainly refers to irrigation of crops. Works for the watering of pastures began in 1956, including providing water for cattle in the pasturing period. Sources of pasture watering are springs, mountain melted snow, and non-discharge water bodies (UNDP 2005). Surface water withdrawals represent 78 percent of the total water withdrawals (Figure 2).

In most of Armenia's territory, it is possible to use groundwater for drinking needs without any additional treatment. Indeed, about 95 percent of the water used for drinking purposes comes from groundwater sources (MNP, 2003). Both surface water and underground springs are used for industrial water supply. Industrial water supply is provided by independently operating water supply systems as well as from the city drinking water supply network. For the past 10–15 years, the water requirements of industrial enterprises have significantly decreased due to the reduction of the activity of many enterprises. It should be mentioned

FIGURE 1
Water withdrawal
Total: 2.827 km^3 in 2006

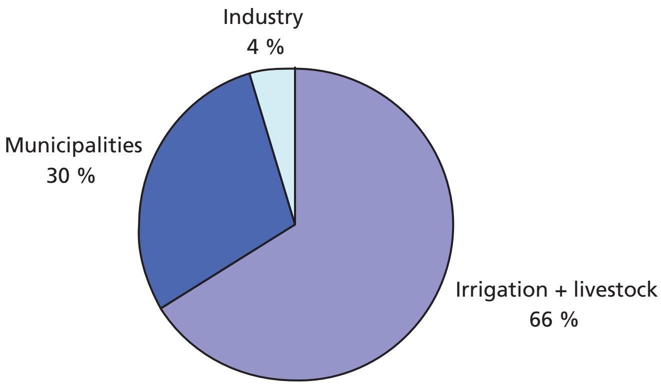
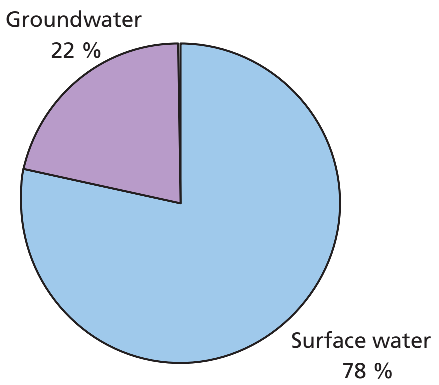


FIGURE 2
Water withdrawal by source
Total: 2.827 km^3 in 2006



that 40 percent of the industrial enterprises using water are located in Yerevan. The largest water-using industrial enterprise is the Armenian Nuclear Power Plant which uses about 35 million m^3/year (UNDP, 2005). There are 35 high and middle capacity hydropower plants in Armenia, nine of which are the plants at the Vorotan and Hrazdan hydropower cascades. As a result of insufficient regulation of volumes, hydropower production is also subject to seasonal variations (MNP, 2005).

While the industrial sector is not considered a major water user, an important problem for this sector is the implementation of industrial wastewater removal and treatment. Most industrial facilities were never equipped individually because they had been connected to the public sewer network during the Soviet Era, and thus were able to access municipal wastewater treatment. Attention should therefore be paid to those industries that have resumed production and from which the wastewater generated is channelled to the municipal wastewater treatment system, where only the mechanical treatment step is currently being operated. Also, the industries that are not connected to a municipal sewerage system discharge their mostly untreated wastewater directly into a stream or river. In general, old industries that resume production are the most polluting.

The total quantity of wastewater produced in 2006 amounted to 363 million m^3, of which 89 million m^3 was treated.

International water issues

Most river basins are transboundary and through a number of bilateral agreements Armenia assumes obligations related to the development and use of international waters. Armenia has an agreement with Turkey concerning the use of the Araks and Akhuryan rivers, according to which the water of these two transboundary rivers is divided equally between the two countries. Another agreement with Turkey concerns the joint use of the dam and the reservoir of the Akhuryan River. According to an agreement between the Islamic Republic of Iran and Armenia, the water of the Araks River is divided equally between them. Though these agreements were signed by the USSR, Armenia is considered a successor country, and consequently is required to fulfil any related obligations. There have been decrees issued and agreements signed between Armenia and Georgia concerning the Debet River. Corresponding decrees were passed between Armenia and Azerbaijan concerning the use of the water of the Arpa, Vorotan, Aghstay and Tavush rivers.

In 1998, Armenia ratified the agreement with Georgia on environmental protection according to which the governments pledged their cooperation in creating specifically protected areas within the transboundary ecosystems. The Ministry of Nature Protection (MNP) develops and implements international environmental projects, some of which are related to water issues. Part of the Caucasus Initiative, launched by the German Ministry of Cooperation and Development, involves the implementation of the "Ecoregional Nature Protection Programme for the Southern Caucasus". The programme, covering the three Caucasus countries, is going to be implemented in the very near future and will facilitate the protection and sustainable use of water resources in the region.

In 2002, the Republic of Armenia Commission on Transboundary Water Resources was established, which is chaired by the Head of Water Resources Management Agency. This commission, together with corresponding commissions in neighbouring countries, dealt with issues related to transboundary water resources use and protection.

From 2000 to 2002, USAID, in collaboration with Development Alternatives, Inc. (DAI), implemented the South Caucasus Water Management project which has the aim of strengthening the cooperation among water-related agencies at the local, national and regional levels, to provide integrated water resources management. In parallel, between 2000 and 2006, the EU and the Technical Assistance Commonwealth of Independent States (TACIS) developed the Joint River Management Program on Monitoring and Assessment of Water Quality on Transboundary Rivers, aimed at the prevention, control and reduction of transboundary pollution. The program covers four basins, including the Kura River basin. In addition, regional organisations such as REC and the Eurasia Foundation, as well as numerous local foundations, promote national and regional activities in the field of water resources management and protection (UNDP, 2002). USAID also funded the national project for Sustainable Water Resources Management in Armenia.

From 2002 to 2007, NATO-OSCE developed the South Caucasus River Monitoring Project whose general objectives were "to establish the social and technical infrastructure for an international, cooperative, Transboundary River water quality and quantity monitoring, data sharing and watershed management system among the Republics of Armenia, Azerbaijan and Georgia." (OSU, 2008).

The project Reducing Transboundary Degradation in the Kura-Araks River Basin, implemented by the UNDP Bratislava Regional Centre in collaboration with the GEF, has involved four of the basin countries - Armenia, Azerbaijan, Georgia and the Islamic Republic of Iran. The project preparation phase lasted 18 months and began in July 2005. It is co-funded by Sweden. The project aims to ensure that the quality and quantity of the water throughout the Kura-Araks river system meets the short and long-term needs of the ecosystem and the communities that rely upon this ecosystem. The project will achieve its objectives by fostering regional cooperation, increasing capacity to address water quality and quantity problems, demonstrating water quality/ quantity improvements, initiating the required policy and legal reforms, identifying and preparing priority investments and developing sustainable management and financial arrangements.

There are currently no water treaties between the three South Caucasian countries, a condition directly related to the political situation in the region. Nagorno-Karabakh is one of the main obstacles, making it difficult for Azerbaijan and Armenia to sign a treaty even one relating only to water resource management (Berrin and Campana, 2008).

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

Irrigation in Armenia started about 3 000 years ago. Clay pipes were used to transport water to orchards and fields and some are still intact. In the fourth century, the total irrigated area was estimated at about 100 000 ha, in 1920 it had dropped to 60 000 ha, and in 1990 it was 320 000 ha (UNDP, 2006). The actually irrigated area declined from more than 300 000 ha in 1985 to 176 000 ha at present. Major factors that have contributed to this decline are the widespread deterioration of the irrigation conveyance systems, high pumping costs, the disintegration of the former collective farms into many small private farms (with a size of 1 to 2 ha), and drainage problems, particularly in the Ararat Valley, where groundwater tables are shallow.

At present, the area equipped for full or partial control irrigation is estimated at almost 274 000 ha (Table 4). The reason for the decrease in recent years has been, on the one hand, the earthquake of 1988 that destroyed part of the area, and on the other, the difficult economic situation due to the transition period, that has made it difficult to keep or maintain the irrigation infrastructure. The major irrigation schemes are located on the left bank of the Araks River.

The irrigation systems of Armenia were mainly established during the Soviet period. The irrigation infrastructure includes 80 reservoirs (77 of which are used only for irrigation and 3 used for both irrigation and drinking water), together with more than 3 000 km of main and secondary canals, about 15 000 km of tertiary canals, over 400 small and large pumps, 1 276 tubewells, and 945 artesian wells. Eight major conveyance systems distribute irrigation water to some 150 000 ha, and minor systems cover the rest of the areas. The conveyance systems are served by main, branch and secondary canals/pipes. Three-quarters of the canals are lined with concrete or are pipes. The

TABLE 4
Irrigation and drainage

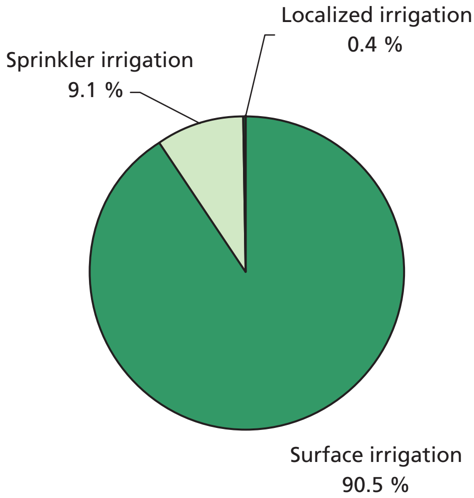
Irrigation potential	-	660 000	ha
Irrigation			
1. Full or partial control irrigation: equipped area	2006	273 530	ha
- surface irrigation	2006	247 530	ha
- sprinkler irrigation	2006	25 000	ha
- localized irrigation	2006	1 000	ha
• % of area irrigated from surface water	2006	81.4	%
• % of area irrigated from groundwater	2006	18.6	%
• % of area irrigated from mixed surface water and groundwater	2006	0	%
• % of area irrigated from non-conventional sources of water	2006	0	%
• area equipped for full or partial control irrigation actually irrigated	2006	176 000	ha
- as % of full/partial control area equipped	2006	64.3	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)		-	ha
3. Spate irrigation		-	ha
Total area equipped for irrigation (1+2+3)	**2006**	**273 530**	**ha**
• as % of cultivated area	2006	49.3	%
• % of total area equipped for irrigation actually irrigated	2006	64.3	%
• average increase per year over the last 11 years	1995-2006	-0.40	%
• power irrigated area as % of total area equipped	2002	42.6	%
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)	**2006**	**273 530**	**ha**
• as % of cultivated area	2006	49.3	%
Full or partial control irrigation schemesCriteria			
Small-scale schemes < 200 ha	2006	55 697	ha
Medium-scale schemes			ha
Large-scale schemes > 200 ha	2006	217 833	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	2006	176 000	ha
• Annual crops: total	2006	125 100	ha
- Wheat	2006	35 000	ha
- Barley	2006	5 900	ha
- Maize	2006	3 100	ha
- Potatoes	2006	24 000	ha
- Sugar beet	2006	200	ha
- Pulses	2006	2 000	ha
- Vegetables	2006	23 200	ha
- Tobacco	2006	200	ha
- Fodder	2006	26 000	ha
- Sunflower	2006	200	ha
- Other annual crops	2006	5 300	ha
• Permanent crops: total	2006	50 900	ha
- Other perennial crops	2006	50 900	ha
Irrigated cropping intensity (on full/partial control area actually irrigated)	2006	100	%
Drainage – Environment			
Total drained area	2006	34 457	ha
- part of the area equipped for irrigation drained	2006	34 457	ha
- other drained area (non-irrigated)		-	ha
• drained area as % of cultivated area	2006	6.2	%
Flood-protected areas		-	ha
Area salinized by irrigation	2006	20 415	ha
Population affected by water-related diseases	2001	1 644	inhabitants

main water structures, together with the main and secondary canals, are under state ownership whereas the tertiary level irrigation system (the intra-community irrigation network) was transferred to community ownership with the establishment of the Local Self-Governments in 1997. Around 80 percent of the total irrigated land is irrigated through the main network operated by the "Vorogum-Jrar" Closed Joint Stock Company (CJSC), while the remaining 20 percent is irrigated through the community-owned networks (WB-IBRD, 2004).

Surface irrigation is practised on over 90 percent of the area equipped for irrigation and can be divided into four categories of irrigation: furrow, borderstrip, flooding or basin, and that using hydrants and flexible hose systems (Figure 3). Flooding is used where soil depth does not permit the grading of either furrows or borderstrips. The water is let out over the land by cutting an irrigation head canal at intervals. In the case of irrigation using hydrants, the hydrants are generally spaced in a 50 x 50 m grid and discharge water directly onto the ground, from where it is distributed by any of the surface irrigation methods. Conveyance of water to the hydrant is by buried steel pipes, but may be by open canals further upstream. Sprinkler irrigation and localized irrigation are practised on the remaining area equipped for full or partial control irrigation.

Groundwater is used for irrigation on 19 percent of the equipped area (Figure 4). The remaining part is irrigated from surface water through reservoirs, river diversion or pumping in rivers.

FIGURE 3
Irrigation techniques
Total 273 530 ha in 2006



Role of irrigation in gricultural production, economy and society

The irrigation potential has been estimated at about 660 000 ha and 41 percent of this had been equipped for irrigation in 2006. Almost 71 percent of the irrigated area was occupied by annual crops. Cereals, mainly wheat, covered 20 percent, fodder 15 percent, potatoes 14 percent and vegetables 13 percent (Table 4 and Figure 5). More than 80 percent of total crop production is produced under irrigation. The difference in productivity between irrigated and rainfed agriculture is estimated at about US$900 per hectare. Table 5 gives an illustration of estimated returns for irrigation water at the farmgate by main crop and agro-economic zone.

An analysis based on standardized farm models indicates that even

FIGURE 4
Source of irrigation water
Total: 273 530 ha in 2006

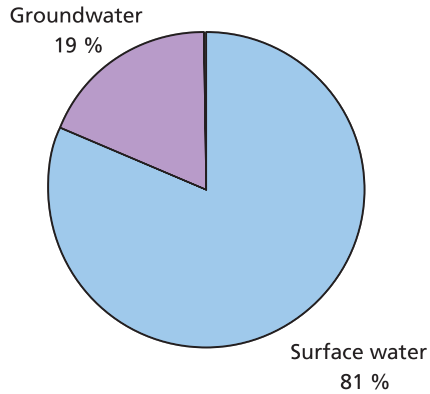
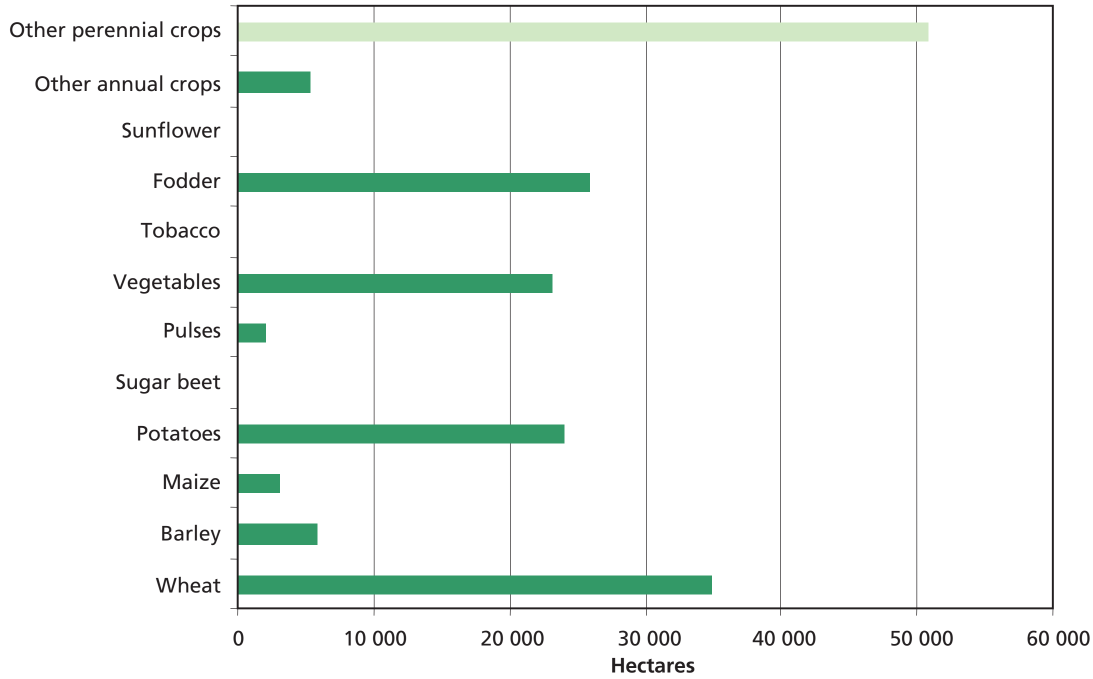


FIGURE 5
Irrigated crops
Total harvested area 176 000 ha in 2006 (cropping intensity on actually irrigated: 100%)



without taking into account changing cropping patterns in response to the increased reliability of irrigation, a 30 percent increase in irrigated land for an average farm will generate sufficient incremental net income to lift a family out of poverty, providing that other sources of income remained unchanged. However, an analysis based on information collected from 54 Water Users' Associations (WUAs) revealed that although irrigation in 2005 clearly improved in terms of reliability of supply, only 125 000 ha was actually irrigated out of the 228 000 ha equipped for the service. Three main problems explain this situation. First, the high cost of water supply in areas with predominantly pumping irrigation makes irrigation economically non-viable due to very inefficient pumping schemes. Second, water losses in secondary and tertiary canals are reported to be in the order of 40–50 percent, which effectively reduces the total irrigated area, since additional water supplies are unavailable in most cases for technical or/and economic reasons. Third, most of the pumping stations have very high levels of electricity consumption compared with their design parameters and high maintenance costs due to frequent service disruptions beyond what was designed.

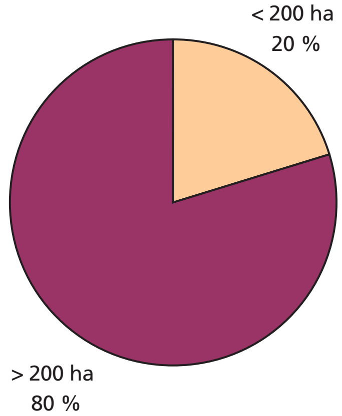
TABLE 5
Net return to irrigation water at the farm gate (US$ cents per m^3)

Crop	Ararat Plain Area	Hilly Area	Mountainous Area	Subtropical Area
Wheat	12	6	5	11
Vegetables	26	2	20	33
Potatoes	54	11	42	29
Alfalfa	1	0	1	0
Fruit	23	72	25	61
Grapes	51	22	-	11

TABLE 6
Assessment of water demand for irrigation for WUAs (2005)

Marz	Actually irrigated area	Water withdrawal	Water used in the field	Average losses	Water volume for 1 ha of irrigated lands (m³)	
	(ha)	(million m³)	(million m³)	(%)	gross	net
Ararat	27 584	285	169	41	10 332	6 127
Armavir	42 597	525	314	40	12 325	7 371
Kotayk	8 102	85	49	42	10 491	6 048
Aragatsotn	18 899	192	113	41	10 159	5 979
Gegharkunik	4 366	19	12	37	4 352	2 749
Shirak	10 157	31	16	48	3 052	1 575
Vayots Dzor	3 165	17	10	41	5 372	3 160
Syunik	4 703	22	14	36	4 678	2 977
Tavush	2 816	14	9	36	4 972	3 196
Lory	2 875	8	5	38	2 783	1 739
TOTAL	**125 264**	**1 198**	**711**	**41**	**9 564**	**5 676**

FIGURE 6
Type of irrigation schemes
Total 273 530 ha in 2006



Annual irrigation water demand begins to increase in late April, peaks in early July, and drops off in October. Nearly 40 percent of the irrigation area depends on high-lift pumping, with pumping lifts of more than 100 m. For the larger irrigation systems, losses may amount to 50 percent of the water intake. Information about actually irrigated lands is presented in Table 6, containing data provided by WUAs in 2005 on the demand for water for irrigation purposes.

There are pronounced differences between the communities with respect to share of irrigated land. In 2003, 24 percent of rural communities did not have access to irrigation, 5 percent had less than 20 percent of their total arable land under irrigation, 24 percent had between 20 and 80 percent under irrigation, while 47 percent had over 80 percent of their total arable land under irrigation (WB-IBRD, 2004). In 2006, small schemes (< 200 ha) covered 20 percent of total equipped area for irrigation, while large schemes (> 200 ha) covered 80 percent (Figure 6).

Crop budgets were prepared based on the monitoring and evaluation of WUAs in 2004 and prices were obtained through farm surveys. The country was divided into four agro-economic zones (valley, upland, high mountainous and subtropical), in three of which rainfed farming is possible. Composition of crops, yields, incomes per hectare by crop and by zone are presented in Table 7 and Table 8.

Status and evolution of drainage systems

In 2006 drainage was practised on 34 457 ha, of which 7 729 ha of horizontal closed drainage, 26 408 ha of horizontal open drainage and 320 ha of vertical drainage. The part of the irrigated land that is waterlogged is 18 722 ha.

TABLE 7
Crop budgets by agro-economic zones (2004)

Crop / Budget	Valley		Hilly		Mountainous		Subtropical	
	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated
Wheat	-	42%	50%	24%	65%	54%	60%	16%
Vegetables	-	20%	-	10%	-	6%	-	9%
Potatoes	-	5%	-	1%	-	27%	-	2%
Alfalfa	-	8%	50%	31%	35%	11%	40%	-
Fruit	-	17%	-	26%	-	2%	-	44%
Grape	-	8%	-	8%	-	-	-	29%
Total	-	100%	100%	100%	100%	100%	100%	100%

TABLE 8
Crop yield and net income by agro-economic zones (2004)

Zone	Yield (kg per ha)		Net Income (US$ per ha)	
	Non-irrigated	Irrigated	Non-irrigated	Irrigated
Valley				
Wheat		3 350		470
Vegetables		37 810		2 098
Potatoes		30 750		4 196
Alfalfa		11 920		75
Fruit		5 600		1 631
Grapes		12 410		3 596
Weighted average				1 385
Hilly				
Wheat	1 200	2 760	57	303
Vegetables	-	16 200	-	141
Potatoes	-	13 000	-	540
Alfalfa	3 000	7 000	13	14
Fruit	-	11 850	-	4 297
Grapes	-	5 860	-	1 291
Weighted average				1 316
Mountainous				
Wheat	1 400	2 570	116	286
Vegetables	-	22 500	-	992
Potatoes	-	21 070	-	2 110
Alfalfa	2 500	6 200	12	57
Fruit	-	6 100	-	1 265
Weighted average				820
Subtropical				
Wheat	2 300	6 000	366	1 137
Vegetables	-	28 700	-	2 615
Potatoes	-	19 700	-	1 436
Alfalfa	3 000	-	35	-
Fruit	-	10 000	-	4 243
Weighted average				2 328

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

Institutions

The most important institutions involved in water resources development and management are:

- The National Water Council (NWC): the highest advisory body in the water sector, chaired by the Prime Minister. It advises on water management issues, and makes recommendations on policies, legal documents, and the National Water Program.

- The Ministry of Nature Protection, with:
  - the Underground Resources Protection Department;
  - the Environmental Protection Department;
  - the Water Resources Management Agency, which controls the use of water resources through water use permits;
  - the Climate Change Information Center;
  - the State Environmental Inspectorate.
- The Ministry of Agriculture: responsible for the development of agriculture policy and strategies, including irrigation and drainage policies, with:
  - the Planning of Agricultural and Social Development of Rural Areas Department;
  - the Crop Production, Forestry and Plant Protection Department.
- The Vorogum-Jrar Closed Joint Stock Company (CJSC): brings together State organizations with responsibilities for the provision of irrigation and drainage services. This company pumps or diverts the water from the river, operates and maintains the primary canals, and sells the water to WUAs under seasonal water supply contracts.
- The Public Services Regulatory Commission (PSRC): responsible for the economic regulation of natural monopolies in the irrigation and municipal water sectors. The main responsibilities are water infrastructure use permits, the monitoring of the quality of service provisions, and setting of tariffs.
- The Ministry of Territorial Administration, with:
  - the State Committee on Water Systems (SCWS), which is responsible for the management and operation of state-owned municipal and irrigation water supply, sewerage and wastewater treatment systems; it includes the "Melioration" CJSC, which is responsible for operation and maintenance of drainage systems;
- The Armenian State Hydrometeorological and Monitoring Service (Armstatehydromet) and Environmental Impact Monitoring Center (EIMC): provide surface water monitoring data;
- The Hydrogeological Monitoring Center: responsible for monitoring all groundwater bodies.

Water management

Reforms in the water sector have been initiated since the implementation of the World Bank-supported "Integrated Water Resources Management Project" in 1999–2000. The idea of river basin management was also proposed through the introduction of annual and perspective planning mechanisms for water resources. One of the most important steps towards reform in the water sector was the adoption of a new Water Code on 4 June 2002 and, in order to ensure its enforcement, 80 regulations have been adopted by the Government since 2002, which relate, among others, to the procedures for water use permit provisions, transparency and public participation in the decision-making processes, accessibility of information, establishment of the state water cadaster, formation of water resources monitoring, management of transboundary water resources. The Code also contains the idea of integrated river basin management, for which a methodology of developing integrated water basin management plans has been developed, making it possible to use economic tools for water resources management and cost recovery. In order to promote more efficient, targeted and decentralized management of water resources, five territorial divisions (Basin Management Organizations) have been established under the umbrella of the Water Resources Management Agency: Northern, Akhuryan, Araratian, Sevan-

Hrazdan and Southern. The Law on “Fundamental Provisions of the National Water Policy” was adopted in 2005; this represents a forward-looking development concept for water resources and water systems’ strategic use and protection. Since 2005 the water basin management principle is being applied in the sector of water resources management. In addition to this, a law concerning the “National Water Programme” has been developed. This law is the main document for the prospective development of water resources and water systems management and protection. As a result of the above-mentioned legal and institutional reforms, Armenia is currently one of the leaders in the region in the sector of water resource management.

By law, local mayors are responsible for providing the water service within a municipality unless the water sources and facilities serve more than one municipality, in which case one of the five State-owned water companies provides the water service. In 2006, about 80 percent of the population was served by the State water companies. The remainder of the population is served by small municipal systems and numerous community-based organizations. The “Yrevan Djur” CJSC is the largest of the five State companies and provides water and sewer services to the city of Yerevan and 28 neighbouring villages, covering around 50 percent of the total population. It operates under a recently signed lease contract with a French water company. The next largest State water company is the Armenian Water and Sewerage Company (AWSC) which operates under the terms of a management contract with another French water company. AWSC provides service to roughly 22 percent of the population. The other three State water companies, Lori, Shirak and Nor Akunk are managed with significant input from foreign consultants under the terms of a financing agreement between the State and a German lending agency. At the beginning of 2006, the average monthly water bill for most residential customers in Armenia was less than US$2. The collection rate has been improving but is still less than desirable.

Hydropower accounts for 20 percent of electricity generation. The total installed hydropower generating capacity of Armenia is about 1 100 MW, of which 1 050 MW is operational. Almost 95 percent of this capacity is installed along two important hydropower cascades: the Sevan-Hrazdan Cascade and the Vorotan Cascade. Electricity generation at the Sevan-Hrazdan Cascade is tied to irrigation releases from Lake Sevan on the basis of an annual water allocation plan (USAID, 2006).

USAID designed the Programme for Institutional and Regulatory Strengthening of Water Management in Armenia (2004-2008) to provide technical assistance, training and equipment to improve water resource management and the regulation of the increasingly decentralized irrigation and municipal water sectors. The programme will lay the foundation for effective water resource management and planned investment in the Armenian drinking water, sewerage, and irrigation sectors and assist the Government and leading water sector agencies to enhance their effectiveness through initiatives based on international best practices adapted for the Armenian context.

Finances

Currently, the State funds about 50 percent of the annually assessed Operation and Maintenance (O&M) requirements of the water services for irrigation. For 2005, the O&M requirements were estimated to be US$16 million, with a contribution from the State budget of US$8 million, which essentially covers the electricity costs for operating the pumping stations. The irrigation tariffs that WUAs or other users pay to the Vorogum-Jrar differ by region and mode of water delivery (pumped or gravity) and are capped at approximately US$20/1 000 m^3 or US$150/ha. Maintenance is still inadequate to sustain the irrigation systems due to an underestimation of the annual O&M requirements and lower than expected tariff collection rates. The real O&M costs may vary from US$5/1 000 m^3 or US$40/ha for gravity schemes to more than

US$50/1 000 m^3 or US$400/ha for some high-lift pumped schemes. The latter costs are higher than the incremental income earned by many subsistence farmers as a result of irrigation and may range from US$200/ha to US$400/ha per year (USAID, 2006).

Investments, such as the recently approved grant of US$236 million from the US Millennium Challenge Corporation may go a long way toward stabilizing the irrigation subsector. The grant will support a five-year programme of strategic investments in irrigation and rural roads, aimed at increasing agricultural production. The grant will also fund the improvement of drainage facilities, the rehabilitation of irrigation infrastructure, the strengthening of the Vorogum-Jrar and WUAs, and a water-to-market project that will provide training and access to credit for farmers who want to make the transition to more profitable, market-oriented agricultural production (USAID, 2006).

Policies and legislation

As mentioned in the "Water management" section above, the legal and institutional structure of the water sector is based on the National Water Code adopted in 2002. The Water Code defines three major functions in the water sector: management of water resources, management of water systems, and regulation of water supply and wastewater services.

ENVIRONMENT AND HEALTH

Most of the drinking water is provided by groundwater, which has high organoleptic properties and is very pure. Due to the poor state of the water supply networks, however, the risk of water contamination is high. Due to the lack of liquid and lime chlorine, and the electric power deficit, in most cases, water is supplied without chlorination. In many places sewage and drinking water supply networks are put together and at present the sewage system is in an emergency situation: 63 percent of the network is more than 20 years old and 22 percent requires immediate renewal. According to the data provided by the Ministry of Health, during 1984–1991, no infection outbreak episodes related to drinking water quality were recorded in Armenia. However, since 1992 such episodes have been periodically registered. During the 1999–2002 period, 18 outbreak episodes related to water pollution were recorded with the total number of 5 690 diseased persons (UNDP, 2005). In 2003, 21 839 incidents were recorded, 5 839 of which (26.7 percent) occurred in Yerevan.

Solonetzic soils, which are characterized by a tough, impermeable hardpan that may vary from 5 to 30 cm or more below the surface soils, are widespread. These soils are most of all exposed to the risk of irrigation-related salinization, mainly as a result of rising groundwater in the plains, where the majority of irrigated lands are located. In the Ararat plain, solonetzic soils cover about 10 percent of the area. In 2006, the part of the irrigated land that is salinized was 20 415 ha, of which 15 137 ha weakly salinized, 2 385 ha medium salinized, and 2 893 ha strongly salinized (MTA, 2007).

The malaria situation was stable in Armenia until 1994. In subsequent years, a downgrading of malaria prevention services and a weakening of the malaria surveillance system resulted in a steady increase in the number of malaria cases, reaching 1 156 by 1998. Over 98 percent of these cases were detected in the Masis district of the Ararat Valley, an area bordering Turkey. In recent years, owing to epidemic control interventions, the number of autochthonous malaria cases has continued to decrease, dropping to 8 in 2003. However, although numbers have been on the decline, the situation must be monitored closely, because of the existence of favourable conditions for malaria transmission. In 2003, Armenia redefined and adjusted the present malaria control strategy, objectives and approaches, bearing in mind the results achieved to date, the extent of the problem, and potential threats in the country (MTA, 2007).

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

To reduce the burden of high expenditure in the State budget for government bodies engaged in water resource management, steps have been taken to involve the private sector.

Within the framework of the Agricultural Sustainable Development Strategy, the main priorities in the development of crop production are an increase in crop yield and a reduction in expenses per production unit through the application of advanced agro-technologies.

Main and secondary canals with high water losses, the collector-drainage system in the Ararat valley, and the tertiary irrigation systems need rehabilitation. About half of the total amount of the Agreement (US$113 million), signed between US Government Millennium Challenge Corporation and Armenia, will be directed to solve the main problems in the irrigation sector.

The main directions in the development of the irrigation sector are as follows:

a. Improvement of the managerial structure and technical conditions of the irrigation system;
b. Substitution of pumped irrigation with gravity irrigation conveyance systems and introduction of clear mechanisms for the management, supply and stock-taking of irrigation water;
c. Support to the establishment of water users' unions, as well as to the development of water users' associations;
d. Support to the rehabilitation of inter-farm irrigation networks;
e. Implementation of the "Cleaning and maintenance of the collector-drainage network programme" to regulate the level and mineral content of subsoil water located in the irrigated areas under the drainage systems, to prevent secondary salinization, floods and infectious diseases, to reclaim land and to provide a sustainable yield from agricultural crops;
f. Decrease in water tariffs; provision of sustainable water supply; decrease in water losses and water utilization prices through improvement of the water systems; increase in efficiency of farming activities due to the additional water supply; creation of favourable conditions for the utilization of the irrigation systems and denationalization of maintenance procedures; improvement of efficient management of the network through implementation of structural reforms, provision of transparency for water tariffs and switching to self-financing of the network by the end of the programme;
g. Implementation of the first and second dam safety programmes. The first programme aims at the provision of dam safety for a population of 360 000 and at increased efficiency in the supply of the irrigation system. The programme includes rehabilitation of the 20 most dangerous 20 dams and some other activities besides. The second programme includes the rehabilitation of 47 dams;
h. Implementation of the subprogramme on "Irrigated agriculture" under the Millennium Goal programme. According to the programme, US$113 million will be spent on solving the existing problems in the irrigation system (over 5 years). The programme includes irrigation schemes for 21 districts and the construction of 18 gravity-fed systems, 5 new water reservoirs and rehabilitation of 2 non-finished water reservoirs, rehabilitation of 6 big water pipes for a total length of 200 km, rehabilitation and re-equipping of 68 pump stations, rehabilitation of inter-farm irrigation networks on a total area of 75 000 ha with the assistance of water users; and rehabilitation of the Ararat valley irrigation-drainage network and, as a result, ensuring soil quality improvement over an area of 25 000 ha. The implementation of the programme will enable a decrease in electricity use of 30 percent, and a rehabilitated irrigation network covering 30 000 ha, thus a decrease in total expenses of 20 percent;

i. Implementation of the programme on the watering of natural pastures. Annually, over US$530 000 (160 million AMD at 2008 rate) will be spent on these activities, with the aim of increasing the crop yield of the pastures and net income, which will promote poverty reduction;
j. Implementation of the programme on improvement of soil quality of the secondary salinized irrigated land of the Ararat valley. As a result, the subsoil water level will be regulated over about 8 000 ha, secondary salinization and flooding of the settlements will be prevented, and sustainable crop yield will be ensured thus promoting poverty reduction;
k. Implementation of the programme on the definition of irrigation norms and regimes for agricultural crops. The programme aims to develop new norms and regimes to replace those in place for the last thirty years. The new norms will meet the actual requirements, supplying crops with sufficient water for growth. Moreover, there will be a saving of water resources in the order of 10–15 per cent. (FAO and MOA, 2002)

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Azerbaijan

GEOGRAPHY, CLIMATE AND POPULATION

Geography

Azerbaijan, with a total area of 86 600 km^2, is located on the southeastern slopes of the Caucasus Mountains. It is bordered to the east by the Caspian Sea, to the south by the Islamic Republic of Iran, to the southwest by Turkey, to the west by Armenia, to the northwest by Georgia and to the north by the Russian Federation. The Nakhchivan Autonomous Republic of Azerbaijan in the southwest is separated from the rest of the country by Armenia.

About 43 percent of the area of Azerbaijan is situated more than 1 000 m above sea level. The country can be divided into five main physiographic regions:

- the Greater Caucasus mountain range in the north, extending from the Black Sea in the west to the Caspian Sea in the east, over the northern part of Georgia and Azerbaijan and the southern part of the Russian Federation;
- the Lesser Caucasus mountain range, south of the Greater Caucasus and covering the south of Georgia and Azerbaijan and the north of Armenia;
- the lowlands around the Kura and Araks Rivers;
- the Talish Mountains with the adjoining Lankaran lowland in the southeast, along the border with the Islamic Republic of Iran;
- the Nakhchivan Autonomous Republic in the southwest.

The cultivable area is estimated to be about 4.32 million ha, which is 50 percent of the total area of the country. In 2005, the cultivated area was 2.06 million ha, or 48 percent of the cultivable area, of which 1.84 million ha were annual crops and 0.22 million ha permanent crops (Table 1). Between 1993 and 2005 the cultivated area increased by 15 percent.

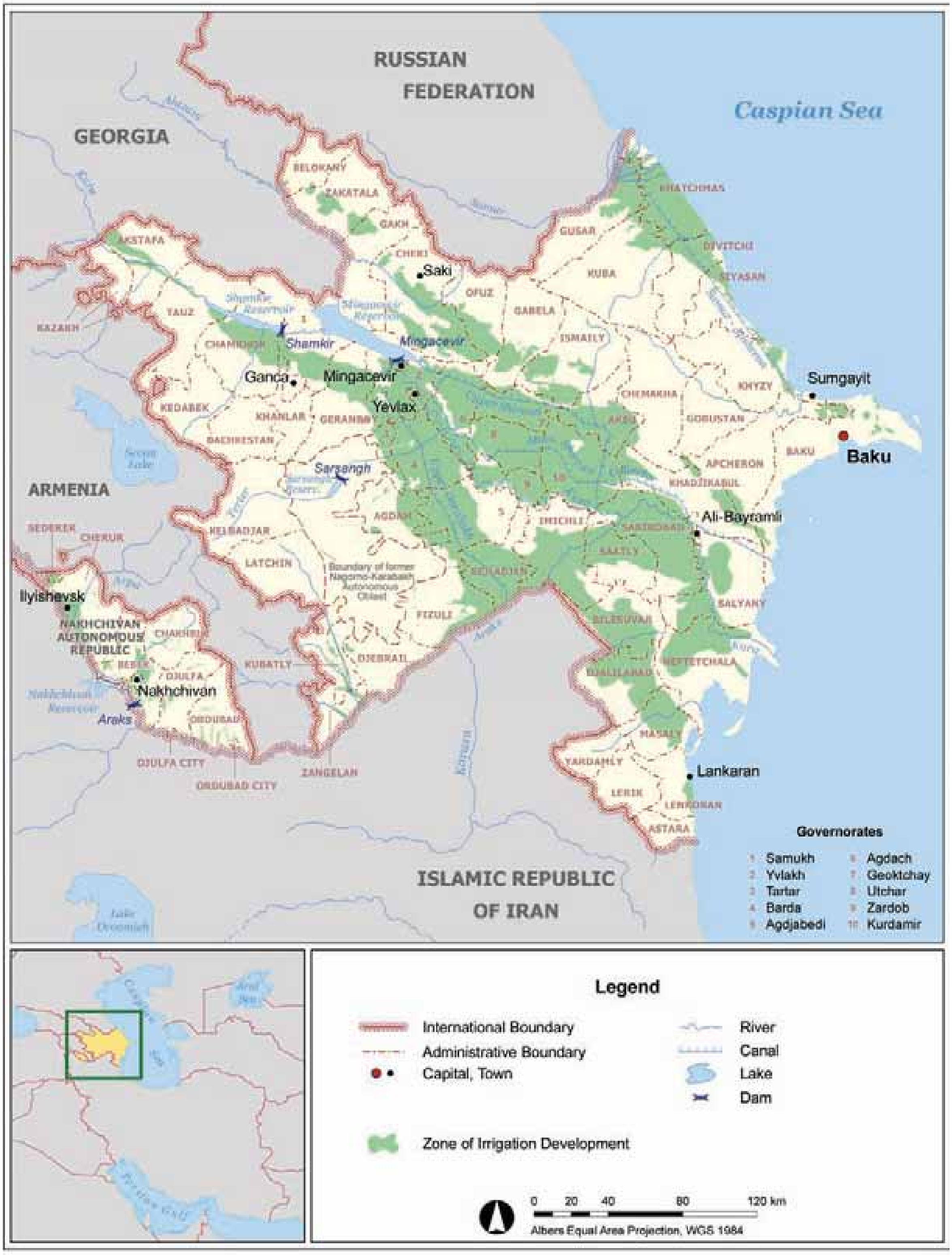
Climate

Azerbaijan is situated on the northern edge of the subtropical zone. Its climatic diversity is the result of its particular geographical location and landscape, the proximity of the Caspian Sea, the effect of sun's radiation and air masses of different origin.

The climate in Azerbaijan is continental. The weather in the lowlands is arid, with average summer temperatures of over 22 °C. In the mountain regions, temperatures can fall below 0 °C in winter and in Nakhchivan severe frost may occur. Humid tropical weather prevails in the coastal zone near the Caspian Sea, mainly in the Lankaran lowlands in the southeast. The estimated average precipitation is 447 mm/year.

Population

The total population is 8.4 million (2005), around 50 percent of which is rural. The average population density is 97 inhabitants/km^2.



AZERBAIJAN **FAO - AQUASTAT, 2008**

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TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2005	8 660 000	ha
Cultivated area (arable land and area under permanent crops)	2005	2 064 700	ha
• as % of the total area of the country	2005	23.8	%
• arable land (annual crops + temp fallow + temp. meadows)	2005	1 843 200	ha
• area under permanent crops	2005	221 500	ha
Population			
Total population	2005	8 411 000	inhabitants
• of which rural	2005	50.1	%
Population density	2005	97.1	inhabitants/km^2
Economically active population	2005	3 980 000	inhabitants
• as % of total population	2005	47.3	%
• female	2005	46.2	%
• male	2005	53.8	%
Population economically active in agriculture	2005	982 000	inhabitants
• as % of total economically active population	2005	24.7	%
• female	2005	52.4	%
• male	2005	47.6	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2007	31 250	million US$/yr
• value added in agriculture (% of GDP)	2007	6	%
• GDP per capita	2005	1 569	US$/yr
Human Development Index (highest = 1)	2005	0.746	
Access to improved drinking water sources			
Total population	2006	78	%
Urban population	2006	95	%
Rural population	2006	59	%

In 2006, 80 percent of the population had access to improved sanitation (90 and 70 percent in urban and rural areas respectively) and 78 percent had access to improved water sources (95 and 59 percent in urban and rural areas) (Table 1).

ECONOMY, AGRICULTURE AND FOOD SECURITY

Agriculture plays an important role in the Azerbaijan's development and in guaranteeing the supply of staples and constitutes one of the main sectors of the economy.

In 2007, the Gross Domestic Product (GDP) was US$31.3 billion (Table 1). The share of agriculture dropped from 39 percent in 1990 to 6 percent in 2007, due to extensive industrial development from 1995 to 2004. Production sharing agreements with large foreign companies regarding oil and gas fields have led to the rapid development of these industries.

In 2005, the total economically active population was 3.98 million, or just over 47 percent of the total population, with some 25 percent employed in the agricultural sector. Women make up about 52 percent of the rural labour force.

Plant cultivation is one of the key sectors of agriculture in Azerbaijan. Its fertile lands, good climate and topography provide opportunities for the production of agricultural products year-round (Heydar Aliyev Foundation, 2008). The most important crops are wheat, cotton, potatoes, vegetables, tobacco, melon, sugar beet, sunflowers and fruit trees.

WATER RESOURCES AND USE

Water resources

It is estimated that internal renewable water resources amount to about 8.12 km^3/year (Table 2). Annual surface runoff is estimated at 5.96 km^3 and groundwater recharge

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	447	mm/yr
	-	38.7	10^9 m^3/yr
Internal renewable water resources (long-term average)	-	8.115	10^9 m^3/yr
Total actual renewable water resources	-	34.675	10^9 m^3/yr
Dependency ratio	-	76.6	%
Total actual renewable water resources per inhabitant	2005	4 123	m^3/yr
Total dam capacity	2003	21 542	10^6 m^3
Water withdrawal			
Total water withdrawal	2005	12 211	10^6 m^3/yr
- irrigation + livestock	2005	9 330	10^6 m^3/yr
- municipalities	2005	521	10^6 m^3/yr
- industry	2005	2 360	10^6 m^3/yr
• per inhabitant	2005	1 452	m^3/yr
Surface water and groundwater withdrawal	2005	12 050	10^6 m^3/yr
• as % of total actual renewable water resources	2005	34.8	%
Non-conventional sources of water			
Produced wastewater	2005	659	10^6 m^3/yr
Treated wastewater	2005	161	10^6 m^3/yr
Reused treated wastewater	2005	161	10^6 m^3/yr
Desalinated water produced		-	10^6 m^3/yr
Reused agricultural drainage water		-	10^6 m^3/yr

at 6.51 km³, of which 4.35 km³ constitutes the base flow of the rivers. The estimated incoming surface flow is 25.38 km³/year, of which 11.91 km³ from Georgia, 7.50 km³ from the Islamic Republic of Iran and 5.97 km³ from Armenia. The Sumar River, with a total flow of 2.36 km³/year, forms the border between Azerbaijan and the Russian Federation. The total renewable surface water resources (RSWR), including incoming and bordering flows, are therefore estimated at 32.52 km³/year. In the case of the Kura and Araks Rivers, which flow through Turkey, Georgia, Armenia, the Islamic Republic of Iran and Azerbaijan, discussions are under way on a water sharing agreement.

The groundwater resources are famous for their quality as mineral drinking water and are also used for medical purposes. The Nakhchivan Autonomous Republic is especially rich in mineral groundwater.

Azerbaijan has four major river basins, two of which are international:

- The basin of the Kura and Araks Rivers. This is by far the largest basin in the country (excluding the occupied zone and the zone declared neutral in May 1994). The Kura River rises in the Kars upland in northeast Turkey. It then flows into Georgia and crosses the border to Azerbaijan in the northwest. The total length of the Kura River system is 1 515 km, of which 900 km is located within Azerbaijan. The total annual inflow from Georgia is estimated at 11.91 km³. The Araks River also rises in the northeast of Turkey. It forms the border between Turkey and Armenia, Turkey and Azerbaijan, the Islamic Republic of Iran and Azerbaijan, the Islamic Republic of Iran and Armenia, and the Islamic Republic of Iran and Azerbaijan again, before flowing into the eastern part of Azerbaijan. About 100 km downstream of the border it joins the Kura River, which continues to flow southeast towards the Caspian Sea. The total inflow of the main branch of the Araks River and its tributaries from Armenia and Iran is estimated at 13.47 km³/year, bringing the total inflow into Azerbaijan to an estimated 25.38 km³/year.
- The Samur River Basin, located in the northeast of the country. The Samur River rises in the Russian Federation and then forms its border with Azerbaijan. Its estimated annual discharge is 2.36 km³, half of which is considered to be available

for Azerbaijan. The river divides into several branches before flowing into the Caspian Sea.

- The Caspian Sea coastal river basins in the northeast, between the Samur and Kura River Basins.
- The Caspian Sea coastal river basins in the Lankaran region in the southeast, south of the Kura River Basin.

The total reservoir capacity of Azerbaijan's dams is around 21.54 km³. Most of this capacity, 21.04 km³, comes from large dams, of more than 100 million m³ each. The four largest reservoirs are the Mingacevir and Shamkir on the Kura River, the Araks dam on the Araks River, and the Sarsang on the Terter River, in Armenia.

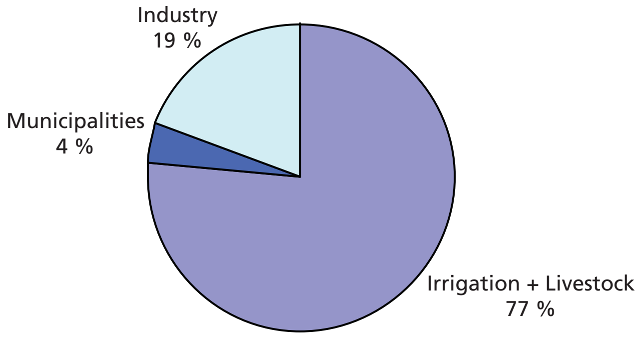
In 2005, wastewater production totalled some 659 million m³. Most wastewater is produced by the cotton cleaning, cotton oil production, fish-curing and grape processing industries. In 2005, 161 million m³ of wastewater was treated for reuse (Table 2). Although wastewater treatment plants exist in 16 towns and cities, the majority are partly or completely out of operation.

Water use

In 2005 water withdrawal was estimated at 12.21 km³, of which 76.4 percent for agricultural purposes, 4.2 percent for municipal uses and 19.3 percent for industrial processes (Table 2 and Figure 1).

In 2004, total freshwater withdrawal amounted to 11.44 km³, of which 10.73 km³ surface water and 0.71 km³ groundwater. In 2005, freshwater withdrawal totalled 12.05 km³ (Figure 2).

FIGURE 1
Water withdrawal by sector
Total: 12.211 km³ in 2005

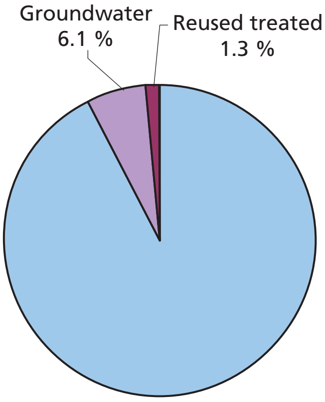


International water issues

Azerbaijan is party to three agreements with its neighbours on transboundary rivers: with the Islamic Republic of Iran on the Araks River, with Georgia on Gandar Lake and with the Russian Federation on the Samur River. No agreement exists regarding the Kura River, the most important transboundary river in the region (UNECE, 2004). Issues of critical importance are the sharing and joint management of the Kura and Araks Rivers and of the Caspian Sea to prevent further pollution and ensure sustainable development of their resources.

In 1997 the Government of Georgia ratified an agreement with Azerbaijan concerning environmental protection, providing for cooperation in the creation of specifically protected areas within transboundary ecosystems.

FIGURE 2
Water withdrawal by source
Total: 12.211 km³ in 2005



The Caucasus Initiative, launched by the German Ministry of Cooperation and Development, envisages, among other things, the implementation of the "Ecoregional Nature Protection Programme for Southern Caucasus" covering the three Caucasus countries: Georgia, Azerbaijan and Armenia. It will be implemented in the nearest future and will facilitate to protect and sustainable use of water resources in the region (Tsiklauri, 2004).

A number of international organizations have cooperated on initiatives in Azerbaijan in the field of ecology through the UN mission and the UNDP. Negotiations have been held with representatives of the UN, UNEP, UNESCO, World Bank and environmental protection organizations of the USA, UK, Germany, Turkey, the Islamic Republic of Iran and CIS countries. One of the results has been the adoption of the "Agreement on cooperation in the field of ecology and environmental protection between Azerbaijan and Turkey" (UNEP/GRID-Arendal, 2005).

From 2000 to 2002, USAID, in collaboration with Development Alternatives Inc. (DAI), implemented the South Caucasus Water Management project. Its aim was to strengthen co-operation among water agencies at local, national and regional levels and demonstrate integrated water resources management. In parallel, between 2000 and 2006, the EU and the Technical Assistance Commonwealth of Independent States (TACIS) carried out the Joint River Management Programme on Monitoring and Assessment of Water Quality on Transboundary Rivers for the prevention, control and reduction of the impact of trans-boundary pollution. The programme covered four basins, including the Kura River Basin. In addition, regional organisations such as REC, Eurasia Foundation, and numerous local foundations have promoted national and regional activities concerning water resources management and protection (UNEP, 2002).

Between 2002 and 2007, NATO-OSCE realized the South Caucasus River Monitoring Project. Its general objectives were to establish the social and technical infrastructure for a joint international Transboundary River water quality and quantity monitoring, data sharing and watershed management system among the Republics of Armenia, Azerbaijan and Georgia (OSU, 2008).

The project Reducing Transboundary Degradation in the Kura-Araks River Basin, implemented by the UNDP Bratislava Regional Centre in collaboration with the Global Environmental Facility (GEF), has involved four of the basin countries: Armenia, Azerbaijan, Georgia and the Islamic Republic of Iran. Efforts are being made to involve Turkey in the project as well. The preparation phase, which is co-funded by Sweden, began in July 2005 and will last 18 months. The objective of the project is to ensure that the quality and quantity of the water throughout the Kura-Araks River system meets the short and long-term needs of the ecosystem and the communities that rely upon it. It will be achieved by fostering regional cooperation, increasing the capacity to address water quality and quantity problems, demonstrating water quality/quantity improvements, initiating required policy and legal reforms, identifying and preparing priority investments, and developing sustainable management and financial arrangements.

Currently there are no water treaties between the three south Caucasian countries owing to the political situation in the region. Nagorno-Karabakh is one of the main obstacles, making it difficult for Azerbaijan and Armenia to sign a treaty even one only relating to water resources management (Berrin and Campana, 2008).

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

The irrigation potential is estimated at 3.2 million ha. In the last century, irrigation was concentrated alongside the rivers and it was only at the beginning of this century that the construction of large irrigation canals started. In 1913, 582 000 ha were irrigated. The most intensive development took place after the Second World War and in 1975 the area equipped for irrigation was 1.17 million ha. By 1995 this had become 1.45 million ha, which is 45 percent of the irrigation potential.

In 1995, the total length of all irrigation canals was 65 900 km, of which only 2 400 km, or 3.6 percent, were concrete canals. National irrigation efficiency was estimated at 55 percent. The largest canals are the Upper Garabakh, the Upper Shirvan and the Samur-Apsheron, all earthen. The Upper Gabarakh canal runs southeast from the Mingacevir reservoir to the Araks River. It is about 174 km long and has a capacity of 113.5 m^3/s. About 85 000 ha were irrigated by this canal in 1995. The Upper Shirvan canal also starts from the Mingacevir reservoir and runs east to the Akhsu River. It is about 126 km in length and has a capacity of 78 m^3/s and in 1995 irrigated about 91 100 ha.

In 1995, almost 90 percent of the irrigation was surface irrigation, mainly furrow and border strip irrigation. Sprinkler irrigation and localized irrigation were used mainly on perennial plantations and vineyards (Table 3 and Figure 3). Surface water was used on 93 percent of the area, mainly from reservoirs and through direct pumping in rivers and canals (Figure 4). About 96 700 ha were irrigated by groundwater through more than 5 000 wells. Private farmers exploit this source intensively as the major irrigation installations are seriously degraded.

In 1995, small schemes (<10 000 ha) covered 5.3 percent of the total area equipped for irrigation, medium size schemes (10 000–20 000 ha) 13.3 percent and large schemes (>20 000 ha) 81.5 percent (Figure 5). Most schemes were state-owned. Farmer-owned irrigation started to appear in 1992 and in 1996 represented 1 percent of the area.

In 2003, the total area equipped for irrigation was about 1 426 000 ha and the power-irrigated area was estimated at 479 249 ha.

FIGURE 3
Type of irrigation
Total: 1 453 618 ha in 1995

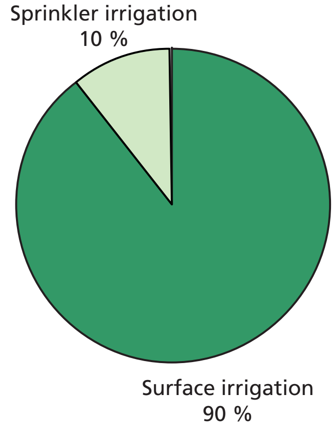


FIGURE 4
Source of irrigation water
Total: 1 453 700 ha in 1995

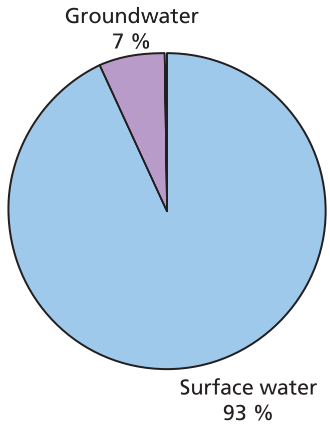


FIGURE 5
Type of irrigation schemes
Total: 1 453 020 ha in 1995

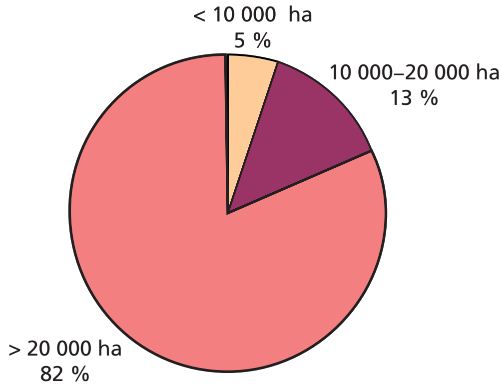
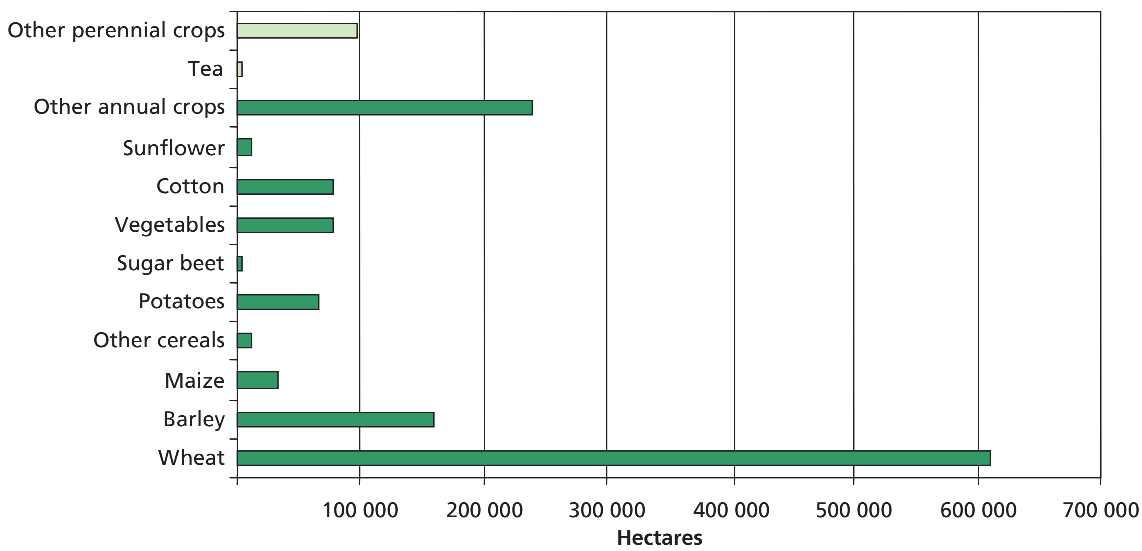


TABLE 3
Irrigation and drainage

Irrigation potential		-	3 200 000	ha
Water management				
1. Full or partial control irrigation: equipped area		2003	1 426 000	ha
- surface irrigation		1995	1 302 000	ha
- sprinkler irrigation		1995	149 000	ha
- localized irrigation		1995	2 618	ha
• % of area irrigated from surface water		1995	93	%
• % of area irrigated from groundwater		1995	7	%
• % of area irrigated from mixed surface water and groundwater		1995	0	%
• % of area irrigated from non-conventional sources of water		1995	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)		**2003**	**1 426 000**	**ha**
• as % of cultivated area		2003	69	%
• % of total area equipped for irrigation actually irrigated			-	%
• average increase per year over the last 8 years		1995-2003	- 0.23	%
• power irrigated area as % of total area equipped		2003	33.6	%
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**	**1 426 000**	**ha**
• as % of cultivated area		2003	69	%
Full or partial control irrigation schemes	**Criteria:**			
Small-scale schemes	< 10 000 ha	1995	77 420	ha
Medium-scale schemes		1995	192 600	ha
large-scale schemes	> 20 000 ha	1995	1 183 000	ha
Total number of households in irrigation			-	
Irrigated crops in full or partial control irrigation schemes				
Total irrigated grain production (wheat and barley)			-	metric tons
• as % of total grain production			-	%
Harvested crops				
Total harvested irrigated cropped area		2004	1 391 521	ha
• Annual crops: total		2004	1 290 114	ha
- Wheat		2004	610 919	ha
- Rice		2004	2 573	ha
- Barley		2004	158 909	ha
- Maize		2004	33 194	ha
- Other cereals		2004	9 302	ha
- Potatoes		2004	65 796	ha
- Sugar beet		2004	3 202	ha
- Vegetables		2004	77 248	ha
- Cotton		2004	78 161	ha
- Tobacco		2004	2 649	ha
- Sunflower		2004	11 381	ha
- Other annual crops		2004	236 780	ha
• Permanent crops: total		2004	101 407	ha
- Tea		2004	3 658	ha
- Other perennial crops (bananas, olives, grapes, strawberries)		2004	97 749	ha
Irrigated cropping intensity (on full/partial control irrigation equipped area)		2004	97.6	%
Drainage - Environment				
Total drained area		2003	608 336	ha
- part of the area equipped for irrigation drained		2003	608 336	ha
- other drained area (non-irrigated)			-	ha
• drained area as % of cultivated area			-	%
Flood-protected areas			-	ha
Area salinized by irrigation		2003	635 800	ha
Population affected by water-related diseases			-	inhabitants

FIGURE 6
Irrigated crops
Total harvested area: 1 391 521 ha in 2004 (cropping intensity on equipped area: 97.6%)



Role of irrigation in agricultural production, the economy and society

In 2004, the harvested irrigated area was 1 391 521 ha. Annual crops represent 93 percent of this area and permanent crops 7 percent. The main irrigated crops are wheat (44 percent), barley (11 percent), cotton (5.6 percent) and vegetables (5.6 percent), while the most important permanent crops are tea, bananas, olives, grapes and strawberries (Table 3 and Figure 6).

Status and evolution of drainage systems

The total drainage network covers 608 336 ha, all in the areas equipped for irrigation. In more than half the drained area the installations need to be renovated. In 2003 the area salinized by irrigation was estimated at 635 800 ha (Table 3).

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

Institutions

The main institutions involved in water management are all state institutions. They are:

- the Ministry of Ecology and Natural Resources, which has overall responsibility for the conservation of water resources and the prevention of pollution. It issues wastewater discharge permits, which are valid for 3–5 years. Its regional offices control and enforce discharge permits;
- the Committee on Ecology and Nature Use, which is in charge of monitoring salinization and water pollution;
- the State Committee on Amelioration and Water Management, which is responsible for monitoring water use and for issuing permits for surface water. It also levies charges for water use. The committee's activities concern mainly irrigation, for which it sets rules on water use and handles public relations. It is also in charge of land improvement on irrigated land and the operation and maintenance of the irrigation infrastructure;

- the Ministry of Health, whose Centre for Epidemiology and Hygiene is responsible for monitoring drinking water quality.

Water management

The rehabilitation of irrigation and drainage systems to ensure the sustainability of the subsector remains a priority. Major policy changes in land ownership and irrigation management play an important role in improving irrigation performance.

Control of erosion is another major issue as, according to the Ecological Committee's data, this problem affects almost 43 percent of the country. Effective measures to combat water erosion are the creation of a wood belt to protect fields, as well as wood belts along the banks of large rivers, canals and reservoirs.

There are several problems affecting the irrigation infrastructure (UNECE, 2004). They include:

- deterioration of infrastructure and pumping equipment due to insufficient maintenance;
- heavy reliance on pumped irrigation, which in many instances would make agriculture uneconomic if the energy were valued at its real cost;
- negligible contribution from users to operation and maintenance expenses;
- inefficient water distribution and application.

As a result of recent efforts to improve the situation, institutional mechanisms have been established for the collection and use of water charges and the transfer of responsibility to water users. It is estimated that 40–45 percent of the irrigation infrastructure is in need of renovation. The inefficient use of water and the heavy water losses in irrigation represent major problems for water resources and soils.

Finances

Since 1997 water used for agricultural purposes is chargeable. Rates were changed in June 2003. The fee is charged for technical-operational costs and not for the use of water as a natural resource.

Charges on wastewater discharge were also introduced in 1992. The rates are very low, as is the collection rate, making the charge system less effective (UNECE, 2004).

The Presidential Decree of 23 October 2004 authorized the establishment of a public corporation "Agroleasing" and a series of measures to develop leasing in the agricultural sector. It was decided to provide AZM100 billion and 150 billion from the state budget in 2005 and 2006 for Agroleasing's activities (Heydar Aliyev Foundation. 2008).

Policies and legislation

The water sector is regulated by the following legislation:

- The Water Code (1997)
- The Law on Water Supply and Wastewater (1999)
- The Law on Amelioration and Irrigation (1996)
- The Law on Environmental Protection (1999)

The Water Code is the basis for water management in Azerbaijan and sets out the following main principles for use and protection:

- economic development and environmental protection;
- provision of the population with quality water;
- water management to be based on river basins;
- water protection functions to be separate from water use and water industry functions.

The Law on Water Supply and Wastewater sets the legal framework for this sector.

The Law on Amelioration and Irrigation regulates the planning, design, construction and operation of amelioration and irrigation systems. Accordingly, design and construction activities require special permits (licences) and systems have to be certified with technical passports.

The Law on Environmental Protection identifies the legal, economic and social bases of environmental protection. It governs the use of natural resources, amongst which water, and protection against domestic and industrial pollution. The Law also sets the basis for economic mechanisms, such as payment for the use of natural resources and for the disposal of domestic and industrial waste and economic incentives for environmental protection.

In July 1996, a land reform law was adopted by the National Assembly (Milli Majlis), establishing private property rights to land. The land is to be transferred to all rural inhabitants free of charge. It can then be sold freely, exchanged, transferred by right of succession, leased or used as mortgage security.

In November 2003, the presidential decree "On intensification of the socio-economic development in the Republic of Azerbaijan" envisioned the start of the second stage of the agrarian reforms and the accomplishment of appropriate activities. It has been followed up by the state programme for socio-economic development of the regions of the Republic of Azerbaijan (2004-2008), adopted on 11 February 2004. The implementation of the programme will create the opportunities for radical changes and wider business development in agriculture. Among other activities, the state programme will restore agricultural processing enterprises, establish new production enterprises, increase the efficiency of local resources, build or modernize the infrastructure for regional development, step up the second stage of agrarian reforms, establish technical service centres in the region, and extend seed depots and other important activities (Heydar Aliyev Foundation. 2008).

ENVIRONMENT AND HEALTH

Water losses in the irrigation distribution systems, estimated at 50 percent, cause waterlogging and salinization. Moreover, only 600 000 ha of irrigated land, the most naturally saline areas, have drainage. The increased water level of the Caspian Sea has also made land on the coast more saline. Salinization is particularly widespread on the Kura-Araks lowland (UNECE, 2004).

The rapid development of all spheres of economics and human activity has had an increasingly negative impact on the environment, partly due to the inefficient use of natural resources. Like many other countries, Azerbaijan is interested in finding solutions to the problems of environmental protection and rational utilization of natural resources. In support of the country's environmental protection goals, a number of important laws, legal documents and state programmes, all conforming to European law requirements, have been approved.

Almost 30 percent of the Caspian Sea coastal area is exposed to contamination. More than half of the rivers more than 100 km long are considered to be contaminated. All the lakes of the low-lying parts of the country are exposed to the changes in the thermal, biological and chemical regimes. The lakes of the Apsheron Peninsula and the Kura Araks Lowland, covering a total area of more than 200 km^2, are in a critical state. The main sources of contamination of water resources are industry, agriculture, the municipal domestic sector, energy, heating and recreation (UNEP/GRID-Arendal, 2005).

Irrational use of water resources and pollution of water bodies can be put down to the fact that cities, regional centres and other human settlements are poorly equipped with sewerage systems and wastewater treatment facilities, as well as to the obsoleteness of the existing technical facilities. Untreated wastewater released from Baku, Ganja, Sumgayit, Mingacevir, Ali-Bayramli, Nakhchivan and other urban centres significantly contributes to the pollution of the water bodies.

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

Major positive factors in Azerbaijan's environmental outlook include the enactment of new legislation and the signing of international conventions. Although economic development is not advanced, the country is moving slowly in the right direction for water resources management.

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Bahrain

GEOGRAPHY, CLIMATE AND POPULATION

Geography

The Kingdom of Bahrain is a group of islands located off the central southern shores of the Persian Gulf. The archipelago comprises 40 islands, with a total land area of about 710 km^2 (Table 1). The largest of these is Bahrain Island where the capital city, Manama, is situated. Bahrain Island accounts for nearly 85 percent of the total area of the country. Next largest is the southern archipelago called Hawar (50 km^2), not far from the coast of Qatar, followed by the desert island of Umm Nasan (19 km^2), the populous Muharraq Island (18 km^2) connected by causeways to Bahrain, and finally Sitra (10 km2), a mainly industrial island also connected to Bahrain by causeways. The remaining small islands, islets and coral reefs make up the rest of the land mass (around 1.5 percent).

Bahrain is low lying. Limestone bedrock slopes rise gently towards the roughly central peak of Jebel Dukhan, with its highest point at 137 meters above sea level. Land use varies greatly, from extensive urban development and diligently cultivated areas in the north, to sandy wastes spreading south, east and west from Jebel Dukhan. Here there are true desert conditions with only sparse tough desert plants growing among the barren limestone rimrock and sands of varying depth.

Climate

Bahrain has an arid to extremely arid environment. According to the aridity criteria used, Bahrain has been regarded as arid or hyperarid as a result of the very great variations in climatic conditions (Elagib and Abdu, 1996). The country is characterized by high temperatures, erratic and often scanty rainfall, high evapotranspiration rates (with peaks of over 10 mm/day in July) and high humidity levels due to the surrounding Gulf waters.

Temperature averages from 17 °C in winter (December–March) to 35 °C in summer (June–September). The rainy season runs from November to April, with an annual average of 83 mm, sufficient only to support the most drought resistant desert vegetation. Mean annual relative humidity is over 67 percent. The annual average potential evaporation is 2 099 mm (Al-Noaimi, 2005).

Population

Total population is 727 000 (2005), of which around 10 percent is rural (Table 1). With a population density of 1 024 inhabitants/km^2, Bahrain is one of the world's most densely populated countries. It has experienced high rates of population growth and urbanization since the early 1960s following the sudden increase in the country's oil revenues, leading to a fast increase in its economic base and an improvement in the standard of living. The average annual demographic growth rate was 4 percent during

BAHRAIN **FAO - AQUASTAT, 2008**

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TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2005	71 000	ha
Cultivated area (arable land and area under permanent crops)	2000	4 235	ha
• as % of the total area of the country	2000	6	%
• arable land (annual crops + temp. fallow + temp. meadows)	2000	1 015	ha
• area under permanent crops	2000	3 220	ha
Population			
Total population	2005	727 000	inhabitants
• of which rural	2005	9.8	%
Population density	2005	1 024	inhabitants/km^2
Economically active population	2005	353 000	inhabitants
• as % of total population	2005	48.6	%
• female	2005	23.2	%
• male	2005	76.8	%
Population economically active in agriculture	2005	3 000	inhabitants
• as % of total economically active population	2004	0.85	%
• female	2005	0	%
• male	2005	100	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2005	16 040	million US$/yr
• value added in agriculture (% of GDP)	2002	0.85	%
• GDP per capita	2005	17763	US$/yr
Human Development Index (highest = 1)	2005	0.866	
Access to improved drinking water sources			
Total population		-	%
Urban population	2006	100	%
Rural population		-	%

the period 1980–1991 but this has dropped to 2.5 percent during the last 10 years. The water supply and sanitation coverage are 100 percent in urban areas. The total economically active population is 353 000 (2005), of which 77 percent are men and 23 percent women. Only 3 000 people work in agriculture.

Urban development at the expense of agricultural land has caused a significant loss of traditionally agricultural areas. Furthermore, soil salinization resulting from deterioration in the quality of the groundwater used in irrigation has led to a general reduction of cultivated land. In 2005, the total cultivated area was estimated at 6 000 ha, or 8 percent of the total area of the country, of which around 95 percent was equipped for irrigation. This area is mainly used for growing date palms, alfalfa and vegetables (FAO, 2002).

ECONOMY, AGRICULTURE AND FOOD SECURITY

The Gross Domestic Product (GDP) is around US$16 billion (current US$), with an annual growth of 7.8 percent (2005). Agriculture is one of the traditional activities in Bahrain but its contribution to national GDP is less than 1 percent (Table 1). Agriculture provided many job opportunities for Bahraini nationals, who accounted for 75 percent of agricultural labour during the 1970s. In 2004, the total economically active population in agriculture was only 3 000, all of whom were men. Agriculture in Bahrain is generally in an unhealthy state with tenancy problems, small farm holdings, labour shortages and lack of financial incentives, all of which restrict investment.

Bahrain is heavily dependent on imports to satisfy its need for animals and animal products, at the cost of home-based production. In an open-market economy, local animal products, especially dairy and eggs, face tough competition from imports. Part of this competition comes from some Gulf States which have the advantage of relatively well-established multifaceted livestock enterprises that started much earlier with more favourable cost structures. Sheep imports in Bahrain are subsidized. Rehabilitation of the national livestock industry would require improvement of the cost structure of locally produced animals and animal products (FAO, 2004).

There are some animal production activities based on local agricultural products, such as milk production or on imported feed, such as poultry and egg production. Nevertheless, livestock productivity is low because of poor management, which is reflected in poor growth rates, high mortality, late sexual maturity, long parturition intervals, inbreeding and poor-quality meat. The availability of feed for the livestock industry is uncertain and most feed ingredients are imported (FAO, 2003).

WATER RESOURCES AND USE

Water resources

Total annual surface runoff is only about 4 million m^3 and there are no rivers, perennial streams or lakes (Table 2). There are also no dams. Bahrain receives groundwater by lateral under-flow from the Damman aquifer, which forms only a part of the extensive regional aquifer system (the Eastern Arabian Aquifer). This aquifer extends from central Saudi Arabia, where its main recharge area is located at about 300 meters above sea level, to eastern Saudi Arabia and Bahrain, which are considered the discharge areas. The rate of groundwater inflow has been estimated at about 112 million m^3/year under steady-state conditions (before 1965) and this figure is considered to be the safe groundwater yield in Bahrain. But groundwater reserves suffer from severe degradation, in terms of both quality and quantity, as a result of over-extraction and seawater intrusion.

Over-utilization of the Dammam aquifer, the principal aquifer in Bahrain, by the agricultural and domestic sectors has led to its salinization through water coming from adjacent brackish and saline water bodies (particularly from the underlying saline aquifer of Umm er Radhuma). A hydrochemical study identified the locations of the sources of aquifer salinization and delineated their areas of influence. The investigation indicates that the quality of aquifer water quality has been significantly modified as groundwater flows from the northwestern parts of Bahrain, where the aquifer receives its water by lateral underflow from eastern Saudi Arabia, to the southern and southeastern parts. Four types of salinization of the aquifer have been identified:

- Brackish water up-flow from the underlying brackish water zones in north-central, western, and eastern regions;
- Seawater intrusion in the eastern region;
- Intrusion of sabkha water (saline water from saline areas) in the southwestern region;
- Irrigation return flow in a local area in the western region.

Four alternatives for the management of groundwater quality are under discussion by the water authorities in Bahrain. Priority areas have been proposed based on the type and extent of each salinization source, in addition to groundwater use in that area. Simulation modelling could be used to evaluate the effectiveness of the proposed management options in controlling the degradation of water quality in the Dammam aquifer (Zubari, 1999).

Since it has become the policy to curb the abstraction of groundwater resources in the Damman aquifer and to improve its quality, further development of water sources will undoubtedly involve desalination, either by a thermal process or reverse osmosis. The choice will depend on site-specific conditions and economy or cost. The first multi-stage flash (MSF) seawater desalination plant was introduced in Bahrain in 1976. The use of reverse-osmosis (RO) desalination for saline groundwater on Bahrain Island began in 1984–1986. One of the world's largest RO plants for the treatment of saline groundwater, located 25 km south of the capital of Bahrain at Ras Abu-Jarjur, was commissioned in 1984. The plant has an installed capacity of 45 500 m^3/day and its source of raw water is the highly saline brackish groundwater in the Umm er Radhuma formation. The RO plant was designed to meet the domestic water demand of Manama city, taking into account its advantages over an MSF plant, such as short construction time, lower energy cost, ease of operation and maintenance (UNU, 1995). In 2002, the total installed gross desalination capacity (design capacity) in Bahrain was 500 259 m^3/day (Wangnick Consulting, 2002).

The reuse of treated wastewater for agriculture and landscape irrigation started in 1985. The main wastewater treatment plant in Bahrain is the Tubli Water Pollution Control Centre (Tubli WPCC) which is currently (2005) producing about 160 000 m^3/day of secondary treated effluent and around 60 674 m^3/day receives tertiary treatment. There are also eleven minor wastewater treatment plants with a total designed capacity of about 9 720 m^3/day. Treated sewage effluent is expected to reach 200 000 m^3/day or 73 million m^3 per year by 2010 (Al-Noaimi, 2005). The additional amount treated, if properly used for irrigation, could significantly reduce water extraction, reserving the limited freshwater resources for potable supply and other priority uses. In Bahrain the cost of tertiary treated effluent is about US$0.317/$m^3$, while the cost of desalinated water is about US$0.794/$m^3$ (FAO/WHO, 2001).

Water use

Historically, Bahrain has utilized groundwater for both agricultural and municipal requirements. Natural freshwater springs used to flow freely in the northern part of Bahrain and before 1925 the water supply depended on these springs and some hand-dug wells, the total discharge of which was estimated at 93 million m^3/year. With increased water demand after the exploration of offshore reservoirs of crude oil and gas in 1946, spring flow decreased and water started being pumped from boreholes. During the 1980s, most of the springs ceased flowing, and increased demand for water caused deterioration in water quality, including the intrusion of seawater into the aquifer system (UNU, 1995). In 1988, groundwater use in Bahrain was estimated to be 153 million m^3/year, including 138 million m^3 of tube-well abstraction, 8.1 million m^3 of water from land springs, and 6.6 million m^3 of water from marine springs.

In 2003, total water withdrawal in Bahrain was 357.4 million m^3 (Table 2 and Figure 1). The part used for irrigation and livestock watering purposes dropped to 45 percent whereas it was 56 percent in 1991. Total annual water demand was met by three sources: groundwater (238.7 million m^3), desalinated water (102.4 million m^3) and treated sewage effluent (16.3 million m^3) (Table 3 and Figure 2). This means that non-conventional water sources accounted for 34 percent of total water withdrawal in 2003. About 90 percent of the water used in agriculture, including livestock, was groundwater and 10 percent treated wastewater. For municipal and industrial purposes about 48 percent of the water used was groundwater and the remaining part was desalinated water.

The total surface water and groundwater withdrawal represented 206 percent of the total renewable water resources in 2003, meaning that abstraction of fossil water and groundwater mining was taking place.

FIGURE 1
Water withdrawal by sector
Total: 0.357 km^3 in 2003

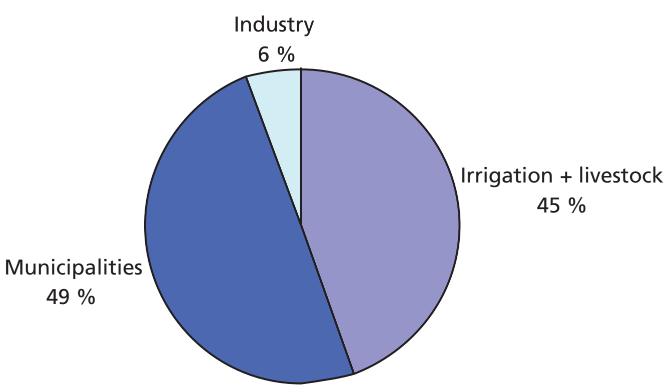


TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	83	mm/yr
	-	0.059	10^9 m^3/yr
Internal renewable water resources (long-term average)	-	0.004	10^9 m^3/yr
Total actual renewable water resources	-	0.116	10^9 m^3/yr
Dependency ratio	-	97	%
Total actual renewable water resources per inhabitant	2005	160	m^3/yr
Total dam capacity	1995	0	10^6 m^3
Water withdrawal			
Total water withdrawal	2003	357.4	10^6 m^3/yr
- irrigation + livestock	2003	159.2	10^6 m^3/yr
- municipalities	2003	177.9	10^6 m^3/yr
- industry	2003	20.3	10^6 m^3/yr
• per inhabitant	2003	506	m^3/yr
Surface water and groundwater withdrawal	2003	238.7	10^6 m^3/yr
• as % of total actual renewable water resources	2003	205.8	%
Non-conventional sources of water			
Produced wastewater	1991	44.9	10^6 m^3/yr
Treated wastewater	2005	61.9	10^6 m^3/yr
Reused treated wastewater	2005	16.3	10^6 m^3/yr
Desalinated water produced	2003	102.4	10^6 m^3/yr
Reused agricultural drainage water	2001	3	10^6 m^3/yr

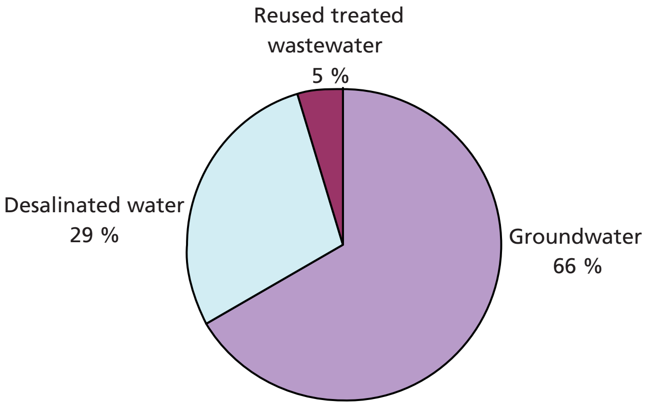
TABLE 3
Water uses in Bahrain by sources and categories of use for the year 2003 (million m^3)

Source	Municipal	Agriculture	Industrial	Total uses
Groundwater	83.3	143.2	12.2	238.7
Desalinated water	94.3	-	8.1	102.4
Treated sewage effluent	-	16.3*	-	16.3*
Total	**177.6**	**159.5**	**20.3**	**357.4**

*Year 2005

The excessive pumping of groundwater caused a sharp decrease in groundwater storage and a reduction in potentiometric levels of about 4 meters between 1965 and 1992. As a result, more than half the original groundwater reservoir has been completely degraded due to seawater intrusion and saline water up-flow from the deeper zones. Table 4 shows that annual extraction is almost twice the annual recharge, leading to an ever-increasing groundwater deficit. While the average annual groundwater depletion over the period 1965-1992 was approximately 40 million m^3, in 1991/92 it was over 96 million m^3.

FIGURE 2
Water withdrawal by source
Total: 0.357 km^3 in 2003



In 2003, the total quantity of desalinated water used was 102.4 million m^3 against 44.1 million m^3 in 1991. In 2005 treated wastewater amounted to about 62 million m^3/year of wastewater (secondary treatment) against about 45 million m^3 in 1991. Despite an increase of 100 percent compared with 1991, only 16.3 million m^3/year received tertiary treatment and part was used for irrigation purposes in

TABLE 4
Groundwater depletion in Bahrain, 1991/92

Component	Average annual rate (million m³)
Inflow:	
Recharge by under-flow (aquifer safe yield)	112.00
Recharge by rainfall on outcrop and irrigation return flows	0.28
Total inflow	112.28
Outflow:	
Wells abstraction for irrigation, livestock, domestic, industrial and other purposes	190.20
Sabkha natural discharge	12.72
Natural springs discharge	5.40
Total outflow	208.32
Total inflow - Total outflow	**- 96.04**

government farms and some private farms, while the rest was discharged to the sea. The chemical and hygienic properties of the tertiary treated water are within international limits and are considered good for agricultural purposes. Although the government has plans for the full utilization of Treated Sewage Effluent (TSE) water through major agricultural projects, delays and lack of funds for these projects have limited the use of these waters.

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

The limited availability of good quality soil and water has resulted in the concentration of agricultural development in a relatively narrow strip of land along the northwestern coast of Bahrain Island with isolated pockets in the north central areas and along the east coast. Most soils have a sandy texture, traces of organic matter (0.05–1.5 percent), a deficiency in major nutrients, low water-holding capacity (available moisture 2–6 percent), and high infiltration rates (> 120 mm/hr). In areas along the coastal strip, calcareous impermeable layers are found at depths of 1–3 metres, causing waterlogging and impeding leaching. Electrical conductivity (EC) in irrigated soils lies within a range of 4–12 mmhos/cm, while in the areas of recently abandoned agriculture (1 065 ha) it could reach 60 mmhos/cm.

In the period from 1956 to 1977, agricultural land decreased from about 6 460 ha (with 3 230 ha cultivated) to about 4 100 ha (with 1 750 ha cultivated). This decrease was attributed mainly to urban expansion, waterlogging and soil salinization due to the deterioration of the quality of the groundwater used in irrigation. In an attempt to reverse the situation, the government initiated a major agricultural development programme in the early 1980s consisting of:

- Replacement of surface irrigation with more water efficient localized irrigation by subsidizing more than 50 percent of the implementation cost;
- Construction of major drainage systems to reduce waterlogging and salt accumulation;
- Provision of agricultural extension services in terms of training and advising farmers on types of crops suitable for agriculture under prevailing conditions;
- Introduction of TSE water in irrigation;
- Reclamation of new agricultural lands.

This resulted in a gradual increase and restoration of agricultural lands to about 4 230 ha, with 4 015 ha cultivated and irrigated at present, all power irrigated. Between 1994 and 2000, there was a 4 percent average increase per year of the area equipped for irrigation. It is difficult to estimate the quantity of groundwater available in the future for agriculture since groundwater quality, and hence its availability for irrigation, changes with time. In 2003, groundwater accounted for 90 percent of the total irrigation water (Table 5 and Figure 3).

In 1991, the utilization of 8 million m³/year of tertiary TSE water in reclaimed government lands (280 ha) and on some private farms (150 ha), using sprinkler and localized irrigation techniques, had a palpable effect on the increase of agricultural lands and their productivity. Government subsidy for installation of modern irrigation systems stopped in the 1990s because of lack of funds. Despite efforts to introduce modern irrigation techniques, most farms still use traditional surface irrigation, which

TABLE 5
Irrigation and drainage

Irrigation potential		**-**	**4 230**	**ha**
Irrigation:				
1. Full or partial control irrigation: equipped area		2000	4 015	ha
- surface irrigation		2000	3 390	ha
- sprinkler irrigation		2000	160	ha
- localized irrigation		2000	465	ha
• % of area irrigated from surface water		2003	0	%
• % of area irrigated from groundwater		2003	90.3	%
• % of area irrigated from mixed surface water and groundwater		2003	0	%
• % of area irrigated from non-conventional sources of water		2003	9.7	%
• area equipped for full or partial control irrigation actually irrigated			-	ha
- as % of full/partial control area equipped		1994	100	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)		2000	0	ha
3. Spate irrigation		2000	0	ha
Total area equipped for irrigation (1+2+3)		**2000**	**4 015**	**ha**
• as % of cultivated area		2000	94.8	%
• % of total area equipped for irrigation actually irrigated			-	%
• average increase per year over the last 6 years		1994-2000	4	%
• power irrigated area as % of total area equipped		1994	100	%
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**	**4 015**	**ha**
• as % of cultivated area		2000	94.8	%
Full or partial control irrigation schemes:	**Criteria:**			
Small-scale schemes	< 50 ha	1994	2 885	ha
Medium-scale schemes		1994	0	ha
large-scale schemes	> 50 ha	1994	280	ha
Total number of households in irrigation		1994	-	
Irrigated crops in full or partial control irrigation schemes:				
Total irrigated grain production		2000	0	metric tons
• as % of total grain production			-	%
Harvested crops:				
Total harvested irrigated cropped area		2000	4 015	ha
• Annual crops: total		2000	1 015	ha
- Vegetables (mainly tomatoes)		2000	1 015	ha
• Permanent crops: total		2000	3 000	ha
- Fodder (mainly alfalfa)		2000	790	ha
- Other perennial crops (dates, fruits)		2000	2 210	ha
Irrigated cropping intensity (on full/partial control area actually irrigated)		2000	100	%
Drainage - Environment:				
Total drained area		1994	1 300	ha
- part of the area equipped for irrigation drained			-	ha
- other drained area (non-irrigated)			-	ha
• drained area as % of cultivated area		1994	41	%
Flood-protected areas		1995	1 300	ha
Area salinized by irrigation		1994	1 065	ha
Population affected by water-related diseases			-	inhabitants

causes higher water losses, estimated at between 24 and 40 percent. Sprinkler irrigation is used only in government projects, while localized irrigation is used in government projects and on a limited number of private farms (Figure 4). Most of the land is cultivated either directly by the owner, often with hired labour, or by tenant farmers under a lease agreement lasting one or two years. Such short and insecure periods do not encourage tenants to invest in the installation of modern irrigation systems, which cost 40 percent and even up to 100 percent more than surface irrigation systems since government subsidies for the installation of modern irrigation systems are no longer available. The small size of agricultural landholdings, ranging between 0.5 and 10 ha, with an average of 2.5 ha, and in particular the fragmentation of the agricultural land of farm holdings, further restrict investment in the more expensive modern irrigation techniques.

FIGURE 3
Source of irrigation water
In 2003

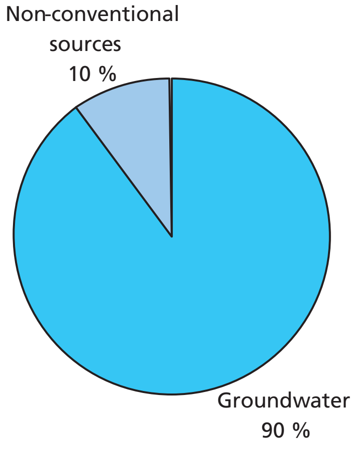
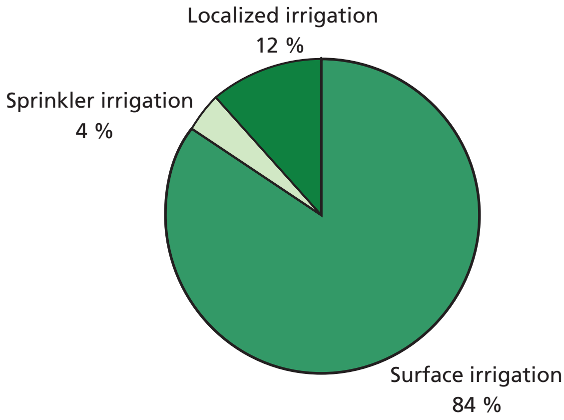


FIGURE 4
Irrigation techniques
Total: 4 015 ha in 2000



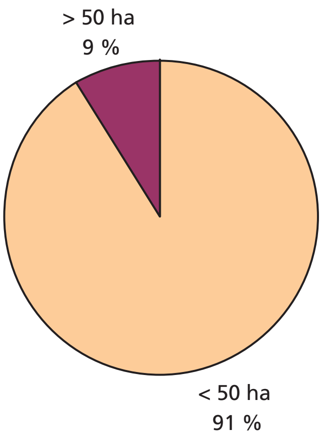
About half of the cultivated area is covered with high water-consuming perennial date palms under traditional surface irrigation practices. Some basic installations with modern irrigation systems (drip irrigation for vegetables and bubbler irrigation for dates) have been established too, but they are rather poorly operated with no irrigation schedules. Unfortunately, many drip and sprinkler systems have been designed on the basis of incorrect criteria, using the outdated irrigation equipment of the 1970s which is poorly installed and inadequately maintained (FAO, 2002). The overall irrigation efficiency is very low, also demonstrated by the huge amount of water used (almost 160 million m^3) on a total irrigated area of just over 4 000 ha.

Role of irrigation in agricultural production, economy and society

In 1991, of the total equipped area of 3 165 ha, 2 885 ha consisted of small schemes (< 50 ha). Most farms in these small-scale schemes were run under the tenancy system and there were about 250 households on these schemes. The remaining 280 ha of large schemes (> 50 ha) were owned and completely run by the government and irrigated by treated wastewater, with a total of 80 government workers of whom 11 were involved in irrigation (Figure 5).

In 1991, the average cost of irrigation development on small schemes varied between US$6 600/ha for surface irrigation, US$9 300/ha for localized irrigation and US$13 200/ha for sprinkler irrigation. For large schemes the cost was US$16 200/ha for

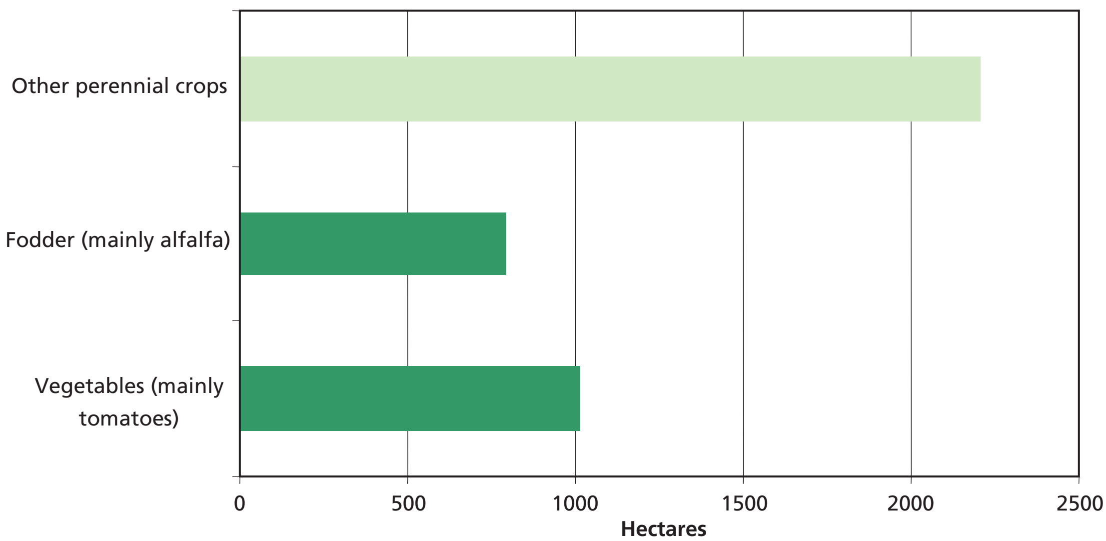
FIGURE 5
Type of irrigation schemes
Total: 3 165 ha in 1994



surface irrigation, US$13 600/ha for localized irrigation and US$19 800/ha for sprinkler (central pivot) irrigation. The high costs for large scheme development were attributed to the fact that the major projects were carried out by the government on reclaimed lands. Operation and maintenance costs varied between 10 and 15 percent of the irrigation development costs on small schemes and between 5 and 15 percent on large schemes.

The major crops grown are: dates and fruit trees with a yield of 7.5 tons/ha; vegetables, mainly tomatoes, with a yield of 11.7 tons/ha; and fodder crops, mainly alfalfa, with a relatively high yield of 74.5 tons/ha. There is no cereal production. In the 1980s, there had been an increasing trend in the cultivation of alfalfa for fodder production rather than the cultivation of the traditional date and vegetable crops. Alfalfa tolerates high salinity and is a cash crop grown all year round with high local demand. However, because of the very high irrigation water requirements of alfalfa, it is expected that this trend will have negative implications for the country's groundwater resources. Horticulture and agriculture flourish in the north, using water from some artesian wells or desalination plants. Gardens grow dates, almonds, pomegranates, figs, citrus fruit, and a wide range of vegetables. In 2000, permanent crops (mainly alfalfa and date palms) covered 75 percent of the irrigated area while vegetables represented the remaining 25 percent (Table 5 and Figure 6). In 2004, Bahrain produced 14 000 tons of fruits and dates and 7 700 tons of vegetables.

FIGURE 6
Irrigated crops
Total harvested area: 4 015 ha in 2000 (cropping intensity on equipped area actually irrigated:100%)



Status and evolution of drainage systems

Drainage works have been carried out on 1 850 ha of the irrigated area. The remaining areas still suffer from shallow water tables resulting in waterlogging in the crop root zones and an increasing salinization of the top soil. Drainage requirements are exacerbated by the inefficient surface irrigation systems used. In 1994, drainage works had been completed on about 1 300 ha (Table 5). The existing drainage network consists of open drains, which are very inefficient and difficult to maintain. The average cost of drainage development was estimated at US$6 600/ha.

The only flood protection works carried out in Bahrain are those against rainfall floods and are developed in one residential, modern town located in the west, over an area of 1 300 ha, where there are no agricultural activities.

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

Institutions

The Ministry of Municipalities, Affairs and Agriculture is responsible for the country's groundwater resources development, management and utilization. This ministry also manages the utilization of TSE in agriculture. The current organizational structure and staff shortages in the Directorates of the Ministry and the services dealing with water development and use, i.e. the Agricultural Engineering Service and the Water Resources Service, are a major constraint to the efficient performance of these services, both of which lack human resources and updated know-how. One of the constraints in developing optimum irrigation facilities is the lack of engineers and technicians as well as of farmers trained in modern irrigation techniques.

The Ministry of Electricity and Water is responsible for providing adequate electricity and water supplies in a safe and cost effective manner to the different segments of consumers in Bahrain.

Water-related research is carried out by the Arabian Gulf University and the University of Bahrain.

Water management

Given the limited land and water resources, recent development plans for improved agricultural production (FAO, 2003) have the goals of:

- Conservation and rational utilization of the limited water resources through the adoption of modern irrigation and drainage techniques, the promotion of the use of treated wastewater and the implementation of legislation related to water use and management;
- Conservation and rehabilitation of land resources and the implementation of legislation to regulate agricultural and non-agricultural land uses;
- Conservation and rational utilization of marine resources;
- Increased agricultural productivity and profitability through the intensification and utilization of treated wastewater;
- Creation of an enabling environment to promote private sector participation in agricultural investment and enhance the productivity and competitiveness of Bahrain's agricultural products in domestic and regional markets;
- Reduction of natural resource degradation through the promotion of agricultural activities that generate sufficient income and employment to sustain the livelihoods of rural communities.

The authorities intend to take a comprehensive approach to water resources planning, recognizing the close inter-relationship between the country's available water resources and the growing demand for additional quantities from the various sectors of economy, i.e. agriculture, landscape development, industry and domestic supplies. Pressure is also increasing to reallocate water in agriculture from high water consuming to lower water consuming crops, and to higher value uses, such as the expanding the domestic, tourist and services sector.

Policies and legislation

The privately-owned water use rights are the only water rights that exist in Bahrain. The general principle governing these rights is that groundwater is the property of the landowners and, therefore, they have an exclusive right to extract and use as much water as they wish and for any purpose they want without being liable for any damage caused to their neighbours or to the groundwater in general. At present, the agricultural sector's utilization of water is not subjected to any licensing system nor is it controlled by a pricing system. However, from the mid-1980s on, agricultural wells have been metered by the government and the government is in the process of passing a law that would make it compulsory for all well owners to install meters on their wells. The total number of wells metered in 1995 was about 1 670 (86 percent of total). The final objective of this programme is to observe irrigation water requirements, and subsequently to set up a licensing system for groundwater withdrawal and design an appropriate pricing system for excess water utilization.

There is no well-defined national water master plan for sustainable water resources development and management. However, a number of rather fragmented water policies and water conservation measures have been initiated over the last three decades to resolve the escalating water shortage problems in the country (Al-Noaimi, 2005). These include, but are not limited to, the following:

- Increased supply as a result of a major desalination and wastewater treatment programme;
- Demand management measures;
- Water pricing;
- Institutional and legal reforms;
- Enhanced monitoring and information systems.

ENVIRONMENT AND HEALTH

The toxicity level of the groundwater of the semi-arid tract of Bahrain was examined for the fluoride concentration and other chemical constituents such as the sodium absorption ratio (SAR), chloride, sulfate, bicarbonate, and boron. The fluoride concentration varied from 0.50 to 1.46 mg/litre and 38 percent of the water contained concentrations of fluoride deemed harmful for drinking. However, the fluoride concentration in the water is not harmful for most crops. Spring and well water have rather high salinity but could be used for agricultural purposes, particularly for crops that can tolerate high salinity levels (Akther, 1998).

While the standard of living and quality of life of the people has improved in the last 20 years, these improvements have produced negative effects on the terrestrial, coastal and marine environments due to overexploitation of these ecosystems and to unsustainable development practices. Also as a consequence of two Gulf wars and unstructured economic diversification, the country has been subjected to serious environmental and health hazards. However, under its constitution, Bahrain is committed to managing its natural and human resources and has since 1996 implemented a programme to reorganize the country's environmental planning. The government has recognized that sustainable development can only be assured if the full range of potential impacts of development projects is assessed in a timely fashion and that action can only proceed from that assessment. Unfortunately, due to the limitations on the institutional capacity of government authorities and other relevant institutions in this field, there have been no comprehensive environmental health impact assessments.

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

A FAO study entitled '*Comparative advantage, competitiveness and policy options for sustainable agricultural development in Bahrain*' was conducted in 2003. The results of the study indicated that most plant production and livestock activities showed a good level of comparative advantage, as measured by the Domestic Resource Cost (DRC) indicator. The activities that appeared to have the best comparative advantage were the production of high-quality date palm varieties, Khalas and Khinezi in particular, and greenhouse production of cucumbers and tomatoes. Most open-field vegetables under drip irrigation also seemed to have a clear comparative advantage, although leafy vegetables generally showed much higher values than other vegetables. However, the production of vegetables under traditional irrigation systems did not show any clear comparative advantage with the possible exception of green onions (FAO, 2003).

Since the 1980s, the government has been taking several steps and courses of action to provide solutions to the water crisis in the country and to stem deterioration in the agricultural sector. These include: water conservation campaigns in all sectors, water pricing in the domestic sector and more reliance on non-conventional water sources (TSE in agriculture and desalinated water for domestic purposes).

Government policy with regard to water use is to reduce groundwater dependency for the domestic water supply, the second main water user, by constructing additional desalination plants. It is planned that groundwater will be exclusively used for irrigation. Additional requirements for future agricultural development should be supplemented by TSE water, which is expected to reach 73 million m^3 by 2010, especially through the expansion and upgrading of the plant production facilities at Tubli under TSE Phase-2 and the construction of transmission and distribution networks. On completion of 150 000 metres of closed pipes distribution network, it will irrigate 588 farms over an area of 2 200 ha. In addition, a drainage network to dispose of highly saline subsoil water will be constructed. However, these plans are still awaiting major government funds for the construction of a TSE conveyance system and farmers' acceptance. Although the intentions exist, an agricultural licensing system and water pricing have still to be put in place.

Although government policy indicates the will to develop a modern farming sector on larger production units using mechanization and up-to-date techniques, these aims have not yet been reflected clearly in the government's capital investment and subsidy programs.

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Georgia

GEOGRAPHY, CLIMATE AND POPULATION

Geography

Georgia has a total area of 69 700 km². It is located in the Caucasus region and is bordered by the Russian Federation to the north and northeast, Azerbaijan to the southeast, Armenia and Turkey to the south, and the Black Sea to the west for a distance of 309 km. For administrative purposes, the country is divided into 11 regions (comprising some 67 districts) plus the capital city Tbilisi. It declared independence from the Soviet Union in April 1991.

The country can be divided into three physiographic regions: mountains covering about 54 percent of the total area, highlands about 33 percent, and valleys some 13 percent. The Caucasus Mountains form Georgia's northern boundary, their highest peak standing some 5 000 m above sea level. About 70 percent of the country lies below 1 700 m above sea level. Cropping is possible throughout the country up to 2 000 m. At higher altitudes, there are only pastures.

The total cultivable area, which according to Georgian statistics is equal to the agricultural area, was estimated in 1996 at some 3 million ha, or 43 percent of the country. About 2.2 million ha are forest, which, under the 1978 Forest Code, cannot be transformed into agricultural cropped areas. A process of land privatization has been under way since the end of the Soviet period. Agricultural production is generally small-scale, but commercial farming is progressively gaining importance. Of the total 3 million ha of agricultural land, some 0.7 million ha are owned and cultivated by private farmers; 0.3 million ha have been leased to farmers for short-term (3–5 years), medium-term (25 years) or long-term (49 years) periods; and 2 million ha are still owned by the state. Most of the state agricultural land is not cultivated. Only about 30 percent is rented, mainly due to the complicated orography, poor soil, distance from habited areas, and damaged irrigation and drainage systems.

In 2005, the total cultivated area was estimated at 1.07 million ha, of which 802 000 ha consisted of annual crops and 264 000 ha of permanent crops (Table 1). Water and wind erosion, environmentally degrading agricultural practices and other anthropogenic and natural processes have led to an almost 35 percent degradation of farmland (Government of Georgia, 2002).

Climate

Georgia, with an average rainfall of 1 026 mm/year, can be divided into two climatic regions:

- West Georgia, which has a subtropical humid climate, with mild winters and not very hot summers. The average precipitation is estimated at between 1 100 and 1 700 mm/year. Drainage of excess water is one of the main problems for

GEORGIA **FAO - AQUASTAT, 2008**

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agriculture in this part of the country. Average temperatures vary between 5 °C in January and 22 °C in July.

- East Georgia, which has a subtropical dry climate, with fairly cold winters and arid, hot summers. The average precipitation varies between 500 and 1 100 mm/year. About 80 percent of the rainfall occurs from March to October, while the longest dry period is about 50–60 days. Drought years are common. Hail occurs in spring and autumn. There is a need for irrigation in the areas where precipitation is less than 800 mm/year. Average temperatures vary between -1 °C in January and 22 °C in July.

Population

The total population is estimated at 4.47 million (2005), of which 48.5 percent is rural. The average population density is 64 inhabitants/km² (Table 1). Before independence, the population growth rate was about 1 percent per year, but since 1991 the growth has been negative. During the period 1992–2000 it was -1.5 percent and during the period 2000–2005 -1.1 percent.

In 2006, 93 percent of the population had access to improved sanitation (94 and 92 percent in urban and rural areas respectively) and 99 percent to improved water sources (100 and 97 percent in urban and rural areas, respectively).

ECONOMY, AGRICULTURE AND FOOD SECURITY

In 2007, the national Gross Domestic Product (GDP) of Georgia was US$10.2 billion of which agriculture accounted for 11 percent (Table 1). The total economically active population was 2 287 000 or just over 51 percent of the total population (2005), of which 52 percent male and 48 percent female. The economically active population in agriculture is estimated at 395 000, 40 percent of which is female.

TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2005	6 970 000	ha
Cultivated area (arable land and area under permanent crops)	2005	1 066 000	ha
• as % of the total area of the country	2005	15.3	%
• arable land (annual crops + temp. fallow + temp. meadows)	2005	802 000	ha
• area under permanent crops	2005	264 000	ha
Population			
Total population	2005	4 474 000	inhabitants
• of which rural	2005	48.5	%
Population density	2005	64.2	inhabitants/km²
Economically active population	2005	2 287 000	inhabitants
• as % of total population	2005	51.1	%
• female	2005	48.1	%
• male	2005	51.9	%
Population economically active in agriculture	2005	395 000	inhabitants
• as % of total economically active population	2005	17.3	%
• female	2005	39.5	%
• male	2005	60.5	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2007	10 180	million US$/yr
• value added in agriculture (% of GDP)	2007	11	%
• GDP per capita	2005	1 430	US$/yr
Human Development Index (highest = 1)	2005	0.754	
Access to improved drinking water sources			
Total population	2006	99	%
Urban population	2006	100	%
Rural population	2006	97	%

WATER RESOURCES AND USE

Water resources

The country can be divided into two main river basin groups:

- The Black Sea Basin, in the west of the country. The internal renewable surface water resources (IRSWR) generated in this basin are estimated at 42.5 km³/year. The main rivers are, from north to south, the Inguri, the Rioni and the Chorokhi. The main stream of the Chorokhi rises in Turkey (the Corub River) and the estimated inflow from Turkey is 6.3 km³/year.
- The Caspian Sea Basin, in the east of the country. The IRSWR generated in this basin are estimated at 14.4 km³/year. The main rivers are, from north to south: the Terek and the Andiyskoye, which rise in the north of the country and flow northeast to the Russian Federation before entering the Caspian Sea; the Alazani, the Iori and the Kura, which rise in Georgia and flow into Azerbaijan in Lake Adzhinour, before flowing southeast in Azerbaijan and then entering the Caspian Sea. Two tributaries of the Kura River rise in Turkey: the Mtkvari, with an estimated inflow from Turkey of 0.91 km³/year, and the Potskhovi, with an estimated inflow from Turkey of 0.25 km³/year. The inflow of the Debet River, a southern tributary of the Kura River, is estimated at 0.89 km³/year from Armenia.

The renewable groundwater resources are estimated at 17.23 km³/year, of which 16 km³/year are drained by the surface water network (overlap). This gives a total of 58.13 km³/year for internal renewable water resources (IRWR). The total actual renewable water resources (ARWR) are 63.33 km³/year (Table 2).

In 1990, the total water abstraction was estimated at 3 km³/year from some 1 700 tube-wells. According to a recent assessment a further 7 km³/year could be abstracted in the future. Groundwater use was not greatly developed during the Soviet period, due to the emphasis on large-scale state-run surface irrigation schemes.

Georgia has 25 075 rivers exist with a total length 54 768 km; 99.4 percent of them are small rivers with a total length of less than 25 km. Hydrological studies are made of 555 rivers of the Black Sea Basin and 528 rivers of the Caspian Sea Basin. More than 17 000 rivers (total length 32 574 km) belong to the Black Sea Basin. There are about

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	1 065	mm/yr
	-	74.23	10^9 m³/yr
Internal renewable water resources (long-term average)	-	58.13	10^9 m³/yr
Total actual renewable water resources	-	63.33	10^9 m³/yr
Dependency ratio	-	8.21	%
Total actual renewable water resources per inhabitant	2005	14 155	m³/yr
Total dam capacity	2004	3 414	10^6 m³
Water withdrawal			
Total water withdrawal	2005	1 621	10^6 m³/yr
- irrigation + livestock	2005	1 055	10^6 m³/yr
- municipalities	2005	358	10^6 m³/yr
- industry	2005	208	10^6 m³/yr
• per inhabitant	2005	362	m³/yr
Surface water and groundwater withdrawal	2005	1 621	10^6 m³/yr
• as % of total actual renewable water resources	2005	2.6	%
Non-conventional sources of water			
Produced wastewater		-	10^6 m³/yr
Treated wastewater	2005	9	10^6 m³/yr
Reused treated wastewater		-	10^6 m³/yr
Desalinated water produced		-	10^6 m³/yr
Reused agricultural drainage water		-	10^6 m³/yr

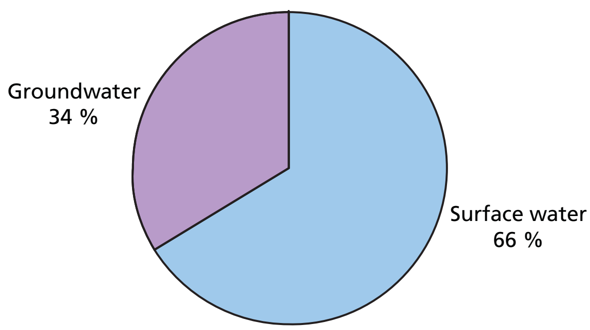
43 dams in Georgia, 35 of which are in the east and 8 in the west; their total reservoir capacity is estimated at about 3.4 km^3. The water is primarily used for irrigation and hydropower generation and less for water supply. The largest dam, for hydropower is the Inguri dam, with a reservoir capacity of 1.092 km^3. In 1995, hydropower supplied 89 percent of electricity. Some 31 dams have been built for irrigation purposes; they have a total reservoir capacity of 1 km^3, of which 782 million m^3 are active. The three largest irrigation reservoirs are: the Sioni reservoir (325 million m^3) on the Iori River, the Tbilisi reservoir (308 million m^3) on the Kura River and the Dalimta reservoir (180 million m^3) on the Iori River.

In 2005, the total treated wastewater was estimated at 9 million m^3. There is no tradition of treated wastewater reuse in Georgia.

Some wetlands have a primary environmental importance such as:

- central Kolkheti (33 710 ha), on both sides of the Rioni River mouth along the central part of the eastern Black Sea coast, in the regions Guria and Samegrelo near the city of Poti. The site contains many relicts and endemic species of flora and fauna. The area is a coastal alluvial plain, composed of quaternary deposits. The average water flow rate (over a long period) of the River Rioni (the largest river in the site) is 399 m^3/second. Kolkheti State Reserve (500 ha) was established in 1947.
- Ispani (513 ha) in the autonomous Republic of Adjara, one kilometre from the Black Sea coast near the city of Kobuleti. The area supports rare mammal species and migratory waterbirds of international importance. The area is a coastal alluvial plain, composed of quaternary, lake-riverine and additional lake deposits, which have developed to a depth of 9–14 m.

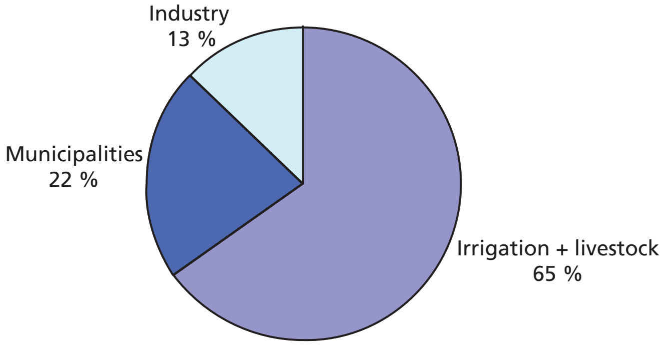
FIGURE 1
Water withdrawal by source
Total: 1.6 km^3 in 2005



Water use

Between 1985 and 1990, the total water withdrawal decreased from 4 600 to 3 500 million m^3 because of the industrial decline since the end of the Soviet Union. During 2005 the total water withdrawal was 1 621 million m^3, 66 percent of which came from surface water and 34 percent from groundwater (Table 2 and Figure 1). Agricultural water withdrawal accounted for 1 055 million m^3 and water withdrawal for municipal purposes for 358 million m^3. Industrial water withdrawal was estimated at 208 million m^3 (Figure 2).

FIGURE 2
Water withdrawal by sector
Total: 1.6 km^3 in 2005



International water issues

In 1925, an agreement with Turkey was reached on the use of water from the Chorokhi River, allocating half of the average surface water flow to each country. This agreement dealt only with water flow and did not consider the sediment flow, estimated at 5 million m³/year. About 46 percent of these sediments form the sand beach and are an important resource, as tourism is of prime importance to Georgia's earnings. Turkey plans to construct a cascade of 11 dams on the Chorokhi River, which will affect the sediment flow and thus the beaches on the Georgian shore. Georgia is pressing for a reconsideration of the agreement, which should not only deal with the allocation of water but also address the issue of sediment flow.

In 1997, Georgia ratified the agreement between the Governments of Georgia and Azerbaijan on environmental protection. In 1998, Georgia ratified a similar agreement with Armenia. According to both agreements, the governments will cooperate in creating specifically protected areas within the transboundary ecosystems.

The implementation of the "Ecoregional Nature Protection Programme for Southern Caucasus" is part of the Caucasus Initiative, launched by the German Ministry of Cooperation and Development. The programme covers the three Caucasus countries, Georgia, Azerbaijan and Armenia, and will facilitate the protection and sustainable use of water resources in the region.

Measures are already being taken in support of the development of protected areas in Georgia. Within the Black Sea Integrated Management Programme, supported by the Global Environment Facility (GEF) and the World Bank, implementation of the system of protected wetland areas in the coastal zone of Georgia is in progress (Tsiklauri, 2004).

From 2000 to 2002, USAID, in collaboration with Development Alternatives Inc. (DAI), implemented the South Caucasus Water Management Project, designed to strengthen co-operation between water-related agencies at all local, national and regional levels, and demonstrate integrated water resources management. In parallel, between 2000 and 2006, the EU and the Technical Assistance Commonwealth of Independent States (TACIS) have developed the Joint River Management Programme on Monitoring and Assessment of Water Quality on Transboundary Rivers; its aim is the prevention, control and reduction of trans-boundary pollution impact. The programme covers four basins, including the Kura River Basin. In addition, regional organisations such as REC, Eurasia Foundation and numerous local foundations are promoting national and regional activities in the field of water resources management and protection (UNEP, 2002).

The main objective of the USAID/Caucasus-Georgia Strategic Plan (2004–2008) is to ensure continued support for the South Caucasus Regional Water Management Programme as a principal component of its regional conflict-prevention and confidence-building objectives. It hopes to maintain the dialogue between the three countries that has already contributed to confidence-building measures (USAID, 2006).

From 2002 to 2007, the NATO-OECD has developed the South Caucasus River Monitoring Project. Its general objectives are to establish the social and technical infrastructure for an international, cooperative, transboundary river water quality and quantity monitoring, data sharing and watershed management system among the Republics of Armenia, Azerbaijan and Georgia (OSU, 2008).

The project Reducing Transboundary Degradation in the Kura-Araks River Basin, currently being implemented by the UNDP Bratislava Regional Centre in collaboration with the Global Environmental Facility (GEF), has involved four of the basin countries: Armenia, Azerbaijan, Georgia and the Islamic Republic of Iran. Efforts are being made to involve Turkey in the project. The project preparation phase is 18 months and began in July 2005. It is co-funded by Sweden. The project aims to ensure that the quality and quantity of water throughout the Kura-Araks River system meets the short and long-term needs of the ecosystem and the communities relying upon it.

The project will achieve its objectives by fostering regional cooperation, increasing capacity to address water quality and quantity problems, demonstrating water quality/quantity improvements, initiating required policy and legal reforms, identifying and preparing priority investments, and developing sustainable management and financial arrangements.

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

The irrigation potential in Georgia is estimated at 725 000 ha. The country has a tradition of land improvement through irrigation and drainage. At the beginning of the twentieth century, the total irrigated area in Georgia was about 112 000 ha. Major investments were made in the irrigation sector during the Soviet period, resulting in a total area of about 500 000 ha equipped for irrigation at the beginning of the 1980s, mainly located in the more arid eastern part of the country.

During the 1990s, civil strife, war, vandalism and theft, as well as problems associated with land reform, the transition to a market economy, and the loss of markets with traditional trading partners, contributed to a significant reduction of the irrigated area. It has been reported that during the severe drought of 2000 only about 160 000 ha were irrigated. Almost all pumping schemes (about 143 000 ha) were out of order. As a consequence, Georgia's State Department of Melioration and Water Resources started a rehabilitation programme to renew the infrastructure of existing irrigation and drainage schemes and to establish Amelioration Service Cooperatives. About 255 000 ha are covered by these programmes.

In 2007, irrigation covered 432 790 ha, of which 31 500 ha equipped wetland and inland valley bottoms and 401 290 ha full or partial control irrigation. River diversion is the main source of water for irrigation and groundwater is not used for irrigation in Georgia. The main irrigation technology is surface irrigation (372 980 ha). Localized irrigation is practiced on 28 300 ha (Table 3 and Figure 3).

Most of the schemes are large-scale (Figure 4). The largest one are: the upper Alazani (41 100 ha), the lower Alazani (29 200 ha), the upper Samgori (28 100 ha), and the lower Samgori (29 200 ha). There is no private irrigation in Georgia. All irrigation schemes are managed by the State through its Department of Melioration and Water Resources. Though irrigation remains the responsibility of the State, the land irrigated can be owned either by private farmers or by the State but leased to farmers, cooperatives or agro-firms.

FIGURE 3
Irrigation techniques
Total: 401 290 ha in 2007

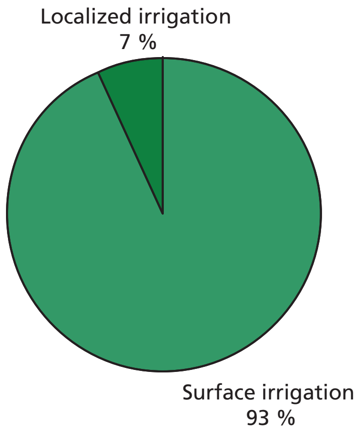


FIGURE 4
Type of irrigation schemes
Total: 401 290 ha in 2007

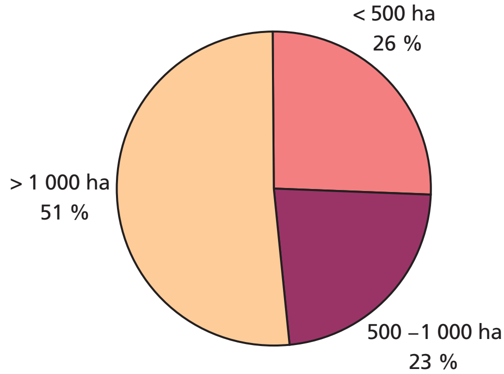


TABLE 3
Irrigation and drainage

Irrigation potential		-	725 000	ha
Irrigation				
1. Full or partial control irrigation: equipped area		2007	401 290	ha
- surface irrigation		2007	372 980	ha
- sprinkler irrigation		2007	0	ha
- localized irrigation		2007	28 310	ha
• % of area irrigated from surface water		2007	100	%
• % of area irrigated from groundwater		2007	0	%
• % of area irrigated from mixed surface water and groundwater		2007	0	%
• % of area irrigated from non-conventional sources of water		2007	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)		1996	31 500	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)		**2007**	**432 790**	**ha**
• as % of cultivated area		2007	40.6	%
• % of total area equipped for irrigation actually irrigated			-	%
• average increase per year over the last 11 years		1996-2007	-0.72	%
• power irrigated area as % of total area equipped		2007	21.9	%
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)		**2007**	**432 790**	**ha**
• as % of cultivated area		2007	40.6	%
Full or partial control irrigation schemes	**Criteria**			
Small-scale schemes	< 500 ha	2007	103 770	ha
Medium-scale schemes		2007	90 350	ha
Large-scale schemes	> 1000 ha	2007	207 170	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		2006	126 060	ha
• Annual crops: total			-	ha
- Wheat			-	ha
- Rice			-	ha
- Barley			-	ha
- Maize			-	ha
- Potatoes			-	ha
- Other annual crops			-	ha
• Permanent crops: total			-	ha
- Fodder			-	ha
- Citrus			-	ha
- Other perennial crops (bananas, olives, grapes, strawberries)			-	ha
Irrigated cropping intensity (on full/partial control irrigation: equipped area)		2006	31.4	%
Drainage - Environment				
Total drained area		1996	164 700	ha
- part of the area equipped for irrigation drained		1996	31 800	ha
- other drained area (non-irrigated)		1996	132 900	ha
• drained area as % of cultivated area			-	%
Flood-protected areas			-	ha
Area salinized by irrigation		2002	113 560	ha
Population affected by water-related diseases			-	inhabitants

The unfavourable location of plots, low soil fertility, the failure of old irrigation and drainage systems, desertification, secondary bogging, salinization and erosion processes contribute to the non-lease and non-transfer of land to private owners. In addition, the slow pace of registering land ownership is due to the fact that the existing system deals with owner registration only, which is an insufficient basis for the full exercise of land ownership rights and the conclusion of subsequent transactions. Moreover, land registration and the process of proving land ownership are time consuming as old Soviet data have to be checked thoroughly (Government of Georgia, 2002).

Role of irrigation in agricultural production, economy and society

At the beginning of 1997, irrigation water charges were introduced in Georgia, at a rate of US$3 per 1 000 m^3. This figure was the same for all schemes in Georgia. The water charges covered about 12 percent of total O&M costs, the government budget covered 15 percent of the total, while the remaining 73 percent was not covered, resulting in the degradation of irrigation systems. In 1996, over 300 000 ha were estimated to be in need of rehabilitation. The current policy is for the government to pay for the O&M of the dams and headworks which have been constructed, while the O&M costs of the distribution and on-farm network are to be paid by irrigation users through a higher water charge.

No recent data for irrigation costs are available. In 1996 the average cost of irrigation development varied between US$3 500 and US$4 500/ha for surface irrigation, and between US$6 500 and 7 200/ha for sprinkler irrigation. Average O&M costs vary between US$55 and US$70/ha per year respectively.

In 2006, the total irrigated crop area was estimated at 126 060 ha, but no details for the different crops are available. In 1986, the major crops cultivated under full or partial control irrigation were fruit trees and grapes, pasture and fodder crops, vegetables, potatoes, wheat, maize and sunflower. Irrigated crop yields compared relatively favourably with rainfed crop yields, although the average difference is very small due to the good climatic conditions in the areas where rainfed agriculture is practiced. In 1986, in the full or partial control irrigation schemes, the average irrigated crop yields were 3.0 tonnes/ha for winter wheat, 2.9 tonnes/ha for maize, 4.8 tonnes/ha for grapes, 5.0 tonnes/ha for fruits and 12 tonnes/ha for potatoes.

Status and evolution of drainage systems

In 1996, the total drained area was estimated at 164 740 ha, consisting mainly of surface drainage. However, the infrastructure deteriorated drastically during the 1990s, reducing the drainage area to 65 000 ha.

Drainage has been developed mainly in the high rainfall region of western Georgia (Kolkhety lowland), on 132 940 ha out of a total of 164 740 ha for the whole country. The total area of the Kolkhety lowland where drainage infrastructure could be developed in the future is about 800 000 ha.

About 31 800 ha of full or partial control irrigation equipped areas are also equipped with a network of surface and subsurface drains (Table 3). About 31 100 ha of the equipped wetland and inland valley bottoms are also power drained. They are located in the coastal regions of west Georgia, in polder systems where electric pumps drain seawater and excess floodwater.

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

Institutions

The main institutions involved in water resources management are:

- The Ministry of Food and Agriculture with: (i) the Department of Melioration and Water Resources, responsible for planning, monitoring, and promoting irrigated agriculture. This department defines the water requirements for irrigation and supervises the management of the irrigation schemes; (ii) the Hydraulic Design Institute (Saktskalproject), responsible for irrigation, drainage, flood control, land reclamation, hydroelectric and water supply schemes design; (iii) the Georgian Scientific Research Institute of Water Management and Engineering Ecology, responsible for research into all issues related to water.

- The Ministry of Environment Protection and Natural Resources with the Centre for Monitoring and Prognostication, responsible for the assessment of surface water quantity, including the Black Sea, as well as groundwater. The Centre unites several departments for monitoring quantity and quality of surface water and groundwater, namely: (i) the Department of Hydrometeorology, responsible for surface water quantity observations (except of the rivers of the Ajara Autonomous Republic and the Black Sea); (ii) the Department of Monitoring of Environmental Pollution, responsible for surface water quality (except of the rivers of the Ajara Autonomous Republic and the Black Sea); (iii) the Black Sea Branch (located in Batumi), responsible for surface water quantity and quality monitoring of the Black Sea and rivers from the Ajara Autonomous Republic.

Water management

During the Soviet period, many administrative units were involved in the management of the same irrigation scheme. With the institutional changes, every scheme is directly managed by one of the 48 administrative units of the Department of Melioration and Water Resources.

Developing an Integrated Water Resources Management Plan for Georgia is a complicated task at this moment, because first new water legislation, based on a basin approach, must be enacted.

Policies and legislation

The policy document “Concept of agrarian policy in Georgia” was adopted by presidential decree in 1997; it covers the following issues relating to irrigation:

- the main irrigation infrastructure will remain in the hands of the State, while the inter-farm distribution will be included in the privatization programme;
- there should be an increase in state investment in irrigation, soil protection, research, selection, breeding information and plant protection services, development of environmental protection for rural infrastructure.

While there is no separate policy document that directly spells out Georgian policy for protecting and managing water availability and quality, the Law on Water does outline a number of key principles that comprise a policy framework (UNECE, 2003). Some of these are:

- water protection is a major element of environmental protection for Georgian citizens, in view of both current and future needs;
- drinking water for the population is the highest priority of all uses;
- both groundwater and surface water are under state control;
- management of water varies according to hydrologic importance;
- a system of “user-polluter pays” is key;
- pollution is not allowed, although a definition of what constitutes pollution is lacking.

There are more than 10 major laws in Georgia that have significant influence on the protection and management of water resources and associated environmental concerns. The most comprehensive is the above Law on Water, which has been in force since October 1997 and was last amended in June 2000. The 96 separate articles of this Law cover a very wide and comprehensive set of issues, such as pollution control policies, protection of drinking water sources, licensing of water use and discharge, categorization and protection of resources, particular measures for the Black Sea, flood control, and many others. All surface water, groundwater and near-coastal water is deemed to be under the control of the national government. Many of the provisions of the Law are supplemented by legislative orders and decrees, as well as by regulations of the Ministry of Environment Protection and Natural Resources, which specify necessary actions in greater detail. The Ministry holds overarching responsibility for implementing the Law on Water, although other ministries are key players on specific topics. The Law is implemented by personnel at the regional or municipal level. The Law on Water does provide for the licensing of water use and the discharge of pollutants, an approach that has been in place since 1999.

The government has prepared the national programme of harmonization of Georgian legislation (including water legislation) to EU legislation (Tsiklauri, 2004).

ENVIRONMENT AND HEALTH

Regardless of the fact that Georgia is a country with abundant fresh water resources, the current situation of the water supply is extremely complicated. This is largely due to anthropogenic contamination, deficit of drinking water and low sanitary standards of the water supply system. About 60 percent of existing water pipelines are depreciated. Their sanitary and technical conditions are unsatisfactory, resulting in frequent accidents and this, in turn, leads to water contamination. Due to water network damages, large quantities of water are lost. According to data for 1999, such losses amounted to 40 percent of the overall quantity of water supplied to households.

Due to the degradation of the water supply and sewerage infrastructure, the quality of drinking water often does not comply with human health and safety standards. Some 38 percent of the water pipeline system of the cities and regions belongs in the high-risk water pipeline category, in which the microbiological contamination index is high. The poor quality of water has resulted in several outbreaks of infectious intestinal diseases and epidemics (Government of Georgia, 2002).

In eastern Georgia there is a salinization problem relating to irrigation. Currently, 59 220 ha are severely salinized and 54 340 ha are moderately salinized. The poor quality of management and infrastructure of the irrigation systems has added to these problems during the past decade (UNECE, 2003).

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

Small-scale irrigation is developing without any subsidies from the government. Groundwater irrigation is likely to increase in the future for small-scale irrigation schemes, but only in western Georgia where the shallow aquifers are located.

Future irrigation development is expected to be on a very limited scale, particularly for large-scale and medium-scale schemes, mainly because of the high opportunity cost and the shortage of funds. Flow regulation through dams would be needed for these schemes, but there is competition between hydropower and irrigation.

Drainage works might be carried out in the future, particularly in the Kolkhety lowland, with attention to ecological and environmental analysis. The eradication of malaria in this area would be one of the goals of these drainage works. However, opponents of this project propose halting land reclamation in the Kolkhety lowland and the creation of a national park.

Donors and international financial institutions have developed projects for the rehabilitation of irrigation and drainage. The “irrigation and drainage community development project”, which started in 2002, is funded by the World Bank.

Finally, legislative acts need to be passed to ensure biodiversity protection and conservation, as well as to envisage the rational use of land resources (forests, water, mineral deposits) during territorial-spatial development planning (Government of Georgia, 2002)

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Iran
(Islamic Republic of)

GEOGRAPHY, CLIMATE AND POPULATION

Geography

The Islamic Republic of Iran covers a total area of about 1.75 million km². The country is bordered by Armenia, Azerbaijan, the Caspian Sea and Turkmenistan to the north, Afghanistan and Pakistan to the east, the Gulf of Oman, the Strait of Hormuz and the Persian Gulf to the south, and Iraq and Turkey to the west. About 52 percent of the country consists of mountains and deserts and some 16 percent of the country has an elevation of more than 2 000 m above sea level. The largest mountain massif is that of the Zagros, which runs from the northwest of the country southwards first to the shores of the Persian Gulf and then continues eastwards till the most south-eastern province. Other mountain ranges run from the northwest to the east along the southern edge of the Caspian Sea. Finally, there are several scattered mountain chains along the eastern frontier of the country. The Central or Interior Plateau is located in between these mountain chains and covers over 50 percent of the country. It is partly covered by a remarkable salt swamp (kavir) and partly by areas of loose sand or stones with stretches of better land near the foothills of the surrounding mountains.

The cultivable area is estimated at about 51 million ha, which is 29 percent of the total area. In 2005 18.1 million ha were cultivated. Of this area, 16.5 million ha consisted of annual crops and 1.6 million ha of permanent crops (Table 1). In 2003, 72.5 percent of the landholders cultivated less than 5 ha, 22.5 percent between 5 and 20 ha, and only 5 percent more than 20 ha.

Climate

The climate of the Islamic Republic of Iran is one of great extremes due to its geographic location and varied topography. The summer is extremely hot with temperatures in the interior rising possibly higher than anywhere else in the world; certainly over 55 °C has been recorded. In winter, however, the great altitude of much of the country and its continental situation result in far lower temperatures than one would expect to find in a country in such low latitudes. Minus Temperatures of –30 °C can be recorded in the northwest and –20 °C is common in many places.

Annual rainfall ranges from less than 50 mm in the deserts to 2 275 mm in Rasht near the Caspian Sea. The average annual rainfall is 228 mm and approximately 90 percent of the country is arid or semi-arid. About 23 percent of the rain falls in spring, 4 percent in summer, 23 percent in autumn and 50 percent in winter.

Population

Total population is about 69.5 million (2005), of which 32 percent are living in rural areas (Table 1). This means that the ratio between urban and rural population has been

ISLAMIC REPUBLIC OF IRAN **FAO - AQUASTAT, 2008**

TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2005	174 515 000	ha
Cultivated area (arable land and area under permanent crops)	2005	18 107 000	ha
• as % of the total area of the country	2005	10.4	%
• arable land (annual crops + temp. fallow + temp. meadows)	2005	16 533 000	ha
• area under permanent crops	2005	1 574 000	ha
Population			
Total population	2005	69 515 000	inhabitants
• of which rural	2005	31.9	%
Population density	2005	39.8	inhabitants/km^2
Economically active population	2005	27 594 000	inhabitants
• as % of total population	2005	39.0	%
• female	2005	30.3	%
• male	2005	69.7	%
Population economically active in agriculture	2005	6 689 000	inhabitants
• as % of total economically active population	2005	24.2	%
• female	2005	44.3	%
• male	2005	55.7	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2007	270 940	million US$/yr
• value added by agriculture (% of GDP)	2007	9	%
• GDP per capita	2005	3 207	US$/yr
Human Development Index (highest = 1)	2005	0.759	
Access to improved drinking water sources			
Total population	2000	94	%
Urban population	2006	99	%
Rural population	2000	84	%

reversed over the last 50 years, the urban population being around 31 percent in 1955 (Mahmoodian, 2001). Average population density is 40 inhabitants/km^2, but ranges from less than 10 in the eastern part of the country up to more than 150 in the Gilan province, located on the Caspian Plain in the north, which is by far the most densely populated region in the country after Tehran province where the capital is located and where the population density reaches 400 inhabitants/km^2. The annual demographic growth rate was estimated at 3.7 percent over the period 1980–1990 and decreased to 0.9 percent over the period 2000–2005.

In 2006, 99 percent of the urban population had access to safe drinking water. In 2000, 84 percent of the rural population had access to safe drinking water. In 2000, 86 and 78 percent of the urban and rural populations respectively had access to improved sanitation.

ECONOMY, AGRICULTURE AND FOOD SECURITY

In 2007 the Gross Domestic Product (GDP) was US$270.9 billion (Table 1). Agriculture accounted for around 9 percent of GDP, while in 1992 it accounted for 23 percent. The economically active population is about 27.6 million (2005) of which 70 percent is male and 30 percent female. In agriculture, 6.7 million inhabitants are economically active of which 56 percent male and 44 percent female.

Agriculture is mostly practiced on small farming units. From 1960 to 1993 the number of farming units increased from 1.8 to 2.8 million units, with the average area per unit decreasing from just over 6 ha to less than 5.5 ha. More than 80 percent of these farming units have a total size of less than 10 ha and even these 10 ha are on average scattered over five different locations. About 5 percent of the agricultural land is used by cooperative companies, consisting of both traditional and modern systems. Usually each cooperative has 8 members with an average size of 40 ha. Commercial companies cover around 14 percent of the agricultural land, mostly located in Khozestan province in the southwest of the country.

WATER RESOURCES AND USE

Water resources

Of the average rainfall volume of 376 km³/year an estimated 66 percent evaporates before reaching the rivers. The total long-term total renewable water resources are estimated at 137.5 km³ of which about 9 km³/year are external water resources (Table 2). Internal renewable water resources are estimated at 128.5 km³/year. Surface runoff represents a total of 97.3 km³/year, of which 5.4 km³/year come from drainage of the aquifers, and groundwater recharge is estimated at about 49.3 km³/year, of which 12.7 km³/year are obtained from infiltration in the river bed, giving an overlap of 18.1 km³/year. The Islamic Republic of Iran receives 6.7 km³/year of surface water from Afghanistan through the Helmand River. The flow of the Araks River, at the border with Azerbaijan, is estimated at 4.63 km³/year. The surface runoff to the sea and to other countries is estimated at 55.9 km³/year, of which 7.5 km³/year to Azerbaijan (Araks) and 10 km³/year from affluents of the Tigris to Iraq. About 24.7 km³/year flows from the Karun into Iraq, but since this is just before it discharges into the sea, it does not count as inflow into Iraq.

The Islamic Republic of Iran is divided into 6 main and 31 secondary catchment areas. The 6 major basins are: the Central Plateau in the centre (Markazi), the Lake Oroomieh basin in the northwest, the Persian Gulf and the Gulf of Oman basin in the west and south, the Lake Hamoon basin in the east (Mashkil Hirmand), the Kara-Kum basin in the northeast (Sarakhs) and the Caspian Sea basin in the north (Khazar) (Figure 1). All these basins, except the Persian Gulf and the Gulf of Oman basin, are interior basins. Almost half of the country's renewable water resources are located in the Persian Gulf and the Gulf of Oman basin, which only covers one fourth of the country (Table 3). On the other hand the Markazi basin, covering over half of the country, has less than one third of the total renewable water resources. With an area

TABLE 2

Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	228	mm/yr
	-	397.9	10^9 m³/yr
Internal renewable water resources (long-term average)	-	128.5	10^9 m³/yr
Total actual renewable water resources	-	137.5	10^9 m³/yr
Dependency ratio	-	6.6	%
Total actual renewable water resources per inhabitant	2005	1 978	m³/yr
Total dam capacity	2006	31 610	10^6 m³
Water withdrawal			
Total water withdrawal	2004	93 300	10^6 m³/yr
- irrigation + livestock	2004	86 000	10^6 m³/yr
- municipalities	2004	6 200	10^6 m³/yr
- industry	2004	1 100	10^6 m³/yr
per inhabitant	2004	1 356	m³/yr
Surface water and groundwater withdrawal	2004	93 100	10^6 m³/yr
• as % of total actual renewable water resources	2004	67.7	%
Non-conventional sources of water			
Produced wastewater	2001	3 075	10^6 m³/yr
Treated wastewater	2001	130	10^6 m³/yr
Reused treated wastewater		-	10^6 m³/yr
Desalinated water produced	2004	200	10^6 m³/yr
Reused agricultural drainage water		-	10^6 m³/yr

of 424 240 km², the Caspian Sea is the largest landlocked water body in the world and its surface lies about 22 metres below sea level.

There are several large rivers, but the only navigable one is the Karun, the others being too steep and irregular. The Karun River, with a total length of 890 km, flows in the southwest of the country to the Shatt al Arab, which is formed by the Euphrates and the Tigris in Iraq after their confluence. The few streams that empty into the Central Plateau dissipate into the saline marshes. All streams are seasonable and variable. Spring floods do enormous damage, while there is little water flow in summer when most streams disappear. Water is however stored naturally underground, finding its outlet in subterranean water canals (qanats) and in springs. It can also be tapped by wells.

FIGURE 1
Major basins in Iran

TABLE 3
Water resources in major basins

Name of basin	Percentage of total area of the country	Percentage of renewable water resources
Khazar	10	15
Persian Gulf and Gulf of Oman	25	46
Lake Oroomieh	3	5
Markazi	52	29
Hamoon	7	2
Sarakhs	3	3
Total for country	**100**	**100**

Dams have always played an important role in harnessing precious Iranian water reserves and the long-term objective of the Islamic Republic of Iran's water resources development plan is based on the control and regulation of water resources through dams. In 2006, 94 large storage dams with a total capacity of 31.6 km³ were operating and 85 large dams with a capacity of 10 km³ were under construction. Aside from hydropower, dams also play an important role in flood control through the routing of floods. Several reservoirs behind the dams would seem to offer good sailing and water-skiing facilities, but have not been used for recreation so far.

In 2001, there were 39 wastewater treatment plants with a total capacity of 712 000 m³/day, treating the wastewater produced by a population of 3.8 million. The wastewater actually treated was around 130 million m³/year (Mahmoodian, 2001). Some 79 treatment plants with a total capacity of 1.917 million m³/day were under construction and 112 treatment plants with a total capacity of 1.590 million m³/day were being studied for completion by the year 2010.

In 2002, the total installed gross desalination capacity (design capacity) in the Islamic Republic of Iran was 590 521 m³/day or almost 215.5 million m³/year (Wangnick Consulting, 2002). The desalinated water produced was around 200 million m³ in 2004.

Water use

In 2004, the total agricultural, municipal and industrial water withdrawal was estimated at about 93.3 km³, of which 40.0 km³ from surface water, 53.1 km³ from groundwater (qanats and wells) and 0.2 km³ desalinated water (Table 2, Table 4 and Figure 2). Groundwater depletion is estimated at 3.8 km³/year. Most of the overexploitation happens in the central basins where less surface water is available. Total surface water and groundwater withdrawal represents almost 68 percent of the total actual renewable water

FIGURE 2
Water withdrawal by source
Total: 93.3 km³ in 2004

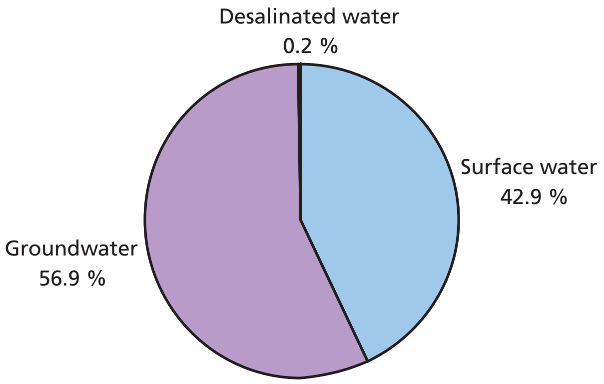
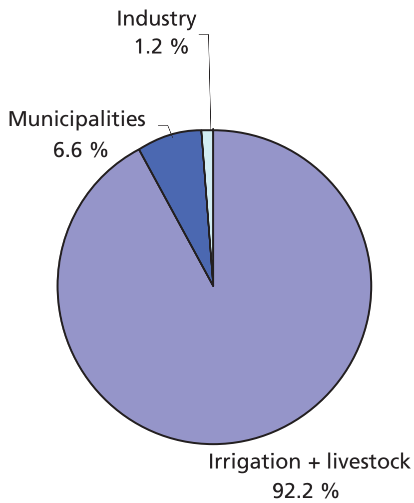


FIGURE 3
Water withdrawal by sector
Total: 93.3 km³ in 2004



resources. Use of non-conventional sources of water is minimal. The treated wastewater is said to be indirectly used in agriculture. In some towns, albeit in a limited form, raw wastewater is used directly for irrigation, resulting in some health-related problems (Mahmoodian, 2001). Agriculture is the main water withdrawal sector, with 86 km^3 in 2004 (Figure 3). Its part of the total water withdrawn remains identical compared to 1993 (around 92 percent). Municipal and industrial water withdrawal amount to 6.2 and 1.1 km^3 respectively. About 16 km^3 of water was used for electrical power generation in 1999.

Groundwater discharge (through wells, qanats and springs) varied from less than 20 km^3/year in the early 1970s to over 74 km^3/year at the beginning of the present millennium (Table 4). The number of wells during that period increased fivefold, from just over 9 000 to almost 45 000.

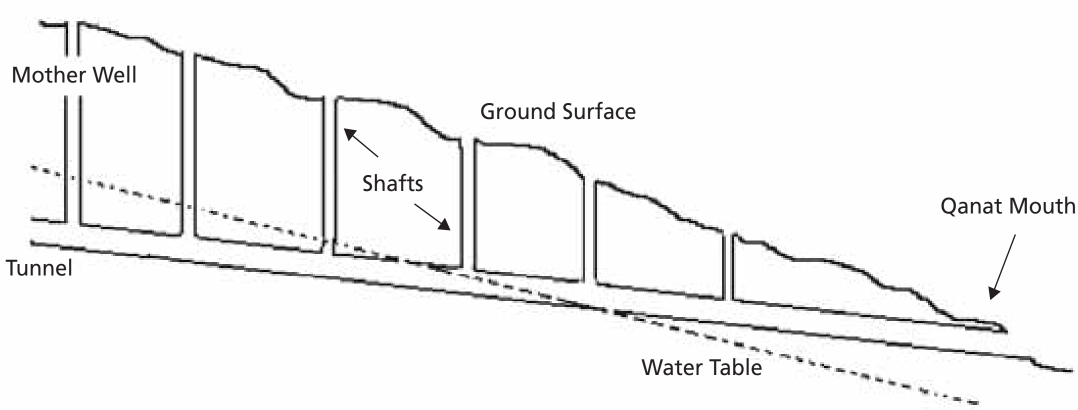
The qanat is a traditional system in the Islamic Republic of Iran for using groundwater. It is a subterranean water collection and conduction device for bringing water from one place to another. It consists of three parts (Figure 4):

i. the mother well dug at the beginning of the qanat where water is available;
ii. access shafts built along the tunnel to provide ventilation and for the removal of debris, at a distance of 20–50 meters and with the depth depending on the depth of the underground tunnel;

TABLE 4
Groundwater discharges in major sub-basins (2001)

name of basin	Wells		Qanats		Springs		Total Discharge (km^3/year)
	Quantity	Discharge (km^3/year)	Quantity	Discharge (km^3/year)	Quantity	Discharge (km^3/year)	
Khazar	130 267	4.39	2 611	0.45	25 404	3.00	7.83
Persian Gulf and Gulf of Oman	97 376	10.08	3 950	1.06	13 529	15.24	26.38
Lake Oroomieh	72 019	1.97	1 540	0.23	943	0.12	2.32
Markazi	155 415	25.93	22 017	5.79	13 681	2.47	34.18
Hamoon	3 873	0.80	2 606	0.40	1 140	0.06	1.26
Sarakhs	9 099	1.73	1 631	0.29	1 215	0.35	2.36
Total	**468 049**	**44.89**	**34 355**	**8.23**	**55 912**	**21.24**	**74.35**

FIGURE 4
The qanat system



iii. the tunnel per se dug from downstream to upstream with a slope gradient of 1/500 to 1/2 500 in order to prevent erosion and siltation, and with a length varying from about 100 metres to 120 km in a qanat in the Yazd region. Its diameter is just enough for a maintenance worker to crawl through.

International water issues

Prior to the Taliban regime in Afghanistan there was an agreed flow of 27 m^3/s (850 million m^3/year) of the Helmand River entering the Islamic Republic of Iran. However during the Taliban regime in Afghanistan (1995–2001), this agreement ceased completely and this caused an economic and environmental disaster in the provinces of Sistan and Baluchistan bordering Afghanistan and Pakistan (Bybordi, 2002). The Helmand River is the longest river in Afghanistan. It stretches 1 150 km from the Hindu Kush mountains about 80 km west of Kabul and crosses southwest through the desert to the Seistan marshes and the Hamun-i-Helmand lake region around Zabol on the Afghan-Iranian border.

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

Water supply has been a constant preoccupation since the beginning of the country's history, thousands of years ago. Its inhabitants learnt to design and implement efficient techniques for harnessing their limited water resources and for irrigation. Apart from the qanat, which was a major source of irrigation and domestic water supply for centuries, Iranians have in the past built dams of various types and weirs. Some of these head control structures, built as long as 1 000 years ago, are still in good condition.

Agricultural land availability is not a major constraint. The major constraint is the availability of water for the development of these lands. The irrigation potential, based on land and water resources, has been estimated at about 15 million ha, or 29 percent of the cultivable area (Table 5). However, this would require optimum storage and water use.

The total area equipped for irrigation is about 8.13 million ha in 2003, compared to 7.26 million ha in 1993. About 62 percent of that area is irrigated by groundwater (Figure 5). Surface irrigation is the main irrigation technology used in the Islamic Republic of Iran, covering 91.4 percent of the area equipped for irrigation (Figure 6). Localized and sprinkler irrigation cover 5.2 and 3.4 percent respectively, compared to only 0.6 percent each in 1993. Almost all pressurized irrigation systems are manufactured in

TABLE 5
Irrigation and drainage

Irrigation potential		**-**	**15 000 000**	**ha**
Irrigation				
1. Full or partial control irrigation: equipped area		2003	8 131 564	ha
- surface irrigation		2003	7 431 564	ha
- sprinkler irrigation		2003	280 000	ha
- localized irrigation		2003	420 000	ha
• % of area irrigated from surface water		2003	37.9	%
• % of area irrigated from groundwater		2003	62.1	%
• % of area irrigated from mixed surface water and groundwater			-	%
• % of area irrigated from non-conventional sources of water			-	%
• area equipped for full or partial control irrigation actually irrigated			-	ha
- as % of full/partial control area equipped			-	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)			-	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)		**2003**	**8 131 564**	**ha**
• as % of cultivated area		2003	46.0	%
• % of total area equipped for irrigation actually irrigated			-	%
• average increase per year over the last 10 years		1993-2003	1.13	%
• power irrigated area as % of total area equipped		1993	32.2	%
4. Non-equipped cultivated wetlands and inland valley bottoms		1993	0	ha
5. Non-equipped flood recession cropping area		1993	10 000	ha
Total water-managed area (1+2+3+4+5)		**2003**	**8 141 564**	**ha**
• as % of cultivated area		2003	46.1	%
Full or partial control irrigation schemes	**Criteria**			
Small-scale schemes	< 10 ha	2003	4 000 000	ha
Medium-scale schemes		2003	3 281 564	ha
large-scale schemes	> 50 ha	2003	850 000	ha
Total number of households in irrigation		2004	2 828 646	
Irrigated crops in full or partial control irrigation schemes				
Total irrigated grain production		1993	10 000 000	metric tons
• as % of total grain production		1993	61	%
Harvested crops				
Total harvested irrigated cropped area		2003	8 592 554	ha
• Annual crops: total		2003	7 258 899	ha
- Wheat		2003	2 634 106	ha
- Rice		2003	628 105	ha
- Barley		2003	607 485	ha
- Maize		2003	275 941	ha
- Other cereals		2003	65	ha
- Sweet potatoes		2003	186 671	ha
- Other roots and tubers		2003	48 758	ha
- Sugar beet		2003	152 875	ha
- Vegetables		2003	563 011	ha
- Pulses		2003	159 716	ha
- Tea		2003	2 934	ha
- Tobacco		2003	10 142	ha
- Cotton		2003	143 233	ha
- Soybeans		2003	56 586	ha
- Groundnuts		2003	647 852	ha
- Fodder		2003	878 181	ha
- Sunflowers		2003	77 781	ha
- Flowers		2003	61 860	ha
- Other annual crops		2003	123 597	ha
• Permanent crops: total		2003	1 333 655	ha
- Sugar cane		2003	63 385	ha
- Bananas		2003	2 889	ha
- Citrus fruit		2003	213 348	ha
- Other perennial crops		2003	1 054 033	ha
Irrigated cropping intensity (on equipped area)		2003	106	%

TABLE 5
Irrigation and drainage (continued)

Drainage - Environment			
Total drained area	2002	1 508 000	ha
- part of the area equipped for irrigation drained	2002	1 508 000	ha
- other drained area (non-irrigated)		-	ha
• drained area as % of cultivated area	2002	8.6	%
Flood-protected areas		-	ha
Area salinized by irrigation	1993	2 100 000	ha
Population affected by water-related diseases		-	inhabitants

the country. The water in the surface irrigation schemes arrives through a combination of gravity and water lifting systems. Most of the dams constructed in the Islamic Republic of Iran are for irrigation purposes with main and secondary canals built downstream, covering a total area of 1.56 million ha and which are called modern systems. The rest of the irrigated areas have traditional canals built by farmers that in many cases have to be rebuilt every year. Small schemes (< 10 ha) cover 50 percent of the total equipped area for irrigation, medium size schemes (10–50 ha) 40 percent and large schemes (>50 ha) 10 percent (Figure 7). Among the holdings practicing irrigation, the average irrigated area is 2.9 ha.

In 1993 non-equipped flood recession cropping was practiced in an area of about 10 000 ha in the southwest of the country.

FIGURE 5
Source of irrigation water
Total: 8 131 564 ha in 2003

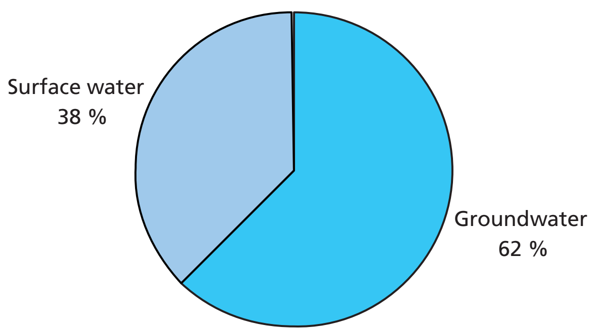
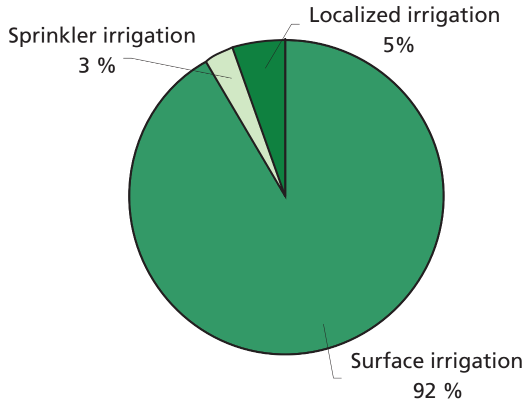


FIGURE 6
Irrigation techniques
Total: 8 131 564 ha in 2003



Role of irrigation in agricultural production, the economy and society

About 98.5 percent of the agricultural land in the Islamic Republic of Iran is under private ownership. Rainfed cultivation is possible in the higher rainfall areas in the northwest, the west and in the littoral zone along the Caspian Sea. About 89 percent of the total agricultural products in the last 5 years have come from the irrigated land.

The total harvested irrigated cropped area was 8 592 554 ha in 2003 (Table 5 and Figure 8). By far the most important harvested irrigated crop is wheat (almost 31 percent of the total harvested irrigated area), followed by fodder (10 percent), groundnuts (7.5 percent), rice (7 percent), barley (7 percent) and vegetables (6.5 percent). Wheat is also by far the most important rainfed crop. In 2003, around 40 percent of the area under wheat was irrigated and 60 percent rainfed. In 1993 the yield for irrigated wheat was estimated at 2.78 tonnes/ha against 0.95 tonnes/ha for rainfed wheat

Crop yields on irrigated land, although generally 2–3 times higher than on rainfed land, are still on the low side by international standards. Water shortage and soil salinity are mentioned among the main causes of this yield gap (Smedema, 2003).

Irrigation efficiency is generally low, 33 percent on average at national level. This causes waterlogging and salinization in the irrigated areas, which are major problems in the Islamic Republic of Iran.

The average cost of surface irrigation development is about $US7 500/ha for public schemes. The cost of sprinkler and localized irrigation for on-farm installations is estimated at $US1 700/ha and US$2 500/ha respectively.

In 1995, the average price of water delivered to farmers by the government was $US0.2 to 0.8 per 1 000 m³, while the cost of groundwater withdrawal was $US5 to 9 per 1 000 m³ and the cost for regulating surface water in existing projects was $US 3 to 5 per 1 000 m³. This means that the government heavily subsidized delivered water, which is probably one of the main reasons for the low irrigation efficiency throughout the country.

FIGURE 7
Type of irrigation schemes
Total: 8 131 564 ha in 2003

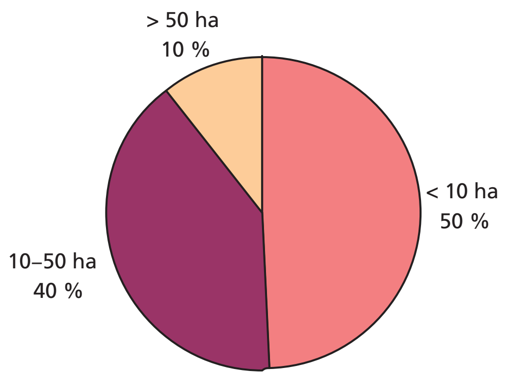
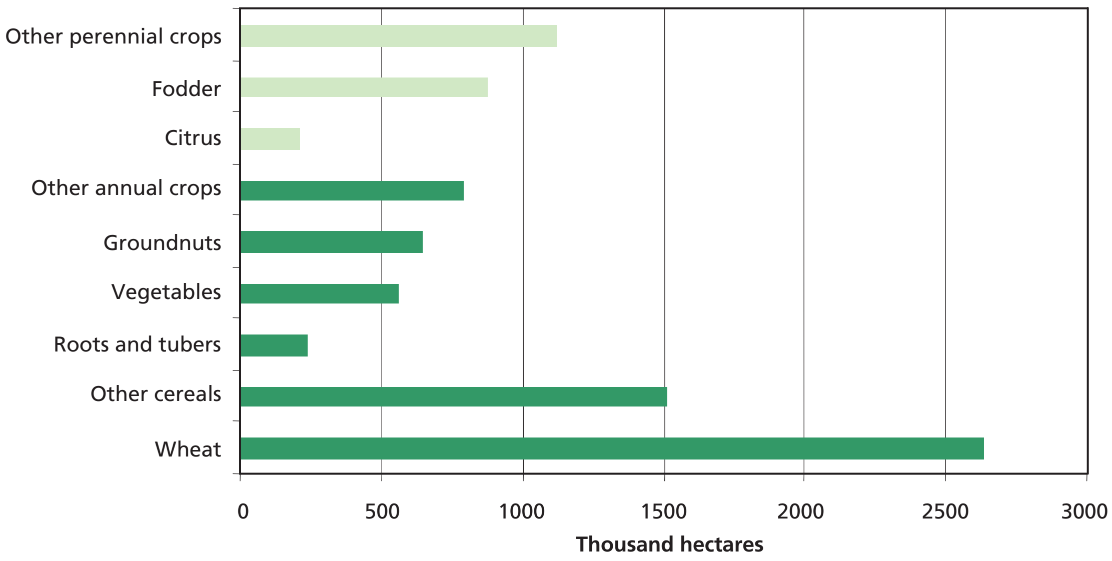


FIGURE 8
Irrigated crops
Total harvested area: 8 592 554 ha in 2003 (cropping intensity on equipped area: 106%)



Status and evolution of drainage systems

Drainage is not as extensive as irrigation is. Almost all modern irrigation systems have surface drainage systems, which cover about 1.5 million ha (Table 5). Subsurface drainage systems have been constructed on a total of 170 000 – 180 000 ha, of which about half is in Khozestan Province in the southwest of the country.

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

Institutions

According to the water legislation, three ministries are directly in charge of water resources assessment and development:

- The Ministry of Energy (MOE) has two responsibilities: energy supplies and water resources. As far as irrigation is concerned, it is in charge of the construction of large hydraulic works, including dams and primary and secondary irrigation and drainage canals for the distribution of water. Within the MOE, the Water Affairs Department (WAD) is responsible for overseeing and coordinating the planning, development, management and conservation of water resources. The WAD consists of the following sections: Water Resources Management Company (WRMC), Provincial Water Authorities (PWA), Irrigation and Drainage Operation and Maintenance Companies (O&M). WRMC is the mother company that manages all water sectors within the MOE except drinking water distribution for rural and urban areas. PWAs are responsible for the water sector in each province including irrigation and drainage development and operation. Drinking water distribution is the responsibility of provincial water and wastewater companies. O&M companies are responsible for modern irrigation and drainage operation and maintenance. 49 percent of the shares of these companies belong to the MOE and 51 percent belong to private sectors. There are 19 O&M companies working under the supervision of the PWAs.
- The Ministry of Agriculture (MOA) is responsible for supervising rainfed and irrigated crop development. It is in charge of subsurface drains, tertiary and quaternary canals as well as farm development and irrigation techniques, planned and operated by the Provincial Agricultural Organizations and the Deputy Ministry for Infrastructure Affairs of the Ministry of Agriculture.
- The Ministry of Jihad-e-Sazandagi (MOJ) deals with watershed management and rural development.

The Islamic Republic of Iran's Department of the Environment (DOE) is responsible for the preparation of the environmental protection policy and the laws, directives and systems necessary for evaluating the impacts of social and economic development projects, particularly irrigation and hydropower projects, on the environment and following up their implementation.

The "Farmers' House" was established in order to protect the rights of the farmers. Its role is to streamline and coordinate the farmers' activities, including their commitments in the fields of farming, fruit growing, animal husbandry, hunting, poultry production, supportive industries and so on.

Water management

Traditionally, the provision of water has been the responsibility of the government. As far as groundwater is concerned, the private sector invests in well drilling after which it is operated and managed by farmers. In recent years there has been a large increase in private sector financing of water projects, especially irrigation and drainage systems. Between 1994 and 1999 the cumulative new private sector capital expenditures in water projects in the Islamic Republic of Iran came to US$84 million. The construction of a total of about 300 000 ha surface irrigation networks has been financed and/or by farmers and the operation of these systems has been or will be transferred to the water user associations (WUAs) upon completion. In addition, the operation of some parts of the old systems has been transferred to the WUAs as pilot projects. These projects are located in Qazvin, Fomanat, Zabol and Khozestan. Another role of the WUAs is to decrease the number of water delivery points and it is also their responsibility to further distribute the irrigation water and collect the fees.

Irrigation development has always featured quite prominently in the Five Year Plans (FYP). In the first FYP (1989–1994) and second FYP (1995–2000), the area under modern irrigation was expanded and additional water resources were mobilized. The third FYP (2000–2005) marked a shift in the country's irrigation development policy. Since further withdrawal of water will be increasingly costly and in future more water needs to be allocated to other water use sectors (drinking water, industry and environment), more attention must be given to water saving measures than to further expansion of the irrigated area: more demand management as opposed to the current supply management practiced, canal and watercourse lining, sprinkling and other types of pressurized field irrigation, land levelling and so on (Smedema, 2003).

Policies and legislation

According to national law all water bodies (rivers, lakes, seas, etc.) are public property and the government is responsible for their management. The first water law after the revolution in the Islamic Republic of Iran was approved in 1982. Based on this law, allocating and issuing permits to use the water for domestic, agricultural and industrial purposes is the responsibility of the MOE. The MOA is appointed to distribute water for agriculture among farmers and collect the water fees. Water and wastewater companies are responsible for the distribution of water for domestic use in urban and rural areas and for collecting fees.

In the traditional irrigation systems, farmers receive their share of water based on their water rights, usually in proportion to the land area. This right to water use is usually measured based on the water delivery time. The water rights are attached to the land and when selling the land the water rights are also transferred to the new owner. Water rights can be rented or traded. Groundwater is mainly private property and it is traded between farmers. Wells can be sold with or without the land. Qanats have shared ownerships. Those who have built the qanat or participate in its maintenance are entitled to use its water. The oldest water rights legislation in the country is about how to use and divide the qanats' water among farmers.

ENVIRONMENT AND HEALTH

Salinity is one of the biggest problems in the Islamic Republic of Iran. The total area affected by salinity and waterlogging is estimated to be about 15.5 million ha or 9.4 percent of the total country area. About 7.32 million ha have saline affected soils. Leaching, built into the irrigation network, has proved to be a successful way to treat these soils. Because of the existing high concentration of calcium in soils, it is possible to treat sodic soils with leaching without using any additive materials. No comprehensive study has been undertaken regarding the extent of irrigation-induced salinity, but it is estimated that over 2 million ha are salt-affected and/or waterlogged.

Although the extent is unknown, water-related diseases are prevalent in some irrigated areas where the water is also used for domestic purposes.

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

The Water Resources Management Policy emphasizes an integrated approach in water resources development to maximize positive impacts and avoid or minimize any negative effects of irrigation development. Based on the country's perspective on water resources, in order to control the overexploitation of groundwater resources, the surface water withdrawal percentage should change from 43 percent at the present to 55 percent. In addition, the country aims at decreasing the agricultural share from 92 percent to 87 percent by increasing water use efficiency. Water productivity is expected to increase from 0.7 kg/m^3 to 1.4 kg/m^3 over the next 20 years. The country plans to develop irrigation for another 1.76 million ha in the next 20 years.

The increasing water shortage in the country has forced many decision-making bodies to consider the reuse of effluent as an appealing option. Among the recent decisions taken by the Expediency Council were the adoption and implementation of general plans for recycling water nationwide. The proposed policies and strategies are as follows (Mahmoodian, 2001):

- Fully satisfy the drinking water demand potential from freshwater, prior to any other use.
- Guarantee future urban water demands by replacing the agricultural water rights to using freshwater (from brooks, rivers, springs well, etc.) with using treated effluents.
- Avoid the use of high quality urban water to create green spaces, and instead allot low quality water for this purpose.
- Cut off water supply to industries which have not taken practical measures for treating and reusing their wastewater.
- Expand research projects for the establishment of reasonable standards for the safe and reliable reuse of wastewater. Replacing freshwater with treated effluents in agriculture necessitates introducing farmers to the positive and economic advantages of using wastewater, and consequently convincing them to exchange freshwater with effluents. This in itself requires research and study on the sanitary, economic and environmental impacts of using wastewater for agriculture and the artificial recharging of groundwater resources.

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Iraq

GEOGRAPHY, CLIMATE AND POPULATION

Geography

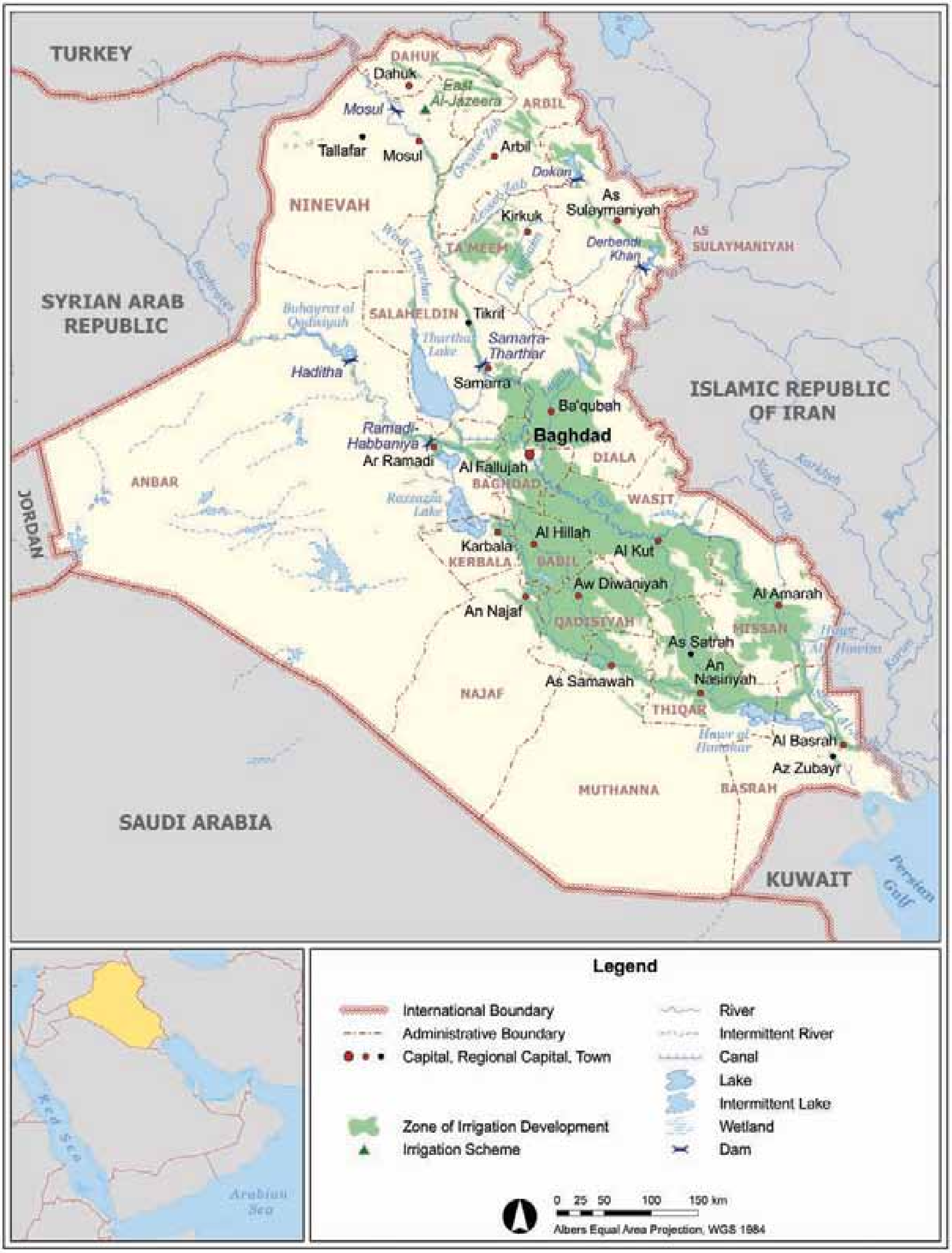
Iraq, with a total area of 438 320 km², is bordered by Turkey to the north, the Islamic Republic of Iran to the east, the Persian Gulf to the southeast, Saudi Arabia and Kuwait to the south, and Jordan and the Syrian Arab Republic to the west. Topographically, Iraq is shaped like a basin, consisting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

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

Climate

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

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



IRAQ **FAO - AQUASTAT, 2008**

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TABLE 1

Basic statistics and population

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

TABLE 2

Water: sources and use

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

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

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

Population

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

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

ECONOMY, AGRICULTURE AND FOOD SECURITY

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

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

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

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

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

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

WATER RESOURCES AND USE

Water resources

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

The area of the Tigris River Basin in Iraq is 253 000 km^2, which is 54 percent of the total river basin area. The average annual runoff is estimated at 21.33 km^3 as it enters Iraq. All the Tigris tributaries are on the left bank. From upstream to downstream:

- the Greater Zab, which originates in Turkey. It generates 13.18 km^3 at its confluence with the Tigris; 62 percent of the total area of this river basin of 25 810 km^2 is in Iraq;
- the Lesser Zab, which originates in the Islamic Republic of Iran and which is equipped with the Dokan Dam (6.8 km^3). The river basin of 21 475 km^2 (of which 74 percent is in Iraqi territory) generates about 7.17 km^3, of which 5.07 km^3 of annual safe yield after construction of the Dokan Dam;
- the Al-Adhaim (or Nahr Al Uzaym), which drains about 13 000 km^2 entirely in Iraq. It generates about 0.79 km^3 at its confluence with the Tigris. It is an intermittent stream subject to flash floods;
- the Diyala, which originates in the Islamic Republic of Iran and drains about 31 896 km^2, 75 percent of which in Iraqi territory. It is equipped with the Derbendi Khan Dam and generates about 5.74 km^3 at its confluence with the Tigris;
- the Nahr at Tib, Dewarege (Doveyrich) and Shehabi rivers, draining together more than 8 000 km^2. They originate in Iranian territory and bring together about 1 km^3 of highly saline waters in the Tigris;
- the Karkheh, the main course of which is in the Islamic Republic of Iran and which, from a drainage area of 46 000 km^2, brings around 6.3 km^3 yearly into Iraq, namely into the Hawr Al Hawiza during the flood season and into the Tigris River during the dry season.

The average annual flow of the Euphrates as it enters Iraq is estimated at 30 km^3, with a fluctuating annual value of between 10 and 40 km^3. Unlike the Tigris, the Euphrates receives no tributaries during its passage in Iraq. About 10 km^3 per year are drained into the Hawr al Harnmar (a marsh in the south of the country). The Shatt Al-Arab is the river formed by the confluence downstream of the Euphrates and the Tigris; it flows into the Gulf after a course of only 190 km. The Karun River, originating in Iranian territory, has a mean annual flow of 24.7 km^3 and flows into the Shatt Al-Arab, to which it brings a large amount of fresh water just before reaching the sea.

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

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

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

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

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

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

Total gross dam capacity of the major dams in the Tigris Basin is estimated at 102.2 km^3, of which on-river dam capacity is 29.4 km^3 (7 dams). The off-river storage Samarra-Tharthar Dam, constructed in 1954, has a capacity of 72.8 km^3. It is filled with Wadi Tharthar waters and, since 1985, also with Euphrates water.

Total gross capacity of the major dams in the Euphrates Basin is estimated at 37.5 km^3, of which on-river dam capacity is 34.2 km^3. The off-river Ramadi-Habbaniya Dam, constructed in 1951, has a capacity of 3.3 km^3; it can be filled with upstream Euphrates waters and drains into the Euphrates downstream (UNEP, 2001a).

There are eleven major wastewater treatment plants in Iraq, three of which are in Baghdad. All the treatment plants are located near rivers (three near the Euphrates, two near the Tigris, two near the Diala, and one each near the Kahla, the Aw Diwaniyah, the Husseinya and the Shatt Basrah). The total treatment capacity of these plants is 650 000 m^3/day. The technologies used are: primary sedimentation, aeration and secondary sedimentation (chlorination) at five plants; primary sedimentation, trickling filtering and chlorination at three plants; primary sedimentation, extended aeration and chlorination at two plants; aeration lagoons and secondary sedimentation at one plant (UNEP, 2001b). Until now, the majority of wastewater after treatment has been discharged into rivers and drainage canals by gravity and there is no definite canal network for wastewater collection.

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

In 2002, the total installed desalination capacity was 384 513 m^3/day. This refers to the installed gross capacity (design capacity) (Wangnick Consulting, 2002).

Water use

In 2000, total water withdrawal was estimated at 66 km^3, of which 79 percent for agricultural purposes, 6.5 percent for domestic supplies and 14.5 percent for industrial use (ESCWA, 2005) (Table 2, Figure 1 and Figure 2).

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

FIGURE 1
Water withdrawal by sector
Total: 66 km^3 in 2000

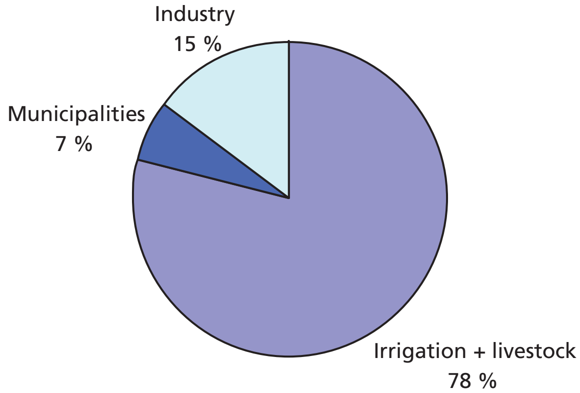
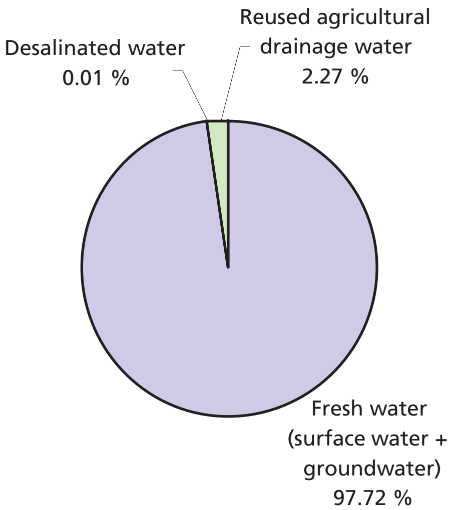


FIGURE 2
Water withdrawal by source
Total: 66 km^3 in 2000



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

International water issues

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

The protocol concerning the regulation of water use of the Euphrates and Tigris rivers dates back to 1946 when Turkey and Iraq agreed that the rivers' control and management depended to a large extent on the regulation of flow in Turkish source areas. At that time, Turkey agreed to begin monitoring the two rivers and to share related data with Iraq. In 1980 Turkey and Iraq further specified the nature of the earlier protocol by establishing a Joint Technical Committee on Regional Waters. After a bilateral agreement in 1982, the Syrian Arab Republic joined the committee. Turkey has unilaterally guaranteed to allow 15.75 km^3/year (500 m^3/s) of water of the Euphrates across the border to the Syrian Arab Republic, but no formal agreement has been reached so far on the sharing of the Euphrates water. According to an agreement between the Syrian Arab Republic and Iraq (1990), Syria agrees to share the Euphrates water with Iraq on a 58 percent (Iraq) and 42 percent (Syria) basis, which corresponds to a flow of 9 km^3/year at the border with Iraq when using the figure of 15.75 km^3/year from Turkey. Up to now, there has been no global agreement between the three countries concerning the Euphrates waters (FAO, 2004).

The construction of the Ataturk Dam, one of the projects of GAP completed in 1992, has been widely portrayed in the Arab media as a belligerent act, since Turkey began the process of filling the Ataturk Dam by shutting off the river flow for a month (Akanda *et al*, 2007). Both the Syrian Arab Republic and Iraq accused Turkey of not informing them about the cut-off, thereby causing considerable harm. Iraq even threatened to bomb the Euphrates dams. Turkey countered that its co-riparians "had been informed in time that river flow would be interrupted for a period of one month, due to technical necessity" (Kaya, 1998). Turkey returned to previous flow-sharing agreements after the dam became operational, but the conflicts were never fully resolved as downstream demands had increased in the meantime (Akanda *et al*, 2007).

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

As shown, a number of crises have occurred in the Euphrates-Tigris Basin, partly due to lack of communication, conflicting approaches, unilateral development, and inefficient water management practices. The Arab countries have long accused Turkey of violating international water laws with regard to the Euphrates and the Tigris rivers. Iraq and the

Syrian Arab Republic consider these rivers to be international and thus claim a share of their waters. Turkey, in contrast, refuses to concede the international character of the two rivers and only speaks of the rational utilization of transboundary waters. According to Turkey, the Euphrates becomes an international river only after it joins the Tigris in lower Iraq to form the Shatt al-Arab, which then serves as the border between Iraq and the Islamic Republic of Iran until it reaches the Gulf only 193 km further downstream. Furthermore, Turkey is the only country in the Euphrates Basin to have voted against the United Nations Convention on the Law of Non-navigational Uses of International Watercourses. According to Turkey, if signed, the law would give the lower riparians "a veto right" over Turkey's development plans. Consequently, Turkey maintains that the Convention does not apply to it and is therefore not legally binding (Akanda *et al*, 2007). Problems regarding sharing water might arise between Turkey, the Syrian Arab Republic and Iraq, since according to different scenarios full irrigation development by the countries in the Euphrates-Tigris river basins would lead to water shortages and solutions will have to be found at basin level through regional cooperation.

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

In April 2008, Turkey, the Syrian Arab Republic and Iraq decided to cooperate on water issues by establishing a water institute consisting of 18 water experts from each country to work towards the solution of water-related problems among the three countries. The institute will conduct its studies at the facilities of the Atatürk Dam, the biggest dam in Turkey, and plans to develop projects for the fair and effective use of transboundary water resources (Yavuz, 2008).

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

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

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

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

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

TABLE 3

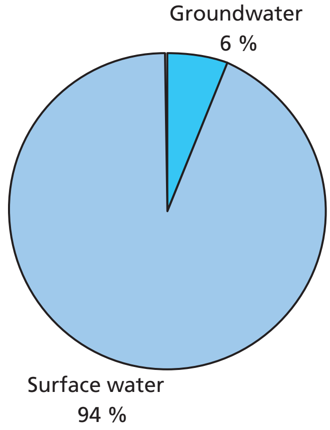
Irrigation and drainage

Irrigation potential	2007	5 554 000	ha
Irrigation			
1. Full or partial control irrigation: equipped area	1990	3 525 000	ha
- surface irrigation		-	ha
- sprinkler irrigation		-	ha
- localized irrigation	1994	8 000	ha
• % of area irrigated from surface water	1990	93.8	%
• % of area irrigated from groundwater	1990	6.2	%
• % of area irrigated from mixed surface water and groundwater		-	%
• % of area irrigated from non-conventional sources of water		-	%
• area equipped for full or partial control irrigation actually irrigated	1997	3 404 000	ha
- as % of full/partial control area equipped		-	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)		-	ha
3. Spate irrigation		-	ha
Total area equipped for irrigation (1+2+3)	**1990**	**3 525 000**	**ha**
• as % of cultivated area	1990	59	%
• % of total area equipped for irrigation actually irrigated		-	%
• average increase per year over the last ... years		-	%
• power irrigated area as % of total area equipped		-	%
4. Non-equipped cultivated wetlands and inland valley bottoms		-	ha
5. Non-equipped flood recession cropping area		-	ha
Total water-managed area (1+2+3+4+5)	**1990**	**3 525 000**	**ha**
• as % of cultivated area	1990	59	%
Full or partial control irrigation schemes **Criteria**			
Small-scale schemes < ha		-	ha
Medium-scale schemes		-	ha
large-scale schemes > ha		-	ha
Total number of households in irrigation		-	
Irrigated crops in full or partial control irrigation schemes			
Total irrigated grain production		-	metric tons
• as % of total grain production		-	%
Harvested crops			
Total harvested irrigated cropped area	1998	2 428 000	ha
Annual crops: total	1998	2 068 000	ha
- Wheat	1998	717 000	ha
- Rice	1998	126 000	ha
- Barley	1998	785 000	ha
- Maize	1998	60 000	ha
- Millet	1998	3 000	ha
- Sorghum	1998	3 000	ha
- Other cereals	1998	1 000	ha
- Potatoes	1998	26 000	ha
- Pulses	1998	26 000	ha
- Vegetables	1998	226 000	ha
- Tobacco	1998	2 000	ha
- Cotton	1998	19 000	ha
- Soybean	1998	1 000	ha
- Sunflower	1998	49 000	ha
- Sesame	1998	23 000	ha
- Other annual crops	1998	1 000	ha
Permanent crops: total	1998	360 000	ha
- Sugar cane	1998	3 000	ha
- Citrus	1998	72 000	ha
- Other perennial crops	1998	285 000	ha
Irrigated cropping intensity (on full/partial control area actually irrigated)	1998	71	%

TABLE 3
Irrigation and drainage (continued)

Drainage - Environment		
Total drained area	-	ha
- part of the area equipped for irrigation drained	-	ha
- other drained area (non-irrigated)	-	ha
• drained area as % of cultivated area	-	%
Flood-protected areas	-	ha
Area salinized by irrigation	-	ha
Population affected by water-related diseases	-	inhabitants

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



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

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

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

Role of irrigation in agricultural production, economy and society

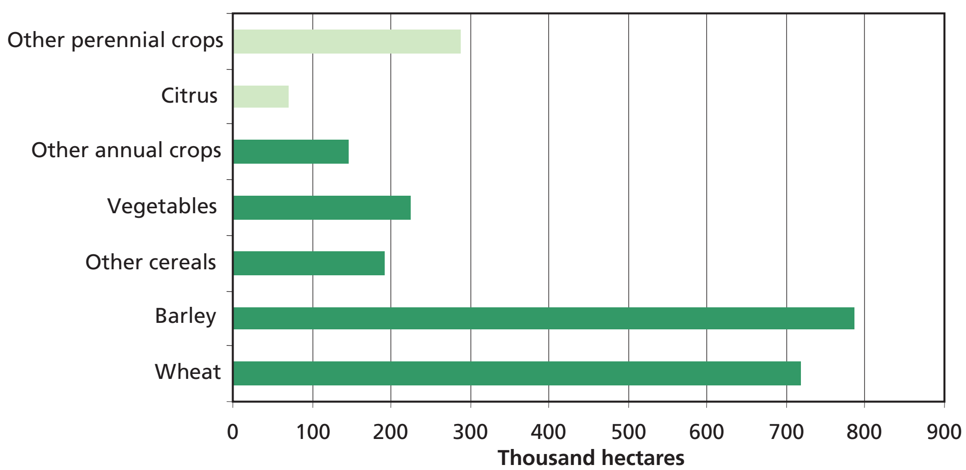
During the 1980s the State attempted to foster private sector investment in Iraq's agriculture. Oil revenues were used to acquire western technology and to lavish government subsidies on the sector. The government distributed high-yielding seeds and invested heavily in the irrigation infrastructure.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

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

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

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

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



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

Status and evolution of drainage systems

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

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

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

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

Institutions

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

Policies and legislation

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

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

ENVIRONMENT AND HEALTH

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

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

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

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

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

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

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

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

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

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Israel

GEOGRAPHY, CLIMATE AND POPULATION

Geography

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

The country is divided into four regions:

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

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

ISRAEL **FAO - AQUASTAT, 2008**

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TABLE 1
Basic statistics and population

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

Climate

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

Population

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

ECONOMY, AGRICULTURE AND FOOD SECURITY

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

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

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

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

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

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

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

WATER RESOURCES AND USE

Water resources

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

- Lake Kinneret or Lake Tiberias (the Sea of Galilee), which divides the upper and lower portions of the Jordan River system, is the only natural freshwater lake in Israel. It has traditionally provided about a third of the country's domestic, agricultural and industrial water requirements. Lake Tiberias' catchment area is 2 730 km^2 and the surface area of the lake is 165 km^2 with an estimated storage volume of 710 million m^3. Lake Tiberias is the lowest freshwater lake in the world. The total average annual inflow of water into Lake Tiberias amounts to 1 km^3, of which some 250 million m^3 serve consumers in the region, about 450 million m^3 are withdrawn from the lake to serve consumers throughout the country by means of the National Water Carrier and about 300 million m^3 are lost by evaporation. The water level has been traditionally regulated between 209 m and 213 m below sea level.

- The Coastal Aquifer is a sandstone aquifer which extends along 120 kilometres of the Mediterranean coastline. It is naturally recharged by precipitation and artificially recharged by water from the National Water Carrier, effluents and excess irrigation water percolating from agricultural, industrial and domestic land uses as well as from streams and wadis. The aquifer is also a valuable storage basin since sandstone layers hold water efficiently. It has a mean annual recharge of 250 million m^3 in addition to 50 million m^3 of agricultural drainage water.
- The Mountain Aquifer (Yarkon-Taninim) is a limestone aquifer which underlies the foothills in the centre of the country. The basin is comprised of three subaquifers: the Western Basin, known as the Yarkon Taninim Aquifer, flows north and westward and discharges in the Taninim Springs on the Mediterranean coast while the Northeastern and Eastern Basins discharge in the Beit Shean Springs and the Jordan Rift Valley and Dead Sea. The Yarkon Taninim Aquifer is regenerated by precipitation with average annual renewable recharges of about 350 million m^3.
- Relatively smaller aquifers are located in Western Galilee, Eastern Galilee, the Jordan Rift, and the Arava valley.

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

TABLE 3
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	435	mm/yr
	-	9.0	10^9 m^3/yr
Internal renewable water resources (long-term average)	-	0.75	10^9 m^3/yr
Total actual renewable water resources	-	1.78	10^9 m^3/yr
Dependency ratio	-	57.87	%
Total actual renewable water resources per inhabitant	2005	265	m^3/yr
Total dam capacity		-	10^6 m^3
Water withdrawal			
Total water withdrawal	2004	1 954	10^6 m^3/yr
- irrigation + livestock	2004	1 129	10^6 m^3/yr
- municipalities	2004	712	10^6 m^3/yr
- industry	2004	113	10^6 m^3/yr
• per inhabitant	2004	296	m^3/yr
Surface water and groundwater withdrawal	2004	1 552	10^6 m^3/yr
• as % of total actual renewable water resources	2004	87.2	%
Non-conventional sources of water			
Produced wastewater	2005	450	10^6 m^3/yr
Treated wastewater	2005	283	10^6 m^3/yr
Reused treated wastewater	2002	262	10^6 m^3/yr
Desalinated water produced	2007	140	10^6 m^3/yr
Reused agricultural drainage water		-	10^6 m^3/yr

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

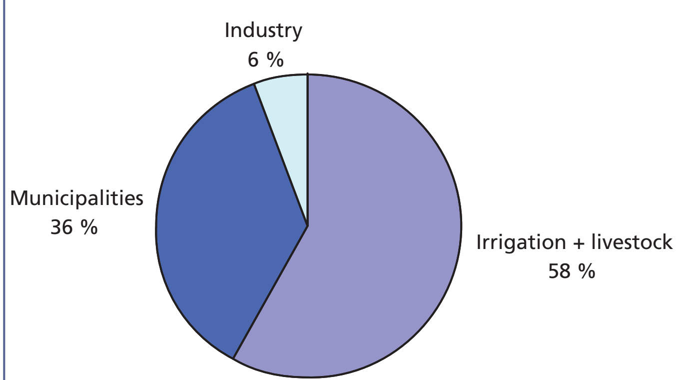
Mekorot, Israel's national water supply company, has built and operated small- and medium-size desalination facilities in the southern part of the country since the 1960s. Eilat at the southern tip of the country by the Red Sea was the first city to use desalination. Some 29 small plants generate 25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

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

Water use

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

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

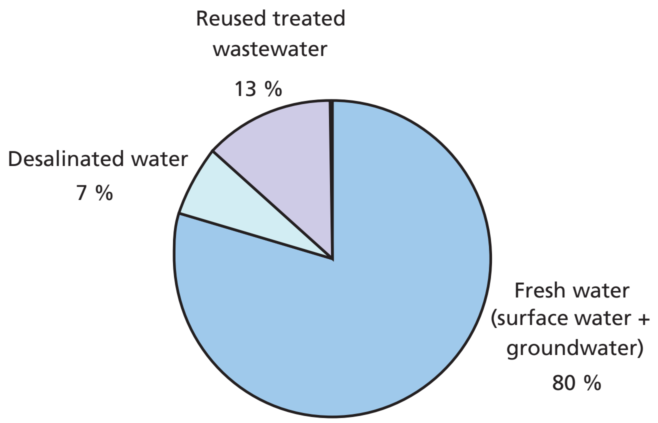


Successive years of drought have dramatically lowered water levels in all of the main reservoirs. In fact, 1998/99 was the worst drought year in Israel for the past 100 years. The following years were also characterized by less than average rainfall which led to a shortfall of some 0.5 million m³ in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

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

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

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



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

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

International water issues

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

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

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

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

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

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

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

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

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

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

FIGURE 3
Irrigation techniques
Total 225 000 ha in 20044

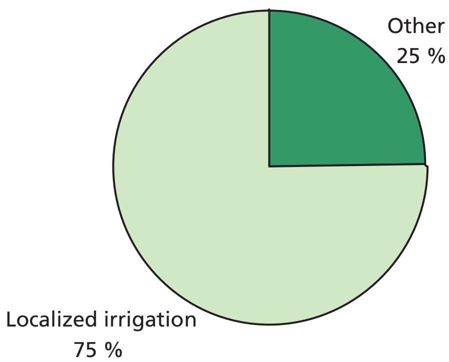


TABLE 5
Irrigation and drainage

Irrigation potential			**-**	**ha**
Irrigation				
1. Full or partial control irrigation: equipped area		2004	225 000	ha
- surface irrigation			-	ha
- sprinkler irrigation			-	ha
- localized irrigation		2004	168 750	ha
• % of area irrigated from surface water			-	%
• % of area irrigated from groundwater			-	%
• % of area irrigated from mixed surface water and groundwater			-	
• % of area irrigated from mixed non-conventional sources of water			-	%
• area equipped for full or partial control irrigation actually irrigated			-	ha
- as % of full/partial control area equipped			-	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)			-	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)		**2004**	**225 000**	**ha**
• as % of cultivated area			57	%
• % of total area equipped for irrigation actually irrigated			-	%
• average increase per year over the last 7 years		1997-2004	2.1	%
• power irrigated area as % of total area equipped			-	%
4. Non-equipped cultivated wetlands and inland valley bottoms			-	ha
5. Non-equipped flood recession cropping area			-	ha
Total water-managed area (1+2+3+4+5)		**2004**	**225 000**	**ha**
- as % of cultivated area			57	%
Full or partial control irrigation schemes	**Criteria:**			
Small-scale schemes	< ha		-	ha
Medium-scale schemes			-	ha
large-scale schemes	> ha		-	ha
Total number of households in irrigation			-	
Irrigated crops in full or partial control irrigation schemes				
Total irrigated grain production (wheat and barley)			-	metric tons
- as % of total grain production			-	%
Harvested crops				
Total harvested irrigated cropped area		2002	181 570	ha
• Annual crops: total		2000	117 190	ha
- Field crops		2000	64 030	ha
- Vegetables (including potatoes)		2000	37 670	ha
- Melons		2000	10 060	ha
- Cotton		2000	11 000	
- Chickpeas		2000	7 500	
- Flowers (including garden plants)		2000	5 430	ha
• Permanent crops: total		2000	73 060	ha
Irrigated cropping intensity (on full/partial control area actually irrigated)			-	%
Drainage – Environment				
Total drained area		1987	100 000	ha
- part of the area equipped for irrigation drained		1987	100 000	ha
- other drained area (non-irrigated)		1987	0	ha
• drained area as % of cultivated area			-	%
Flood-protected areas			-	ha
Area salinized by irrigation		1993	27 820	ha
Population affected by water-related diseases			-	inhabitants

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

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

	Unit	1949	1970	1997	2001	2004
Total cultivated land	1 000 ha	165	411	410	-	380
Cultivated land under irrigation	1 000 ha	30	172	194	-	225
Water consumption	10^6 m^3	257	1 340	1 287	1 021	1 129
Potable water	10^6 m^3	-	-	-	563	601
Recycled and brackish water	10^6 m^3	-	-	-	458	527

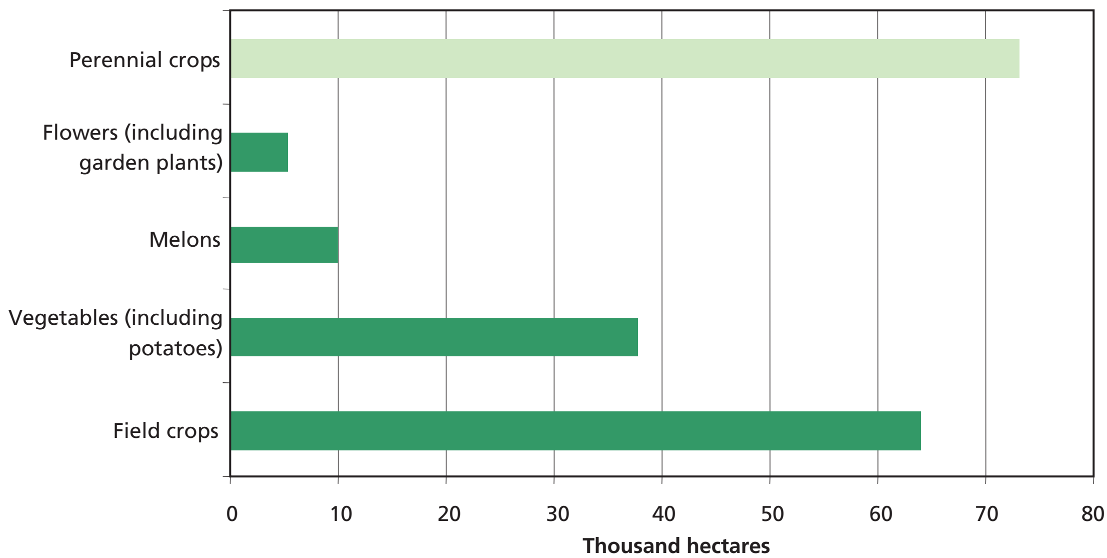
to about 6 800 ha in 2005, with 4 000 ha for vegetables and 2 800 ha for floriculture, representing an average annual growth of 5 to 8 percent. The average farm size is 4 ha for vegetable production and 1.2 ha for flower production (MARD, 2006).

Role of irrigation in agricultural production, the economy and society

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

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

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



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

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

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

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

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

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

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

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

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

Status and evolution of drainage systems

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

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

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

Institutions

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

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

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

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

Water management

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

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

Finances

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

Policies and legislation

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

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

ENVIRONMENT AND HEALTH

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

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

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

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

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

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

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

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

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

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

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

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

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Jordan

GEOGRAPHY, CLIMATE AND POPULATION

Geography

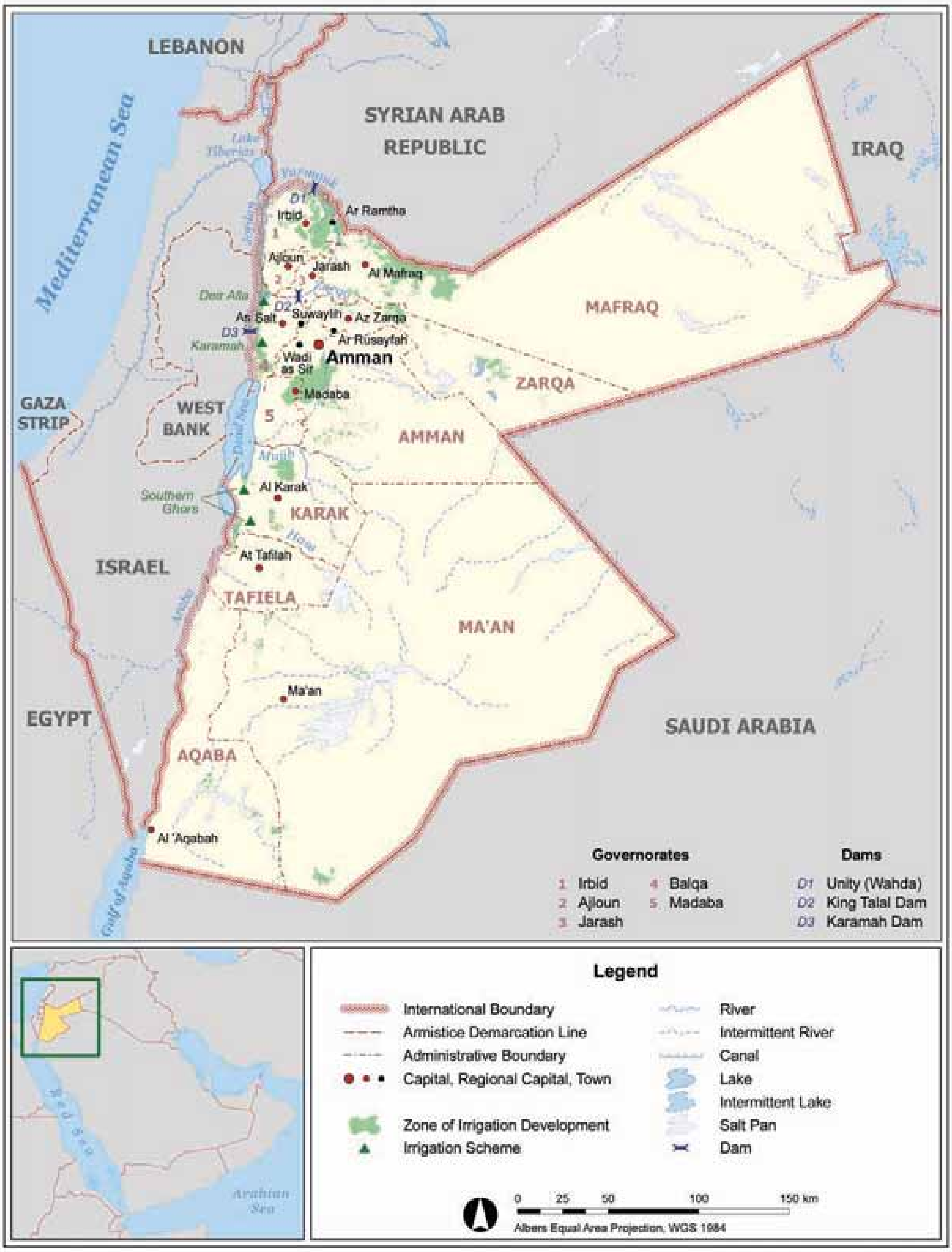
Jordan, with a total area of about 88 780 km², lies to the east of the Jordan River and is divided into twelve administrative governorates: Amman, Zarqa, Irbid, Mafraq, Ajloun, Balqa, Madaba, Karak, Tafileh, Ma'an and Aqaba. It is bordered to the north by the Syrian Arab Republic, to the northeast by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

The country can be divided into four physiographic regions:

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

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

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



JORDAN **FAO - AQUASTAT, 2008**

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TABLE 1
Basic statistics and population

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

Climate

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

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

Population

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

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

ECONOMY, AGRICULTURE AND FOOD SECURITY

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

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

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

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

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

WATER RESOURCES AND USE

Water resources

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

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

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

TABLE 2
Water: sources and use

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

groundwater aquifers. Total internal renewable groundwater resources have been estimated at 450 million m³/year, of which 253 million m³/year constitute the base flow of the rivers. Groundwater resources are concentrated mainly in the Yarmouk, Amman–Zarqa and Dead Sea basins. The safe yield of renewable groundwater resources is estimated at 275.5 million m³/year. At present most of it is exploited at maximum capacity, in some cases beyond safe yield. Of the twelve groundwater basins, six are being overexploited, four are balanced and two are underexploited. Overexploitation of groundwater resources has degraded water quality and reduced exploitable quantities, resulting in the abandonment of many municipal and irrigation water-well fields, such as in the area of Dhuleil. The main non-renewable aquifer presently exploited is the Disi aquifer (sandstone fossil) in southern Jordan, with a safe yield estimated at 125 million m³/year for 50 years. Other non-renewable water resources are found in the Jafer Basin, for which the annual safe yield is 18 million m³. The Water Authority of Jordan estimates that the total safe yield of fossil groundwater is 143 million m³/year for 50 years.

Ten dams have been constructed in the last five decades with a total capacity of around 275 million m³. The main dam is the King Talal Dam on the Zarqa River, with a total capacity of 80 million m³. The Unity Dam on the Yarmouk River shared between Jordan and the Syrian Arab Republic will be completed in 2007 and will have a total reservoir capacity of 110 million m³. All the dams, except the Karamah Dam on Wadi Mallaha, are built on the Side Wadis with their outlets to JRV and are used to store floods and base flows, regulate water and release it for irrigation. According to the water annex in the Jordanian–Israeli treaty, a regulating dam was built on the Yarmouk River downstream of the diversion point of KAC. Another dam should be built in the lower water course of the Jordan River on the border between Jordan and Israel. The dam capacity will be 20 million m³.

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

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

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

Water use

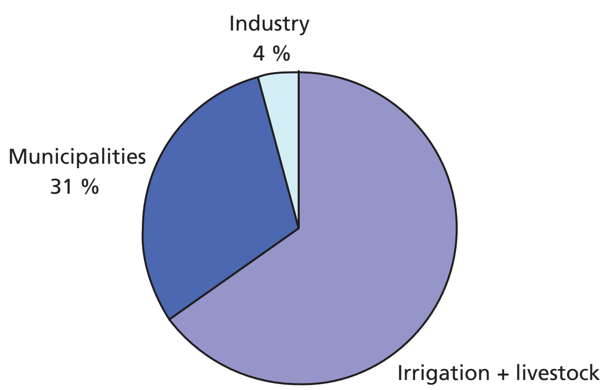
Water withdrawal varies according to the year. It was around 866 and 941 million m^3 in 2004 and 2005 respectively. In 2005, agricultural water withdrawal accounted for 65 percent of the total water withdrawal and water withdrawal for domestic and industrial purposes accounted for 31 and 4 percent respectively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

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

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

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

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

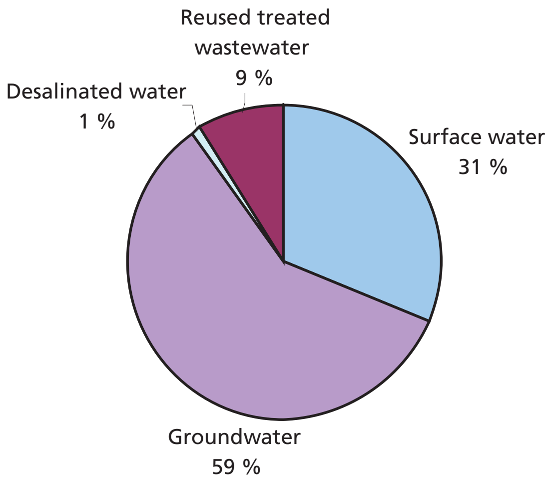


water is generally reused for on-site irrigation (MWI, 2002).

International water issues

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

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



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

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

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

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

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

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

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

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

TABLE 3
Irrigation and drainage

Irrigation potential			**85 000**	**ha**
Irrigation				
1. Full or partial control irrigation: equipped area		2004	78 860	ha
- surface irrigation		2004	13 860	ha
- sprinkler irrigation		2004	1 000	ha
- localized irrigation		2004	64 000	ha
• % of area irrigated from surface water		2004	30.9	%
• % of area irrigated from groundwater		2004	53.3	%
• % of area irrigated from mixed surface water and groundwater			-	%
• % of area irrigated from mixed non-conventional sources of water		2004	15.9	%
• area equipped for full or partial control irrigation actually irrigated		2004	72 009	ha
- as % of full/partial control area equipped		2004	91.3	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)			-	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)		**2004**	**78 860**	**ha**
• as % of cultivated area		2004	26.8	%
• % of total area equipped for irrigation actually irrigated		2004	91.3	%
• average increase per year over the last 9 years		1995-2004	-0.89	%
• power irrigated area as % of total area equipped			-	%
4. Non-equipped cultivated wetlands and inland valley bottoms			-	ha
5. Non-equipped flood recession cropping area			-	ha
Total water-managed area (1+2+3+4+5)		**2004**	**78 860**	**ha**
• as % of cultivated area		2004	26.8	%
Full or partial control irrigation schemes	**Criteria**			
Small-scale schemes	< 100 ha	2004	37 500	ha
Medium-scale schemes		2004	6 000	ha
large-scale schemes	> 1 000 ha	2004	35 360	ha
Total number of households in irrigation			-	
Irrigated crops in full or partial control irrigation schemes				
Total irrigated grain production (wheat and barley)			-	metric tons
• as % of total grain production			-	%
Harvested crops				
Total harvested irrigated cropped area		2004	99 029	ha
• Annual crops: total		2004	43 909	ha
- Wheat		2004	1 676	ha
- Barley		2004	684	ha
- Potatoes		2004	3 483	ha
- Pulses		2004	927	ha
- Vegetables		2004	30 946	ha
- Other annual crops		2004	6 193	ha
• Permanent crops: total		2004	55 120	ha
- Bananas		2004	1 900	ha
- Citrus		2004	6 638	ha
- Other perennial crops (mainly olives, date palm, grapes)		2004	46 582	ha
Irrigated cropping intensity (on full/partial control area actually irrigated)		2004	138	%
Drainage - Environment				
Total drained area		2005	10 506	ha
- part of the area equipped for irrigation drained		2005	10 506	ha
- other drained area (non-irrigated)			-	ha
• drained area as % of cultivated area		2005	3.9	%
Flood-protected areas			-	ha
Area salinized by irrigation		1989	2 280	ha
Population affected by water-related diseases			-	inhabitants

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

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

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

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

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

FIGURE 3
Irrigation techniques
Total: 78 860 ha in 2004

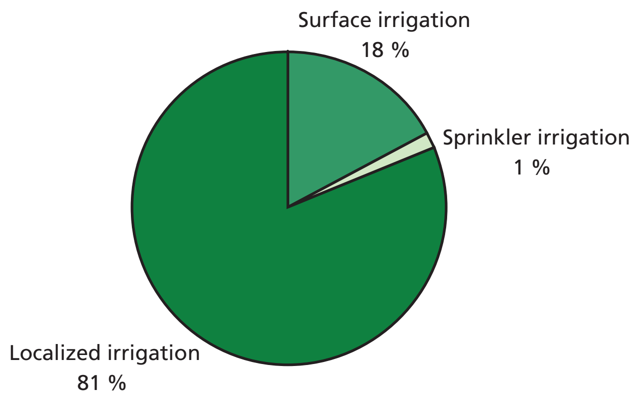
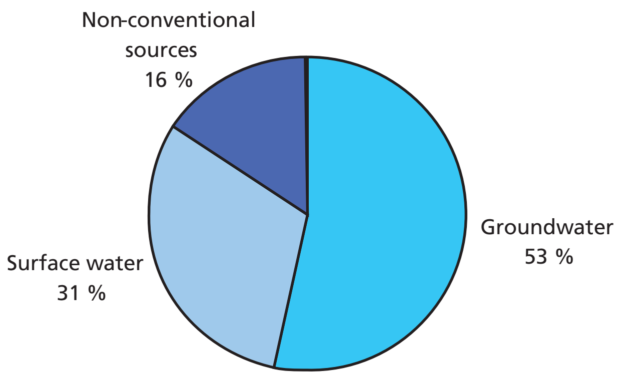
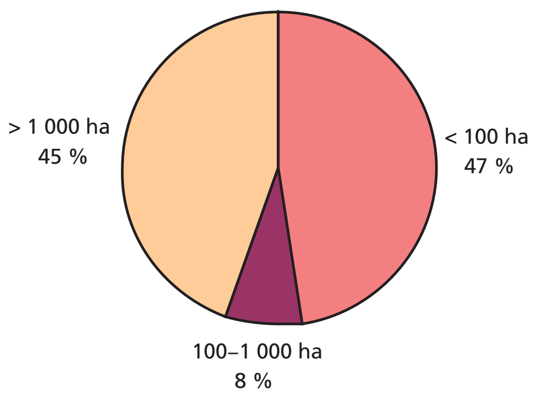


FIGURE 4
Source of irrigation water
Total: 78 860 ha in 2004



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

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



Role of irrigation in agricultural production, economy and society

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

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

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

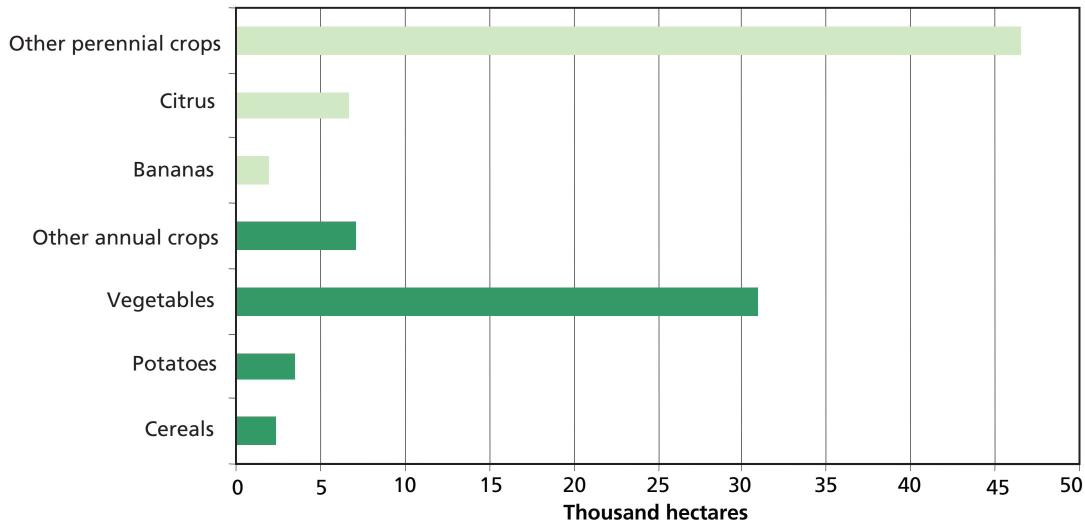
The government and the private sector work together to encourage farmers to adopt localized and sprinkler irrigation methods. Around 85 and 90 percent of

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

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

From the annual report of the Ministry of Agriculture

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



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

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

Status and evolution of drainage systems

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

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

Institutions

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

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

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

The main concerns of the MWI are:

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

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

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

The WAJ is responsible for:

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

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

Water management

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

The main entities involved in irrigation water management are:

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

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

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

Between 2005 and 2006, the International Programme for Technology and Research in Irrigation and Drainage (IPTRID) carried out the Project Design and Management Training Programme (PDM) for Professionals in the Water Sector in some countries of the Near East such as Jordan. The objective of the programme is to strengthen participants' capacities in developing more effective and efficient projects to address pressing water issues in the region (FAO, 2008).

Finances

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

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

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

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

Policies and legislation

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

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

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

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

Environment and health

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

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

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

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

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

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

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

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

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

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

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

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

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

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

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

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Kuwait

GEOGRAPHY, CLIMATE AND POPULATION

Geography

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

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

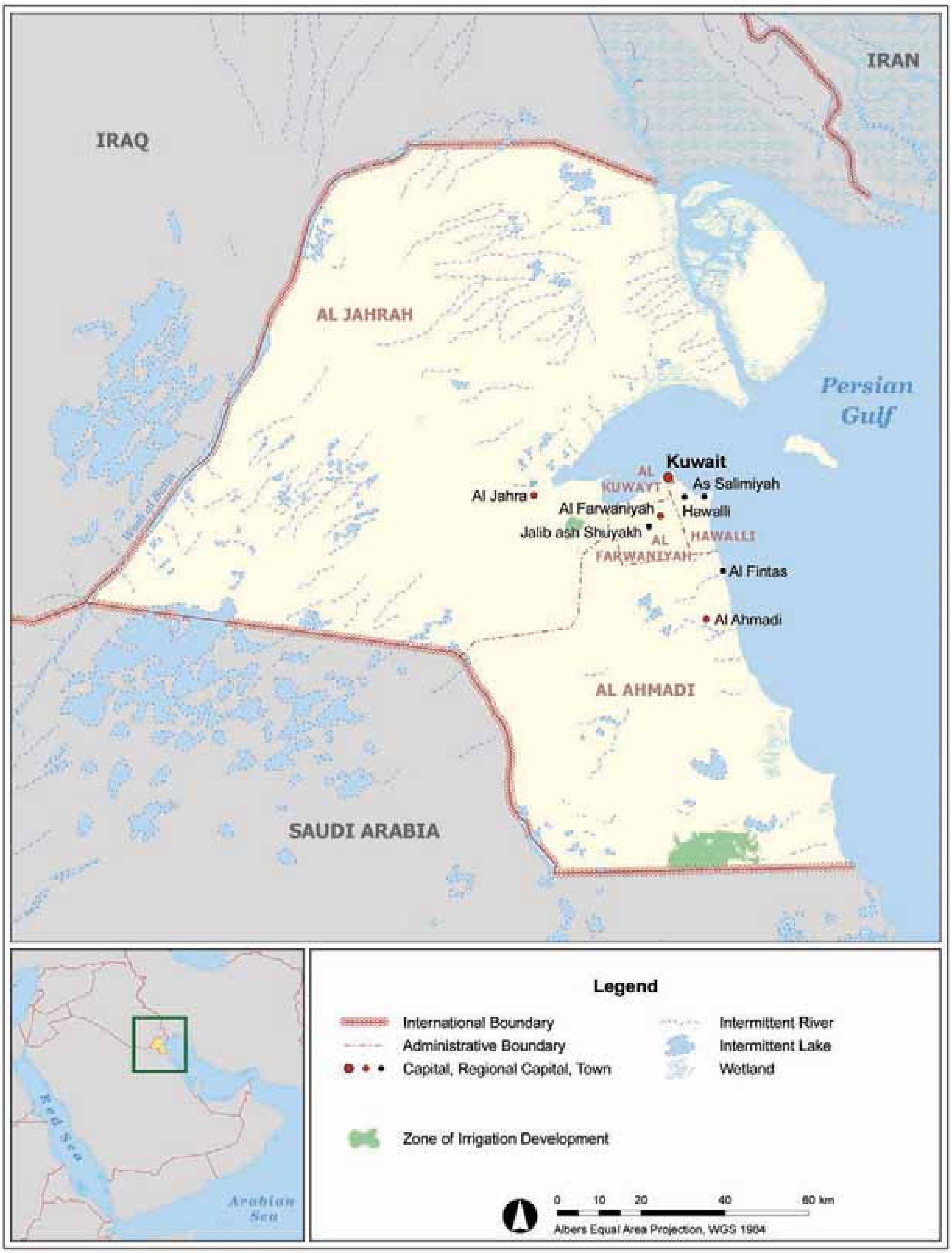
About 154 000 ha have been judged as potentially cultivable land. However, it is almost completely covered by permanent pasture. Estimates for crop production potential vary between 25 000 and 37 500 ha, mainly located in: i) the Al Wafra area near the southern border where there are an estimated 1 495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

Climate

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

Population

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



KUWAIT

FAO - AQUASTAT, 2008

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TABLE 1
Basic statistics and population

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

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

ECONOMY, AGRICULTURE AND FOOD SECURITY

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

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

WATER RESOURCES AND USE

Water resources

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

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

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

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

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

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	121	mm/yr
	-	2.16	10⁹ m³/yr
Internal renewable water resources (long-term average)	-	0	10⁹ m³/yr
Total actual renewable water resources	-	0.02	10⁹ m³/yr
Dependency ratio	-	100	%
Total actual renewable water resources per inhabitant	2005	7.4	m³/yr
Total dam capacity		-	10⁶ m³
Water withdrawal			
Total water withdrawal	2002	913.2	10⁶ m³/yr
- irrigation + livestock	2002	491.9	10⁶ m³/yr
- municipalities	2002	400.5	10⁶ m³/yr
- industry	2002	20.8	10⁶ m³/yr
per inhabitant	2002	375	m³/yr
Surface water and groundwater withdrawal	2002	415	10⁶ m³/yr
• as % of total actual renewable water resources	2002	2 075	%
Non-conventional sources of water			
Produced wastewater	2003	244	10⁶ m³/yr
Treated wastewater	2005	250	10⁶ m³/yr
Reused treated wastewater	2002	78	10⁶ m³/yr
Desalinated water produced	2002	420.2	10⁶ m³/yr
Reused agricultural drainage water		-	10⁶ m³/yr

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

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

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

Water use

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

TABLE 3
Current and projected treated wastewater production in Kuwait

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

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

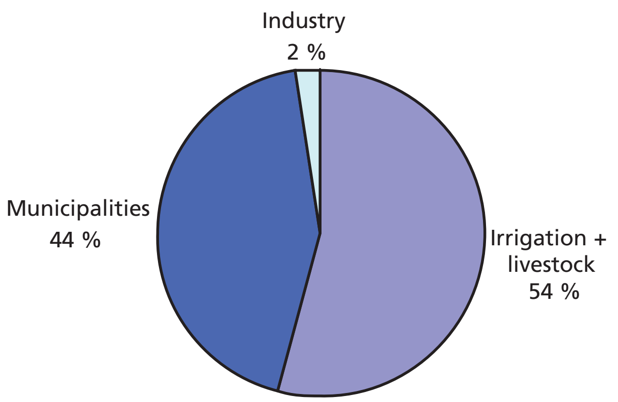
TABLE 4
Water resources availability and use in 2002 (million m³/yr)

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

TABLE 5
Water use in 2002 (million m³/yr)

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

FIGURE 1
Water withdrawal by sector
Total: 0.913 km³ in 2002



54 percent of the water withdrawn was used for agriculture, 44 percent for municipal purposes and 2 percent for industrial purposes (Figure 1). Of the 492 million m³ withdrawn for agriculture, 80 percent was used for productive agriculture, 9 percent for landscape greening and 11 percent for garden watering (but it also includes some non-drinking uses at household level). Of the water withdrawn for productive agriculture, 300 million m³ is brackish water from private farms' boreholes at Al Abdali and Al Wafra (based on 12 hours operation and 270 days/year with an average discharge of 40 m³/h per well). 66 million m³ are treated wastewater effluent (50 percent tertiary treatment and 50 percent more advanced treatment).

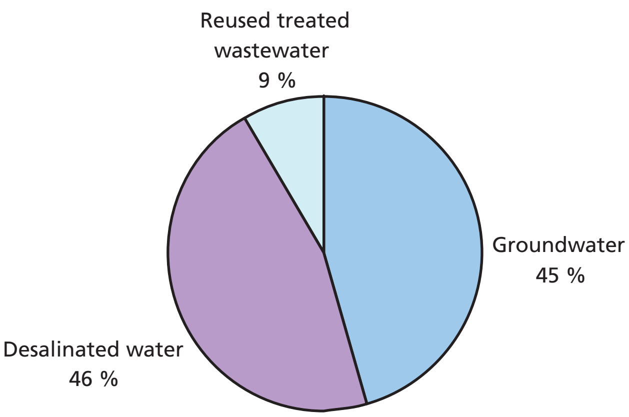
Fresh groundwater withdrawal amounts to 255 million m³/year, leading to an extraction of more than 12 times the annual groundwater inflow (20 million m³) (Figure 2). Farmers are only allowed to withdraw water from the Kuwait group aquifer and there were about 1 767 wells in 1994. The water used for livestock purposes is pumped by the Ministry of Electricity and Water (MEW) from the Damman group aquifer through deep artesian wells. Continued heavy extraction was estimated to have led to a decline in the groundwater level of 200 metres by the year 2000.

Overdrafting of brackish groundwater over the past decades has led to high drawdown and at times even depletion as well as increased salinity levels. Its use for agriculture is limited to plant species that tolerate high salinity levels. As an example, in 1985 crop irrigation was being carried out by pumping 53–67 million m³ of brackish groundwater per year from the well fields in Al Wafra and Abdali-Um Nigga. Existing yield, estimated potential yield, and water salinity of each well field at that time are shown in Table 6 (UNU, 1995).

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

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

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



IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

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

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

There are three types of farming in the irrigation sector:

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

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

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

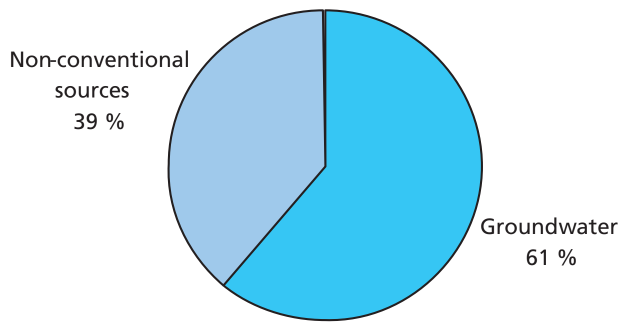
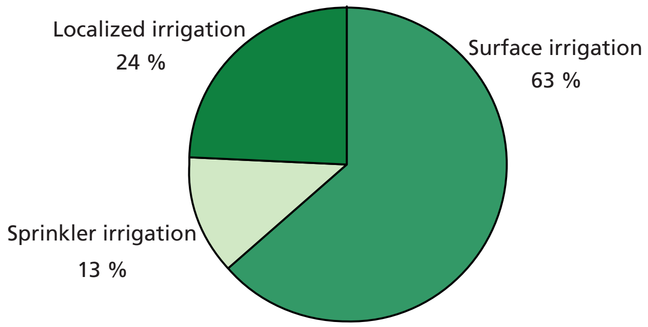


FIGURE 4
Irrigation techniques
Total: 4 770 ha in 1994



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

Role of irrigation in agricultural production, the economy and society

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

There are no water charges for groundwater use. Farmers are charged for desalinated water use and the charge varies from US$0.9/m³ for small schemes to US$1.5/m³ for large schemes. The treated sewage water charge is US$0.07/m³.

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

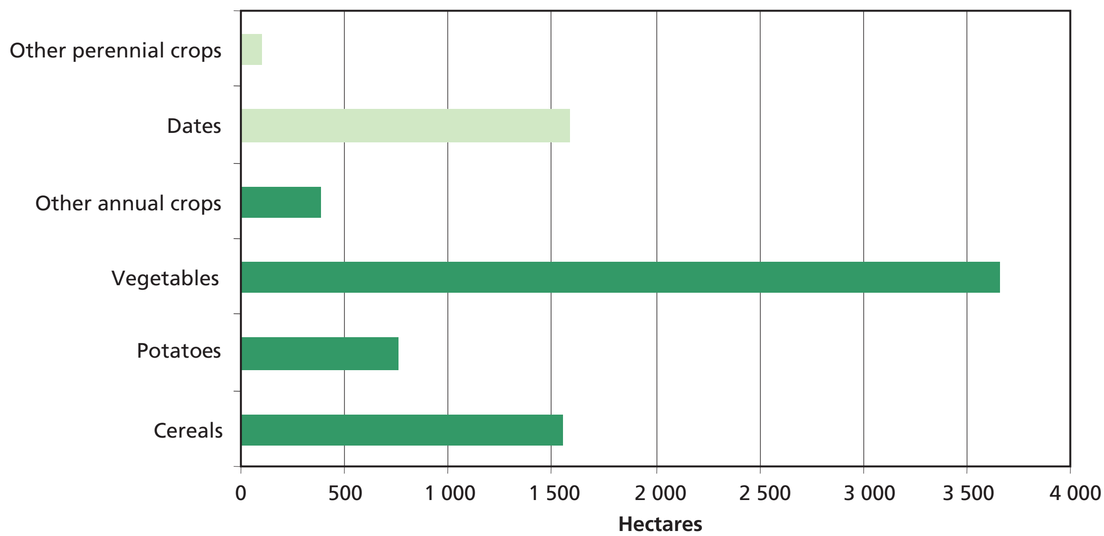
Status and evolution of drainage systems

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

TABLE 7
Irrigation and drainage

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

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



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

Institutions

The main institutions involved in water resources management are:

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

Water management

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

Finances

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

ENVIRONMENT AND HEALTH

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

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

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

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

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

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

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Lebanon

GEOGRAPHY, CLIMATE AND POPULATION

Geography

Lebanon, with a total area of 10 400 km^2, is situated east of the Mediterranean Sea and bordered by the Syrian Arab Republic to the north and east and by Israel to the south. It is a mountainous country, stretching about 60 km in width from west to east and about 225 km along the Mediterranean coast from north to south. About 8 percent is covered by forest and Mediterranean brushwood.

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

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

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

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

Climate

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

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

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

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

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

TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2005	1 040 000	ha
Cultivated area (arable land and area under permanent crops)	2005	328 000	ha
• as % of the total area of the country	2005	31.5	%
• arable land (annual crops + temp fallow + temp. meadows)	2005	186 000	ha
• area under permanent crops	2005	142 000	ha
Population			
Total population	2005	3 577 000	inhabitants
• of which rural	2005	12	%
Population density	2005	343.9	inhabitants/km^2
Economically active population	2005	1 337 000	inhabitants
• as % of total population	2005	37.4	%
• female	2005	30.4	%
• male	2005	69.6	%
Population economically active in agriculture	2005	35 000	inhabitants
• as % of total economically active population	2005	2.6	%
• female	2005	40	%
• male	2005	60	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2007	24 000	million US$/yr
• value added in agriculture (% of GDP)	2007	6	%
• GDP per capita	2005	6 011	US$/yr
Human Development Index (highest = 1)	2005	0.772	
Access to improved drinking water sources			
Total population	2006	100	%
Urban population	2006	100	%
Rural population	2006	100	%

Population

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

ECONOMY, AGRICULTURE AND FOOD SECURITY

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

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

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

WATER RESOURCES AND USE

Water resources

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

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

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

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

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

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

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

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

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

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

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

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

Water use

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

TABLE 2
Water: sources and use

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

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

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

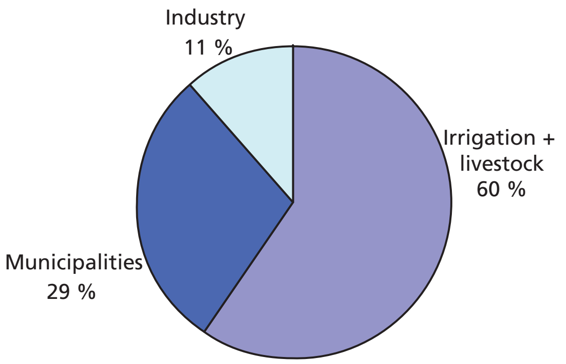
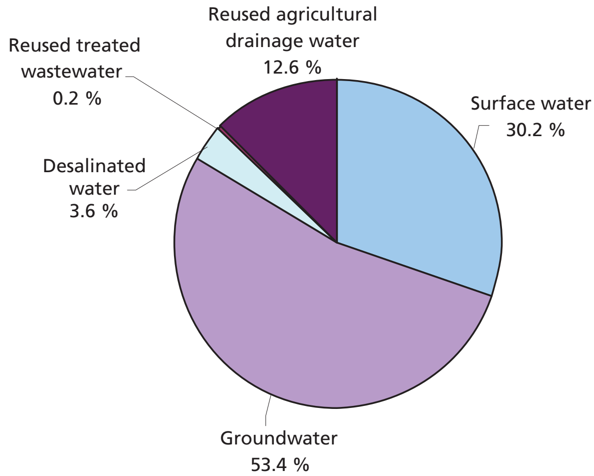


FIGURE 2
Water withdrawal by source
Total: 1.310 km³ in 2005



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

International water issues

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

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

TABLE 3
Irrigation and drainage

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

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

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

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

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

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

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

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

FIGURE 3
Irrigation techniques
Total: 90 000 ha in 2000

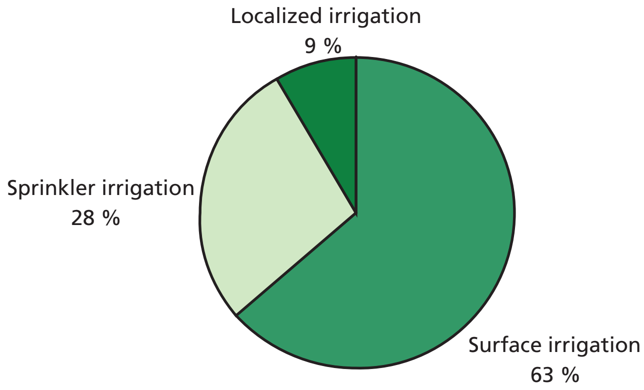


FIGURE 4
Source of irrigation water
Total: 90 000 ha in 2000

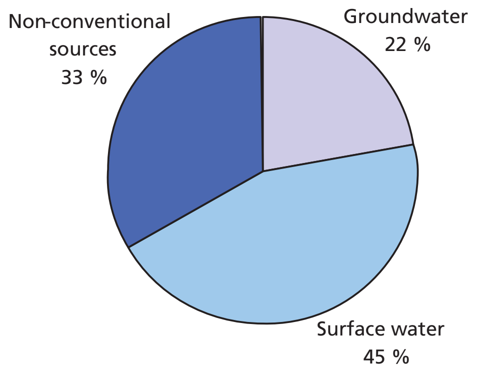
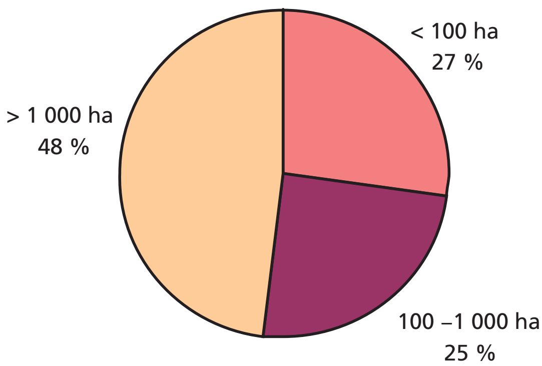


FIGURE 5
Type of irrigation schemes
Total: 90 000 ha in 2000



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

Role of irrigation in agricultural production, economy and society

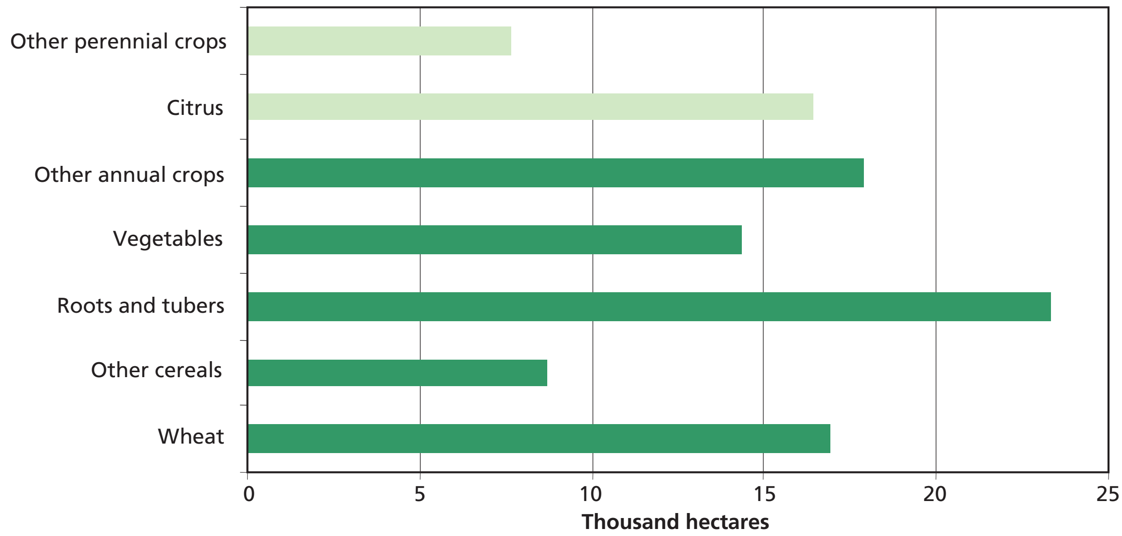
In 2003, the harvested irrigated area was 105 293 ha, half of which (51 percent) was in the Bekaa Valley (MOA and FAO, 2000). Annual crops represent 77 percent of the total harvested irrigated area. The main irrigated crops are cereals (24 percent, mainly wheat), potatoes (18 percent), citrus (16 percent)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

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

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

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

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



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

Status and evolution of drainage systems

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

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

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

Institutions

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

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

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

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

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

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

Water management

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

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

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

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

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

Finances

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

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

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

Policies and legislation

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

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

ENVIRONMENT AND HEALTH

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

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

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

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

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

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

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

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

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Occupied Palestinian Territory

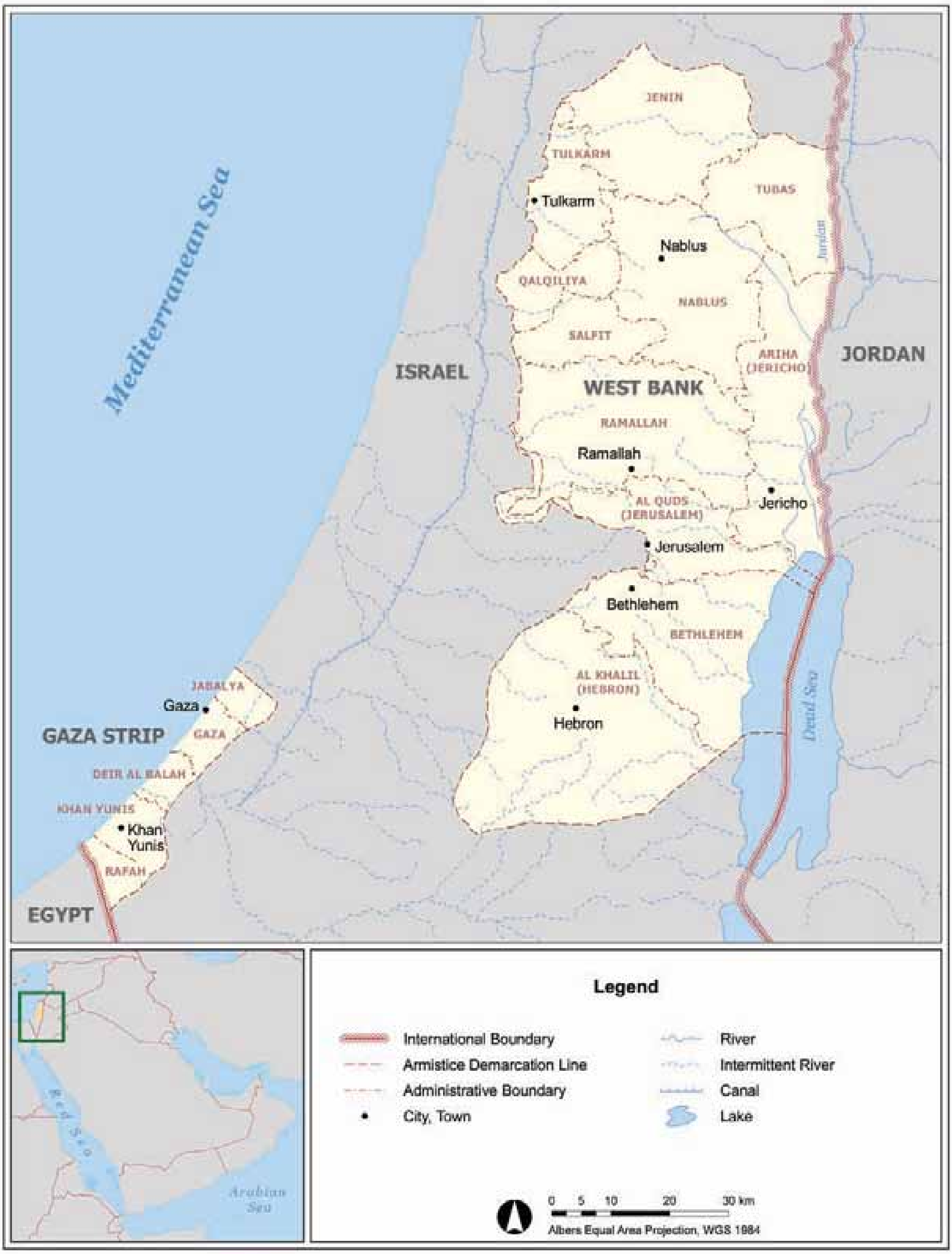
GEOGRAPHY, CLIMATE AND POPULATION

Geography

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

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

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



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

Disclaimer

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TABLE 1
Basic statistics and population in the Occupied Palestinian Territory

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

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

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

Climate

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

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

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

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

Population

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

ECONOMY, AGRICULTURE AND FOOD SECURITY

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

TABLE 2
Basic statistics and population in the West Bank

Physical areas			
Area of the territory	2005	565 500	ha
Cultivated area (arable land and area under permanent crops)	1998	166 702	ha
• as % of the total area of the territory	1998	29.5	%
• arable land (annual crops + temp. fallow + temp. meadows)	1998	61 219	ha
• area under permanent crops	1998	105 483	ha
Population			
Total population	2005	2 302 000	inhabitants
• of which rural	2005	47.0	%
Population density	2005	407.1	inhabitants/km²
Economically active population	-	-	inhabitants
• as % of total population	-	-	%
• female	-	-	%
• male	-	-	%
Population economically active in agriculture	-	-	inhabitants
• as % of total economically active population	-	-	%
• female	-	-	%
• male	-	-	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	-	-	million US$/yr
• value added in agriculture (% of GDP)	-	-	%
• GDP per capita	-	-	US$/yr
Human Development Index (highest = 1)	-	-	
Access to improved drinking water sources			
Total population	-	-	%
Urban population	-	-	%
Rural population	-	-	%

TABLE 3
Basic statistics and population in the Gaza Strip

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

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

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

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

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

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

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

WATER RESOURCES AND USE

Water resources

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

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

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

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

TABLE 4
Water: sources and use in the West Bank

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

TABLE 5
Water: sources and use in the Gaza Strip

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

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

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

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

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

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

Water use

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

TABLE 6
Water withdrawal in the Occupied Palestinian Territory

Water withdrawal			
Total water withdrawal	2005	418	10^6 m³/yr
- irrigation + livestock	2005	189	10^6 m³/yr
- municipalities	2005	200	10^6 m³/yr
- industry	2005	29	10^6 m³/yr
• per inhabitant	2005	113	m³/yr
Surface water and groundwater withdrawal	2005	408	10^6 m³/yr
• as % of total actual renewable water resources	2005	48.7	%

on wells. In 2005, 125 million m³ of the water withdrawn for irrigation came from wells (40 million m³ in the West Bank and 85 million m³ in the Gaza Strip) and the remaining 49 million m³ came from springs in the West Bank. In 2005, groundwater accounted for 408 million m³ and reused treated wastewater accounted for 10 million m³ (Figure 4 and Figure 5).

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

FIGURE 1
Water withdrawal in the Occupied Palestinian Territory
Total 0.418 km³ in 2005

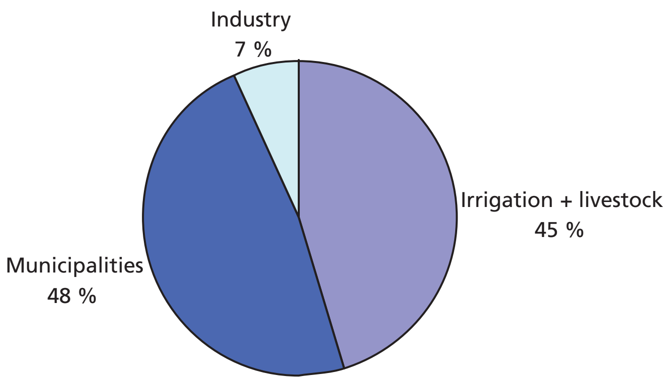
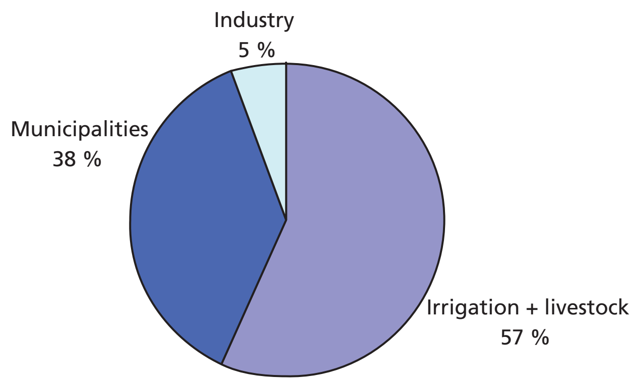


FIGURE 2
Water withdrawal by sector in the West Bank
Total: 0.157 km³ in 2000



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

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

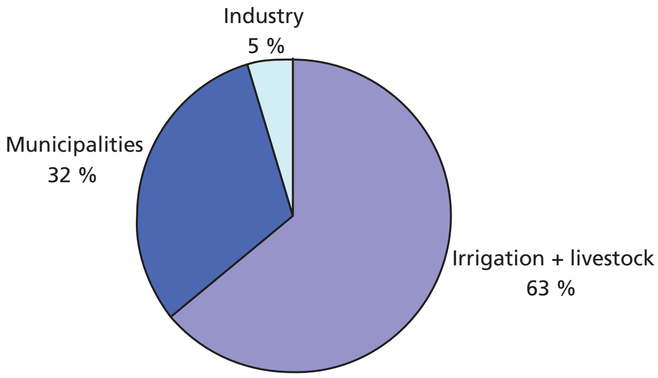


FIGURE 4
Water withdrawal by source in the Occupied Palestinian Territory
Total: 0.418 km³ in 2005

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

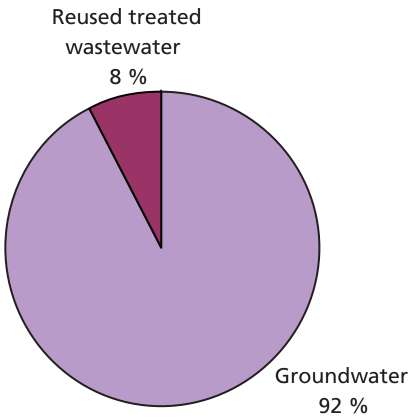
Since the current water extraction from wells cannot be increased in order to maintain a balance between water recharge and extraction, and the spring water flow is basically influenced by the prevailing rainfall, the only way to achieve an early increase in the total water available is through improving the conveyance systems to avoid losses through seepage and evaporation and improving on-farm application and water management practices. It is estimated that improvements in water management applications could reduce amount of water needed for irrigation by around 20 million m^3/year. Attention also needs to be focused on crops with a higher return per m^3 of water utilized. Crops such as bananas and citrus fruits among others have a low return per m^3 of water utilized. Greenhouse crops on the other hand, produced during the winter months with lower evapotranspiration requirements, return higher dividends per m^3 of water utilized. Attention also needs to be focused on the potential use of tertiary treated sewage water for agriculture, the potential development of the Eastern Aquifer with a yield of about 80 million m^3/year (as indicated in the Oslo Accords) as well as the possible desalination of brackish water existing in both the Gaza Strip and the West Bank and currently estimated at 90 million m^3/year.

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

International water issues

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

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



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

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

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

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

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

TABLE 7
Irrigation and drainage in the West Bank

Irrigation potential			**61 000**	**ha**
Irrigation				
1. Full or partial control irrigation: equipped area		2003	12 600	ha
- surface irrigation		-	-	ha
- sprinkler irrigation		-	-	ha
- localized irrigation		-	-	ha
• % of area irrigated from surface water		-	-	%
• % of area irrigated from groundwater		2003	100	%
• % of area irrigated from mixed surface water and groundwater		-	-	%
• % of area irrigated from non-conventional sources of water		-	-	%
• area equipped for full or partial control irrigation actually irrigated		-	-	ha
- as % of full/partial control area equipped		-	-	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)		-	-	ha
3. Spate irrigation		-	-	ha
Total area equipped for irrigation (1+2+3)		**2003**	**12 600**	**ha**
• as % of cultivated area		-	-	%
• % of total area equipped for irrigation actually irrigated		-	-	%
• average increase per year over the last ... years		-	-	%
• power irrigated area as % of total area equipped		-	-	%
4. Non-equipped cultivated wetlands and inland valley bottoms		-	-	ha
5. Non-equipped flood recession cropping area		-	-	ha
Total water-managed area (1+2+3+4+5)		**2003**	**12 600**	**ha**
• as % of cultivated area		-	-	%
Full or partial control irrigation schemes	**Criteria**			
Small-scale schemes	< ha	-	-	ha
Medium-scale schemes		-	-	ha
large-scale schemes	> ha	-	-	ha
Total number of households in irrigation		-	-	
Irrigated crops in full or partial control irrigation schemes				
Total irrigated grain production (wheat and barley)		-	-	metric tons
• as % of total grain production		-	-	%
Harvested crops				
Total harvested irrigated cropped area		-	-	ha
• Annual crops: total		-	-	ha
• Permanent crops: total		-	-	ha
Irrigated cropping intensity (on full/partial control area actually irrigated)		-	-	%
Drainage - Environment				
Total drained area		-	-	ha
- part of the area equipped for irrigation drained		-	-	ha
- other drained area (non-irrigated)		-	-	ha
• drained area as % of cultivated area		-	-	%
Flood-protected areas		-	-	ha
Area salinized by irrigation		-	-	ha
Population affected by water-related diseases		-	-	inhabitants

TABLE 8
Irrigation and drainage in the Gaza Strip

Irrigation potential			**19 000**	**ha**
Irrigation:				
1. Full or partial control irrigation: equipped area		2003	11 400	ha
- surface irrigation		-	-	ha
- sprinkler irrigation		-	-	ha
- localized irrigation		-	-	ha
• % of area irrigated from surface water		-	-	%
• % of area irrigated from groundwater		2003	100	%
• % of area irrigated from mixed surface water and groundwater		-	-	%
• % of area irrigated from non-conventional sources of water		-	-	%
• area equipped for full or partial control irrigation actually irrigated			-	ha
- as % of full/partial control area equipped			-	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)		-	-	ha
3. Spate irrigation		-	-	ha
Total area equipped for irrigation (1+2+3)		**2003**	**11 400**	**ha**
• as % of cultivated area		-	-	%
• % of total area equipped for irrigation actually irrigated			-	%
• average increase per year over the last ... years			-	%
• power irrigated area as % of total area equipped		-	-	%
4. Non-equipped cultivated wetlands and inland valley bottoms		-	-	ha
5. Non-equipped flood recession cropping area		-	-	ha
Total water-managed area (1+2+3+4+5)		**2003**	**11 400**	**ha**
• as % of cultivated area		-	-	%
Full or partial control irrigation schemes:	**Criteria:**			
Small-scale schemes	< ha	-	-	ha
Medium-scale schemes		-	-	ha
large-scale schemes	> ha	-	-	ha
Total number of households in irrigation		-	-	
Irrigated crops in full or partial control irrigation schemes:				
Total irrigated grain production (wheat and barley)		-	-	metric tons
• as % of total grain production		-	-	%
Harvested crops:				
Total harvested irrigated cropped area		-	-	ha
• Annual crops: total		-	-	ha
• Permanent crops: total		-	-	ha
Irrigated cropping intensity (on full/partial control area actually irrigated)		-	-	%
Drainage - Environment:				
Total drained area		-	-	ha
- part of the area equipped for irrigation drained		-	-	ha
- other drained area (non-irrigated)		-	-	ha
• drained area as % of cultivated area		-	-	%
Flood-protected areas		-	-	ha
Area salinized by irrigation		-	-	ha
Population affected by water-related diseases		-	-	inhabitants

TABLE 9
Distribution of irrigation methods in the semi-coastal zone (West Bank)(1994/1995)

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

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

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

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

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

Role of irrigation in agricultural production, economy and society

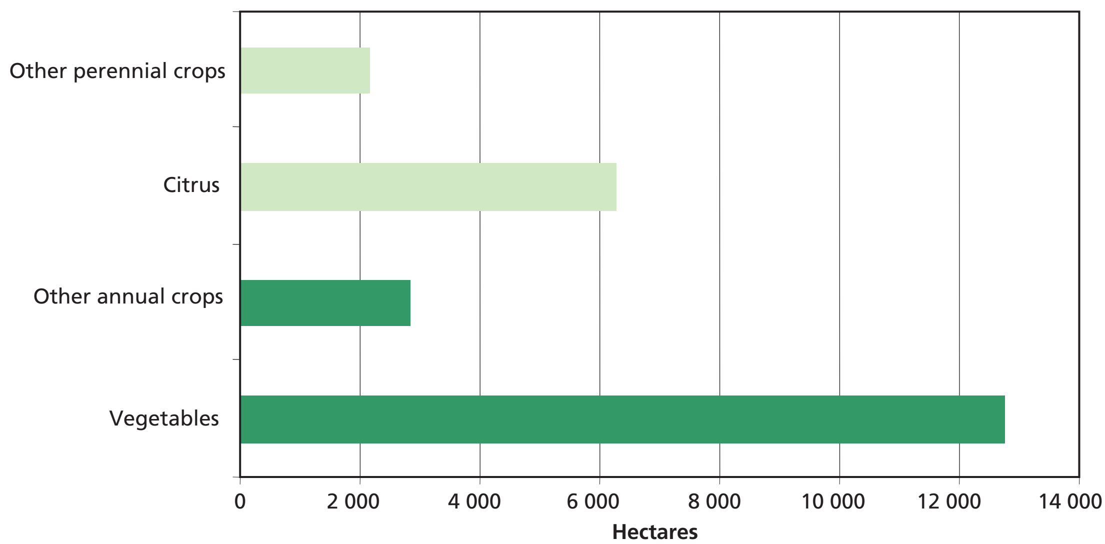
Open field vegetables are grown in the five agro-climatic zones. Common crops include tomatoes, cucumbers, eggplants and squashes. The timing for planting each type of vegetables is site dependent. For the Ghor area, they are either planted in late summer/early fall (August-October), or in late winter/early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

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

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

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

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



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

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

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

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

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

Institutions

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

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

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

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

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

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

Water management

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

High water losses are observed for several reasons:

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

Policies and legislation

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

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

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

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

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

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

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

ENVIRONMENT AND HEALTH

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

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

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

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

Strategic options for alleviating constraints include:

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

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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**

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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/km^2
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

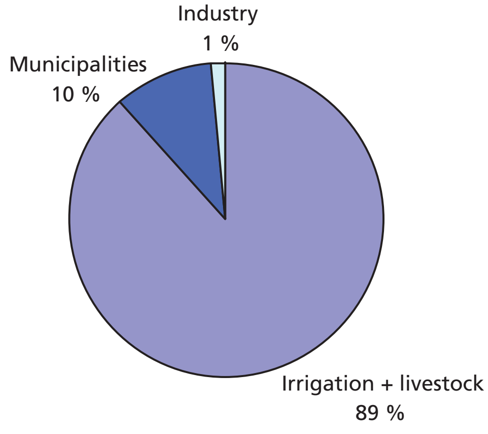


TABLE 3
Irrigation and drainage

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

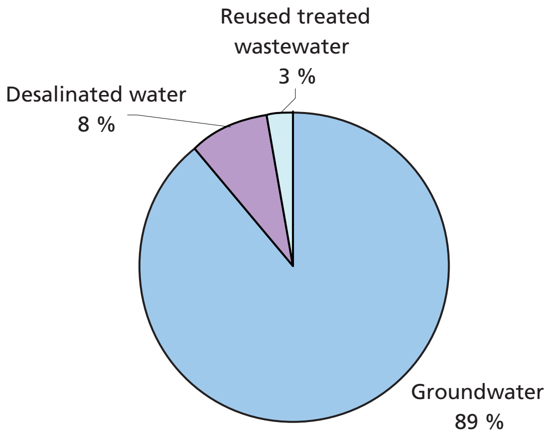
(Ministry of Regional Municipalities, Environment and Water Resources, 2005):

- 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

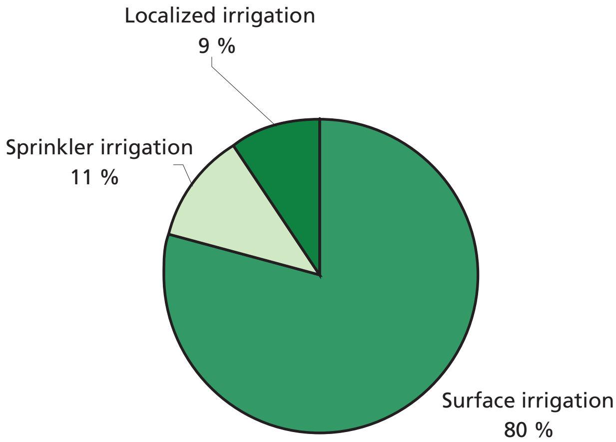
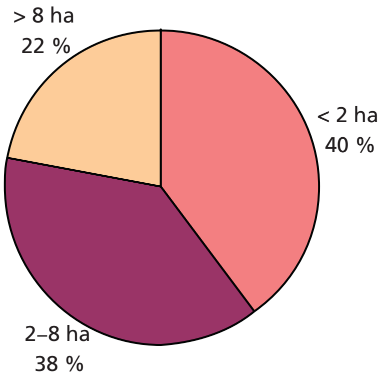


FIGURE 4
Type of irrigation schemes
Total: 58 850 ha in 2004



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

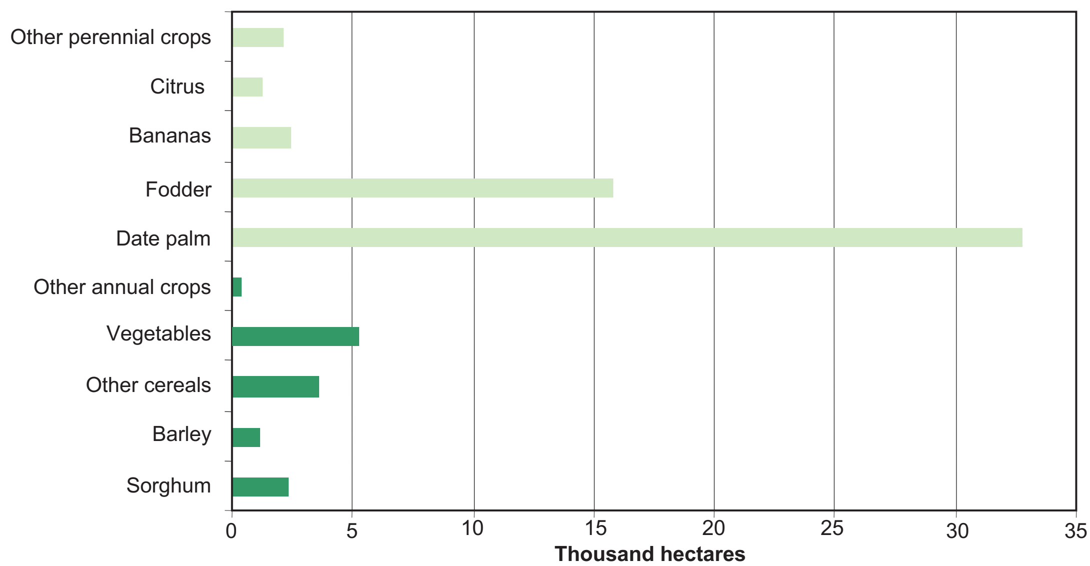
In 2007, the total harvested area was 67 087 ha of which 81 percent were permanent crops (Table 3 and Figure 5). Date palms covered almost 50 percent of the harvested area, fodder 24 percent and cereals 11 percent. There are more than 8 million date palms in Oman, distributed along the coast of Batinah 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.

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Qatar

GEOGRAPHY, CLIMATE AND POPULATION

Geography

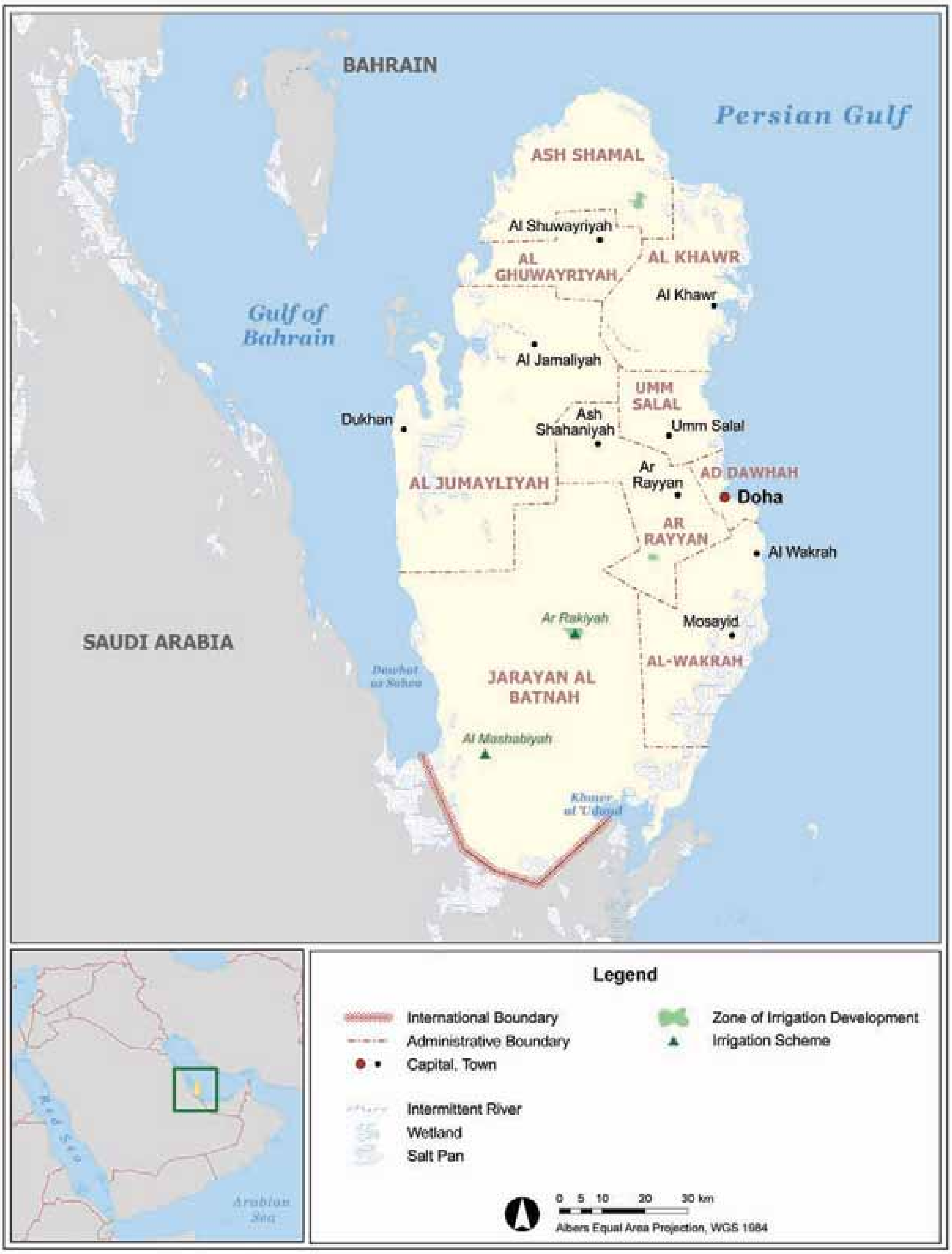
Qatar is a small peninsula in the Persian Gulf covering an area of approximately 11 000 km² including a number of small offshore islands. Its maximum length is about 180 km along the north-south axis, while the east-west width is 85 km at its widest point. It is bounded by the Persian Gulf on all sides 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**

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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 m³ in 2005 and the quantity treated (98 percent tertiary treatment) was 53 million m³ (Public Works Authority, 2005). In 2002, the total installed gross desalination capacity (design capacity) in Qatar was 762 932 m³/day or 278 million m³/year (Wangnick Consulting, 2002). In 2005, the total desalinated sea water produced was 180 million m³ (Water and Electricity Company, 2007).

Water use

In 2005, total water withdrawal was estimated at 444 million m³, of which 262 million m³ 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 m³, 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 m³ (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 m³/year (average for the period 1972–2005). As an example for one year, total groundwater extraction in 2005 was estimated at 221 million m³ (Figure 2). In the same year the groundwater recharge from rainfall was estimated to be about 25 million m³, against a long-

FIGURE 1
Water withdrawal by sector
Total: 0.444 km³ in 2005

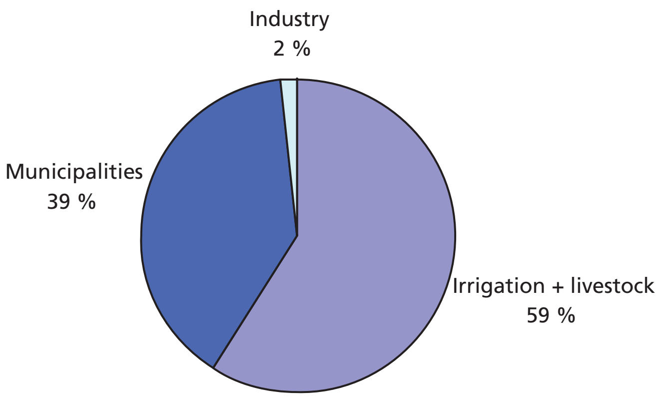


FIGURE 2
Water withdrawal by source
Total: 0.444 km³ in 2005

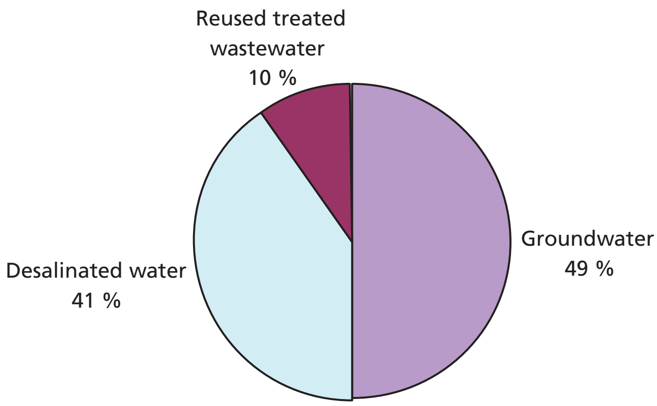


TABLE 3
Water withdrawals by different sectors in Qatar (2005)

	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 m³ (see above). Return flow from irrigation was estimated at 55 million m³ and subsurface outflow at 18 million m³. This means that mining of groundwater was 159 million m³ 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

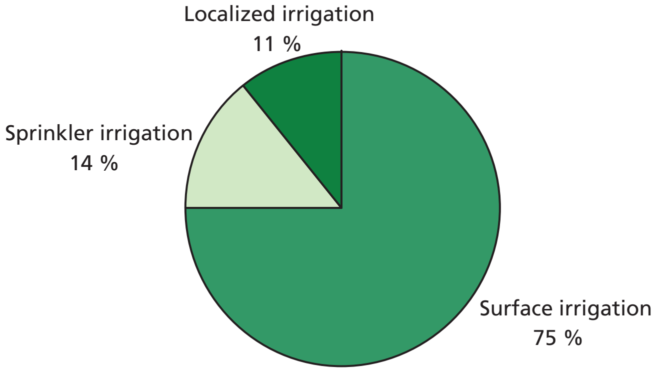
Evolution of irrigation development

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.

FIGURE 3
Irrigation techniques
Total: 12 935 ha in 2001



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.

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

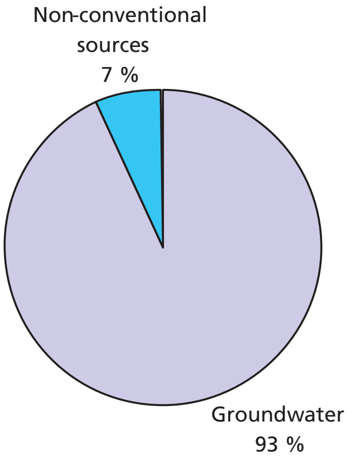
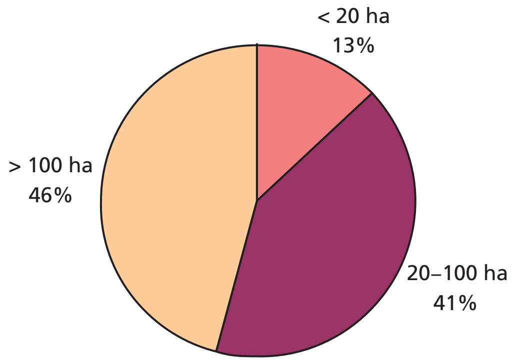


FIGURE 5
Type of irrigation schemes
Total: 12 935 ha in 2001



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).

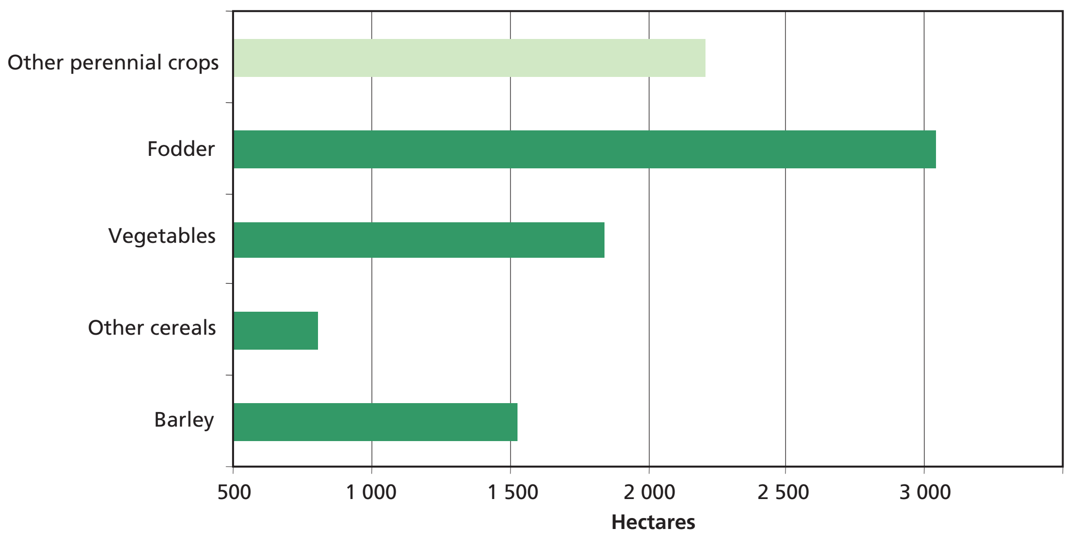
Small schemes (< 20 ha) cover 13 percent of the total equipped area for irrigation, medium size schemes (20-100 ha) 41 percent and large schemes (> 100 ha) 46 percent (Figure 5). All agricultural land in Qatar is owned by Qatari nationals, but farming is not the primary occupation of these landowners.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

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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/km²
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 km³/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

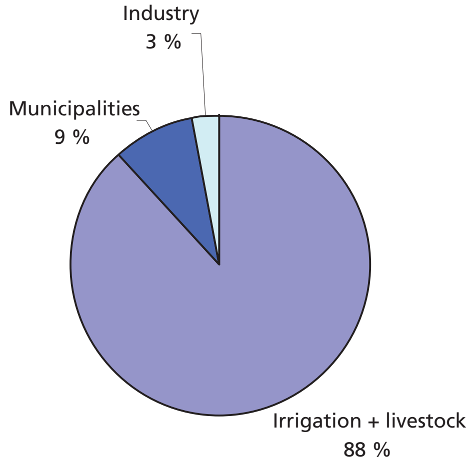
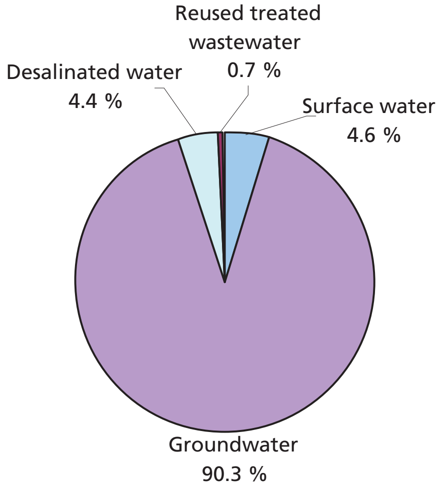


FIGURE 2
Water withdrawal by source
Total 23 666 km³ in 2006



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)

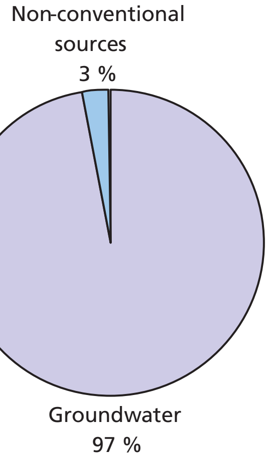
	Traditional irrigation		Modern irrigation		Total	
Region	**Area (ha)**	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**
Riyad	43 010	15	243 275	85	286 286	24
Makkah	43 924	98	1 032	2	44 957	4
Madinah	26 618	93	2 020	7	28 638	2
Quassim	15 541	7	208 712	93	224 253	19
Eastern	16 081	15	92 987	85	109 067	9
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

FIGURE 4
Irrigation techniques
Total 1 608 000 ha in 1992

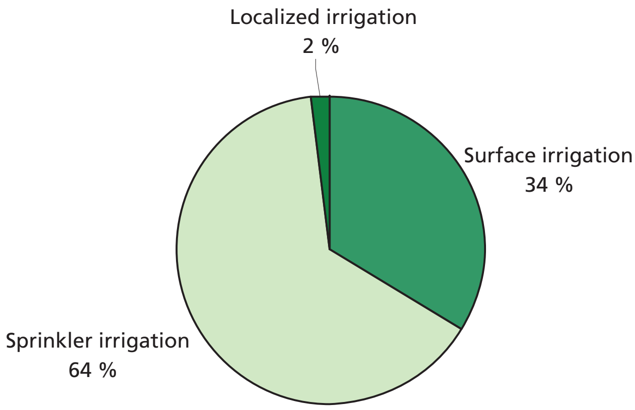
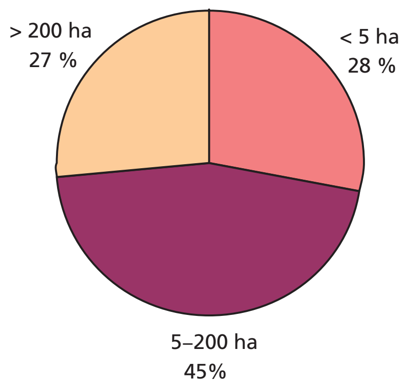


FIGURE 5
Type of irrigation schemes
Total 1 608 000 ha in 1992



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).

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.

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)

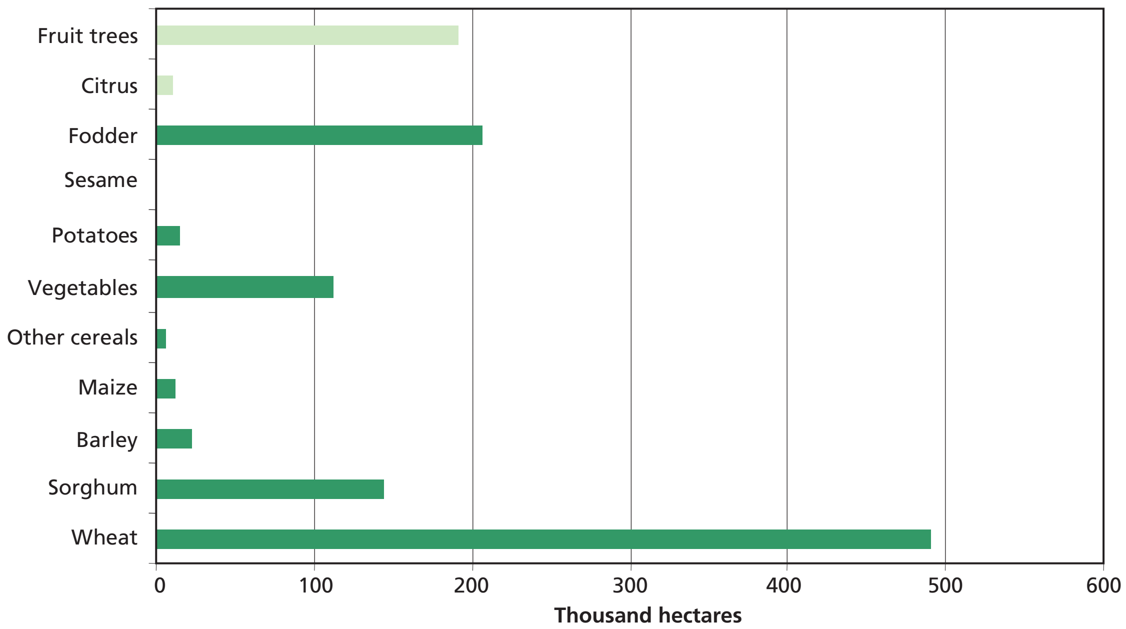
	Traditional irrigation		Modern irrigation		Total	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Permanent crops	136 177	74	47 368	26	183 545	15
- Date Palm	117 473	83	24 098	17	141 571	12
- Citrus	3 320	41	4 708	59	8 028	1
- Grapes	3 463	46	4 088	54	7 551	1
- Olives	4 047	39	6 434	61	10 481	1
Temporary crops	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.

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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.

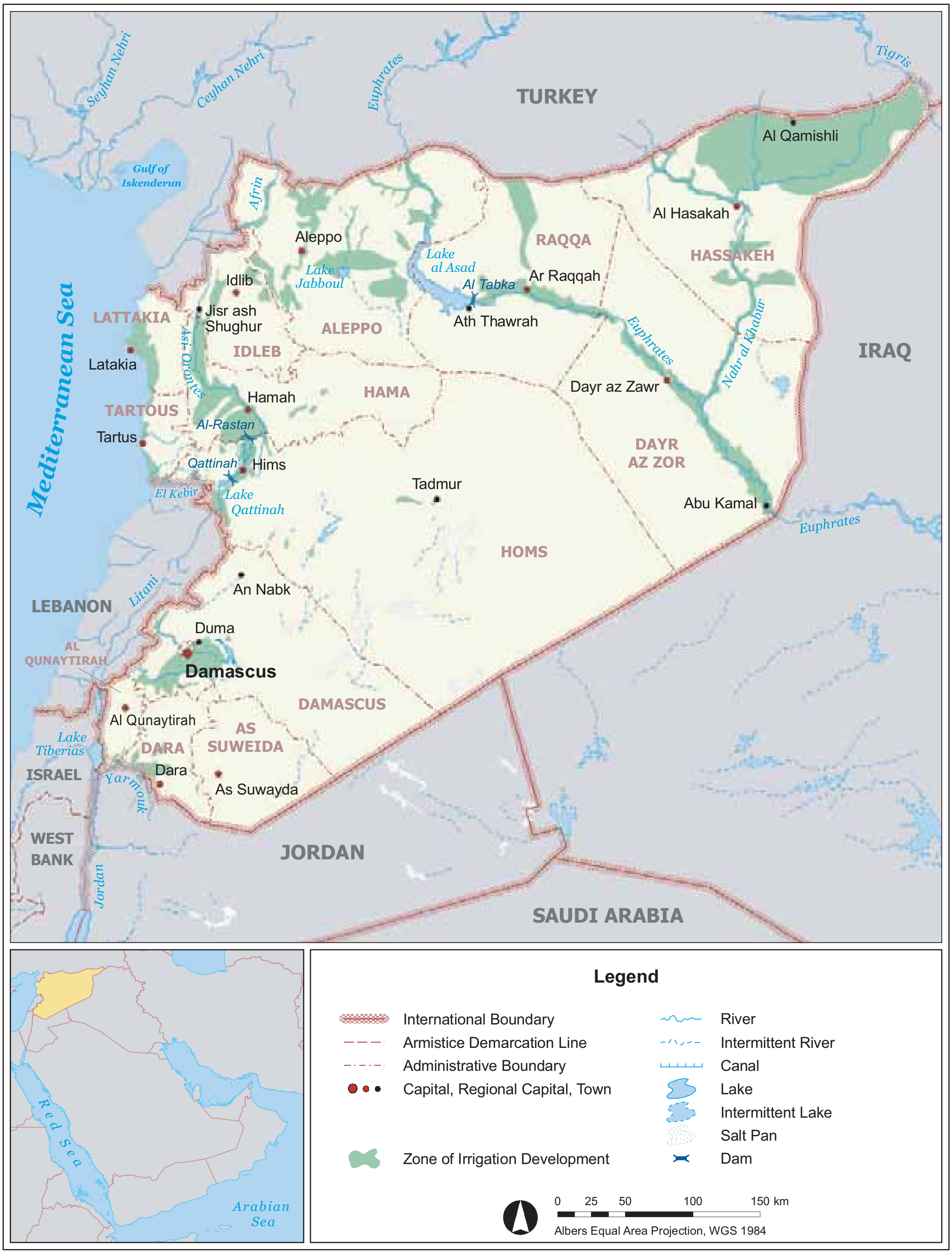
In 2005, total cultivable land was estimated at 5.91 million ha, or 32 percent of the total area of the country and the cultivated land was 5.74 million ha (Table 1). Of the 5.53 million ha of cultivated land in 2004, temporarily fallow land represented 0.80 million ha and the effective cultivated land 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**

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 m³)
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 km³ in 2003

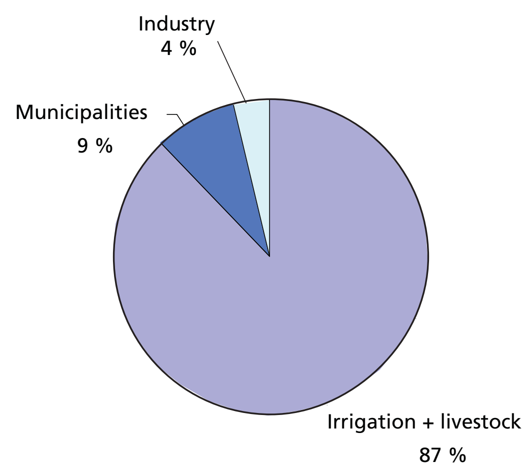
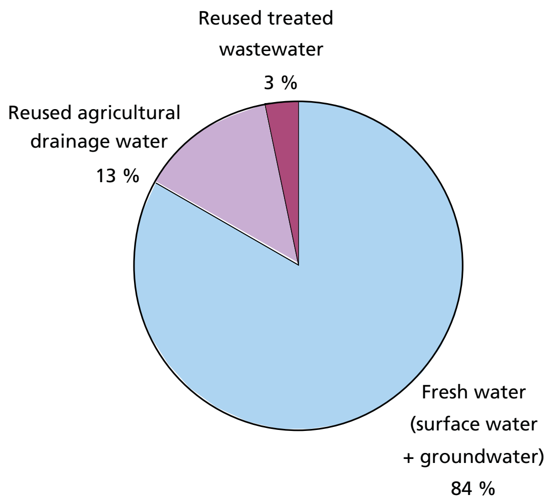


FIGURE 2
Water withdrawal by source
Total: 16.690 km³ in 2003



the Euphrates and forming the Al Assad Lake with a storage capacity of 14.1 km³ and a surface area of 674 km². Medium-size dams include the Al Rastan (228 million m³), the Qattinah (200 million m³), the Mouhardeh (67 million m³) and the Taldo (15 million m³). 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 m³. The treatment of municipal wastewater was carried out mainly in the towns of Damascus, Aleppo, Hims and Salamieh and it reached 550 million m³ in 2002. All treated wastewater is reused. The reused treated wastewater was 330 million m³ 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 m³/day, which is less than 3 million m³/year (Wangnick Consulting, 2002).

Water use

Total annual water withdrawal in the Syrian Arab Republic was estimated at 16.69 km³/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

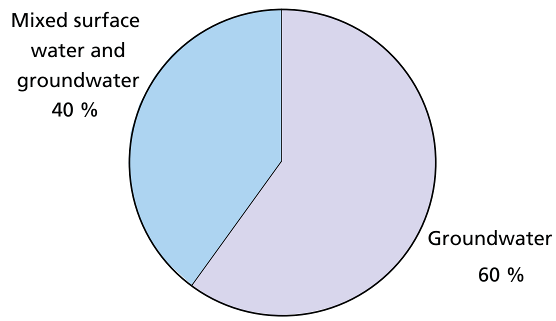
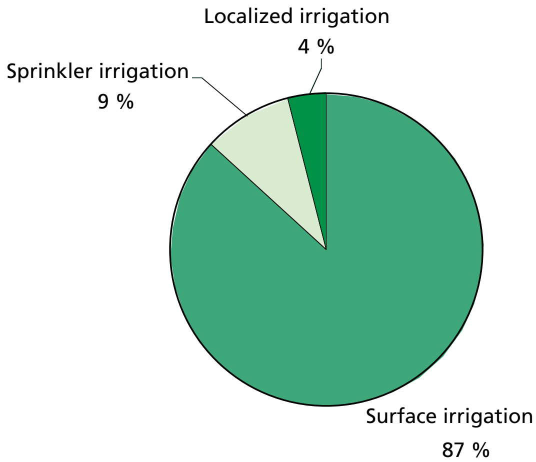


FIGURE 4
Irrigation techniques
Total: 1 439 100 ha in 2004



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).

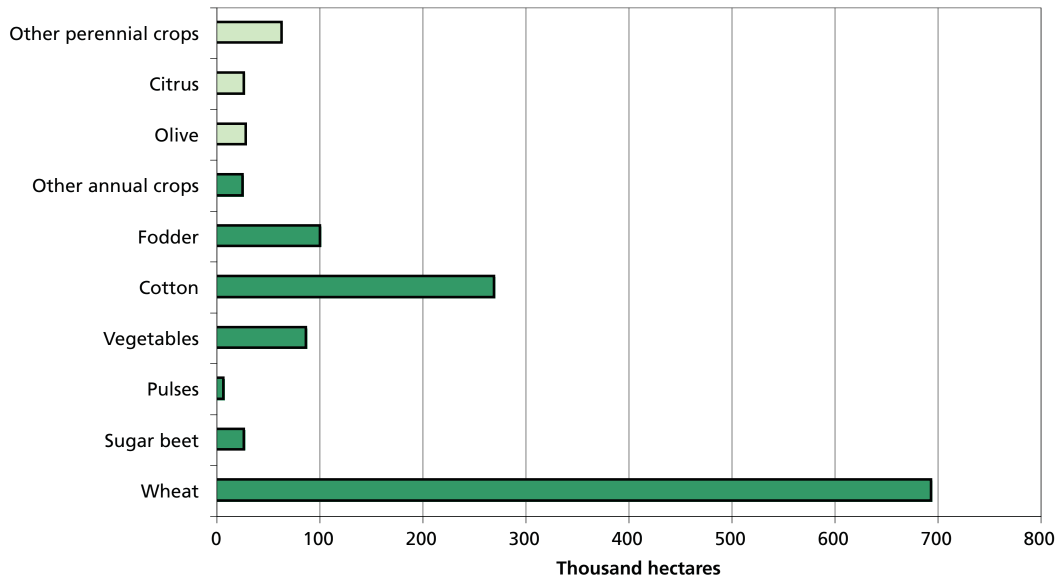
There is a wide variation in cropping patterns in the irrigated areas, depending on the water resources available and the agroclimatological conditions. Strategic crops such as wheat and cotton are concentrated in the northern and eastern parts of the country. More than 50 percent of the wheat and cotton 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).

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Turkey

GEOGRAPHY, CLIMATE AND POPULATION

Geography

Turkey occupies a total area of about 783 560 km² of which approximately 10 400 km² are inland lakes. It forms the bridge between Europe and Asia, with about 3 percent of its land in Europe (Thrace) and the rest in Asia (Anatolia). It is bordered by Georgia, Armenia, Azerbaijan and the Islamic Republic of Iran in the east, by the Islamic Republic of Iran, Iraq and the Syrian Arab Republic in the southeast, by the Mediterranean and Aegean Sea in the south and west, by Bulgaria and Greece in the northwest, and finally by the Black Sea in the north. The total coastline is over 10 000 km, compared to a total land border with other countries of about 2 950 km in length.

The cultivated area of 26.6 million ha covers one-third of the total area of the country, of which about 10 percent is occupied by permanent crops, mainly vineyards, fruit trees and olives (Table 1).

Climate

Turkey has four seasons, but the climate varies widely across the country. Turkey experiences both maritime and continental weather patterns which, combined with its highly varied topography, cause extreme geoclimatic diversity. The Black Sea region in the north receives rain throughout the year and has both mild summers and mild winters. The southern coastal Mediterranean region is regarded as subtropical, characterized by hot, dry summers and mild, rainy winters. The Aegean region (Western Anatolia) has mountains which run roughly east to west (i.e. perpendicular to the coast) and which are interspersed with grassy floodplains. This region also has a Mediterranean type of climate with hot, dry summers and mild winters. Central Anatolia is a vast high plateau with an average altitude of 1 132 meters above sea level and a semi-arid continental climate with hot and dry summers and cold winters.

The average annual temperature is 18–20 °C on the south coast, falling to 14–15 °C on the west coast, and fluctuates between 4 and 19 °C in the interior regions, depending on the distance from the sea and the altitude.

The average annual rainfall in Turkey is about 643 mm, with significant spatial and temporal fluctuations. Rainfall is scarce during the growing season in normal years in most parts of Turkey. Overall, the western and southern coastal regions receive 800–1 000 mm of rainfall per year. The northern coastal zone (the Black Sea region) receives the highest annual rainfall (1 260–2 500 mm). Central Anatolia receives the lowest rainfall (200–600 mm) which, combined with high temperatures and high evaporation rates, causes drought during the summer months. Evaporation and/or evapotranspiration rates are high particularly in the southeast region, which receives almost no rainfall during the summer, and can reach more than 2 000 mm/year. The

TURKEY

FAO - AQUASTAT, 2008

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TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2005	78 356 000	ha
Cultivated area (arable land and area under permanent crops)	2005	26 606 000	ha
• as % of the total area of the country	2005	34	%
• arable land (annual crops + temp fallow + temp. meadows)	2005	23 830 000	ha
• area under permanent crops	2005	2 776 000	ha
Population			
Total population	2005	73 193 000	inhabitants
• of which rural	2005	32.7	%
Population density	2005	93.4	inhabitants/km^2
Economically active population	2005	35 190 000	inhabitants
• as % of total population	2005	48.1	%
• female	2005	39.0	%
• male	2005	61.0	%
Population economically active in agriculture	2005	14 994 000	inhabitants
• as % of total economically active population	2005	42.6	%
• female	2005	64.9	%
• male	2005	35.1	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2007	657 090	million US$/yr
• value added in agriculture (% of GDP)	2007	9	%
• GDP per capita	2005	4 966	US$/yr
Human Development Index (highest = 1)	2005	0.775	
Access to improved drinking water sources			
Total population	2006	97	%
Urban population	2006	98	%
Rural population	2006	95	%

southeast region records very low humidity levels, while the coastal regions have quite high levels, in line with precipitation rates.

Snow can be seen almost everywhere in Turkey, but the number of snowy days and the period covered by snow differ from region to region. There is one or less snowy day in the Mediterranean and Aegean regions, whereas in parts of eastern Anatolia there can be up to 120 days of snow. On the high mountains, snow cover can be seen throughout the year, which melts slowly.

Population

The population of Turkey is 73.2 million (2005) with an average annual population growth rate of 1.4 percent whereas it was almost 2 percent per year in the previous decade. Population density is 93.4 inhabitants/km^2 (Table 1). The rural population declined from 41 percent in 1990 to 33 percent in 2005. In 2006, about 98 and 96 percent of the urban and 95 and 72 percent of the rural population have access to safe drinking water and improved sanitation respectively.

ECONOMY, AGRICULTURE AND FOOD SECURITY

In 2006 the Gross Domestic Product (GDP) was US$402.7 billion, and agriculture contributed almost 10 percent of GDP (Table 1). The economically active population is about 35.2 million (2005) of which 61 percent is male and 39 percent female. In agriculture, 15 million inhabitants are economically active of which 35 percent is male and 65 percent female. The unemployment rate in 2005 was around 9 percent. In 2002 an estimated 1 515 adults in Turkey were infected by HIV, but data on its impact on the labour force are not available.

Turkey is a major agricultural producer. Wheat is the staple food crop with a share of 67 percent in total grain production. The principal agricultural exports are field crops, industrial crops, fruit, vegetables, and small livestock. The share of crop production in total agricultural production is 73.5 percent.

WATER RESOURCES AND USE

Water resources

Turkey is divided into 26 hydrological basins with large differences in specific discharge (Table 2) (GDRS, 2003). Most rivers originate in Turkey and there are more than 120 natural lakes and 579 artificial lakes. Total internal renewable water resources are estimated at 227 km^3/year (Table 3). About 186 km^3 is surface water and 69 km^3 groundwater, while 28 km^3 is considered to be the overlap between surface water and groundwater. Average surface runoff entering the country from Bulgaria and the Syrian Arab Republic is 1.8 km^3/year, of which 0.6 km^3 from the Tunca River coming from Bulgaria and 1.2 km^3 from the Asi-Orontes coming from the Syrian Arab Republic. The Meriç River, originating in Bulgaria, forms the border between Greece and Turkey with a flow of 5.8 km^3/year and therefore the part accounted for by Turkey is considered to be half of the total flow or 2.9 km^3/year. This gives a total inflow of 4.7 km^3/year. Adding the incoming flow to the internal renewable water resources brings the total natural renewable water resources to 231.7 km^3/year. Of the total flow

TABLE 2

Major hydrological basins in Turkey (GDRS, 2003)

Basin No	Name of basin	Area of basin in Turkey (km²)	Area equipped for irrigation by DSI (ha)	Specific discharge (l/s per km²)	Total annual flow (km³/year)	Draining to
1	Euphrates[1]	127 304	377 680	8.3	31.61	Syria/Iraq/Iran (Persian Gulf)
2	Tigris[2]	57 614	31 875	13.1	21.33	Iraq/Iran (Persian Gulf)
3	South Mediterranean	22 048	39 685	15.6	11.07	Mediterranean Sea
4	Antalya	19 577	96 773	24.2	11.06	Mediterranean Sea
5	Western Mediterranean	20 953	47 139	12.4	8.93	Mediterranean Sea
6	Seyhan	20 450	134 675	12.3	8.01	Mediterranean Sea
7	Ceyhan	21 982	162 713	10.7	7.18	Mediterranean Sea
8	Asi (Orontes)	7 796	34 947	3.4	1.17	Mediterranean Sea
9	B.Menderes	24 976	176 732	3.9	3.03	Aegean Sea
10	Northern Aegean	10 003	27 496	7.4	2.09	Aegean Sea
11	Gediz	18 000	118 551	3.6	1.95	Aegean Sea
12	Meriç Ergene	14 560	80 480	2.9	1.33	Aegean Sea
13	K.Menderes	6 907	16 076	5.3	1.19	Aegean Sea
14	Marmara	24 100	42 479	11.0	8.33	Sea of Marmara
15	Susurluk	22 399	105 241	7.2	5.43	Sea of Marmara
16	Eastern Black Sea	24 077	4 848	19.5	14.90	Black Sea
17	Western Black Sea	29 598	36 334	10.6	9.93	Black Sea
18	Kızılırmak	78 180	114 716	2.6	6.48	Black Sea
19	Sakarya	58 160	120 802	3.6	6.40	Black Sea
20	Yeşil Irmak	36 114	114 461	5.1	5.80	Black Sea
21	Çoruh	19 872	13 498	10.1	6.30	To Georgia and then Black Sea
22	Aras	27 548	81 900	5.3	4.63	Armenia/Azerbaijan/ Iran (Caspian Sea)
23	Konya inland basin	53 850	385 173	2.5	4.52	Interior
24	Van inland basin	19 405	47 320	5.0	2.39	Interior
25	Burdur Lakes Area	6 374	47 465	1.8	0.50	Interior
26	Akarçay	7 605	60 706	1.9	0.49	Interior
	Total	**779 452**	**2 519 765**	**209.3**	**186.05**	

[1] The average flow of Euphrates varies between 26.3 and 31.6 km^3 per year and the latter figure is used in this table.

[2] The average flow of Tigris varies between 18.0 and 21.3 km^3 per year and the latter figure is used in this table.

TABLE 3
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	643	mm/yr
	-	503.83	10^9 m^3/yr
Internal renewable water resources (long-term average)	-	227.00	10^9 m^3/yr
Total actual renewable water resources	-	213.56	10^9 m^3/yr
Dependency ratio	-	1.01	%
Total actual renewable water resources per inhabitant	2005	2 918	m^3/yr
Total dam capacity	2006	651 000	10^6 m^3
Water withdrawal			
Total water withdrawal	2003	40 100	10^6 m^3/yr
- irrigation + livestock	2003	29 600	10^6 m^3/yr
- municipalities	2003	6 200	10^6 m^3/yr
- industry	2003	4 300	10^6 m^3/yr
• per inhabitant	2003	563	m^3/yr
Surface water and groundwater withdrawal	2003	39 100	10^6 m^3/yr
• as % of total actual renewable water resources	2003	18.3	%
Non-conventional sources of water			
Produced wastewater	2006	2 770	10^6 m^3/yr
Treated wastewater	2005	1 680	10^6 m^3/yr
Reused treated wastewater	2006	1 000	10^6 m^3/yr
Desalinated water produced	1990	0.5	10^6 m^3/yr
Reused agricultural drainage water		-	10^6 m^3/yr

of 53.74 km^3/year leaving the country, 28.1 km^3 flows to the Syrian Arab Republic (of which 26.29 km^3 is the natural outflow of the Euphrates), 21.33 km^3 to Iraq (Tigris and affluent), and 4.31 km^3 to Georgia. Groundwater flows to other countries are estimated at 11 km3/year, of which 1.2 km3/year to the Khabour Springs feeding the Khabour River, situated in the Syrian Arab Republic, with a runoff of 1.2 km^3/year, have their origin in groundwater coming from Turkey. Taking into consideration the outflow and the flows reserved between countries (see international water issues below), the total actual renewable water resources are equal to 213.56 km^3/year.

Turkey contributes about 90 percent of the total annual flow of the Euphrates, while the remaining part originates in the Syrian Arab Republic and nothing is added further downstream in Iraq. Turkey contributes 38 percent directly to the main Tigris River and another 11 percent to its tributaries joining the main river further downstream in Iraq. In general, the streams and rivers vary greatly in their flow from season to season and from year to year. For example, the Euphrates' annual flow at the border with the Syrian Arab Republic ranged from 15.3 km^3 in 1961 to 42.7 km^3 in 1963.

A trend analysis of annual minimum, maximum and mean stream-flow variables in Turkey showed that there was a significant decreasing trend seen mostly in the basins in western Turkey, whereas some basins draining to the Black Sea exhibited significant increasing trends. Almost no evidence of any significant change was experienced in the rest of the country (Topaloglu, 2006).

A significant part of the water in mountainous coastal areas finds its way to the sea without forming any large groundwater reservoir. Hydrogeological surveys carried out in 342 plains in order to assess groundwater potential, estimated the 'reliable groundwater reserves' or 'exploitable groundwater' at 14 km^3/year (Kırmızıtaş, 2006). The legislation on groundwater reserves taking effect in 1960 mandated the DSI (General Directorate of State Hydraulic Works) to carry out work for the exploration, utilization, maintenance and registration of groundwater reserves in Turkey. Under this mandate, it conducts surveys on groundwater reserves and makes the necessary arrangements for the utilization of identified reserves. So far the DSI has allocated an annual 11.44 km^3 of this reliable reserve, of which 5.20 km^3 for municipal and industrial purposes, 3.90 km^3 for state administered irrigation and 2.34 km^3 for private irrigation schemes (DSI, 2006).

Turkey is a country rich in wetlands, ranking first in this respect among the Middle Eastern and European countries. There are more than 250 wetlands in the country with a total area of approximately one million hectares. Almost 75 wetlands are larger than 100 hectares (TÇV, 1995). Of all Turkish wetlands, 60 percent has freshwater, 20 percent brackish water and 20 percent salt water. Turkey's wetlands are important because they are concentrated in Anatolia, which is crossed by two major bird migration routes. There are four major wetlands: Göksu Delta, Kizilirmak Delta, Sultan Marshes and Kus Cenneti. Five wetlands are identified as "Ramsar" sites: Göksu Delta, Manyas Bird Sanctuary, Sultan Marsh, Lake Burdur and Lake Seyfe. Based on international criteria, 18 wetlands have been classified as first class areas (Class A) that can offer refuge and food to over 25 000 birds at a time. An additional 45 wetlands have been identified as Class B, accommodating 10 000–25 000 birds.

The most serious negative development encountered in the preservation of wetlands is intentional draining. Swamps and marshes have been drained and reclaimed for agriculture and for malaria control (Harmancıoglu *et al*, 2001). A second important threat to the wetlands is pollution, both directly and indirectly by the rivers that feed them. In particular, sediments in contaminated rivers accumulate in wetlands. The heavy metals and pesticides cause mass deaths of fish, frogs and waterfowl. Another threat to wetlands is the collection of bird eggs and frogs, cutting and burning of grasses, grazing cattle, especially water buffalo, in the shallow areas.

By 2006, 208 large dams, mostly rock-fill or earth-fill, had been constructed. In total 579 dams have been completed and put into service for water supply, irrigation, hydropower and flood control (DSI, 2006). Almost 210 dams are under construction. The 208 large dams were constructed in large irrigation schemes (>1 000 ha, with 70 percent >10 000 ha), the rest are in the small irrigation schemes (<1 000 ha). The large dams have a total reservoir capacity of almost 157 km^3, whereas the total capacity of all dams is 651 km^3.

The Ataturk dam on the Euphrates River in the south-eastern part of the country, with a total storage capacity of 48.7 km^3, is one of the 10 largest dams in the world. In the beginning of 1990, the filling of the reservoir behind the dam started and was completed in 1992. The surface area of the reservoir is about 817 km^2. The water obtained from the Ataturk dam is carried to the Harran Plain by the Sanliurfa tunnel system, which is the largest tunnel system in the world in view of its length and flow rate. The water passes through banners which are 26.4 km in length and 7.62 m in diameter with an estimated flow of about 328 m^3/s, which is one-third of the total flow of the Euphrates.

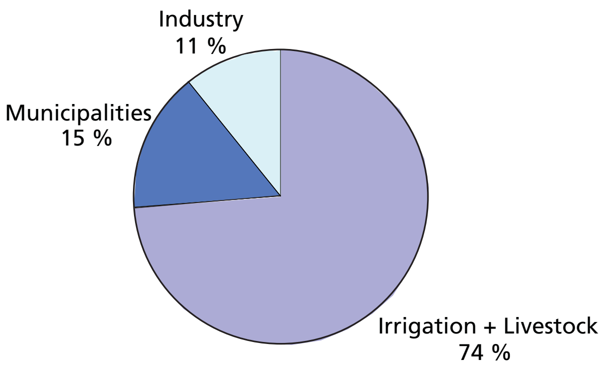
There are 3 215 municipalities in Turkey, 1 327 of which have their own sewage system. About 60 percent of the population is connected to a wastewater treatment plant. Today, almost 1.68 km^3 of municipal wastewater per year is treated using extended aeration, biological nutrient removal (BNR) and trickling filters system (TÜIK, 2003). In 1994 treatment of municipal wastewater was estimated at 0.1 km^3/year. In the year 2000, the GDRS (General Directorate of Rural Services) of the Ministry of Agriculture, Forestry and Village Affairs ordered every village to have a wastewater treatment plant which uses special absorbent crops, such as reed and grass, for treating municipal wastewater. Whereas this project is successful in some regions, no reliable statistically data are available as the GDRS were discontinued following a government reorganization.

Water use

In 2003, the total water withdrawal was estimated at 40.1 km^3/year, of which 74 percent for irrigation, 15 percent for municipal purposes and 11 percent for industrial purposes

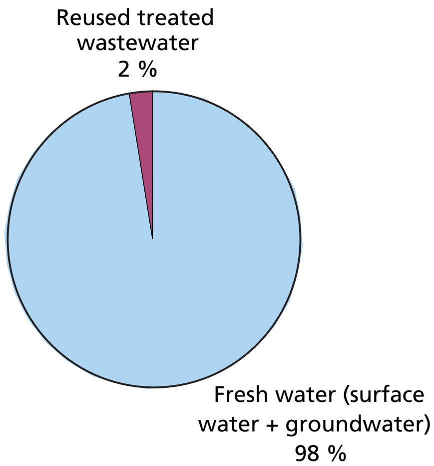
(Table 3, Figure 1 and Figure 2). In 2000, the total water withdrawal was 42 km³. Of this total 10.5 km³ was groundwater withdrawal of which 39 percent for irrigation, 37 percent for municipal purposes and 24 percent for industrial purposes. Demand for groundwater is rapidly increasing, especially in areas where there is a lack or an extreme shortage of surface water. Apart from private initiatives for various purposes, by the end of 1998 the DSI and the GDRS had established irrigation facilities using groundwater to irrigate 505 783 ha of land (net irrigated area 434 120 ha).

FIGURE 1
Water withdrawal by sector
Total: 40.1 km³ in 2003



Since 1975, non-conventional sources of water such as urban wastewater and drainage water have been used as water sources for irrigation. Urban wastewater discharged to the sewage systems was about 2.77 km³ in 2006 (Öztürk, 2006) (Table 3). The treated wastewater of about 1.68 km³ is used in different ways. Its use for irrigation is limited to some dry provinces such as the central and southeastern regions of Turkey, where almost 200 000 ha are irrigated by wastewater (Gökçay, 2004) (Table 4). In some irrigation areas, such as Seyhan and Harran, drainage water is used for irrigation during dry years at the lower part of the scheme where the water delivered is insufficient for irrigation. At present, no data for the amount of drainage water used for irrigation are available.

FIGURE 2
Water withdrawal by source
Total: 40.1 km³ in 2003



International water issues

About 615 km, or one-fifth of the total border length of 2 950 km between Turkey and other countries, is formed by rivers: 238 km with Bulgaria and Greece, 243 km with Armenia and Georgia, 76 km with the Syrian Arab Republic, 58 km with Iraq and the Islamic Republic of Iran. In 1927, Turkey and the USSR signed a “Treaty on the beneficial uses of boundary waters”, in which they agreed to share the water on an equal share basis. A joint Boundary Water Commission was established (without legal identity) to control the use of the frontier water. In 1973, the two governments signed an additional “Treaty on the joint construction of the Arpaçay or Ahurhyan storage dam”. After the Treaty of Lausanne (1923), Turkey and Greece signed several protocols regarding the control and management of the Meriç River which flows along the border between Greece and Turkey.

Concerning the Euphrates and the Tigris rivers a similar protocol was established in 1946 when Turkey and Iraq agreed that the control and management of the rivers

TABLE 4

Reuse of treated wastewater in the central, eastern, southeastern, western, Black sea and Mediterranean regions in Turkey (Gökçay, 2004)

Province	Place	Name of Plant	1 000 m^3/yr	Receiving Environment	Irrigation Status
Aksaray (Primary treatment)	Merkez	Aksaray Municipality WWTP	9 125	Karasu Stream	Indirect[1]
Ankara	Merkez	ASKI, Ankara Municipality WWTP	192 696	Ankara Creek	Indirect
Eskşehir[2, 3]	Merkez	ESKİ, Municipality WWTP	24 820	Porsuk River	Indirect
Gaziantep[2, 3]	Merkez	GASKİ, Municipality WWTP	73 000	S. Creek	Direct
Iğdır	Merkez	Iğdır Municipality WWTP	552	Aras River	Direct
Kayseri [3]	Merkez	Kayseri Municipality WWTP	32 850	Karasu River	Indirect
Adana	Kozan	Kozan Municipality WWTP	2 780	Kozan Creek	Indirect
Adana	Yumurtalık	Yumurtalık Municipality WWTP	48	Ayas Creek	Indirect
Konya	Ilgın	Ilgın Municipality WWTP	2 838	Bulasan River	Indirect
Nevşehir	Ürgüp	Ürgüp Municipality WWTP	-	Damsa Creek	Indirect
İzmir	Merkez	IZSU Municipality WWTP	182 500	İzmir Bay	Direct/Gediz Plain
		Total	**521 209**		

WWTP = Wastewater treatment plant

1 Indirect means that treated wastewater is discharged into a river from which water is withdrawn for irrigation.

2 ESKI WWTP serves to irrigate 50 000 ha of land and GASKI WWTP 80 000 ha of land.

3 Irrigation projects are being constructed by SHW.

The treated wastewater from the smaller plants, Konya-Kadınhanı and Niğde-Bor, is being used directly for irrigation (total of 50 000 ha).

depended to a large extent on flow regulation in the Turkish source areas. In addition, Turkey agreed to begin monitoring the two rivers and to share related data with Iraq. In 1980, Turkey and Iraq further specified the nature of the earlier protocol by establishing a joint Technical Committee on Regional Waters. After a bilateral agreement in 1982, the Syrian Arab Republic joined the committee. Turkey unilaterally guaranteed that it will allow 500 m^3/s water flow (15.75 km^3/year) across the border to the Syrian Arab Republic, but no formal agreement has been obtained so far on sharing of the Euphrates water. Problems regarding sharing water might arise between Turkey, the Syrian Arab Republic and Iraq because, according to the different scenarios established, full irrigation development by the countries in the Euphrates-Tigris river basins would lead to water shortages and solutions will have to be found at basin level through regional cooperation.

The construction of the Ataturk Dam, one of the GAP projects completed in 1992, has been widely portrayed in the Arab media as a belligerent act, since Turkey began the process of filling the Ataturk dam by shutting off the river flow for a month (Akanda *et al*, 2007). Both the Syrian Arab Republic and Iraq accused Turkey of not informing them about the cut-off, thereby causing considerable harm. Iraq even threatened to bomb the Euphrates dams. Turkey countered that its co-riparians had been informed in good time that river flow would be interrupted for a period of one month for reasons of “technical necessity” (Kaya, 1998). Turkey returned to previous flow-sharing agreements after the dam became operational, but the conflicts were never fully resolved as downstream demands had increased in the meantime (Akanda *et al*, 2007).

As shown, a number of crises have occurred in the Euphrates-Tigris basin, amongst other things as a result of 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 the two rivers and only speaks of the rational utilization of transboundary waters. According to Turkey, the Euphrates becomes an international river only after it joins the Tigris in lower Iraq to form the Shatt al-Arab, which then serves as the border between Iraq and the Islamic Republic of Iran until it reaches the 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 Turkey, if signed, the law would give the lower riparians a right of veto 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 April 2008, Turkey, the Syrian Arab Republic and Iraq decided to cooperate on water issues by establishing a water institute consisting of 18 water experts from each country to work toward the resolution of water-related problems between 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 (Yavuz, 2008).

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

Out of the cultivable area of 28 million ha, almost 26 million ha are classified as suitable for irrigation according to the USDA-Reclamation Bureau Method. Considering the availability of water resources, this area is reduced to 12.5 million ha. Moreover, when economic considerations are included, Turkey's official estimated irrigation potential is 8.5 million ha, of which 93 percent from surface water resources and 7 percent from groundwater.

Irrigation development in Turkey is carried out by the public sector, represented by the DSI (General Directorate of State Hydraulic Works) and the GDRS (General Directorate of Rural Services), or by farmers and groups of farmers. Irrigation development by the public sector is called improved irrigation, while irrigation development by farmers themselves without a project is called public (or also primitive) irrigation. In 1965, less than 0.5 million ha had been developed by the government and about 1.1 million ha by farmers. In January 1994, of the total of about 4.2 million ha under irrigation more than 3.1 million ha had been developed by the DSI and the GDRS. In 2006, of the total of 4.97 million ha almost 3.97 million ha had been developed by the public sector, of which 2.8 million ha by the DSI and 1.1 million ha by the GDRS. Table 5 shows the irrigation area by organization type around 2000.

Of the total area equipped for irrigation, which was 4 860 800 hectares in 2005, about 78 percent used surface water resources, 19 percent groundwater and 3 percent non-conventional sources of water, see Table 6 and Figure 3 (DSI, 2006). Table 7 shows the source of the water used by public irrigation schemes in

TABLE 5

Distribution of irrigated areas (ha) according to organization type (Ozlu *et al*, 2002)

Type of organization	Area (ha)
1. SHW (DSI), of which	1 908 954
Directly managed by DSI	245 224
Transferred to farmers, of which:	1 663 730
- Village authority	33 643
- Municipality	56 619
- Water Users Associations (WUA)	1 518 118
- Cooperative operation	54 318
- Other	1 032
2. GDRS	981 000
3. Cooperative (groundwater irrigation developed by DSI and GDRS)	371 000
4. Farmers	1 080 000
5. Other	17 046
Total	**4 358 000**

TABLE 6
Irrigation and drainage

Irrigation potential		**-**	**8 500 000**	**ha**
Irrigation				
1. Full or partial control irrigation: equipped area		2006	4 970 000	ha
- surface irrigation		2006	4 572 400	ha
- sprinkler irrigation		2006	298 200	ha
- localized irrigation		2006	99 400	ha
• % of area irrigated from surface water		2005	78.4	%
• % of area irrigated from groundwater		2005	18.5	%
• % of area irrigated from mixed surface water and groundwater		2005	0	%
• % of area irrigated from non-conventional sources of water		2005	3.1	%
• area equipped for full or partial control irrigation actually irrigated		2006	4 320 000	ha
- as % of full/partial control area equipped		2006	87	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)		2001	13 000	ha
3. Spate irrigation		2006	0	ha
Total area equipped for irrigation (1+2+3)		**2006**	**4 983 000**	**ha**
• as % of cultivated area		2006	19	%
• % of total area equipped for irrigation actually irrigated		2006	87	%
• average increase per year over the last 12 years		1994-2006	1.3	%
• power irrigated area as % of total area equipped		1994	5.4	%
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)		**2006**	**4 983 000**	**ha**
- as % of cultivated area		2006	19	%
Full or partial control irrigation schemes	**Criteria**			
Small-scale schemes	< 1 000 ha	1994	2 265 360	ha
Medium-scale schemes		1994	0	ha
Large-scale schemes	> 1 000 ha	1994	1 805 390	ha
Total number of households in irrigation			-	
Irrigated crops in full or partial control irrigation schemes				
Total irrigated grain production (wheat and barley)		2004	1 160 000	metric tons
- as % of total grain production		2004	3.8	%
Harvested crops				
Total harvested irrigated cropped area		2004	4 206 000	ha
• Annual crops: total		2004	3 392 000	ha
- Wheat		2004	172 000	ha
- Rice		2004	71 000	ha
- Barley		2004	86 000	ha
- Maize		2004	545 000	ha
- Potatoes		2004	179 000	ha
- Sugar beet		2004	315 000	ha
- Pulses		2004	260 000	ha
- Vegetables		2004	483 000	ha
- Cotton		2004	640 000	ha
- Flowers		2004	17 000	ha
- Groundnut		2004	24 000	ha
- Sunflower		2004	550 000	ha
- Other annual crops		2004	50 000	ha
• Permanent crops: total		2004	814 000	ha
- Fodder		2004	475 000	ha
- Citrus		2004	110 000	ha
- Other perennial crops (bananas, olives, grapes, strawberries)		2004	229 000	ha
Irrigated cropping intensity (on full/partial control area actually irrigated)		2004	100	%
Drainage – Environment				
Total drained area		2006	454 518	ha
- part of the area equipped for irrigation drained		2006	340 890	ha
- other drained area (non-irrigated)		2006	113 628	ha
- drained area as % of cultivated area		2006	1.7	%
Flood-protected areas		2006	397 302	ha
Area salinized by irrigation		2004	1 519 000	ha
Population affected by water-related diseases			-	inhabitants

the different regions in 2003 (SIS, 2003).

In the irrigation schemes constructed by the DSI and the GDRS, irrigation water is conveyed by different types of canals: trapezoidal canals (classic type) are used in 45 percent of all schemes, while 48 percent use canalettes (half ellipsoidal open canals constructed above the surface of the ground) and 7 percent use pipes. About 71 percent of the area equipped for irrigation uses a gravity distribution system. In 2006, of the total area equipped for irrigation, 92 percent used surface irrigation methods, 6 percent sprinkler irrigation (mostly hand-move) and 2 percent localized irrigation (Figure 4). In the regions of Marmara (Bursa), Thrace (Edirne) and Middle-East (Kayseri), sprinkler irrigation systems accounted for a larger share with 62, 14 and 11 percent respectively. In the Mediterranean region (around Adana) 47 percent used drip irrigation methods. In the remaining regions, only surface irrigation methods were used. In schemes transferred to farmers, on average 92 percent used surface irrigation, 7 percent sprinkler irrigation and 1 percent drip irrigation methods (Wasamed, 2003).

In 2002, 604 231 ha, of which 118 914 ha of DSI-operated schemes and 485 317 ha of irrigation schemes transferred to farmers to manage, could not be irrigated for various

FIGURE 3
Source of irrigation water
Total: 4 860 800 ha in 2005

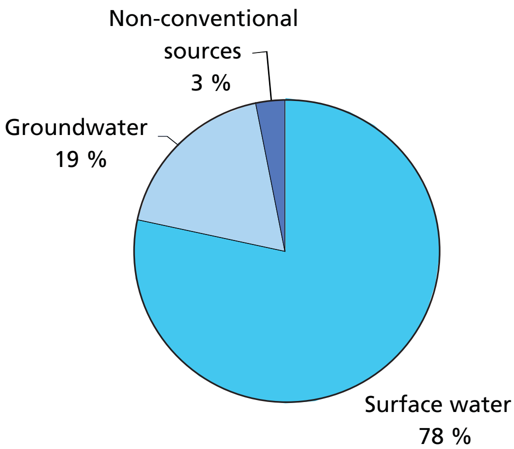


FIGURE 4
Irrigation techniques
Total 4 970 000 ha in 2006

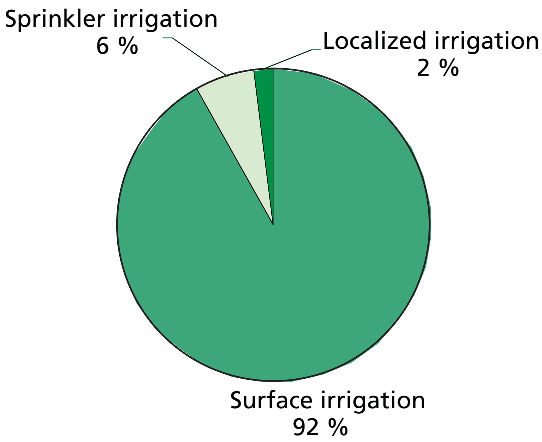


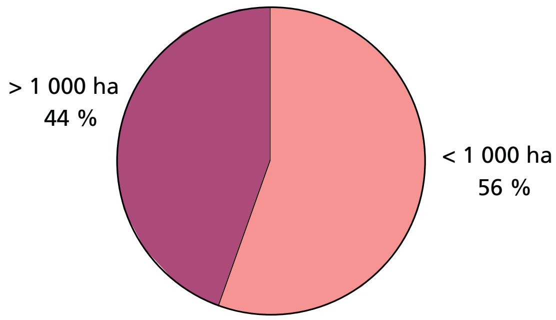
TABLE 7
Sources of irrigation water used in public irrigation schemes in Turkey (SIS, 2003)

Agricultural Regions	Irrigation area by source of irrigation water (1 000 ha)							Total
	Well	Spring	Stream	Lake	Pond	Dam	Other	
Middle North	93.47	14.09	80.37	1.18	7.62	17.16	10.87	224.76
Aegean	249.65	65.39	151.46	22.3	21.72	152.69	22.12	685.33
Thrace	37.22	9.99	62.69	14.28	6.84	12.45	12.28	155.75
Mediterranean	199.16	62.85	198.99	12.46	9.58	170.87	12.96	666.87
Northeast	20.95	40.85	174.21	0.25	14.31	12.49	5.36	268.42
Southeast	264.29	63.26	120.92	1.68	10.8	128.61	7.26	596.82
Black Sea	36.95	11.67	51.27	1.23	7.31	4.23	6.57	119.23
Middle East	34.58	62.42	128.03	8.35	18.56	20.50	3.70	276.14
Middle South	380.02	21.80	35.91	5.93	2.98	37.34	27.88	511.86
Total	**1 316.29**	**352.32**	**1 003.85**	**67.66**	**99.72**	**556.34**	**109.00**	**3 505.18**

TABLE 8
Major reasons for non-irrigation in 2002 in the DSI irrigation schemes and the irrigation schemes where the management was transferred to farmers (DSI, 2002 and 2003)

Reasons for non-irrigation	Areas of DSI		Areas transferred to farmers		Total	
	ha	%	ha	%	ha	%
Inadequate water resources	1 987	1.7	32 693	6.7	34 680	5.7
Insufficient irrigation infrastructure	1 519	1.3	33 690	6.9	35 209	5.8
Inadequate maintenance	7 556	6.4	7 165	1.5	14 721	2.4
Topographic conditions	4 285	3.6	18 545	3.8	22 830	3.8
Used for rainfed cropping	46 364	39.0	144 043	29.7	190 407	31.5
Fallow	20 280	17.1	16 604	3.4	36 884	6.1
Economic and social problems	26 196	22.0	115 504	23.8	141 700	23.5
Drainage related problems:						
Groundwater	2 440	2.1	9 275	1.9	11 715	1.9
Salinity	750	0.6	17 169	3.5	17 919	3.0
Other reasons	7 537	6.3	90 629	18.7	98 166	16.2
Total	**118 914**	**100.0**	**485 317**	**100.0**	**604 231**	**100.0**

FIGURE 5
Type of irrigation schemes
Total: 4 070 746 ha in 1994



reasons, as explained in Table 8. Three years later, in 2005, 678 448 ha could not be irrigated, of which 42 443 ha of DSI-operated schemes and and 636 005 ha of irrigation schemes transferred to farmers to manage. In 2006, the area equipped for irrigation but not irrigated was estimated at 650 000 ha. In 1994, 44 percent of the schemes were larger than 1 000 ha (Figure 5).

Today, in all cities, landscape and public gardens are irrigated, however, data for urban and peri-urban irrigation are not available for the whole of Turkey.

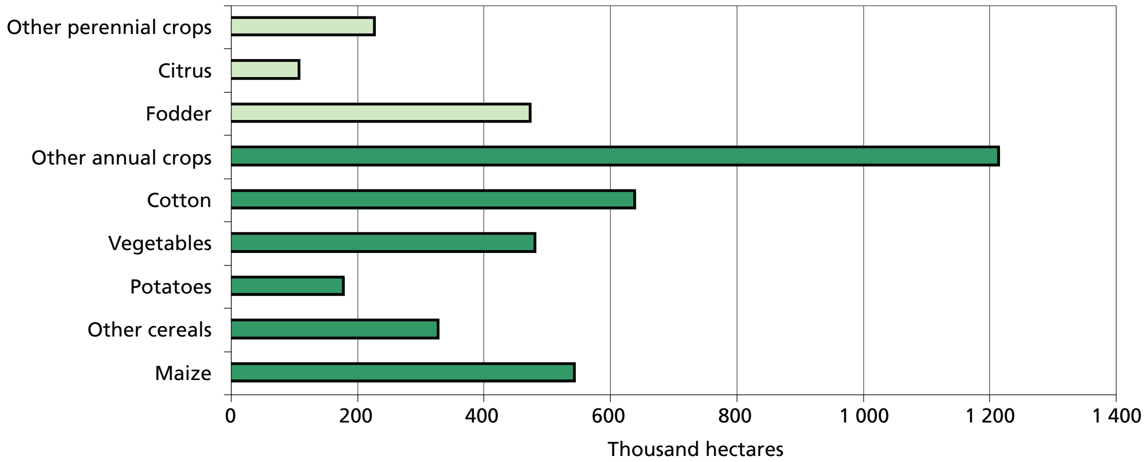
There is no waterharvesting in Turkey. In the past, in the Manisa province of the Aegean region, a water spreading system was used in small vineyards (Akyürek, 1978). However, this has now been replaced by a new irrigation system.

Role of irrigation in agricultural production, economy and society

Diverse geoclimatic characteristics have led to the development of a wide range of farming systems throughout the country under both rainfed and irrigated conditions. The average yield of irrigated land can be five times that of dry farming land and the average value-added per irrigated hectare is 2.6 times that of one rainfed hectare. While the area equipped for irrigation accounts for less than 20 percent of the cultivated area, it contributes 34 percent to the agricultural GDP derived from crops (Nostrum-DSS, 2006).

In 2006, just over 4.2 million ha, or 86 percent of the equipped area, was actually irrigated (Table 6). In general, the percentage of equipped area actually irrigated varies between 38 and 88 percent, with large regional and annual fluctuations. The long-term average value for DSI irrigation areas is about 65 percent. In 2004, the harvested irrigated crop area was about 4.2 million ha. More than 1.7 million ha or over 40 percent of this area was occupied by cotton, maize and sunflower. Other important irrigated crops are vegetables, fodder, sugar beet, potatoes and wheat, occupying another 1.6 million

FIGURE 6
Irrigated crops
Total harvested area: 4 206 000 ha in 2004 (cropping intensity on equipped area actually irrigated: 100%)



ha (Table 6 and Figure 6). The average yield for irrigated cereals (wheat and barley) was 4.5 tonnes/ha as against 2.3 tonnes/ha for rainfed cereals. For irrigated pulses (pea, dry beans, cow vetches, and grass pea) the average weighed yield was 4.5 tonnes/ha, for cotton 3.8 tonnes/ha, for sunflower 1.6 tonnes/ha, for maize 5.5 tonnes/ha, for sugar beet 43 tonnes/ha, and for potatoes 26.8 tonnes/ha (TÜIK, 2006). Rainfed crops include field crops (wheat, barley, etc), nut trees (olive, pistachio, walnut, almond, hazelnut and chestnut), and winter vegetables. Of the total rainfed crop production, 42.5 percent comes from rainfed wheat and barley alone (TÜIK, 2006).

The cost of irrigation development varies between US$7 000/ha for small schemes and US$15 000/ha for large schemes (including pump). The costs of operation and maintenance (O&M) vary from US$100/ha for schemes smaller than 1 000 ha (56 percent of the total area, see Table 5), to US$60/ha for schemes larger than 1 000 ha (including dams). After the economic crisis in 2001, prices in Turkey increased five to tenfold and the cost of irrigation development rose sharply, but water prices did not change as much as those of irrigation development for political reasons. Ten years ago, the average cost of irrigation development was estimated at US$1 750/ha for small schemes and US$3 000/ha for large schemes. Water charges are based on cropped area, with different rates for each crop. During 2001–2005, the average water charges for large schemes were estimated as US$83/ha.

In 2004, the Turkish economy earned US$20.9 billion in production value from irrigated areas. This was equivalent to US$19.1 billion in terms of marketable production. In the same year, total O&M costs were estimated at US$416 million. Data for the rehabilitation and modernization of irrigation schemes are not available for the whole of Turkey, however, during planning 10 percent of net return is assigned for the rehabilitation and modernization of irrigation systems. In addition, it was estimated that collectible water fees on the irrigated areas would amount to US$406.7 million. This brings the total net return from irrigation to about US$19 billion.

While agriculture is one of the most important factors in providing employment, the urban population is increasing and the part of the economically active population working in agriculture is declining steadily, from 64 percent in the 1970s to just over 40 percent at present (Table 1). Of the women working in the agricultural sector, 81 percent are unpaid family workers, 16 percent are self-employed or employers themselves, and 3 percent are regular or casual employees. In rural areas, irrigation is the most important source of employment and an important factor in preventing migration to urban areas. For example, it is estimated that when the irrigated areas reach 6.5 million ha, this will provide work for 2 million unemployed people in rural areas (DSI, 2006). Irrigation also increases the gross domestic agricultural product (GDAP): in 2004 the average GDAP was US$400/ha without irrigation and US$2 000/ha with irrigation. Women represent 64 percent of the agricultural labour force, but more men than women are employed in agricultural water management (for example in irrigation, drainage, and erosion control).

Both the distribution efficiency E_d (the combination of the conveyance efficiency E_c and the field canal efficiency E_b, $E_d = E_c \times E_b$) and the field application efficiency E_a vary depending on regional conditions and the irrigation methods employed. Average field application efficiencies for the country are 84 percent for drip, 80 percent for sprinkler and 55 percent for surface irrigation. Turkey's distribution efficiency shows fluctuations by region and is calculated to be 87–97 percent (Wasamed, 2004). The average total project efficiency E_p ($E_p = E_d \times E_a$) depends on the institutions which operate and manage the irrigation systems. In 2001, it was calculated that the total irrigation efficiency was 38 percent in the DSI-operated irrigation schemes and 48 percent in irrigation schemes where the management was transferred to the farmers (DSI, 2006).

Status and evolution of drainage systems

The DSI and the GDRS construct the drainage infrastructure in the irrigation schemes. The main, secondary and tertiary drainage canals are constructed by the DSI, while the GDRS builds the on-farm drainage systems. In total, 20 716 km of drainage canals have been constructed by the DSI, of which 5 133 km main canals, 6 499 km secondary canals and 9 083 km tertiary drainage canals. For the operation, maintenance and repair of drainage canals, 38 278 km of service-road have been built by the DSI (DSI, 2006). The total area drained in irrigation schemes is 340 890 ha. In addition, 113 628 ha of wetlands had been drained by DSI by 2006. During recent decades, the GDRS has carried out many small on-farm water development works, for example on-farm drainage systems and saline and alkaline soils reclamation.

The area protected from flooding amounts to almost 397 302 ha (GDRS, 2006). It was estimated in 1992, that of the total area operated by the DSI, about 41 000 ha was salinized by irrigation. In 2004, the total area salinized by irrigation in Turkey was estimated at 1.5 million ha. An area of 2.8 million ha are affected by waterlogging and drainage problems (Sönmez, 2004).

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

Institutions

Two institutions are or were responsible for irrigation and drainage development activities, namely the previously mentioned DSI (General Directorate of State Hydraulic Works) and the GDRS (General Directorate of Rural Services).

The DSI was established in 1954 by an exclusive Act No. 6200 (Ozlu *et al*, 2002b). It is the main agency responsible for the planning, development and management of water and soil resources as well as the operation and maintenance of irrigation and drainage systems, including construction of dams for flood control, irrigation, power generation, pumping stations, water supply and groundwater development. In projects it manages directly, the DSI uses its own labour resources and mechanical equipment (Tekinel and Erdem, 1995). Based in Ankara, the DSI operates through its regional directorates situated in the 26 river basins. In these regions, 56 sub-directorates and 14 project directorates carry out operation and maintenance activities in irrigation through their field units (MSDC, 1999; Akusum and Kodal, 2000; Ozlu *et al*, 2002a).

The GDRS was established in 1985 as part of the reorganization of the General Directorate of Soil and Water, the General Directorate of Roads, Water and Electricity and the General Directorate of Soil and Resettlement. The GDRS was mainly responsible for irrigation development and small irrigation works up to 500 l/sec (MSDC, 1999; FNCI, 2001). However, the GDRS was abolished under Law No. 5286 of 13 January 2005 on Village Services and most of its duties and competencies were transferred to special provincial administrations in 79 provinces and to the greater municipalities in the provinces of Istanbul and Kocaeli. Many problems have occurred due to the lack of an inventory and standardization units. In 2005, Law No. 5403 gave powers to the Ministry of Agriculture and Rural Affairs for soil protection and land use.

Water management

Irrigation projects have been implemented by the DSI and the GDRS. As is the case in many other countries, the irrigation schemes developed by the state are operated and managed in two ways: by the government and by local authorities, cooperatives and irrigation farmers unions in the irrigation districts (Uskay, 2001). The DSI can be responsible for the operation, maintenance and management of irrigation facilities it has constructed or it can transfer such responsibility to several organizations according to current legislation. In the case of a transfer, however, it is only the management that is transferred, not the ownership of these facilities. The DSI has transferred the largest area to Water User Associations (WUAs), which cover about 1.52 million ha of land (Table 5). The responsibilities of the former GDRS were reassigned to the Special Provincial Administrations by Law No. 5286 after 2005.

Finances

Historically, Turkey had a poor record as regards collecting water fees before the management of irrigation schemes was transferred from the DSI to the WUAs. For example, the collection rate of water fees was 38 percent in 1989–1994. After management was transferred to the farmers, performance improved and cost recovery was 93 percent in 1997, 76 percent in 2003, and 87 percent in 2006. The two main inputs in the preparation of the water tariffs for irrigation management by the DSI are: cost of operation and maintenance and estimated areas that can be irrigated (Unver and Gupta, 2003). In schemes managed by the WUAs, the water tariffs are set annually when the budget of the association is prepared for the approval of the DSI and the local governorship. Water fees are collected by an official acting under Law No. 6183 on the Collection of Public Receivables. Depending on the decision of the WUAs, payments can be made in two or three instalments. There are economic incentives for early payment and substantial penalties for late payment (Halcrow-Dosar Joint Venture, 2000; Ozlu *et al*, 2003). Nevertheless, the present form of irrigation charges, based on the type of crop and the area irrigated, provides little incentive to irrigators to conserve water.

Policies and legislation

Although the DSI has had a policy of transferring irrigation systems management to users since the 1950s, the average area transferred only amounted to about 2 000 ha/year until 1993 (Doker *et al*, 2001). Since 1993, DSI policy has been to transfer only small and isolated schemes, which are difficult and uneconomical for them to manage. However, with persuasion from the World Bank, since 1993, the DSI also started to apply an Accelerated Transfer Program (ATP). The main purpose of the ATP has been to alleviate the unsustainable operation and maintenance financial burden on both DSI and government resources (Svendsen and Murray-Rust, 2001). The ATP in Turkey was founded on a downward-reaching link between the DSI and local administrations rather than through the bottom-up organization of village-level associations of irrigators (Svendsen and Nott, 1999). The ATP continues to be successfully implemented today (Yıldırım and Çakmak, 2004).

ENVIRONMENT AND HEALTH

The water quality of most rivers can be considered to be suitable for irrigating many soils and crops. Kizilirmak River has the water with the highest salinity - 2.25 dS/m.

Salinity-alkalinity and waterlogging problems are caused by irrigation and insufficient drainage systems. These problems increase gradually because of insufficient on-farm water development project works, insufficient land levelling, lack of maintenance and restoration of drainage systems, inadequate training and education of farmers, and ineffective agricultural extension services to avoid, for example, excessive use of water by farmers.

In areas where agrochemicals are extensively used, the hazardous effects of pesticides and fertilizers threaten the use of groundwater sources for drinking water. In the agricultural plains of Bornova (Izmir) the excessive use of agrochemicals resulted in significant groundwater pollution, with nitrate concentrations in the groundwater reaching the limit value of 45 mg/l (Harmancıoglu *et al*, 2001). Again, in the Nevşehir-Niğde provinces in Middle Anatolia, where 25 percent of the total potato growing area and 44 percent of total produce are located, groundwater resources and soils are seriously polluted with nitrate concentration. Various proportions of pesticide residues (Lindane, Heptachlor, Aldrin, and Endosulfan) are encountered in drains, irrigation canals, small bays, some lakes and in well water. Pesticide use in Turkey is the highest in the Mediterranean region, particularly in the Çukurova region south of Adana. But the Black Sea is also becoming polluted with agricultural pesticides, although the residues are not yet at a level to constitute a hazard for human health. Some rivers and creeks such as the Ankara stream in Ankara province, the Ergene River and its branches in the Thrace region, Karasu creeks, a branch of Sakarya River in Eskişehir, and the Simav stream in the Aegean region are all polluted by industrial, municipal and agricultural wastewater (Doğan *et al*, 1996; Gidişoğlu *et al*, 1996; Öğretir, 1992; Börekçi, 1986).

In several areas, problems emerge as urban activities encroach onto agricultural lands. There is an increasing interest in using the land as a vehicle for the treatment and disposal of the wastewater from agribusiness and urban activities. In particular there is currently concern about the use of polluted water resources to irrigate agricultural lands, especially in western Turkey, which has been experiencing water shortages on a regular basis in recent years.

The two major water-related diseases related to irrigation and water resources development are schistosomiasis (bilharzia) and malaria. Schistosomiasis occurs sporadically, but the implementation of large-scale projects under the Southeastern Anatolia Project (GAP) may eventually lead to epidemics (Harmancıoglu, 2001). Malaria has long been a significant health problem in the country and is still common in areas of irrigation and water resources development.

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

The Southeastern Anatolia Project (GAP) was planned for the lower Euphrates and the Tigris river basins within Turkey's boundaries and is the biggest investment in the history of the country. The GAP is an integrated development project involving irrigated agriculture, agro-industry and supporting services including communications, healthcare and education. It includes 13 major projects of which 7 are in the Euphrates river basin and 6 in the Tigris river basin. After full development it will include 22 dams and 19 hydroelectric power plants and the irrigation of almost 1.82 million ha. By 2005, 75 percent of the investment in energy and 12 percent of the investment in irrigation had been made with 213 000 ha under irrigation. At present, 103 000 ha in the Euphrates river basin and 57 000 ha in the Tigris river basin are under construction. In 1998, the Turkish Government decided to complete all irrigation investment in the GAP at the end of 2010 and, as a result, investment in irrigation is the top priority to cover plans for the remaining 910 000 ha in the Euphrates river basin and 540 000 ha in the Tigris river basin.

In most of the new development areas, sprinkler and localized irrigation will be used, especially drip irrigation. Surface irrigation is permitted only on the flat areas near the southern boundaries of Turkey. These irrigation projects have been financed locally and by international agencies.

Overall, however, the performance of the irrigation schemes have not yet reached acceptable levels (Wasamed, 2003). Irrigation efficiencies in almost all systems are low and, for various reasons, it is not yet possible to irrigate the total area. In all irrigation schemes, there are considerable variations in the size of the irrigated area and cropping pattern from year to year.

Water consumption projections by sector for 2030 have been made considering the needs of a growing population as well as those of the rapidly developing sectors of industry and tourism. These projections are based on the assumption that the DSI and the other agencies involved, including private sector companies, will develop their projects so that by 2030, 110 km^3 of water will be available – the figure now considered to be the total exploitable renewable water resources. The projection presupposes that the 8.5 million ha of land that is economically irrigable will be brought under irrigation by the year 2030 and that total irrigation water withdrawal will reach 71.5 km^3 by the same year. The target is to reduce the share of irrigation water in total water consumption to 65 percent by introducing and promoting more water-saving irrigation techniques (Wasamed, 2003). It is assumed that the present rate of population growth will begin to slow down and that the total population of the country will be around 90 million in 2030. Projections regarding water withdrawal for municipal purposes indicate a need for 25.3 km^3 in 2030, of which 5 km^3 for tourism. Assuming that the industry sector has an average annual growth rate of 4 percent, its projected water need in 2030 will be 13.2 km^3.

As mentioned in the previous paragraph, the exploitable renewable water resources are enough to irrigate only 8–9 million ha. In order to irrigate a larger area, new sources of water need to be developed, such as non-conventional sources of water. Water treatment units are to be constructed in all residential and production areas. In addition, it is planned to equip 4 065 village units to treat wastewater biologically, as required by the Ministry of Agriculture at the end of 2006. Up to now, it is reported that very few village units treat wastewater because of organizational and bureaucratic problems and untreated wastewater is used directly for irrigation. The Government is working to solve these problems and extend the wastewater treatment project to all village units in Turkey.

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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)

UNITED ARAB EMIRATES **FAO - AQUASTAT, 2008**

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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/km^2
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).

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**

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/km^2.

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 m³, 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 m³, 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 m³, which is an increase of almost 48 percent compared to 1995, but total water stored was only 12.3 million m³. 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 m³/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 m³/day or 1 725 million m³/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 m³/yr
Internal renewable water resources (long-term average)	-	0.15	10^9 m³/yr
Total actual renewable water resources	-	0.15	10^9 m³/yr
Dependency ratio	-	0	%
Total actual renewable water resources per inhabitant	2005	48.29	m³/yr
Total dam capacity	2006	118	10^6 m³
Water withdrawal			
Total water withdrawal	2005	3 998	10^6 m³/yr
- irrigation + livestock	2005	3 312	10^6 m³/yr
- municipalities	2005	617	10^6 m³/yr
- industry	2005	69	10^6 m³/yr
• per inhabitant	2005	889.2	m³/yr
Surface water and groundwater withdrawal	2005	2 800	10^6 m³/yr
• as % of total actual renewable water resources	2005	1 867	%
Non-conventional sources of water			
Produced wastewater	1995	500	10^6 m³/yr
Treated wastewater	2006	289	10^6 m³/yr
Reused treated wastewater	2005	248	10^6 m³/yr
Desalinated water produced	2005	950	10^6 m³/yr
Reused agricultural drainage water	-	-	10^6 m³/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.

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.

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

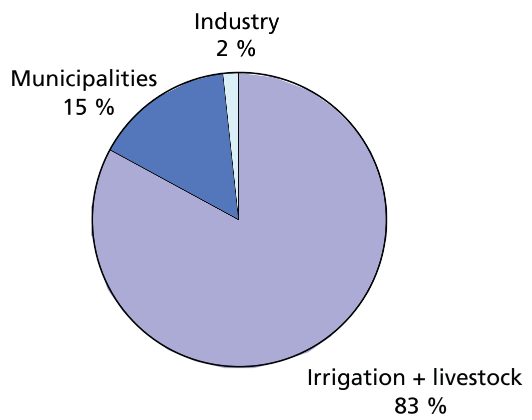
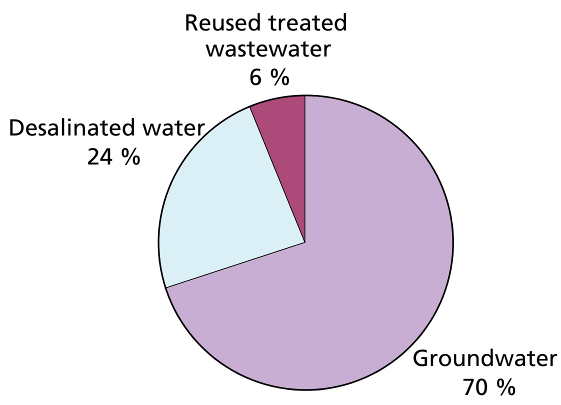


FIGURE 2
Water withdrawal by source
Total: 3 998 km³ in 2005



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

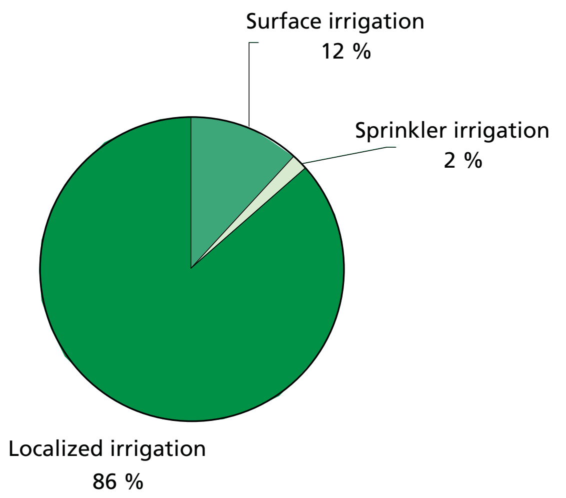
TABLE 5
Irrigation and drainage

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.

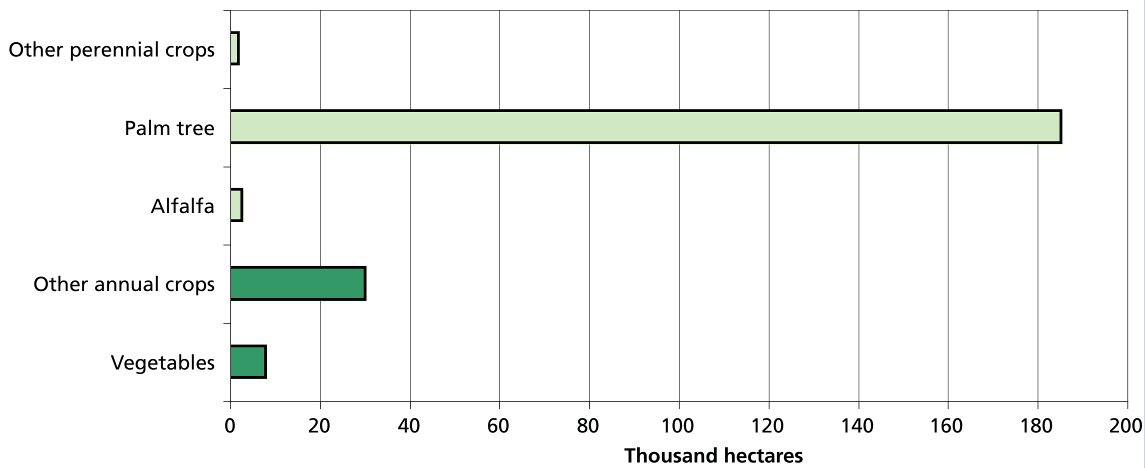
Apart from the government's experimental farms, nurseries, afforestation schemes and public gardens, all the agricultural land is owned and developed by private owners. In 2003, 61 percent of the farm holdings (23 421 units) owned modern irrigation systems (Table 6). More than 86 percent of the farms 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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Yemen

GEOGRAPHY, CLIMATE AND POPULATION

Geography

Yemen, with a total area of 527 970 km², is located on the south-western edge of the Arabian Peninsula. Apart from the mainland it includes many islands, the largest of which are Socotra in the Arabian Sea and Kamaran in the Red Sea. The country is bordered by Saudi Arabia to the north, Oman to the east, the Arabian Sea and the Gulf of Aden to the south, and the Red Sea to the west. The present Republic of Yemen was created in 1990 as a result of the unification of the former Yemen Arab Republic (YAR) and the People's Democratic Republic of Yemen (PDRY). The country is divided into 21 administrative governorates, including the three newly created governorates Amran and Al-Daleh, created in 2000, and Raimah, created in 2004.

The cultivable land is estimated at about 3.62 million ha, which is 7 percent of the total area. In 2004 the total cultivated area was 1.19 million ha, compared with 1.05 million ha in 1994, of which 81 percent consisted of temporary crops and 19 percent of permanent crops (Table 1). The main crops were cereals, covering about 686 000 ha (58 percent of the total cultivated area), and qat, covering 122 844 ha (10 percent). Farm size, including both rainfed and irrigated agriculture, is generally very small: 62 percent of farms have less than 2 ha, while only 4 percent cover more than 10 ha.

Geographically, the country can be divided into three physiographic regions: the western, the eastern and the southern escarpment. Cultivated areas are mostly silty, with a high degree of heterogeneity, both laterally and vertically. Lower wadi reaches are extensively affected by blown sand, which tends to form dunes. The wadi soils are alluvial deposits, mostly consisting of fine sands and silts, which may reach several metres in depth. Agricultural soils have a high pH of about 7.8 to 8.0, very little organic matter and are nearly always deficient in nitrogen and phosphorus. Most of the land areas in the highlands are steep, rugged and badly eroded as a consequence of overgrazing and removal of woody vegetation. Agriculture is restricted to hillside terraces and riparian farms on the sides of the wadis, which range in size from a few metres to more than 100 metres, depending on the geologic and geomorphic features of the wadis. Soils captured by terraces show profiles of varying depths and morphology.

Climate

The climate is semi-arid to arid. Rainy seasons occur during the spring and the summer. Rainfall depends on two main mechanisms: the Red Sea Convergence Zone (RSCZ) and the monsoonal Inter-Tropical Convergence Zone (ITCZ). The RSCZ is active from March to May. Its influence is most noticeable at the higher altitudes in the western parts of the country. The ITCZ reaches Yemen in July-September, moving north and

YEMEN

FAO - AQUASTAT, 2008

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TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2005	52 797 000	ha
Cultivated area (arable land and area under permanent crops)	2004	1 188 888	ha
• as % of the total area of the country	2004	2.3	%
• arable land (annual crops + temp. fallow + temp. meadows)	2004	956 855	ha
• area under permanent crops	2004	232 033	ha
Population			
Total population	2005	20 975 000	inhabitants
• of which rural	2005	73.7	%
Population density	2005	39.7	inhabitants/km^2
Economically active population	2005	6 820 000	inhabitants
• as % of total population	2005	32.5	%
• female	2005	28.5	%
• male	2005	71.5	%
Population economically active in agriculture	2005	3 091 000	inhabitants
• as % of total economically active population	2005	45.3	%
• female	2005	44.2	%
• male	2005	55.8	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2007	22 520	million US$/yr
• value added in agriculture (% of GDP)	2000	10	%
• GDP per capita	2005	796	US$/yr
Human Development Index (highest = 1)	2005	0.508	
Access to improved drinking water sources			
Total population	2006	66	%
Urban population	2006	68	%
Rural population	2006	65	%

then south again so that its influence lasts longer in the south. Rainstorms observed during the winter months of December and January are attributed to the influence of the Mediterranean Sea.

- The country can be divided into fourteen agro-climatic zones, which can be grouped into five regions:
- The Coastal Plains: the plains are located in the west and southwest and are flat to slightly sloping, with maximum elevations of only a few hundred meters above sea level. Temperatures vary from 27 °C to 42 °C and rainfall is low to very low (< 200 mm/year). Nevertheless, the plains contain important agricultural zones due to the numerous wadis that drain the adjoining mountainous and hilly hinterland.
- The Yemen Mountain Massif: this massif constitutes a high zone of very irregular and dissected topography, with elevations ranging from a few hundred meters to 3 760 m above sea level. The climate varies from hot at lower elevations to cool at the highest altitudes. The western and southern slopes are the steepest and enjoy moderate to rather high rainfall, on average 300–500 mm/year, but in some places even more than 1 000 mm/year. The eastern slopes show a comparatively smoother topography and average rainfall decreases rapidly from west to east.
- The Eastern Plateau: this region covers the eastern half of the country. Elevations decrease from 1 800 to 1 200 m at the major watershed lines to 900 m on the northern desert border and to sea level on the coast. The climate in general is hot and dry, with average annual rainfall below 100 mm, except in the higher parts. Nevertheless, floods following rare rainfall may be devastating.
- The Desert: between the Yemen Mountain Massif and the Eastern Plateau lies the Ramlat as Sabatayn, a sand desert. Rainfall and vegetation are nearly absent, except along its margins where rivers bring water from adjacent mountain and

upland zones. The Rub Al Khali Desert in the north extends far into Saudi Arabia and is approximately 500 000 km² in area.

- The Islands: the most important island is Socotra, where more exuberant flora and fauna can be found than in any other region in Yemen.

Population

Total population is almost 21 million (2005), of which 74 percent is rural (Table 1). The average annual demographic growth rate is estimated at 3.2 percent during the period 2000-2005. The average population density is about 40 inhabitants/km², but the population density is quite different from one governorate to another. About 43 percent of the population lives in four governorates: Ta'iiz with 2.4 million, Hodiedah with 2.2 million, Ibb with 2.1 million and the capital city Sana'a with 1.8 million inhabitants. This is closely related to the physical environment. By far the largest part of the population lives in the Yemen Mountain area in the western part of the country, where rainfall is still significant, although not high in many locations. The hostile environment of the desert and eastern upland areas is reflected in low population density.

In 2006, 46 percent of the population had access to improved sanitation (88 and 30 percent in urban and rural areas respectively) and 66 percent had access to improved water sources (68 and 65 percent in urban and rural areas respectively).

ECONOMY, AGRICULTURE AND FOOD SECURITY

In 2007, the national Gross Domestic Product (GDP) of Yemen was US$22.5 billion (Table 1). The total economically active population was 6.8 million (32.5 percent of the total population), of which 71.5 percent male and 28.5 percent female.

The agriculture sector plays an important role in the economy of the country. Although its contribution to GDP is only about 10 percent (2000), the sector employs more than 45 percent of the total economically active population (50.4 percent in 2000) and provides livelihood to more than two-thirds of the population. The discrepancy between the contribution of agriculture to GDP and the percentage of those employed in this sector reflects seasonal employment, underemployment and the low productivity of workers and factors of production, thus resulting in low incomes and poor standards of living for workers in agriculture. Women are involved in nearly all agricultural activities, providing 44 percent of the population economically active in this sector, but cultural traditions keep them at a lower status and prevent them from gaining control over important household resources.

According to the Agriculture Census, the total cereal area showed a negative trend between 1998 and 2004, with total cereal production decreasing by 0.6 percent per year. The average domestic cereal production in 2000–2004 covered only 21 percent of the domestic demand, estimated at 2.73 million tons. The cost of imported cereal has increased from US$195.2 million in 2000 to US$315 million in 2004. When aggregating main food imports, cereals (2.3 million tons), sugar (468 000 tons), vegetables and fruit (77 000 tons), livestock and milk products (164 000 tons), the food import bill reaches US$744 million. Food exports total around US$236 million and are dominated by fish products with 76 percent of food export value (US$181 million), coffee (US$14.4 million), banana (US$8 million), onion (US$7.6 million) and other fruits (US$4.3 million).

WATER RESOURCES AND USE

Water resources

Annual rain volume all over the country varies between 67 and 93 km³. Precipitation falls more on the western highlands, southwest highlands and the upper plateaus. It then gradually becomes lower towards the east. The ratio between the rainfall and potential evaporation reaches around 0.03–0.25 in the Rub Al Khali Desert.

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	167	mm/yr
	-	88.17	10^9 m^3/yr
Internal renewable water resources (long-term average)	-	2.1	10^9 m^3/yr
Total actual renewable water resources	-	2.1	10^9 m^3/yr
Dependency ratio	-	0	%
Total actual renewable water resources per inhabitant	2005	100	m^3/yr
Total dam capacity	2006	462.5	10^6 m^3
Water withdrawal			
Total water withdrawal	2000	3 400	10^6 m^3/yr
- irrigation + livestock	2000	3 060	10^6 m^3/yr
- municipalities	2000	272	10^6 m^3/yr
- industry	2000	68	10^6 m^3/yr
• per inhabitant	2000	187	m^3/yr
Surface water and groundwater withdrawal	2000	3 384	10^6 m^3/yr
• as % of total actual renewable water resources	2000	161.1	%
Non-conventional sources of water			
Produced wastewater	2000	74	10^6 m^3/yr
Treated wastewater	1999	46	10^6 m^3/yr
Reused treated wastewater	2000	6	10^6 m^3/yr
Desalinated water produced	2006	25.1	10^6 m^3/yr
Reused agricultural drainage water		-	10^6 m^3/yr

The country can be subdivided into four major drainage basins, grouping numerous smaller wadis:

- the Red Sea Basin
- the Gulf of Aden Basin
- the Arabian Sea Basin
- the Rub Al Khali Interior Basin

The floods of the wadis are generally characterized by abruptly rising peaks that rapidly recede. Between the irregular floods the wadis are either dry or carry only minor base flows. Surface water resources have been estimated at 2 km^3/year, but this quantity corresponds to the runoff from major rivers and does not include the runoff produced within the smaller catchments. Renewable groundwater resources have been estimated at 1.5 km^3/year of which a large part, estimated at 1.4 km^3/year, probably comes from infiltration in the river beds. Total internal renewable water resources are thus estimated at around 2.1 km^3/year (Table 2).

Surface runoff to the sea measured in some major wadis is estimated at 270 million m^3/year and groundwater outflow to the sea at 280 million m^3/year. There might be some groundwater flowing into Saudi Arabia but no data are available. The existence of surface drainage crossing into Saudi Arabia suggests that some sharing of surface flows could be possible, but details are not known.

The volume of groundwater reaches around 10 km^3, of which 1 km^3 in the Al-Masila Basin, 2.5 km^3 in the Tihama Basin and the remaining distributed over the other regions.

Yemen has a long history of dam construction and the ancient civilization was founded upon the great dam of Ma'areb, the destruction of which marked the end of its existence. After the revolution, the government carried out the reconstruction of the Ma'areb Dam financed by the United Arab Emirates. The new dam has a capacity of 400 million m^3. The remaining dams have a total capacity of 62.5 million m^3, giving a total dam capacity of 462.5 million m^3.

There are over a thousand hydraulic structures falling into three different categories:

1. Dams: 347 storage dams have been constructed in the upper lands to store rainfall water for irrigation and for domestic use, and to recharge sub-aquifers. There are three types: large dams with a capacity above 500 000 m^3, medium dams with a variable capacity from 200 000 to 500 000 m^3 (71 dams of this type have been constructed) and small dams with a capacity of less than 200 000 m^3.
2. Spate water diversion structures: 33 of these structures have been constructed in the main wadis for spate water regulation and diversion.
3. Small water harvesting structures: this category includes cisterns, pits and reservoirs with a storage capacity ranging from 500 m^3 to 50 000 m^3.

Thirteen wastewater treatment plants (WWTP) are in operation. They are concentrated in the capitals of the governorates and in some secondary cities. However, while the cities are growing fast, the capacity of the plants has not increased. For example, in Sana'a the WWTP was designed to treat 25 000 m^3/day of wastewater, but now it receives more than 50 000 m^3/day. Similarly, in Ibb city the WWTP was designed to receive 5 000 m^3/day, but now it receives more than 10 000 m^3/day. These examples reflect the insufficient treatment leading to the production of bad quality water that is not suitable for irrigation. The Ministry of Agriculture and Irrigation considers this water to be harmful and it should be appropriately treated in a way that prevents environmental pollution. In 2000, the total volume of produced wastewater was 74 million m^3 and the treated wastewater was 46 million m^3 in 1999, while the amount of treated wastewater used in agriculture was only 6 million m^3/year in 2000.

In 2002, the total installed gross desalination capacity (design capacity) was 76 596 m^3/day or 28 million m^3/year (Wangnick Consulting, 2002). The production of desalinated water reached 25.1 million m^3 in 2006, an increase of 151 percent compared with 1989, contributing to the water supply of Aden city.

FIGURE 1
Water withdrawal by sector
Total: 3.400 km^3 in 2000

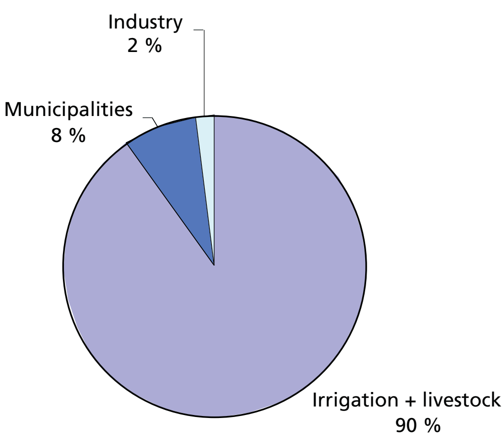
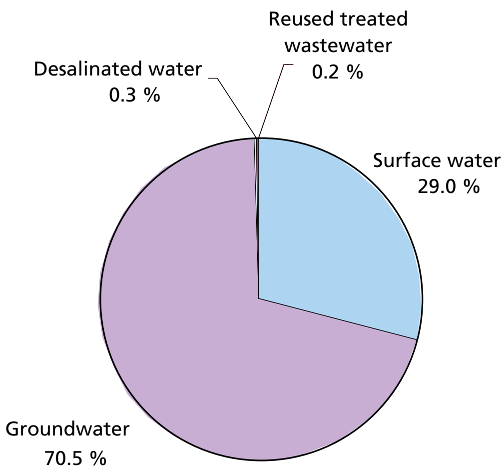


FIGURE 2
Water withdrawal by source
Total: 3.400 km^3 in 2000



Water use

Between 1990 and 2000 total water withdrawal increased from 2.9 km^3/year to 3.4 km^3/year. In 2000, 90 percent of water withdrawal was used for agricultural purposes, 8 percent for municipal use and 2 percent for industrial use (Table 2 and Figure 1). Most of the water withdrawn was groundwater (from wells and springs) (Figure 2), resulting in groundwater depletion as withdrawal exceeded the annual groundwater recharge. The rate of decline of the groundwater levels is alarmingly high in many zones, especially in the highlands, where a decline of 2 to 6 m/year is commonly observed. In coastal zones overexploitation of groundwater leads to salt water intrusion. The decline in groundwater tables has also significantly reduced spring-fed irrigation.

Many farmers are pumping groundwater from wells using diesel or electric pumps. The yield of wells is between 5 and 50 l/sec. It is estimated that there are 52 000 to 55 000 active wells in Yemen. The volume of the water that is pumped every year from these wells is about 1.5 km^3. About 800 water well drilling rigs are in use that are owned by individuals or companies which generally do not have any permits despite government legislation limiting the drilling of wells. Recently, the National Water Resources Authority started a programme of registrations & licensing for the water well drilling companies; the records show that in May 2005 only 70 rigs were licensed and only 1 000 wells were registered and licensed (Al-Asbahi, 2005).

Two types of treated wastewater reuse in agriculture exist (Al-Asbahi, 2001):

- controlled irrigation, which is practiced in government projects by the Ministry of Agriculture and Irrigation to build the green belts, mainly in the coastal plain cities (Aden, Al Hudaydah), and for sand dune fixation or desertification control in the affected areas of coastal plains;
- non-controlled irrigation (commonly in the highlands and wadis), which is practiced by the farmers themselves to grow corn, fodder in some areas (Ta'iiz), and to grow restricted and non-restricted crops, such as vegetables (tomato, carrot) and fruits (in Sana'a area).

An undefined quantity of brackish water is used in the rock cutting industry, mainly in the highlands, as well as for irrigating some salt-tolerant crops, mainly in the coastal plains (Al-Asbahi, 2005).

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

A global figure for irrigation potential is not available. In 2004, the total water management area was estimated at 679 650 ha, an increase of around 41 percent compared with 1994 (Table 3). Three main types of water management exist:

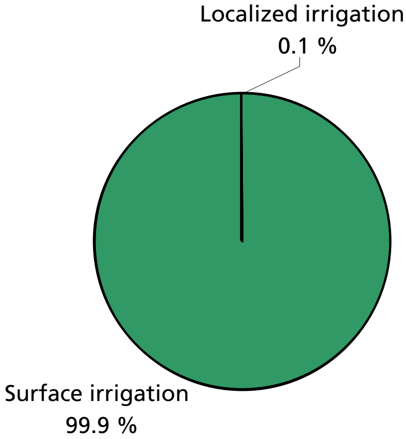
- Full/partial control irrigation: this concerns an area of 454 310 ha (2004), all irrigated from groundwater, of which 420 386 ha from tube wells and 33 924 ha from spring water. In general, the area irrigated from wells has decreased as many wells have gone out of production due to declining water tables.
- Spate irrigation: the area actually irrigated by spate water varies considerably from year to year, depending on the availability of spate water. It is estimated that the area equipped for spate irrigation (command area) may be as large as 217 541 ha, which was the area also actually irrigated in 2001 (Al-Asbahi, 2001), while in 2002 only 124 683 ha were actually irrigated and in 2004 only 89 363 ha. The government constructed many spate water diversion and canal control structures in some of the main wadis, such as wadi Zabid, Tuban, Abyan, Mowr, Seham and Bayhan. Moreover, spate irrigation structures have been maintained and improved for enhancing spate water management and distribution along these wadis. The Irrigation Improvement Project (IIP) has been established recently to introduce the participatory spate irrigation management approach on two pilot wadis (Zabid and Tuban). This project created 'water user associations' (WUAs) to manage the spate structures on the wadis and to take over the operation and maintenance of the spate structures. The project also created the Water Council (WC) from the members of those associations and the local authorities.
- Small-scale irrigation: 347 dams were recently constructed in the different governorates especially in the uplands to capture rainwater for complementary

TABLE 3
Irrigation and drainage

Irrigation potential		**-**	**ha**
Irrigation			
1. Full or partial control irrigation: equipped area	2004	454 310	ha
- surface irrigation	2004	453 825	ha
- sprinkler irrigation		-	ha
- localized irrigation	2004	485	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 non-conventional sources of water	2004	0	%
• area equipped for full or partial control irrigation actually irrigated	2004	454 310	ha
- as % of full/partial control area equipped	2004	100	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)	2004	7 799	ha
3. Spate irrigation	2004	217 541	ha
Total area equipped for irrigation (1+2+3)	**2004**	**679 650**	**ha**
• as % of cultivated area	2004	57.2	%
• % of total area equipped for irrigation actually irrigated	2004	81.1	%
• average increase per year over the last 10 years	1994-2004	3.5	%
• power irrigated area as % of total area equipped	2004	66.8	%
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**	**679 650**	**ha**
• as % of cultivated area	2004	57.2	%
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	2004	527 038	ha
• Annual crops: total	2004	332 784	ha
- Wheat	2004	41 903	ha
- Barley	2004	11 223	ha
- Maize	2004	19 234	ha
- Millet	2004	7 947	ha
- Sorghum	2004	42 888	ha
- Potatoes	2004	16 870	ha
- Pulses	2004	26 832	ha
- Vegetables	2004	55 494	ha
- Tobacco	2004	7 935	ha
- Cotton	2004	17 246	ha
- Sesame	2004	14 440	ha
- Fodder	2004	70 772	ha
Permanent crops: total	2004	194 254	ha
- Coffee	2004	18 753	ha
- Citrus	2004	11 252	ha
- Bananas	2004	8 837	ha
- Other perennial crops	2004	155 412	ha
Irrigated cropping intensity (on full/partial control area equipped)	2004	116	%
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

irrigation purposes in inland valleys. Moreover, 519 small reservoirs and water cisterns have been constructed in different upland villages. The main purpose of these water harvesting or small-scale irrigation schemes is to use the water for complementary irrigation. The total area irrigated by these systems was about 7 799 ha in 2004, including 4 215 ha from dams. It increased to 8 526 ha in 2005 thanks to the construction of new dams.

FIGURE 3
Irrigation techniques
Total: 454 310 ha in 2004



Irrigation efficiency is low, between 35 and 45 percent depending on field levelling and the water conveyance system used. Localized irrigation systems (drip and bubbler) are introduced through several projects on limited demonstration areas and 485 ha have been realized up to now. Because of the high cost of sprinkler irrigation systems, they have been installed in very limited areas only, such as the governmental farms and the big investment farms mostly used for fodder crop production. To enhance water conveyance and distribution efficiency, the government introduced PVC buried pipes and GI pipes to the farmers to replace the earthen distribution canals and offered subsidies reaching 50 percent of the equipment costs. It is estimated that irrigation efficiency could be increased to 60 percent by installing the conveyance pipe system and to over 80 percent by adopting localized irrigation systems. Average yields of crops growing under the improved conveyance pipe system and localized irrigation systems are assumed to increase by 5 percent and 10 percent respectively. In 2004, 99.9 percent was surface irrigation and 0.1 percent was localized irrigation (Figure 3).

Role of irrigation in agricultural production, economy and society

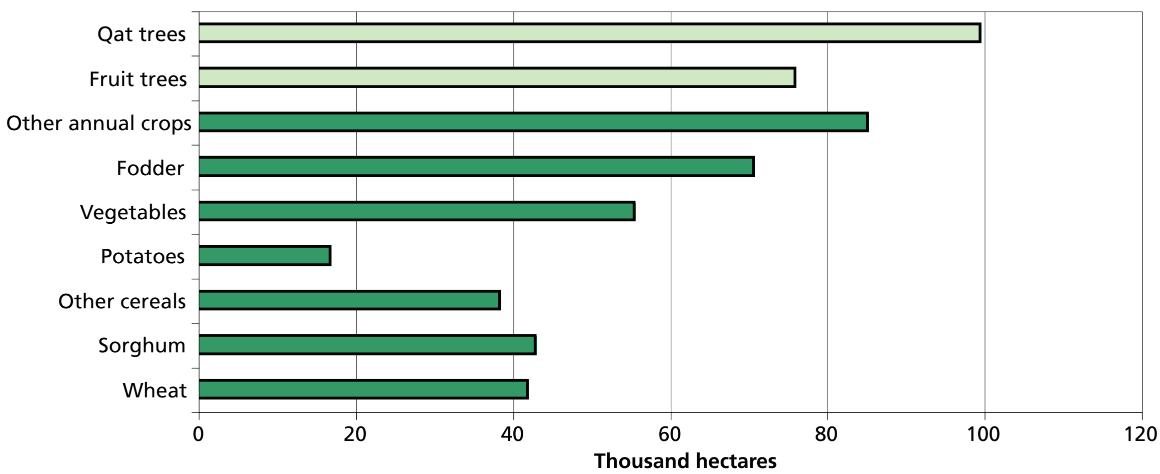
The price of irrigation equipment has increased considerably in recent years. The average cost of a surface irrigation system with a piped conveyance and distribution system is about US$800/ha. The cost of a localized irrigation system depends on the type: the estimated cost of a drip irrigation system for fruit trees is about US$2 600/ha and for vegetables about US$3 600/ha, while a bubbler irrigation system costs about US$3 000/ha. A central pivot sprinkler system is estimated to cost about US$6 000–8 000/ha. The cost of the operation and maintenance is approximately US$120/ha for the piped surface irrigation system and US$300/ha for a localized irrigation system. The farmers are responsible for operation and maintenance costs.

Government action focuses on the construction of water harvesting schemes and spate irrigation structures with the participation of the beneficiaries, as well as on the rehabilitation of those structures. The beneficiaries are responsible for operation and maintenance. The cost of small and medium spate diversion works and water harvesting structures is between US$1 500 and 2 000/ha.

The crops grown under full/partial control irrigation can be aggregated into six types: cereals, fruits, vegetables, cash crops, pulses and fodders. In 2004, the total harvested irrigated cropped area was 527 038 ha distributed as follows (Table 3 and Figure 4):

- cash crops: 157 878 ha or 30 percent, including 99 504 ha of qat; other cash crops are cotton, coffee, tobacco and sesame;

FIGURE 4
Irrigated crops
Total harvested area: 527 038 ha in 2004 (cropping intensity on equipped area actually irrigated: 116%)



- cereals: 123 195 ha or 23 percent, mainly sorghum and wheat and to a lesser extent maize, barley and millet;
- fruit trees: 75 997 ha or 15 percent, of which 11 percent is banana and 15 percent citrus; other crops under this category are grapes, palm dates, papaya, apricots, peach, quince, figs, apples and guava;
- vegetables: 72 364 ha or 14 percent, including 16 870 ha of potatoes cultivated particularly in the Dhamar and Amran governorates;
- fodder: 70 772 ha or 13 percent;
- pulses: 26 832 ha or 5 percent; most pulses are rainfed.

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

Institutions

The Ministry of Agriculture and Irrigation (MAI) is responsible for formulating policies on irrigation, crops, livestock and forestry production and for coordinating public investment and services in the agricultural sector. The General Directorate of Irrigation (GDI) is located within the Ministry and carries out all the duties related to irrigation, particularly the construction of dams and water harvesting and spate structures. Most field services are provided to farmers through decentralized Regional Agriculture and Irrigation Offices (RAIO) in the different governorates of the country. Several projects are working under the supervision of the MAI to provide different services, particularly the introduction of water saving techniques and the construction of water harvesting and spate structures. Other areas of action include wadi bank protection and the rehabilitation of abused terraces, as well as the rehabilitation and maintenance of existing irrigation structures. To support agricultural development at the regional level, three Regional Development Authorities (RDA) have been established in the northern governorates: (i) Tihama Development Authority (TDA), (ii) Sana'a, Sa'dah, Hajjah and Amran Rural Development Authority (SSHARDA) and (iii) Eastern Region Agricultural Development Authority (ERADA). Although RDAs have not been established in the southern governorates, agricultural production in wadis such as Wadi Hadramout, Wadi Tuban, Wadi Beihan has been supported by donor agencies through the Directorates of Agriculture in the respective governorates.

In addition to the above authorities, the Agriculture Research and Extension Authority (AREA) is working under the umbrella of the Ministry. The Agricultural Cooperative Union (ACU) was established in August 1991 with 213 societies. Its main objective is to consolidate integration and coordination with the government effort in setting up several common projects, of which the most important ones are infrastructure projects such as water storage, regulation dams and weirs, and agricultural marketing. It also supplies agricultural inputs and means for livestock development. At present the ACU has four general societies with 400 primary societies and 20 branches in all the provinces of the country.

The Ministry of Water and Environment (MWE) was established in May 2003. It is responsible for water resource planning and monitoring, legislation and public awareness. MWE has many sub-sectors and authorities such as the National Water Resources Authority (NWRA), Environment Protection Authority (EPA), General Rural Water Authority (GRWA), Urban Water Supply and Sanitation Corporation, and Rural Water Supply and Sanitation Corporation.

The Ministry of Public Works and Urban Planning (MPWUP) is responsible for observing and monitoring the drinking water purification stations. The Ministry of Local Administration (MLA) is responsible for water supply and sanitation in rural areas.

Water management

According to the Constitution, surface water and groundwater resources are defined as 'res communis'. However, a landowner has 'precedence' for water taken from a well on his land. In spring-irrigated areas water can be attached to land in the form of 'turns', which give rights to divert the canal into the field for a fixed period of time. The 'turn' can, however, be detached from the land and sold or rented separately. This landowner's 'precedence' has permitted the private development of deep tubewell extraction, which is in some ways in conflict with Islamic principles. Islamic and customary law has no precedent for dealing with a new technology that allows landowners to extract (and sell) unlimited quantities of water from deep aquifers, and modern law has not yet regulated it either.

Following the Water Law, water user associations (WUAs), water user groups (WUGs) and water councils (WCs) were established to transfer operation and maintenance (O&M) functions of the spate irrigation and groundwater irrigation schemes from the MAI to the user organizations. Up to now, 65 WUAs, 1 287 WUGs and 2 WCs (in Wadi Zabid and Wadi Tuban) have been established. They have received training on issues such as technical, financial and administrative management, provided by different projects.

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

Policies and legislation

The government recognizes the critical water situation in the country and is undertaking different actions to deal with it. Several water sector strategies, legislations and policies have been prepared and implementation of some of them has begun. The Water Law was enacted on 31 August 2002, and amended by Parliament in December 2006. Implementation of this law will give a major thrust to the issue of water conservation. On 19 November 2002, the Cabinet passed a decree proclaiming Sa'dah, Sana'a and Ta'iiz protected areas, as stipulated in Article 49 of the Water Law. The National Water Resources Authority (NWRA) will monitor closely these critical areas.

The following policies and the strategies have been developed after assessment of the water sector and irrigation sub-sector:

- water resources policy and strategy (1999-2000)
- irrigation water policy (2001)
- watershed policy (2000)
- agricultural sector reform policy (2000)
- urban water supply and sanitation sector reform policy (1997)
- wastewater reuse strategy (under development).

ENVIRONMENT AND HEALTH

The successful and sustainable exploitation of water resources is threatened by the rapid depletion of groundwater resources. Almost all the important groundwater systems are being over-exploited at an alarming rate. The socioeconomic consequences of groundwater depletion are dramatic because it will become too expensive for use in agriculture and, as a result, regional agricultural economies based on groundwater irrigation are doomed to collapse if the water resources are not adequately controlled. Groundwater availability may be further reduced by groundwater salinization in coastal areas and groundwater pollution in urban areas and areas of intensive agriculture. A study conducted by the Tehama Development Authority (2004) reported that the EC increased from 225 to 3 480 µs/cm (at 25 °C) in the Al-Jar area as a result of sea water intrusion. The Al-Jar region is located in the northwest of the Yemeni coastal area, 8 km away from the Red Sea. During the last ten years there has been a huge investment in this area, leading to the cultivation of more than 3 500 ha of mango trees and the drilling of about 2 000 wells. In the whole country, the area cultivated with high water consuming crops increased, such as the area under qat, which has more than tripled in 25 years.

The quality of treated wastewater varies from one area to another. While the quality is very good in Hajah, it is very bad in Ta'iiz, depending on the method of treatment as well as the capacity of the station and the operational circumstances. The quality affects the farmers' willingness to use such water for their crops (Al-Asbahi, 2005). Moreover, the outflow of the WWTP stations in the coastal areas becomes a source of groundwater pollution.

Environmental degradation occurs in areas where springs have dried up or where treatment plants are not able to treat oil residues and discharge the raw wastewater directly to the wadis (such as from the Sana'a station). Water scarcity leads to ever-increasing competition which, if uncontrolled, might lead to socioeconomic problems.

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

Reducing the gap between water abstraction and available renewable resources and improving the efficiency of water management is a priority. Specific objectives of the second Five-Year Plan are: optimal exploitation of available water resources; improving the means and techniques for water resources recovery and for feeding aquifers; and protecting water resources from pollution.

To achieve these objectives, the government plans to make investments in groundwater recharge, water harvesting, encouragement of traditional and modern water management techniques, and application of modern irrigation techniques. Furthermore, it plans to invest in improving water use efficiency, capacity building, public and social awareness, as well as to pursue policies for equitable distribution of available water resources in rural and urban areas.

Strategies dealing more specifically with the various challenges of irrigated agriculture are set out in the National Water Strategy, adopted by the Council of Ministers in 1999, and in the National Irrigation Strategy, adopted by the Council of Ministers in 2001, which highlight the following aspects:

1. ensuring the sustainability of groundwater irrigation: to reduce the rapid overdraft of aquifers, the government strategy will apply macro-economic measures (diesel price increase, increasing import duty on drilling rigs...);
2. ensuring the sustainability of spate irrigation schemes: most of the spate irrigation infrastructure is deteriorating due to poor maintenance caused by budgetary constraints in the public sector. The government strategy is to improve the cost effectiveness of their management and to involve users in the management and paying for O&M;
3. increasing the productivity of irrigated agriculture: by regional standards, returns to water in irrigation in Yemen are low. The government policy is to promote improved irrigation technologies and research on agricultural water use efficiency and conservation;
4. changing the role of the government: the government strategy is to reduce its role to the essential minimum and to involve users more and more in irrigation investment and management.

Concerning O&M of large spate works, decrees have already been issued for Lahej and Abyan governorates to charge an irrigation fee from the farmers on the basis of areas actually irrigated; this will be used for O&M of the head works and the main canals to be implemented by the Government. Farmers themselves are responsible for O&M of the tertiary canals.

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