

2. MORPHOLOGY, CLIMATOLOGY, HYDROLOGY VEGETATION AND ENVIRONMENT

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

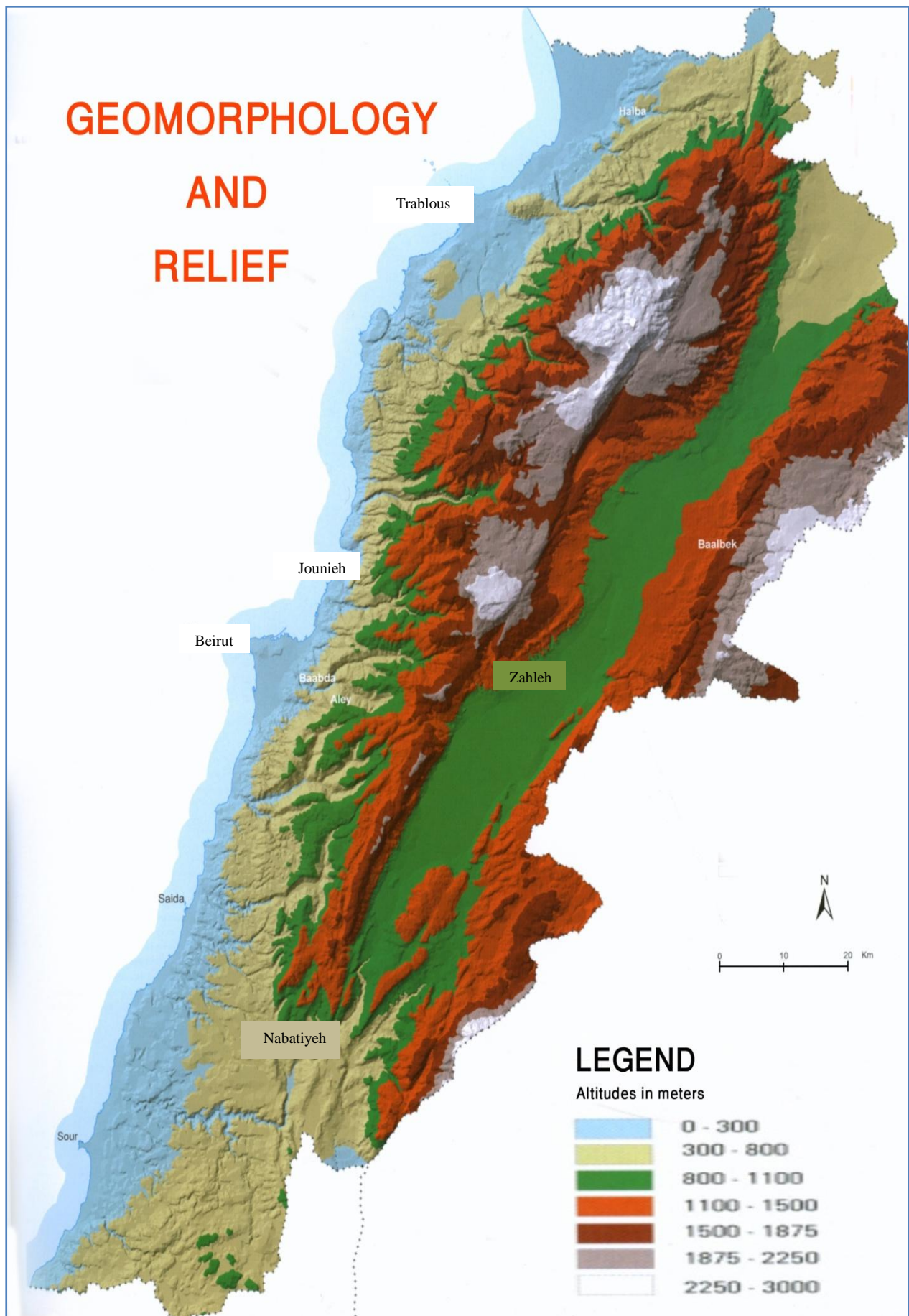
Geomorphology

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

Table 2.1 – Geomorphologic zones of Lebanon

Seashore and Coastal plain	
<i>Lebanese seashore</i>	Extends over 220 km between Arida (North) and Ras Al-Naqoura (South). Deeply cut cliffs showing a recent and accelerated erosion process. Lie at the bottom of these cliffs, gravel beaches, often bordered by sandy beaches, with variable lengths (20% of the entire coast).
<i>Coastal plain</i>	Varies in width beneath the Mount-Lebanon range. Very narrow along the majority of its length (7 km in average). Wider at the Aakkar plain in the North: its width may reach 30 km with an elevation of 500 m. Narrows between Tripoli and Jabal Terbol. Excessively narrow (3km in average) interrupted by the crests of Mount Lebanon. Widens slightly near Beirut and the Choueifat plain, as well as near Saïda plain, from where it extends with no interruption towards the Tyr plain with an average width of 7 km. Broken by a series of humps (crests) until reaching the southern border.
Western mountain range (Mount Lebanon)	
Mount-Lebanon extends from the North of Jabal Aakar southward up to an elevation of 3008 m (Kornet el Saouda) and 1809 m (Jabal Niha), after which point the hills of Jabal Amel take the lead. The total length of the mountain range is 160 km. Its width varies from 25 km at the central part up to 45 km in the North. The middle altitude area of Mount Lebanon is probably the most diversified part of the entire country: after a stiff elevation of abutments, several small hills form an intermediate graduation between the sea and the peak. The western facade of the mountain range is cut by a series of narrow valleys parallel to each other with an inclination seaward, carrying rivers and water courses.	
The eastern slopes overhang the Bekaa valley, and are generally steeper than the western slopes. There is a limited number of seasonal rivers formed in winter as a result of the snowmelt.	
The high altitude areas are totally different than the middle altitudes and are characterized by stiff elevations and scarps that reach the peak. Despite the important precipitations (more than two meters, in the form of snow), the landscape is dry and stripped because of the water being wasted by infiltration through the karstic basins. Crest-line starts at around 1800 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, and measures 120 km (N-S) by 8-12 km (E-W) in average, with an exceptional width of 25 km at Hermel (in the North). Slopes are very soft, with the highest point located near Baalbek at 1100 m, where the valley mingles with the abutments of Anti-Lebanon mountain range.	
<i>Northern and Central Bekaa</i>	Comprises the valley of Nahr el Aassi and expands up till Haouch el Nabi in the south. This region, rich in agriculture, contains the sources of the Litani river.
<i>Southern Bekaa</i>	Expands from Zahleh-Rayak region down to Marjaayoun in the South. This is also a rich agricultural area producing a large variety of fruits and vegetables.
Eastern mountain range (Anti-Lebanon)	
Lower than Mount Lebanon, the high altitude area is a high plateau (dry) with a width of 30 km and an average elevation of 2,300 m (the maximum being 2,616 m at Tallet Moussa). The plateau inclines southward reaching an elevated plain (1,400 m) that creates a natural break-up between Eastern part and Jabal el Cheikh (Mount Hermon). The Anti-Lebanon mountain range has no deep valleys as it is the case in Mount Lebanon. Jabal el Cheikh extends over 100 km starting from Yanta in its North down 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.	

GEOMORPHOLOGY AND RELIEF



Geology and soil

Lebanon geological formations, settled until the Miocene-Pliocene periods, are formed mainly of sedimentary carbon rocks, limestone and dolomite. In a lesser extent, they 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
	Pliocene	Up to 500m	Limestone, marl, volcanic material, sand and conglomerate
Tertiary	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
	Turonian (Maameltain Lst.)	200 to 300m	Marly limestone, limestone
Cretaceous	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, Lebanese 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.

Climatology

Geographical situation (northern temperate zone, as well as Mediterranean zone) and its morphology determine the weather in Lebanon. In fact, there are two mountain chains expanding perpendicularly to the atmospheric circulation and constituting the core of the country. They are at the origin of a climatic variability at small distances. Hence, a 50 km cross section shows climate variations: a subtropical coastal climate succeeded 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. These variations favor 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 2008.

Table 2.3 – Temperature, rainfall and windspeed in 2008

Total/average 2008	Coastal Zones			Bekaa valley
	RHIA	Beirut Golf	Tripoli	Zahleh
Mean temperature (°C)	22.4	22.7	20.4	18.6
Mm of rain	589.0	815.4	728.1	366.1
Mean relative humidity (%)	58.6	58.3	58.6	53.3
Wind mean power (m/second)	3.3	2.7	2.8	2.9
Maximal wind speed (degrees)	236.7	242.5	265.0	237.5
Rainy days	60	64	60	56

Table made by CAS based on General Directorate of Civil Aviation, Climatology Service data (2008)

Temperature

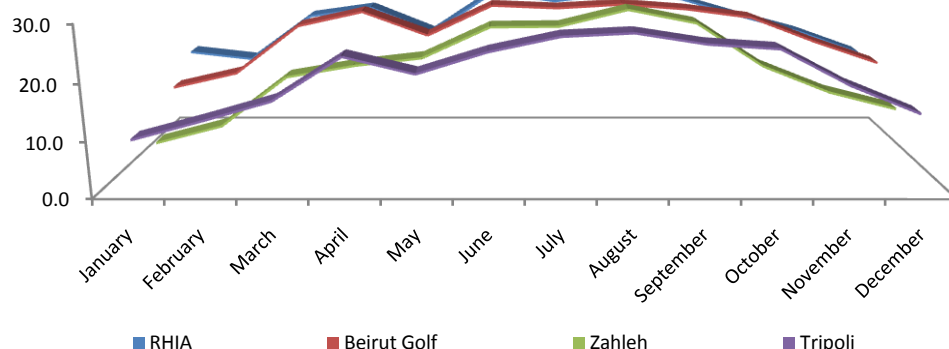
The average annual temperature on the coast varies between 19.5°C and 21.5°C and decreases by around 3°C for each 500 m vertical, reaching 9°C at 1000 m and 1°C at 2000 m. January is the coldest month, with an average daily temperature of -4°C in the mountains and 7°C in coastal zones. The warmest months of the year are July and August, where the daily average reaches up to 28°C in the mountains and 33°C in coastal cities. The day and night temperature variations are soft on the coast (6-8°C), but they increase in the Bekaa valley where they can reach 24 °C in the summer.

Table 2.4 – Temperature peaks and troughs in 2008

Temperature (°C)	Coastal Zones			Bekaa valley
	RHIA	Beirut Golf	Tripoli	Zahleh
Mean temperature	22.4	22.7	20.4	18.6
	General average: 19.5–21.5			
Minimum temperature	6.0 (February)	3.6 (January)	0.1 (January)	-6.5 (January)
	General average: January 7			
Maximum temperature	37.9 (April)	39.3 (April)	36.1 (April)	42.0 (August)
	General average: July-August 33			

Source: Table made by CAS based on General Directorate of Civil Aviation, Climatology Service data (2008)

Graph 2.1 – Monthly mean temperature in 2008



Graph made by CAS based on General Directorate of Civil Aviation, Climatology Service data (2008)

Rainfall

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

The 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:

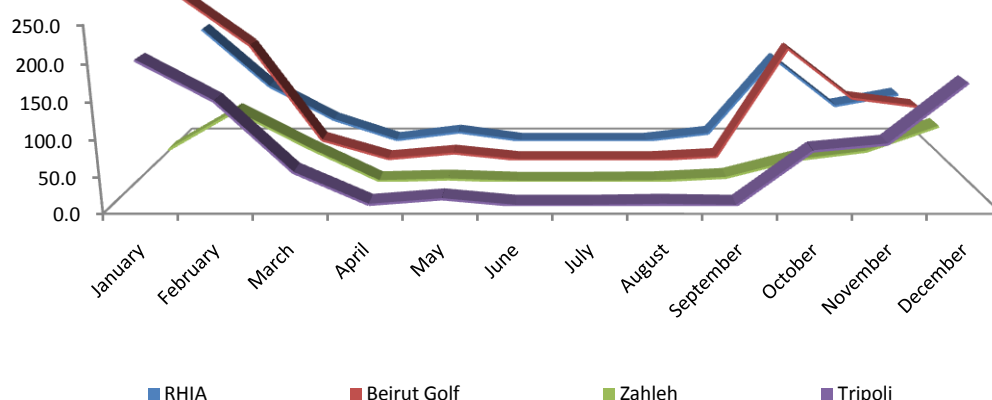
- Lebanon has a high average in rainfall per annum (Beirut, 893 mm).
- Great seasonal variations with 80-90% of the annual rainfall occurring between November and March, and less than 5% between May and September.
- Strong rain showers that can cause floods and erosion.
- Precipitations occur during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

Table 2.5 – Rainfall peaks and troughs in 2008

Rainfall (mm)	Coastal Zones			Bekaa valley
	RHIA	Beirut Golf	Tripoli	Zahleh
Total precipitation	598.0	815.4	728.1	366.1
	General average: 700 – 1 000 mm			200–800 mm
Minimum precipitation	0	0 mm	0 mm	0 mm
	(June-August)	(June-August)	(June-July)	(June-July)
Maximum precipitation	178 mm	247.2 mm	197.8 mm	102.4 mm
	(January)	(January)	(January)	(February)

Table made by CAS based on General Directorate of Civil Aviation, Climatology Service data (2008)

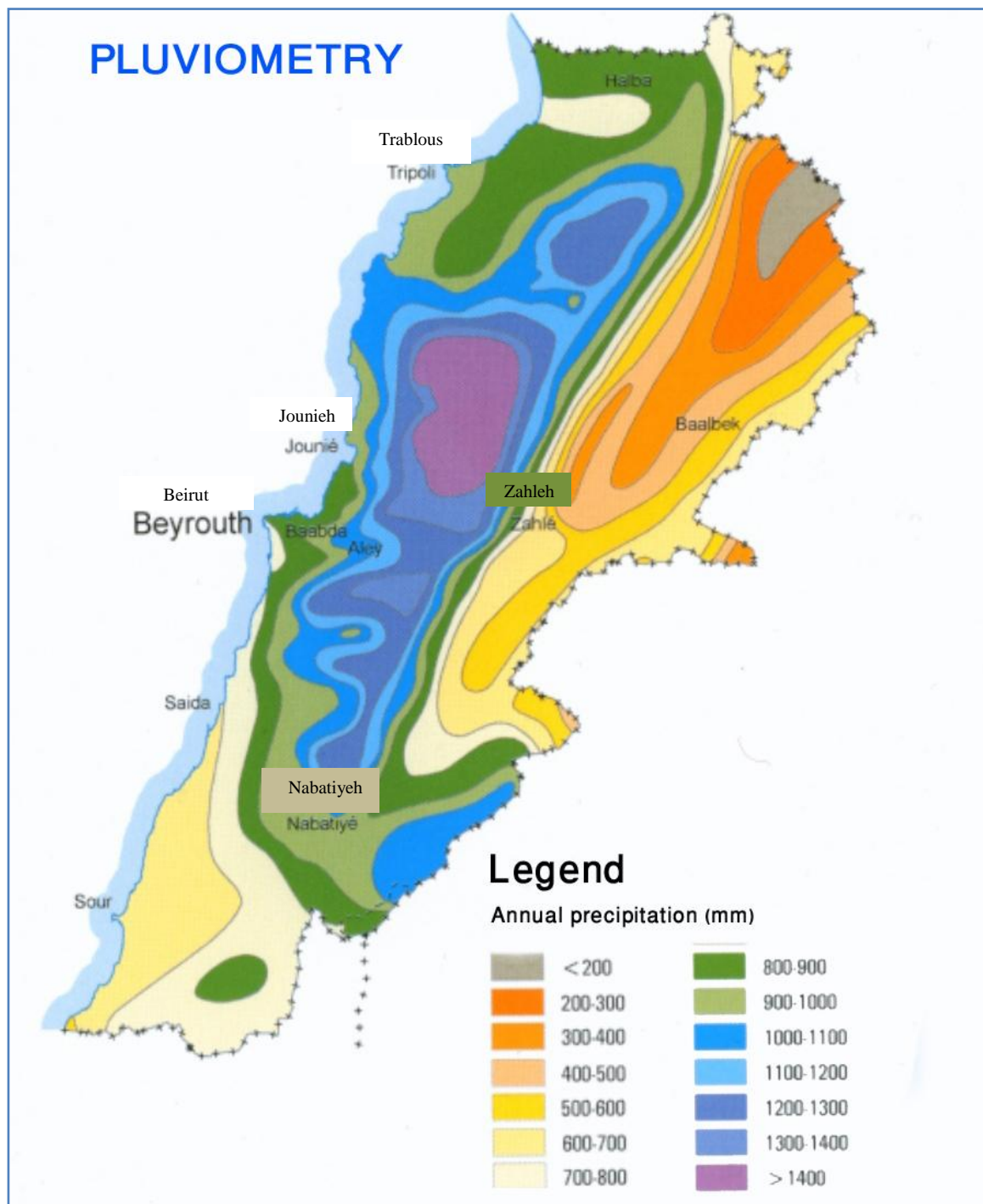
Graph 2.2 – Monthly mm of rain in 2008



Graph made by CAS based on General Directorate of Civil Aviation, Climatology Service data (2008)

The previous tables show that temperature and rainfall general averages are not respected especially on coastal zones; which is a sign of climate change in Lebanon.

PLUVIOMETRY



Source: CDR (2004)

Relative humidity
Table 2.6 – Relative humidity in 2008

Relative humidity (%)	Coastal Zones			Bekaa valley
	RHIA	Beirut Golf	Tripoli	Zahleh
Mean relative humidity	58.6	58.3	58.6	53.3
Minimum relative humidity	16.0	10.0	10.0	7.0
	(March-April)	(March-April)	(March)	(August)
Maximum relative humidity	91.0	95.0	97.0	100.0
	(May)	(May)	(February)	(December)

Table made by CAS based on General Directorate of Civil Aviation, Climatology Service data (2008)

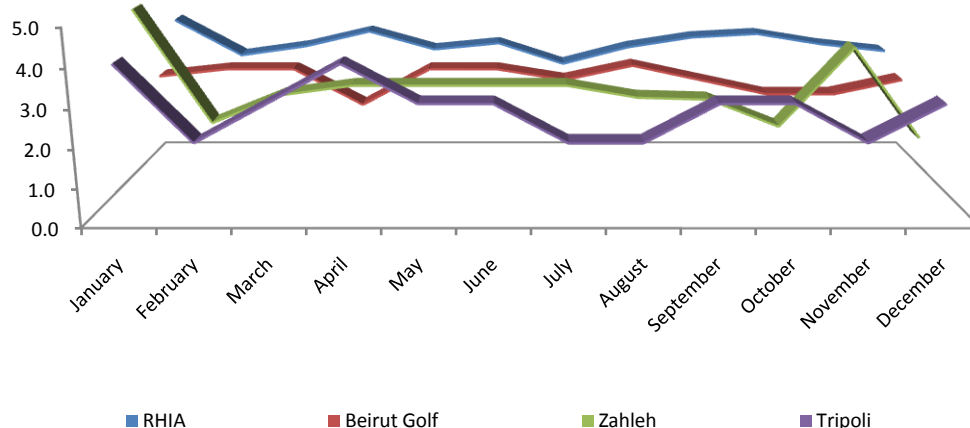
Wind power

Table 2.7 – Wind mean power in 2008

Wind power (m/second)	Coastal Zones			Bekaa valley
	RHIA	Beirut Golf	Tripoli	Zahleh
Mean wind power	3.3	2.7	2.8	2.9
Maximum wind power	28.0 (January)	24.9 (January)	24.0 (January)	21.0 (December)

Table made by CAS based on General Directorate of Civil Aviation, Climatology Service data (2008)

Graph 2.3 – Monthly mean wind power in 2008



Graph made by CAS based on General Directorate of Civil Aviation, Climatology Service data (2008)

Wind direction

Table 2.8 – Maximum wind direction in 2008

Wind direction (°)	Coastal Zones			Bekaa valley
	RHIA	Beirut Golf	Tripoli	Zahleh
Average maximum wind direction	236.7	242.5	265.0	237.5
Maximum wind direction	330.0 (November)	340.0 (November)	340.0 (November-December)	320.0 (April)

Source: Table made by CAS based on General Directorate of Civil Aviation, Climatology Service data (2008)

Rainy days in 2008

Table 2.9 – Rainy days in 2008

Rainy days	Coastal Zones			Bekaa valley
	RHIA	Beirut Golf	Tripoli	Zahleh
Number	60	64	56	64
Minimum number	0 (June-August)	0 (June-August)	0 (June-August)	0 (June-July)
Maximum number	13 (January)	12 (January)	12 (December)	13 (December)

Table made by CAS based on General Directorate of Civil Aviation, Climatology Service data (2008)

Hydrology

Lebanon enjoys a geographic location and a topography on the seafront exposing it to humid and rainy air masses. It is also has 40 perennial and/or seasonal rivers and water courses, originating from the Mount Lebanon mountain range. Generally, these are short rivers with an East-West lateral orientation spilling into the Mediterranean, except for the two transborder rivers which are the Orontes River (Nahr el Aassi) crossing towards Syria and the Hasbani River crossing towards Palestine.

The rivers and water basins are crucial for the Lebanese ecosystem and vital for irrigating 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	

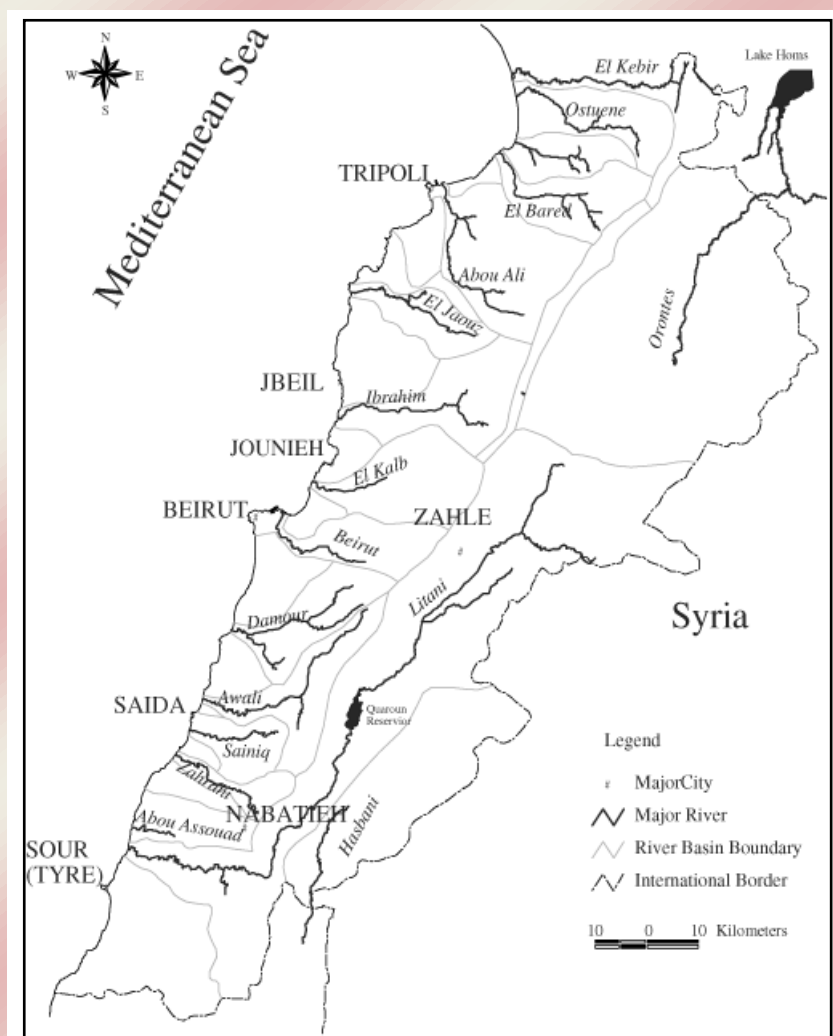


Table 2.11 – Hydrological cycle of Lebanon

Designation	Flow (MCM/year)
Total annual precipitation	8,600
Natural evapo-transpiration	4,500
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

Sources: Comair, F. (2005), *Lebanon water between loss and investment*, Beirut, First Edition, Dakkash printing Est., p. 36 and Comair F. (2008), GESTION INTEGREE DES RESSOURCES EN EAU AU LIBAN, EFFICIENCE D'UTILISATION DE L'EAU, REUNION D'EXPERTS, PNUE et Plan Bleu, 5 Novembre 2008

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 an independent regulator as much as possible.

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.

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 regulators was 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).

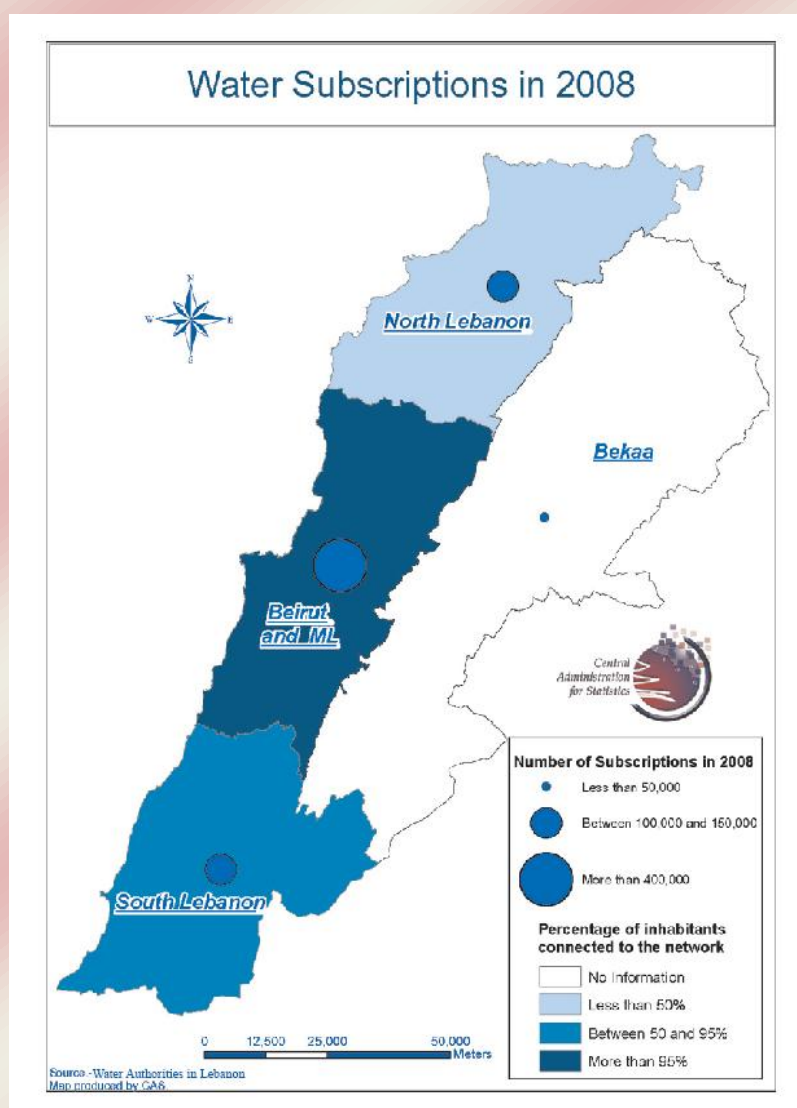


Table 2.12 – Consolidated table of water statistics in Lebanon in 2008

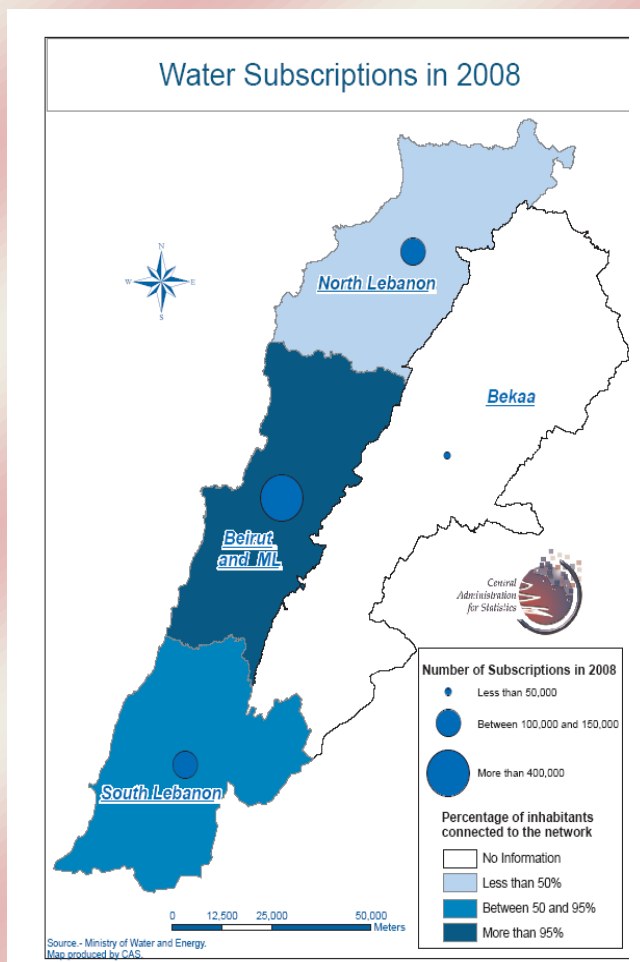
Item / Water Authority	Beirut and Mount-Lebanon	North-Lebanon	Bekaa	South-Lebanon	Total / Average
Water Sources number					
Rivers and springs	22	64	14	35	135
Wells	150	128	121	269	668
Exploited number of wells by Authority	138	98	106	238	580
Wastewater					
Executed wastewater treatment plans	8	1	1	23	33
Tap water subscriptions					
Subscriptions in 2008	483,210	100,545	65,449	130,276	779,840
New subscription in 2008	5,397	1,866	635	2,947	10,845
Installed counters	6,080	30,000	0	18,669	54,749
Number of installed gauges	477,040	70,545	0	11,607	559,192
Volume of charged water (cubic meters/day)	595,160	87,453	71,673	138,036	893,592
Tap water daily consumption					
Subscribers	483,120	100,545	67,000	130,276	780,941
Water liters/inhabitant/day	185.53	186.82	127.0	175.0	674.0
Human resources					
Employees and wagers	1,240	195	266	681	2,382

Table made by CAS based on Water Authorities data (2008)

Beirut and Mount-Lebanon Authority is the biggest. It recruits 52.1% of total Water Authorities employees and wagers, has 61.9% of subscribers, 62.0% of 2008 subscriptions, 49.8% of 2008 new subscriptions, 85.3% of installed gauges and 66.6% of the total volume of charged water in cubic meters/day.

As for rivers and springs, North Lebanon Water Authority is the richest one with 47.1% of the total; While, wells are more common in South Lebanon Water Authority (40.3%). In fact, the Mohafazat of South-Lebanon and Nabatiyeh is very rich in groundwater. This Water Authority exploits the maximum number of water sources (41.0%) and has the maximum number of executed wastewater treatment plants (69.7%).

Finally, North-Lebanon has the biggest number of installed counters (54.8%) and its subscribers have the highest tap water consumption (186.82 liters/inhabitant/day).

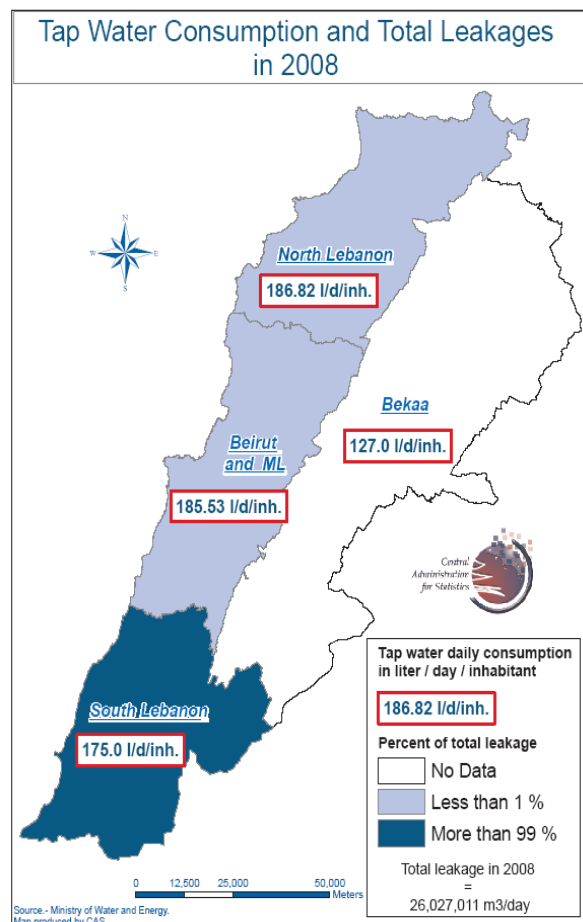


Millennium Development Goal 7: Ensure environmental sustainability

Target 7.C: Halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation

7.8 Proportion of population using an improved drinking water source

7.9 Proportion of population using an improved sanitation facility



Just for information

Internal Renewable water resources
= *Precipitation – evapo-transpiration*
= *4,100 MCM/year*

Dependency ratio = 0% because Lebanon does not have inflows of water from neighboring countries

National water wealth
= *Precipitation – Evapo-transpiration – river inflows*
Inhabitants
= *1,091 CM/inhabitant/year*

Knowing that water stress threshold is equal to 1,700 CM/inhabitant/year

Vegetation zones of Lebanon

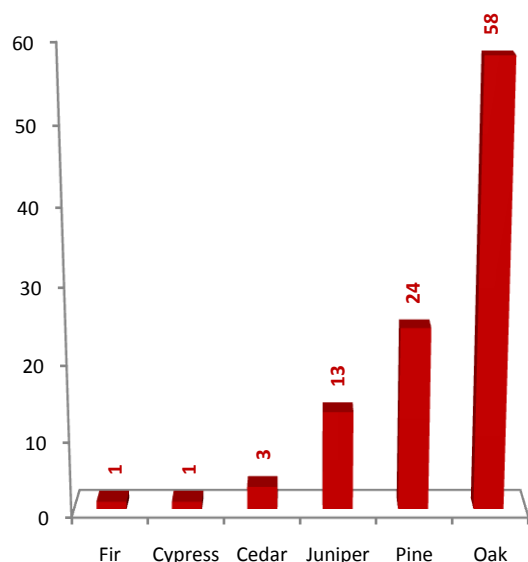
Vegetation zones display vegetation cover and protected vegetal areas.

Vegetation cover

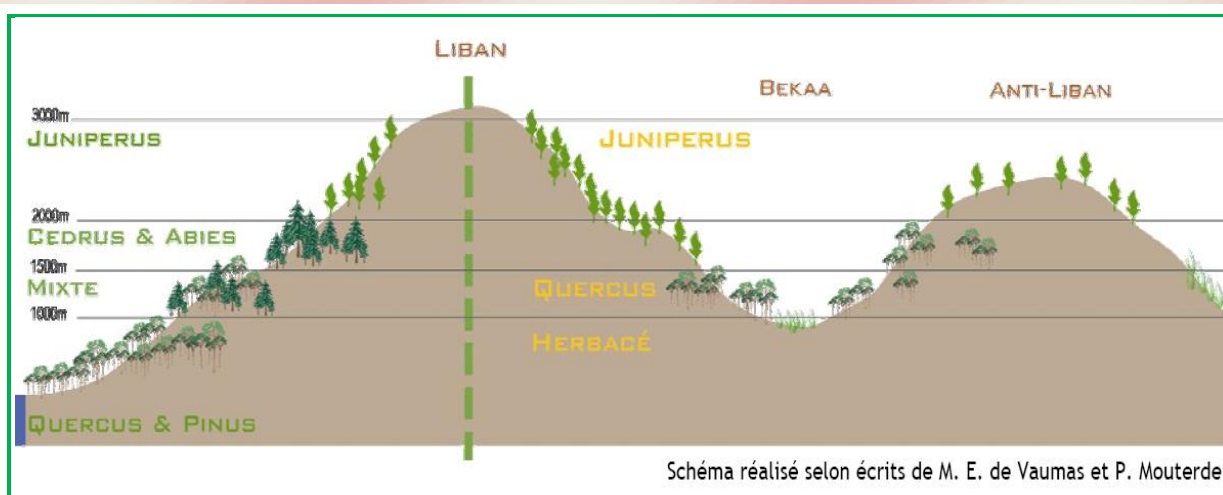
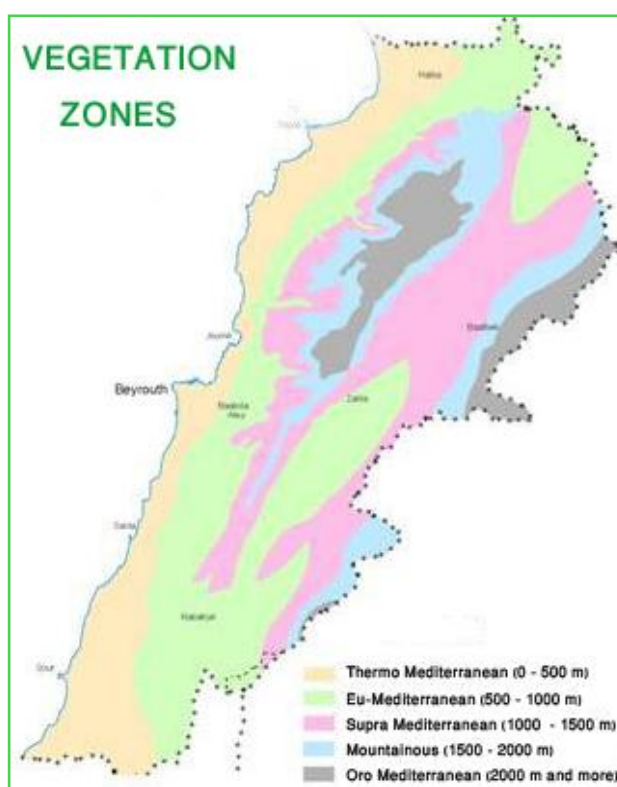
Climate influences the vegetation cover in Lebanon. There are four major phytological (botanical) stages or levels, between the coastline, the mountain then the hinterland:

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

Graph 2.4 – Distribution of forest species in %



Graph made by CAS based on Ministry of Environment (2001), State of the Environment Report



According to the Atlas of Forests in Lebanon, published in 2005 by the Ministry of Agriculture in cooperation with FAO (Inventory & Evaluation of Trees in Lebanon) and in collaboration with the Directorate of Geographic Affairs of the Lebanese Army, Lebanon forest cover area is 134,371.64 ha (including coniferous and deciduous forests) while other forested areas (including woodlands with or without trees) are 120,573.96 ha. Thus, total forest cover is 13.12% of the country total area.

Protected vegetal areas

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

Table 2.13 – 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 (Hbaine)	X	X	X	X	Pine
3/1	8/12/97	Bkassine (Jezzine)					Pine

Beside forest areas, Lebanon has protected areas since 1930. Since, the designation authority of the protected areas is the responsibility of several administrations, including the Ministries of Environment, Agriculture, Culture, etc.

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.

Forest fires in Lebanon

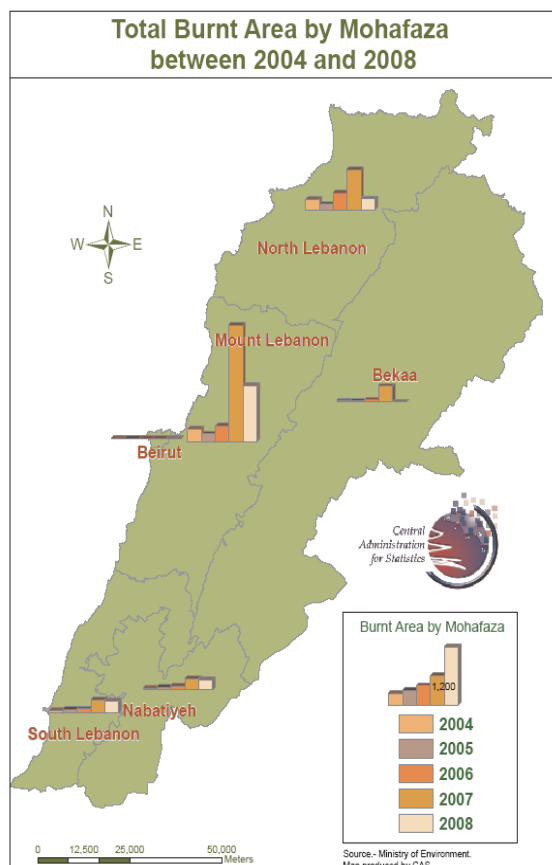
Based on the Ministry of Environment data, forest fires in Lebanon increased since 2004 of 217.9% to reach 1,861 ha in 2008. Total burnt area of Lebanon since 2004 is 7,791 ha, which is almost 77.914 square Km or 7% of total Lebanon area.

Table 2.14 – Total burnt area in ha by Mohafazat between 2004 and 2008

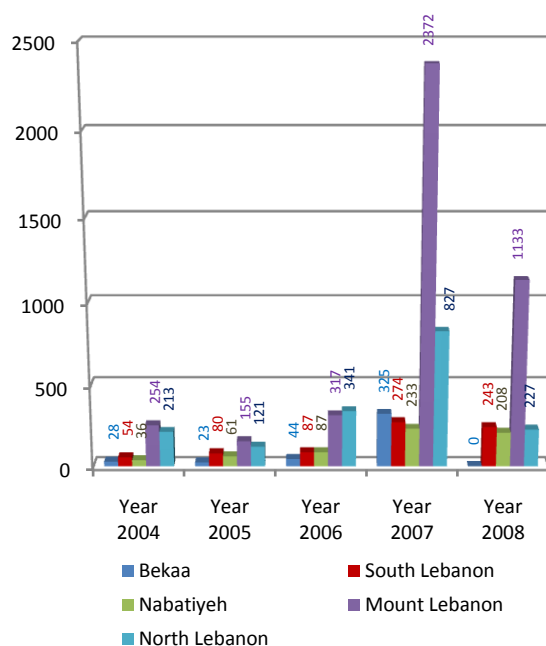
Mohafazat	Total	Percentage
Mount Lebanon	4,231	54.3
North Lebanon	1,730	22.2
South-Lebanon	737	9.5
Nabatiyeh	624	8.0
Bekaa	419	5.4
Lebanon	7,791	100.0

Source: Ministry of Environment (2008)

Mount-Lebanon (54.3%) suffered the most of forest fires followed by North-Lebanon (22.2%).



Graph 2.5 – Burnt Area (in Ha) by Mohafazat 2004-2008



Graph made by CAS based on Ministry of Environment data (2008)

Facing these fires, a reforestation plan was implemented in 2002 and in 2004 to reforest a total area of 564.6 ha (49.3% in 2004 and 50.7% in 2004). This reforested area is equivalent to 7.2% of total burnt area during 2004-2008

Table 2.15 – Total reforested ha by Mohafazat in 2002-2004

Mohafazat	Total	Percentage
Bekaa	219	38.8
Nabatiyeh	114	20.2
North Lebanon	105	18.7
South-Lebanon	86	15.3
Mount Lebanon	40	7.1
Lebanon	565	100.0

Source: Ministry of Environment (2008)

Bekaa (38.83%) was the most reforested region followed by Nabatiyeh (20.2%).

