

PART II –ENVIRONMENT AND AGRICULTURE

2. MORPHOLOGY, WEATHER, HYDROLOGY, VEGETATION, AND ENVIRONMENT

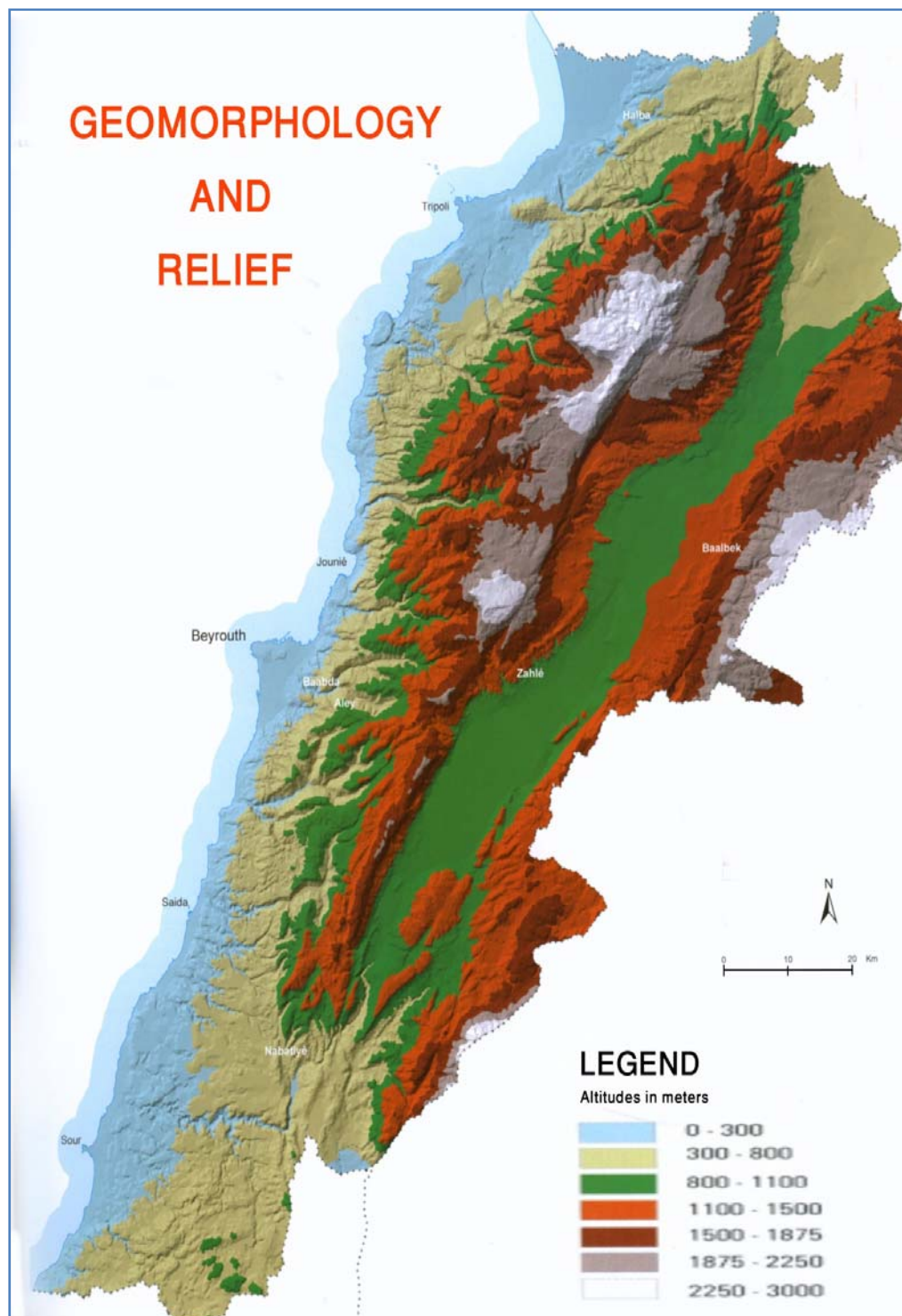
Geomorphology, geology and soil, weather and rainfall, hydrology, water sector calculations, vegetation zones, fire forests, and reforestation are the main topics of this chapter.

Geomorphology

Lebanon little area enjoys climatic and four geomorphologic zones, agricultural orientation, forest species.

Table 2.1 – Geomorphologic zones of Lebanon

Seashore and Coastal plain	
<i>Lebanese seashore</i>	Spreads over 220 km between Arida (North) and Ras Al-Naqoura (South). Deeply cut cliffs showing recent and accelerated erosion. Lie at the bottom of these cliffs, gravel beaches, often bordered by sandy beaches, with variable lengths (20% of the coast).
<i>Coastal plain</i>	Varies in width beneath the Mount-Lebanon range: <ul style="list-style-type: none"> • Very narrow along the majority of its length (7 km in average). • Wider at the Aakkar plain in the North: its width reaches 30 km with an elevation of 500 m. • Narrows between Tripoli and Jabal Terbol. • Excessively narrow (3 km in average) interrupted by the crests of Mount Lebanon. • Widens slightly near Beirut, the Choueifat plain, and near Saida plain, from where it spreads with no interruption towards the Tyr plain with an average width of 7 km.
Western mountain range (Mount Lebanon)	
Mount-Lebanon extends from the North of Jabal Aakar southward up to an elevation of 3,008 m (Kornet el Saouda) and 1,809 m (Jabal Niha). Its total length is 160 km. Width varies between 25 km (central part) and 45 km (North). Mount Lebanon middle altitude area is the most diversified in Lebanon: the stiff elevation of abutments is followed by several small hills form an intermediate graduation between the sea and the peak. The western front is cut by parallel narrow valleys with an inclination seaward, carrying rivers and water courses. The eastern slopes overhanging the Bekaa valley are steeper than the western slopes. There are some seasonal rivers formed in spring as a result of the snowmelt. High altitudes have stiff elevations and scarps reaching the peak. With a big volume of rain and a two meters snow cover, the landscape is dry and stripped because water infiltrates through the karstic basins. Crest-line starts at around 1,800 m and is formed of large, circular and grayish peaks, especially in the North.	
Interior plain (Bekaa valley)	
Depression at an average elevation of 900 m, measures 120 km (North-South) by 8-12 km (East-West) in average, with an exceptional width of 25 km at Hermel (in the North). Soft slopes with a peak of 1,100 m located near Baalbek, where the valley mingles with Anti-Lebanon abutments.	
<i>Northern and Central Bekaa</i>	This agricultural area expands from the valley of Nahr el Aassi till Haouch el Nabi in the south. It contains Litani river water sources.
<i>Southern Bekaa</i>	This agricultural area spreads from Zahleh-Rayak region down to Marjaayoun in the South.
Eastern mountain range (Anti-Lebanon)	
High altitude consists of a dry plateau with a width of 30 km and an average elevation of 2,300 m (maximum is 2,616 m at Tallet Moussa). The plateau inclines southward to reach an elevated plain (1,400 m). This creates a natural break-up between Eastern part and Mount Hermon. Anti-Lebanon has no deep valleys. Mount Hermon extends over 100 km starting from Yanta in its north to Shebaa in the south. Its crests and slopes are a catchment feeding rivers flowing towards Bekaa valley (west), Houla Lake in Palestine (south) and Aaouej plain in Syria (east). Thus, Jabal el Cheikh intercepts and redistributes water resources in this arid region.	



Geology and soil

Lebanon geological formations, settled until the Miocene-Pliocene periods, are formed mainly of sedimentary carbon rocks, limestone and dolomite. They seldom include clastic rocks (detritic rocks), sandstone, mudstone, marl and clay. Locally, some volcanic rocks such as pyroclastic basalt may be found. Jurassic and cretaceous limestone represents the main feature (armature) of Lebanon topography. Apart from recent sediments within the plain of Aakkar or the Bekaa valley, these are the core karstic formations that determine the landscape and water resources in Lebanon.

Table 2.2 - Stratigraphic column of Lebanon

Period	Epoch	Thickness	Lithology
Quaternary	Pleistocene / Recent	Variable	Eolian sands and alluvium
Tertiary	Pliocene	Up to 500m	Limestone, marl, volcanic material, sand and conglomerate
	Miocene	Up to 300m	Marly limestone, sand and conglomerate
	Eocene	Several hundred meters	Marly limestone
	Paleocene	Combined with Senonian	
	Senonian (Chekka marl)	100 to 500m	Marl
Cretaceous	Turonian (Maameltain Lst.)	200 to 300m	Marly limestone, limestone
	Cenomanian (Sannine Lst.)	Up to 700m	Dolomitic limestone, and marly limestone
	Upper Aptian/Albian (Hammana formation)	100 to 400m	Marl and limestone
	Lower Aptian (Mdeirij Lst.)	About 45m	Limestone
	Lower Aptian (Abeih sandstone)	80 to 170m	Sandstone and marlstone
	Neocomian (Chouf sandstone)	10 to 300m	Sandstone
	Portlandian (Salima Lst.)	Up to 180m	Oolitic limestone and clay
Jurassic	Kimmeridgian (Bikfaya Lst.)	Up to 80m	Dolomitic limestone
	Oxfordian (Bhannes volcanics)	Up to 150m	Marly limestone, volcanic complex
	Callovian (Kesrwan Lst.)	Over 1000m	Dolomitic limestone

Photo 2.1 - Limestone in the region of Kesrouane



Source: Picture taken by Vicken Ashkarian (2003)

Resulting from the transformation of rocks under the combined influence of weather, vegetation cover, and slope of the terrain, soils are typically Mediterranean. The majority of soils are calcareous, apart from sandy gravelly soils formed on the cretaceous strata.

The most expanded soils are Terra Rossa and Rendzina.

Photo 2.2 – Terra rossa (red soil)



Source: picture retrieved of www.wikipedia.org

Photo 2.3 - Rendzina



Source: <http://www.inra.fr/internet/Hebergement/afes/Ressources/photos/sol115.php>

Lebanon soils are young, fragile and subject to erosion, especially in the mountains and hills that represent 73% of the country.

Topography, rain intensity and surface runoff are major factors increasing erosion caused by the precipitations, especially where the protective green cover has disappeared. The erosion intensity of Lebanon soils is proved by the stratification of alluvial loam terraces of the coastal rivers.

Lebanon's position at the northern temperate zone and at the Mediterranean zone and its morphology characterize its weather. The two mountain chains, Mount-Lebanon and Anti-Lebanon, expanding perpendicularly to the atmospheric circulation constitute the core of the country. They produce a climatic variability at small distances. Hence, a 50 km cross section shows climate variations: a subtropical coastal climate followed by a typically Mediterranean climate at low elevations and a cold weather at higher elevations covered with snow during the winter, reaching a semi-desert plain, too dry to allow agriculture. This variety means a great diversity in ecosystems and landscapes in a limited surface area.

Rafic Hariri International Airport (RHIA), Beirut Golf, Zahleh (Haoush al Oumara) and Tripoli measure stations provide the General Directorate of Civil Aviation, Climatology Service with weather data for 2010.

Table 2.3 – Temperature, rainfall and windspeed in 2010

Total/average 2009	Coastal Zones			Bekaa valley
	RHIA	Beirut Golf	Tripoli	Zahleh
Mean temperature (°C)	24.6	24.3	22.0	19.8
Rain (mm)	485.6	779.4	574.4	554.2
Mean relative humidity (%)	51.7	57.6	57.4	52.2
Wind mean power (m/second)	3.0	2.7	2.1	2.3
Maximal wind direction (degrees)	211	216	228	225
Rainy days	45	57	59	49

Table made by CAS based on General Directorate of Civil Aviation, Climatology Service data (2010)

Temperature

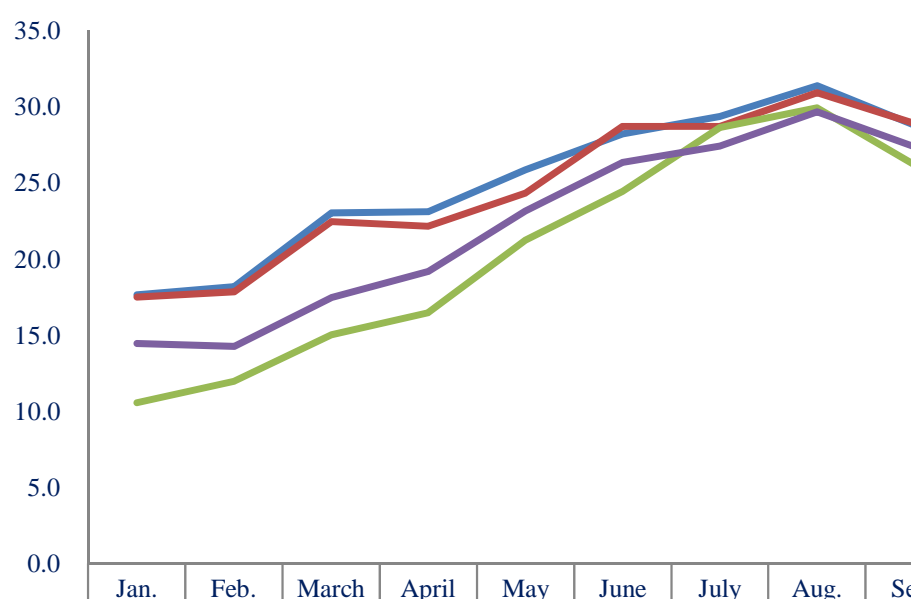
January is in general the coldest month, while July and August are the warmest months. Coastal zones (Beirut and Tripoli) are more humid than internal zones (Bekaa).

Table 2.4 – Maximum and minimum temperature. Degrees Celsius in 2010

Temperature (°C)	Coastal Zones			Bekaa valley
	RHIA	Beirut Golf	Tripoli	Zahleh
Mean temperature	24.6	24.3	22.0	19.8
General average: 19.5–21.5				
Minimum temperature	6.3 (February)	5.2 (February)	4.1 (February)	-3.8 (February)
General average: January 7				
Maximum temperature	37.1 (August)	37.8 (June)	38.2 (October)	43.2 (July)
General average: July-August 33				

Source: Table made by CAS based on General Directorate of Civil Aviation, Climatology Service data (2010)

Graph 2.1 –Mean temperature. °C in 2010



Graph made by CAS based on General Directorate of Civil Aviation, Climatology Service data (2010)

Rainfall

The average annual rainfall on the coastal zones varies between 700 and 1000 mm and increases towards the North-South direction.

Mount-Lebanon forms a barrier against the rain movement and the precipitations can reach more than 1400 mm per annum (the majority of which is snow). Rainfall decreases rapidly in the eastern slope of Mount-Lebanon and registers only 600 mm.

Rainfall in the Bekaa valley varies between 800 mm (southern Bekaa) and 200 mm (extreme north-east of the valley). As for the Anti-Lebanon, rainfall is around 600 mm and increases up to more than 1000 mm in Jabal el Cheikh.

The global amount of precipitations is estimated at 8 600 millions of m³ (MCM) per annum, to which it should be added the amount of snow, which is around 2 200 MCM.

The long term meteorological observations carried out for Beirut and Central Bekaa highlight the following characteristics:

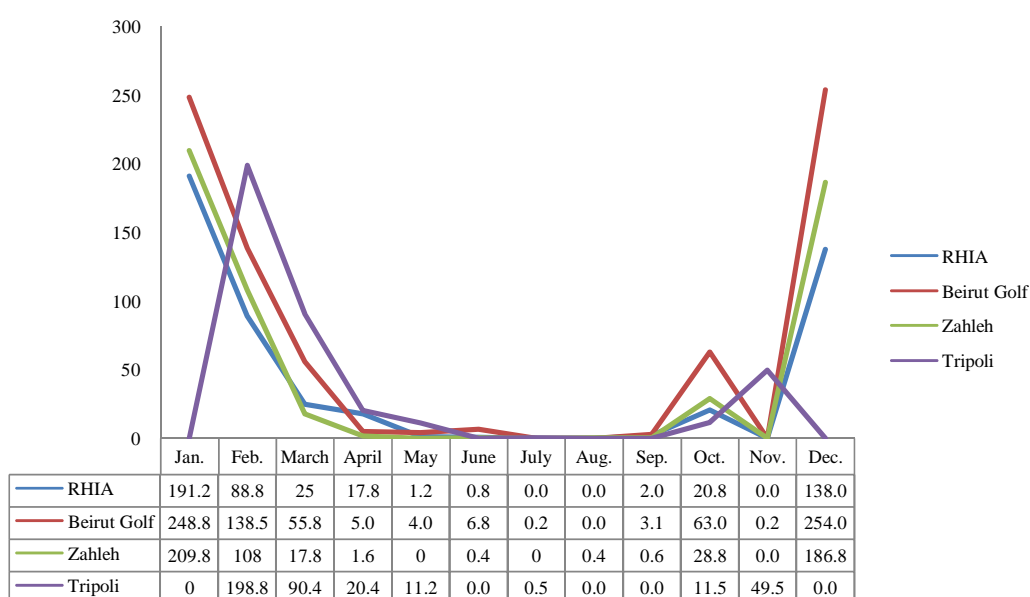
- Lebanon has a high average in rainfall per annum (Beirut, 893 mm).
- Great seasonal variations with 80-90% of the annual rainfall occurring between November and March, and less than 5% between May and September.
- Strong rain showers that can cause floods and erosion.
- Precipitations occur during 80 to 90 days per year, between the months of October and April.

Table 2.5 –Maximum and minimum rainfall. Mm in 2010

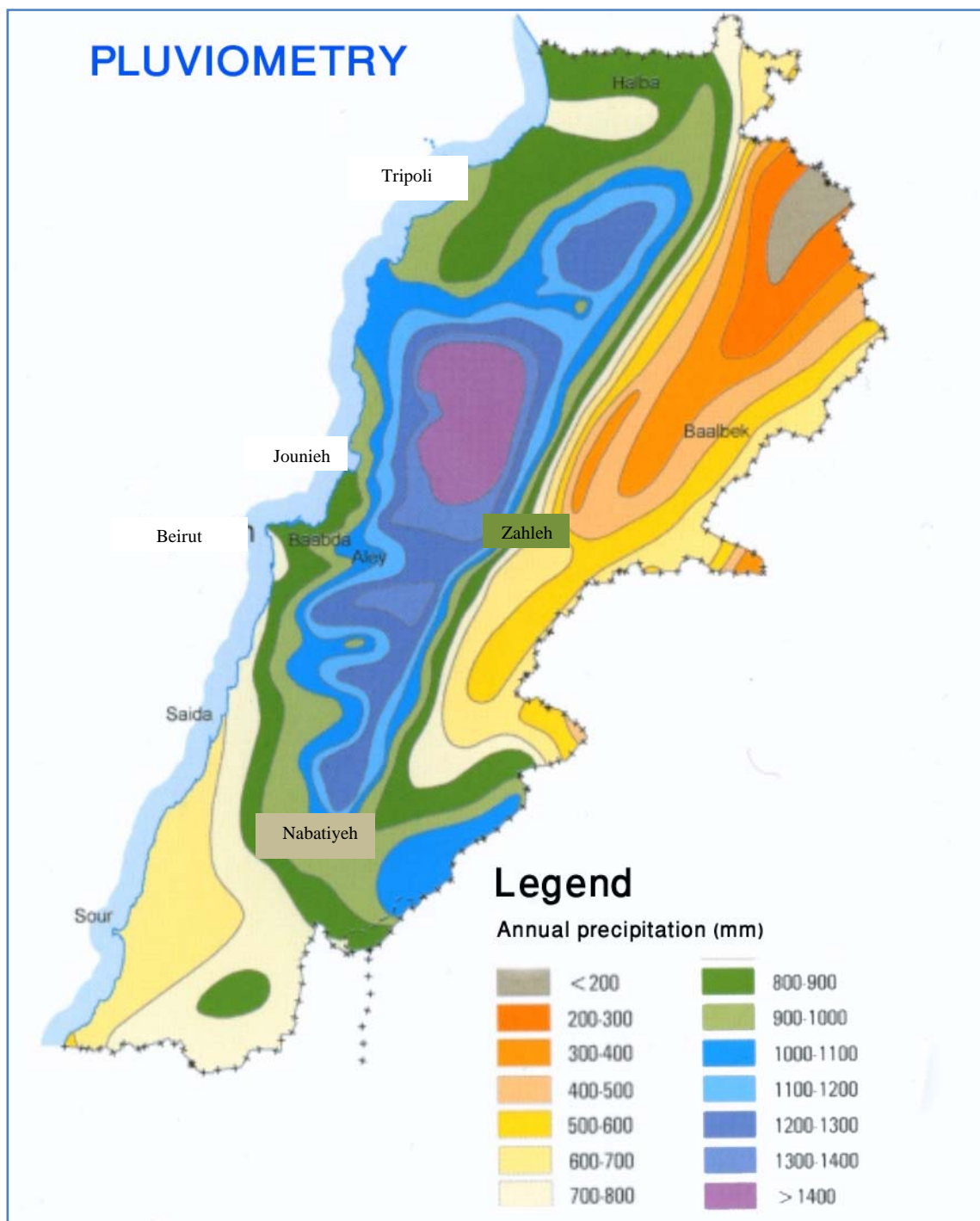
Rainfall. Mm	Coastal Zones			Bekaa valley
	RHIA	Beirut Golf	Tripoli	Zahleh
Total precipitation	485.6	779.4	574.4	554.2
	General average: 700 – 1 000 mm			200–800 mm
Minimum precipitation	0 (July-August)	0 (July)	0 (July-August, November)	0 (May, July, November)
Maximum precipitation	138.0 (December)	254.0 (December)	198.8 (January)	209.8 (January)

Table made by CAS based on General Directorate of Civil Aviation, Climatology Service data (2010)

Graph 2.2 –Rain. Mm in 2010



Graph made by CAS based on General Directorate of Civil Aviation, Climatology Service data (2010)



Source: CDR (2004)

Relative humidity

Table 2.6 – Realtive humidity. % in 2010

Relative humidity. %	Coastal Zones			Bekaa valley
	RHIA	Beirut Golf	Tripoli	Zahleh
Mean relative humidity	51.7	57.6	57.4	52.2
Minimum relative humidity	10 (December)	6 (January)	14 (January)	4 (December)
Maximum relative humidity	95 (December)	97 (March)	94 (February)	100 (December)

Table made by CAS based on General Directorate of Civil Aviation, Climatology Service data (2010)

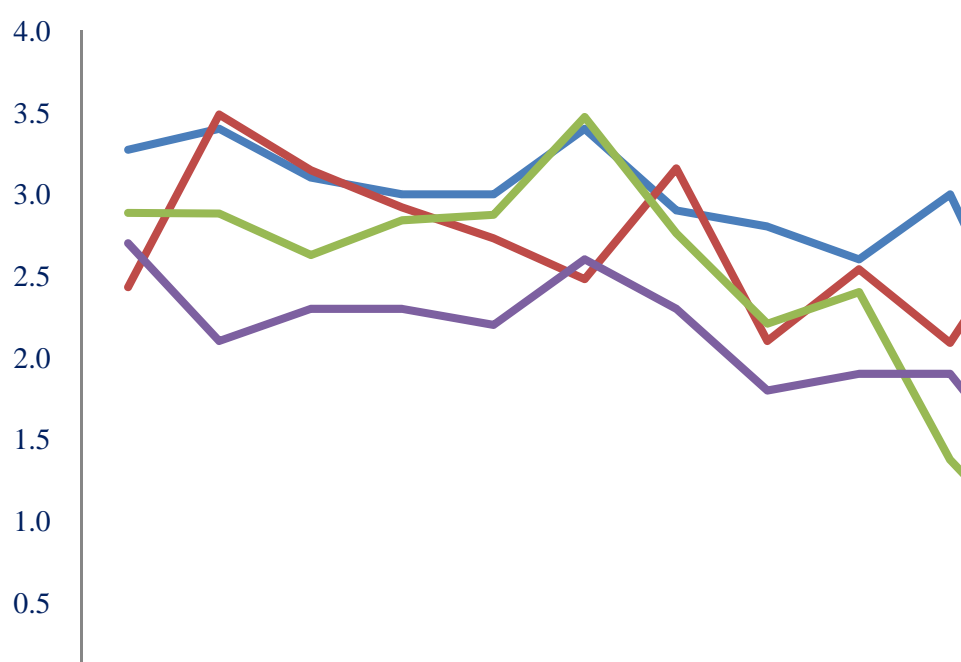
Wind power

Table 2.7 – Wind mean power. M/s in 2010

Wind power. M/second	Coastal Zones			Bekaa valley
	RHIA	Beirut Golf	Tripoli	Zahleh
Wind mean power	3.0	2.7	2.1	2.3
Maximum wind power	16.5 (December)	16.2 (December)	20.0 (April)	23 (January)

Table made by CAS based on General Directorate of Civil Aviation, Climatology Service data (2010)

Graph 2.3 –Wind mean power. M/s in 2010



Graph made by CAS based on General Directorate of Civil Aviation, Climatology Service data (2010)

Wind direction

Table 2.8 – Maximum wind. Degrees in 2010

Wind direction. Degrees	Coastal Zones			Bekaa valley
	RHIA	Beirut Golf	Tripoli	Zahleh
Average maximum wind direction	210.8	216.0	228.3	225.0
Maximum wind direction	260 (February)	250 (January, October)	320 (Februray, July-August)	350 (February)

Source: Table made by CAS based on General Directorate of Civil Aviation, Climatology Service data (2010)

Rainy days
Table 2.9 – Rainy days. Number in 2010

Rainy days	Coastal Zones			Bekaa valley
	RHIA	Beirut Golf	Tripoli	Zahleh
Number	45	57	59	49
Minimum number	0 (July-August, November)	0 (July)	0 (July-August, November)	0 (May, July, November)
Maximum number	13 (January)	12 (January)	15 (January)	12 (January, December)

Table made by CAS based on General Directorate of Civil Aviation, Climatology Service data (2010)

Hydrology

Lebanon has 40 rivers and water courses, originating from the Mount-Lebanon mountain range. These are internal short rivers with an East-West lateral orientation spilling into the Mediterranean, except for the two trans-border rivers which are the Orontes River (Nahr el Aassi) crossing towards Syria and the Hasbani River crossing towards Palestine.

The rivers and water basins maintain the Lebanese ecosystem and irrigate low and middle elevation areas of Mount Lebanon, as well as in the Bekaa valley. Besides, rivers enhance the flora and fauna of the country, particularly in deep valleys where local climate is softer.

Table 2.10 – Lebanese river system

North-Lebanon	
Nahr el-Kebir	Nahr Estouane
Nahr Aarqa	Nahr el Bared
Nahr Abou Ali	Nahr el Jaouz
Mount-Lebanon	
Nahr Ibrahim	Nahr el Kalb
Nahr Damour	
Beirut	
Nahr Beirut	
South-Lebanon	
Nahr Saïniq	Nahr Awali
Nahr Abou Asswad	Nahr el Zahrani
Nahr el Hasbani	
South-Lebanon – Bekaa	
Nahr Litani	
Bekaa	
Nahr el Assi	

The lengthiest river is the Litani (170 Km) and the shortest one is Hasbani (21 Km).

Regarding the annual average volume in 2006-2009, El-Kebir had the highest one (283.9 Mm³) and El-Zahrani had the weakest one (17.5 Mm³).

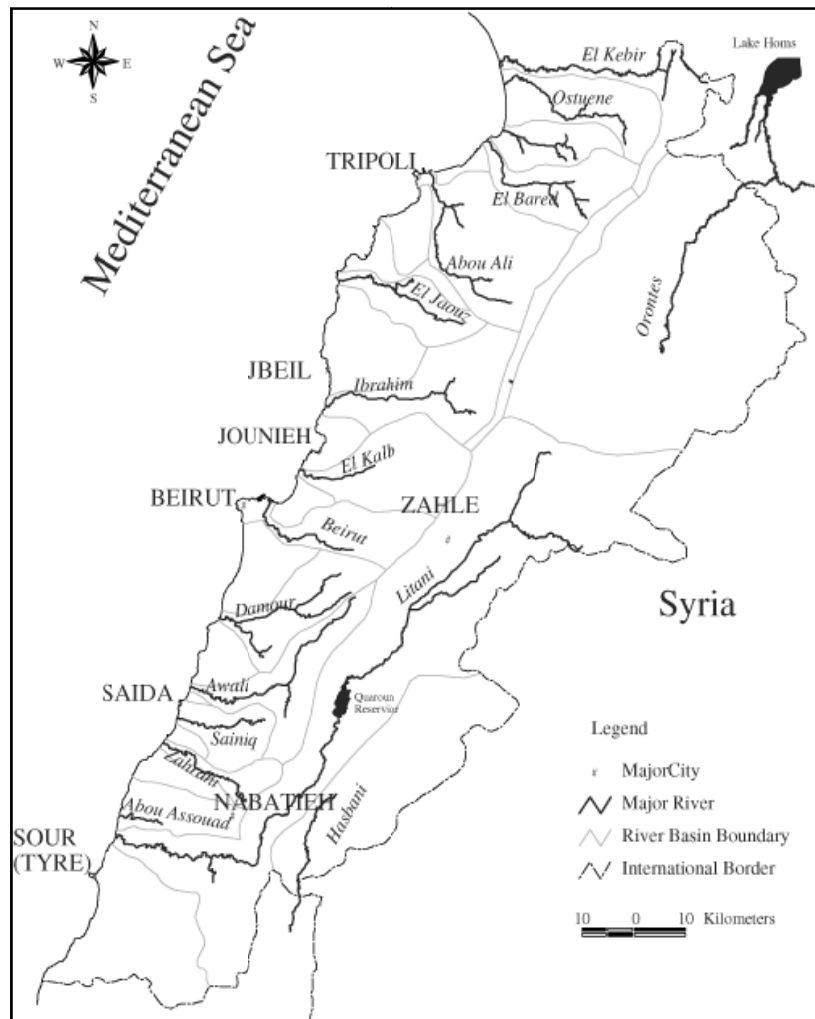


Table 2.11 – Hydrological cycle of Lebanon. Flow in 2010

Designation	Flow. MCM/year
Total annual precipitation	8,200
Natural evapotranspiration	4,100
Loss in surface waters to neighboring countries	648
Loss in underground water to neighboring countries	300
Sub-marine sources	385
Total renewable water in Lebanon	2,767
Surface water	2,200
Ground water	567

Source: Ministry of Energy and Water (2010)

Water sector in Lebanon

Water sector reform began in 1999 to implement the Integrated Water Resources Management which has four standard pillars: decentralization of water service; pricing incentive; Public-Private Partnership in water management; and finally, introducing a regulator.

Concretely, the Ministry of Energy and Water sketched a 10 years plan aiming to build 30 dams and hill lakes to increase available water quantity.

This 10 years plan will try to meet the needs of water in Lebanon with the available quantities:

- Total needs of water are 1,660 MCM.
- Expected stocking volume will be 806 MCM.
- Water shortage will be reduced to 854 MCM.

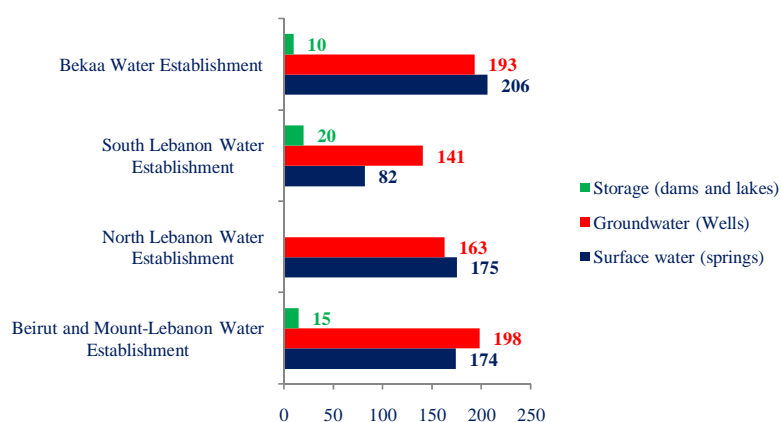
Laws 221/2000, 241/2000 and 337/2001 reduced the numbers of the 22 Autonomous Water Boards and the 210 Water Committees into 4 Water Authorities (Beirut and Mount-Lebanon, North-Lebanon, South-Lebanon and Bekaa) in charge of the production and distribution of drinking water and irrigation water, each in its geographic parameter.

To improve the sector performance, a specialized regulator was theoretically created: the Board of Performance Evaluation under the guardianship of the Ministries of Energy and Water.

The Office National du Litani created by the law published on 14/08/1954 manages and exploits irrigation water in its geographic parameter (South Bekaa and South Lebanon).

Water resources in Lebanon

The four Water establishments exploits 1,377 Mm³/year. Bekaa Establishment is the mode regarding exploitation (29.7%). Ground water is the peak as it constitutes 50% of exploited water resources.

Graph 2.4 –Exploited water resources. Mm³/year in 2010

Graph made by CAS based on General Directorate of Civil Aviation, Climatology Service data (2010)

Groundwater is also exploited in Lebanon by the private, illegal and public sectors.

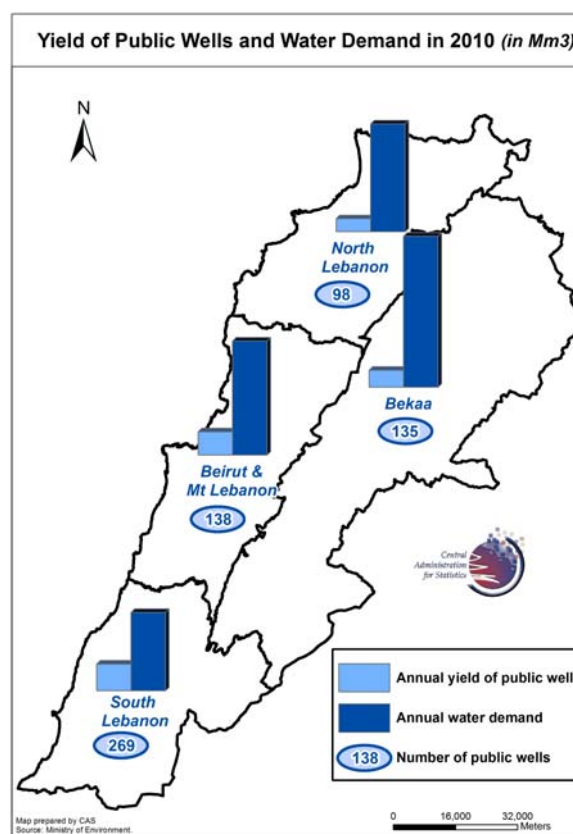
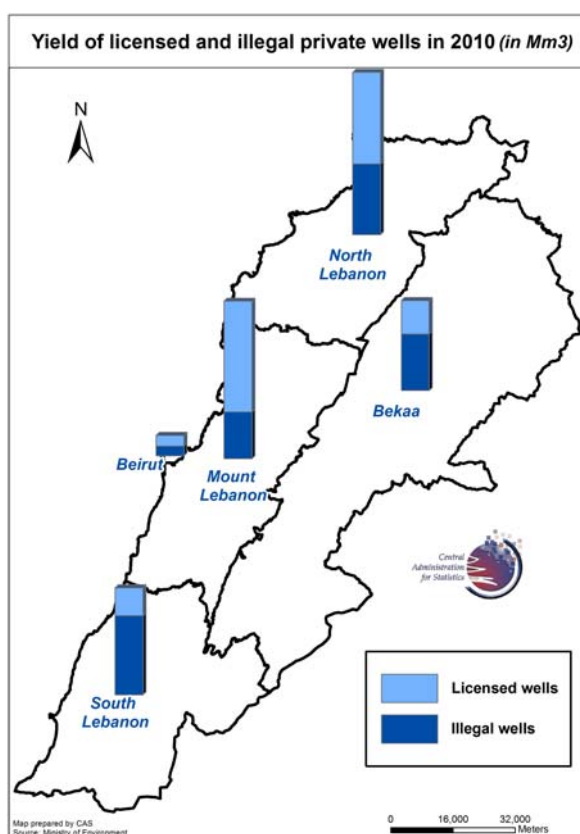
Table 2.12 – Wells in Lebanon. Number and total yield in 2010

Mohafazat	Licensed private wells		Illegal private wells		Wells operated and maintained by Water Establishments	
	Number	Total yield (Mm ³ /year)	Number	Total yield (Mm ³ /year)	Number	Total yield (Mm ³ /year)
Beirut	1,680	7.14	1,500	6.44	98	42
Mount-Lebanon	10,718	74.33	4,500	31.20	269	87
North Lebanon	2,966	61.27	7,000	47.27	135	55
South Lebanon	2,282	18.75	5,000	52.93	640	260
Bekaa	2,678	22.49	4,500	37.77	98	42
Total	20,324	182.31	22,500	175.61	269	260

Source: Ministry of Environment (2010)

Total number of wells in Lebanon is 43,464. Illegal private wells constitute 51.8% of total wells, while those exploited by the private sector form 46.8%. Finally, the wells operated and maintained by Water Establishments are minor (1.5% of total).

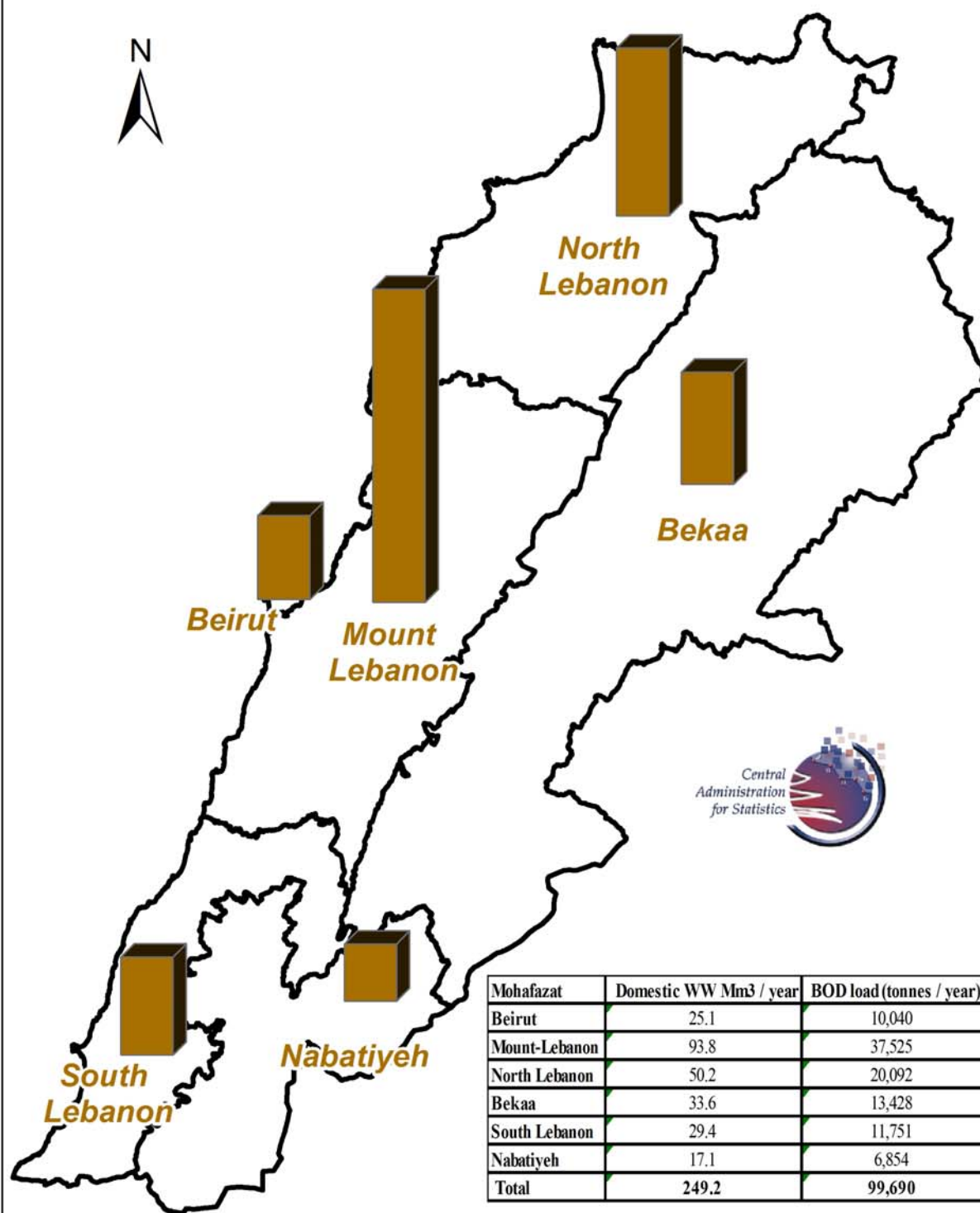
As for the total yield, it is equal to 617.92 Mm³/year. The wells exploited by the private sector enjoy the peak annual total yield (29.5% of the total).



As for water demand, it is equal to 1,473 Mm³ in 2010. Agriculture consumes 58.0%, the domestic sector 31% and finally, the industry sector 11%.

As for domestic wastewater generation it is equal to 249.2 Mm³ in 2010. Mount-Lebanon constitutes the peak with 37.6%. It is followed by North Lebanon (20.1%).

Estimated Domestic Wastewater Generation in 2010 (in Mm3)



Map prepared by CAS
Source: Ministry of Environment.

0 16,000 32,000
Meters

Air quality

Average cost of air pollution is equal to USD 170 million per year.

Table 2.13 – Annual costs of air quality degradation. USD million in 2010

Ambient/ Indoor air pollution	Million dollars per year
Urban Air pollution-Lead	28-40
Urban Air Pollution-PM10	26
Indoor Air Pollution	10-46
Total Costs from Outdoor/ Indoor Air Pollution & Loss of quality of life	112-225
Average Cost of Air	170

Source: Ministry of Environment (2010)

Biodiversity

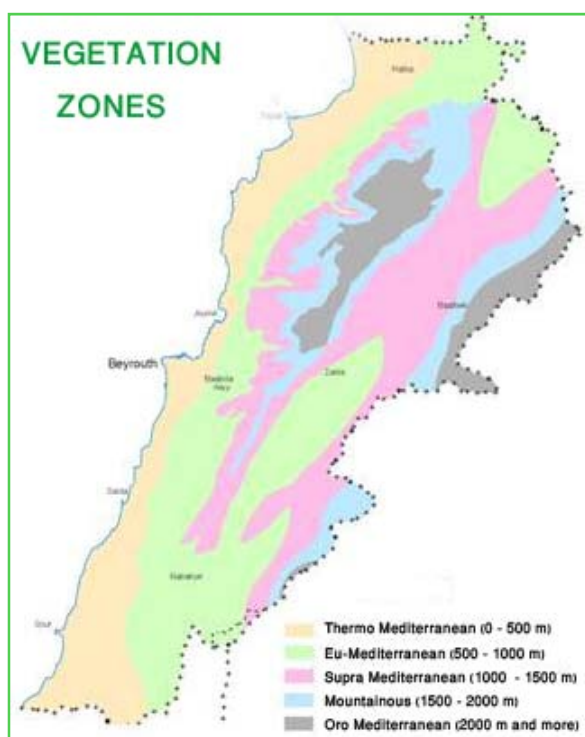
Vegetation zones of Lebanon

Vegetation zones display vegetation cover and protected vegetal areas.

Vegetation cover

Climate influences the vegetation cover in Lebanon. There are four major botanical levels, between the coastline, the mountain then the hinterland:

- Thermo-Mediterranean level (0-1,000 m): pines (Beirut and western slope of Mount-Lebanon), carob trees, storax, oak trees, willows (the slopes of Niha, Baruk Mountains, coastal zones, and the piedmonts of Mount Hermon in the hinterland).
- Supra-Mediterranean level (1,000-1,500 m): cypress, oak trees (Ehden, Sir ed-Dinniye, highlands of Qadisha, piedmonts of mount Mekmel, and Aakkar).
- Mediterranean mountainous level (1,500-2,000 m): cedars, fir trees (Bsharreh, Ehden, Qadisha, Hadath ej-Jebbeh, Tannourine, and Baruk).
- Oro-Mediterranean level (2,000 m -): no fruit trees, only thorn plants such as juniper (Talaat Moussa on the high altitudes of Anti-Lebanon, etc.).



Forest area is 13.1% of Lebanon area. Coniferous and deciduous forests cover 134,372 ha and other forested areas including woodlands with or without trees cover 120,574 ha [Ministry of Agriculture (2005), Atlas of Forests in Lebanon].

Protected vegetal areas

The continuous reduction of green cover in Lebanon has pushed the Government to edict a more strict Legislation, declaring forests of cedar, fir, cypress and juniper *de facto* protected.

Table 2.14 – List of protected forests in Lebanon

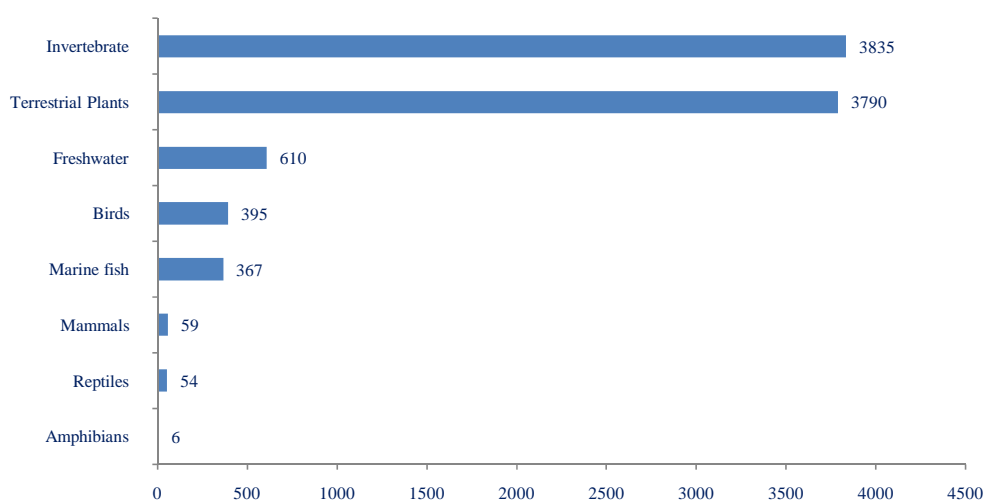
Forests protected by ministerial decisions as per the Code of Forest							
Decision	Date	Location	Description				
			Cedar	Fir	Juniper	Cypress	Other
499/1	14/10/96	Tannourine/Hadath ej Jebbeh, Jaj & Bcharreh	X				
587/1	30/12/96	Swayse (Hermel)	X	X	X	X	
588/1	30/12/96	Aamouah (Aakkar)	X	X	X	X	Pine
589/1	30/12/96	Karm Shbat (Aakkar)	X	X	X		
591/1	30/12/96	Bazbina (Aakkar)	X	X	X	X	
592/1	30/12/96	Knat (Knat)	X	X	X		Oak
10/1	17/1/97	Qaryet Sfina (Aakkar)	X				Oak
11/1	17/1/97	Merbine (Wadi Jhannam)	X	X	X		
8/1	17/1/97	Aïn el Houkaylat/Qornet el Kif (Dinniyeh)	X	X	X		Oak
9/1	17/1/97	Jurd Njas/Jabal el Arbaïn (Dinniyeh)	X	X	X	X	
174/1	25/3/97	Shebaa (Hbaline)	X	X	X	X	Pine
3/1	8/12/97	Bkassine (Jezzine)					Pine

Beside forest areas, Lebanon has protected areas since 1930. The current classification of Protected Areas in Lebanon consists of: 8 Nature Reserves, 24 natural sites, 5 himas, 12 protected forests, 14 touristic sites and other sites to be protected.

Forests and wooded lands

Forests and wooded lands constitute 139,376 ha in 2010. Private property constitutes 60.4%, public 38.6%, and finally unknown 1.0%. These forests and wooded lands encompass several species.

Graph 2.5 – Described species in Lebanon. Number in 2010



Graph made by CAS based on Ministry of Environment data (2010)

Solid waste

In 2010, 4,300 tonnes of waste are generated per day. Mount-Lebanon generates 37.2% and Beirut 20.9%. Organic waste constitutes 55% of the total in rural areas and 50% in urban areas. 51% of the solid waste is land filled, whereas 32% is open dumped. Unfortunately, 8% are only recycled.

Mount-Lebanon displays the highest price regarding waste collection (34.6 USD/Tonne). As for land filling prices, Naameh dump has the highest rate 38-54 USD/Tonne.

