

Lebanon



GEOGRAPHY, CLIMATE AND POPULATION

Geography

Lebanon, with a total area of 10 400 km², 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,



LEBANON

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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/km². 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 km³. Annual surface runoff is around 4.1 km³ and groundwater recharge 3.2 km³, of which 2.5 km³ constitutes the base flow of the rivers. About 1 km³ 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 km³, consisting of 1.580 km³ of surface water and 0.500 km³ 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 km², equal to some 20 percent of the total area of the country. Average annual water flowing in the Litani River is 475 million m³. 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 km² 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 m³. Exploitable groundwater ranges from 400 to 1 000 million m³ (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 m³/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 m³/year of the El Kebir River on the border between Lebanon and the Syrian Arab Republic is thought to be generated by the 707 km² 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 m³/year, of which 160 million m³ to the sea. Surface water outflow to the Syrian Arab Republic is estimated at 415 million m³ through the Asi-Orontes River. Surface water flow into northern Israel from the Hasbani/Wazani complex is estimated at 160 million m³/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 m³/year. Of this total, 740 million m³ is estimated to flow to the sea, 150 million m³ to Israel (Hulah Lake) and 130 million m³ 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 m³ and effective storage of 160 million m³ (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 m³ for irrigation purposes (110 for South Lebanon and 30 for Bekaa), and 20 million m³ 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 m ³ /yr
Internal renewable water resources (long-term average)		4.800	10 ⁹ m ³ /yr
Total actual renewable water resources		4.503	10 ⁹ m ³ /yr
Dependency ratio		0.79	%
Total actual renewable water resources per inhabitant	2005	1 259	m ³ /yr
Total dam capacity	2005	225.65	10 ⁶ m ³
Water withdrawal			
Total water withdrawal	2005	1 310	10 ⁶ m ³ /yr
- irrigation + livestock	2005	780	10 ⁶ m ³ /yr
- municipalities	2005	380	10 ⁶ m ³ /yr
- industry	2005	150	10 ⁶ m ³ /yr
• per inhabitant	2005	366	m ³ /yr
Surface water and groundwater withdrawal	2005	1 096	10 ⁶ m ³ /yr
• as % of total actual renewable water resources	2005	24	%
Non-conventional sources of water			
Produced wastewater	2001	310	10 ⁶ m ³ /yr
Treated wastewater	2006	4	10 ⁶ m ³ /yr
Reused treated wastewater	2006	2	10 ⁶ m ³ /yr
Desalinated water produced	2006	47.3	10 ⁶ m ³ /yr
Reused agricultural drainage water	2001	165	10 ⁶ m ³ /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.

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

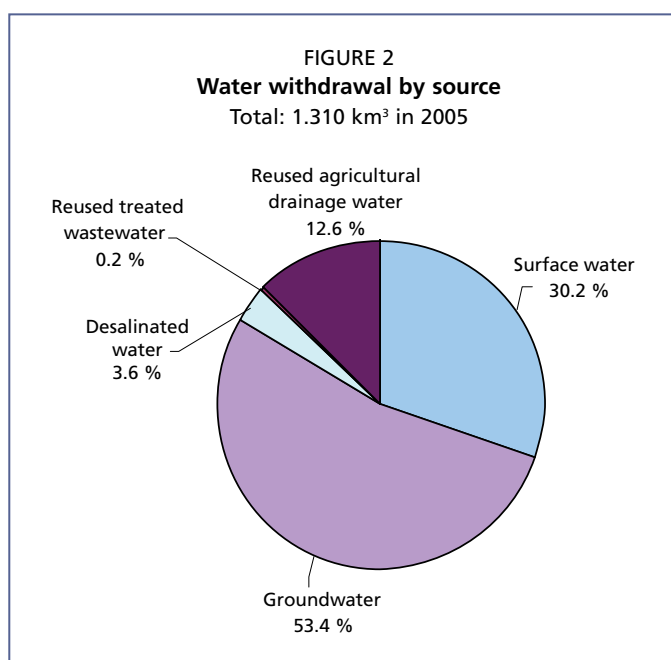
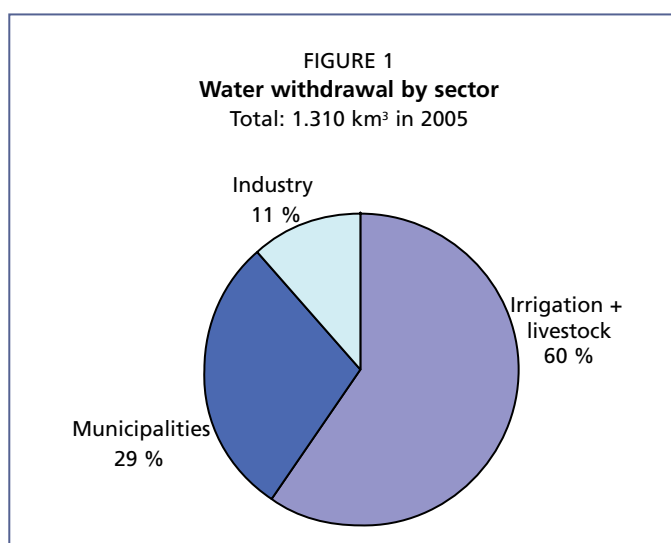


TABLE 3
Irrigation and drainage

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 m³ (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

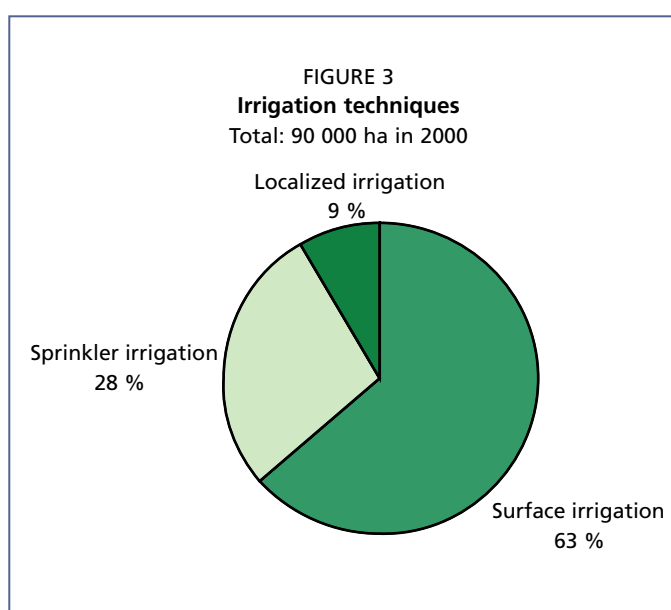
Evolution of irrigation development

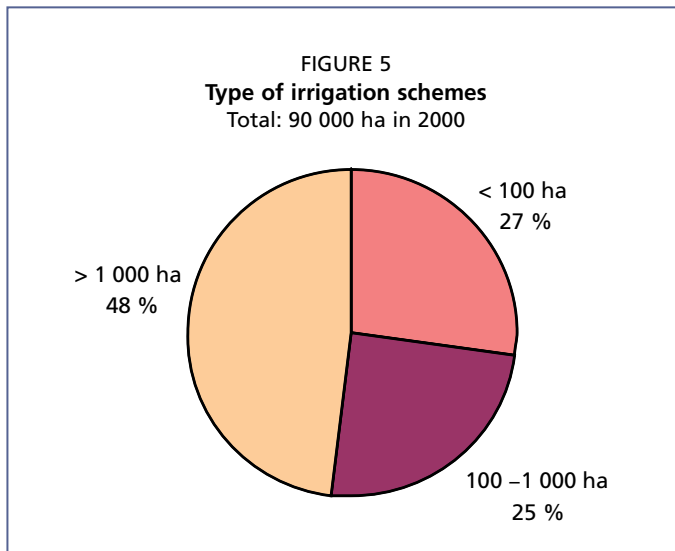
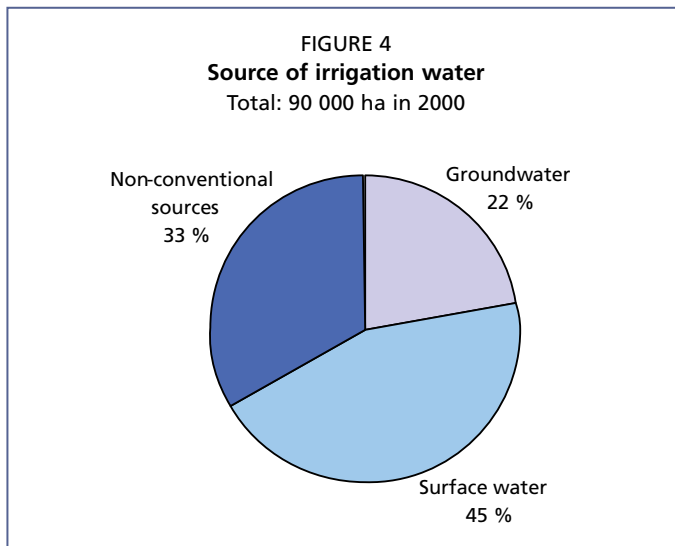
Irrigation potential, based on soil and water resources, is estimated at 177 500 ha. The irrigated area in Lebanon increased from 23 000 ha in 1956 to 54 000 ha in 1966 and then went down to 48 000 ha in the early 1970s. In 1993, the total area equipped for irrigation was estimated at 87 500 ha, of which 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





(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

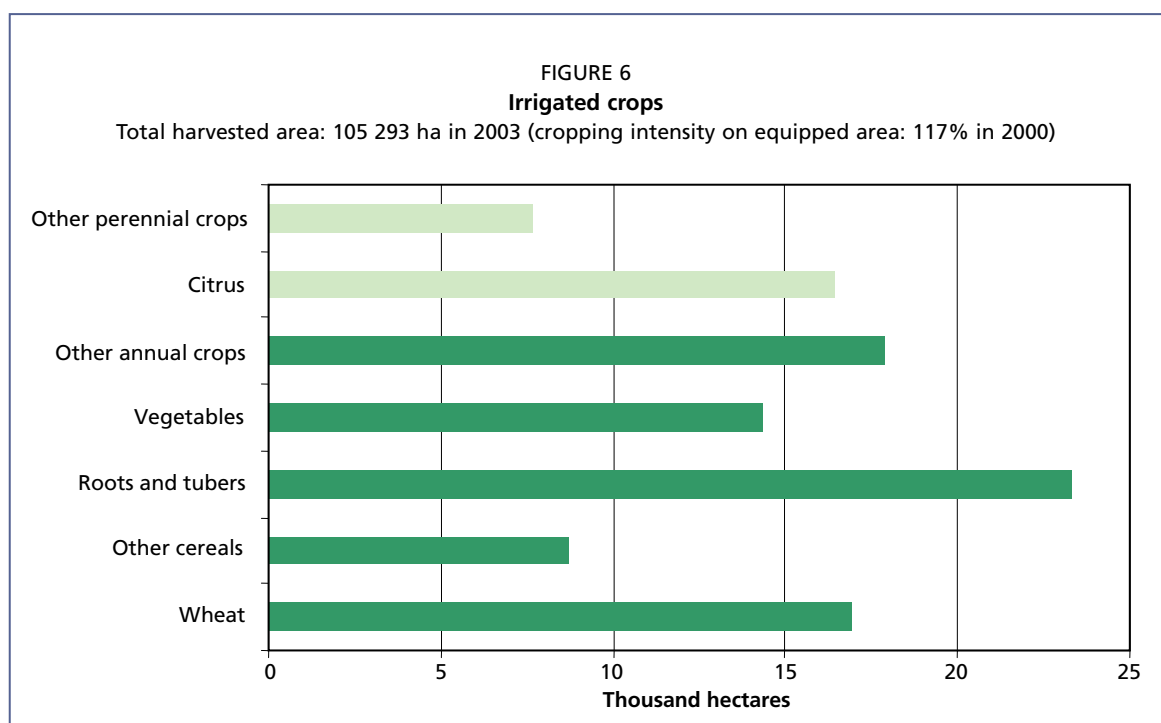
In 2003, the harvested irrigated area was 105 293 ha, half of which (51 percent) was in the Bekaa Valley (MOA and FAO, 2000). Annual crops represent 77 percent of the total harvested irrigated area. The main irrigated crops

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



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 an 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 m³/year where furrow irrigation was used, to 6 500 m³/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 m³/day gauge subscription, which is equivalent to US\$0.12 to US\$0.42 per m³ water per day per household assuming consumption of 1 m³ 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 m³. 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 km³ 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 m³ 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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