WORLD BANK
SUSTAINABLE AGRICULTURAL LIVELIHOODS IN MARGINAL AREAS (SALMA) PROJECT


BACKGROUND PAPER
AND
SELECTED ANNOTATED BIBLIOGRAPHY

ON

HILL LAKE ECOSYSTEM SERVICES AND CLIMATE CHANGE IN LEBANON

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Source: <www.oanda.com>

ACRONYMS

CAS .... Central Administration for Statistics
CDR........................ Council for Development and Reconstruction
EPA .... Environmental Protection Agency of the United States
EU........................... European Union
GDP........................ Gross Domestic Product
GIS .... Geographical Information System
GoL......................... Government of Lebanon
Ha .... Hectare
Kg........................... Kilogram
Km.......................... Kilometer
LP .... Lebanese pound
m............................. meter
m^2 .... Square meter
m^3 .... Cubic meter
MOE....................... Ministry of Environment
NRP .... National Reforestation Program
RTW....................... Reuse of Treated Water
SALMA.................. Sustainable Agricultural Livelihoods in Marginal Areas
TEV .... Total economic value
UNFCCC................ United Nations Framework Convention on Climate Change
UNDP..................... United Nations Development Programme
UNEP .... United Nations Environment Programme
USAID.................... United States Agency for International Development
WHO .... World Health Organisation

HILL LAKE ECOSYSTEM SERVICES AND CLIMATE CHANGE BACKGROUND PAPER AND ANNOTATED BIBLIOGRAPHY PREPARED IN THE CONTEXT OF THE SALMA PROJECT

1. Introduction

1. The Government of Lebanon (GoL) launched the National Reforestation Program (NRP) on "Planting 40 million forest trees" program. Prior to the launching, the World Bank had been requested to provide assistance to the GoL to support the NRP. As a result, the World Bank formulated the Sustainable Agricultural Livelihoods in Marginal Areas (SALMA) Project and included a component on forest restoration and reforestation in the project. The World Bank is also implementing analytical work on "Best fit practices for reforestation to enhance climate resilience in remote hilly areas in Lebanon", financed by a grant from the World Bank's Program on Forests (PROFOR). The development objective of the proposed analytical work is to enhance reforestation practices in Lebanon for increased climate resilience of local ecosystems and improved benefits from rural livelihoods.

2. The forest cover and associated ecosystem services has been under enormous pressures since the end of the 1975-1989 Lebanese Civil War with forest areas shrinking from 20% to 13% of the Lebanese territories according the most recent assessment (FAO, 2005). Urban-rural encroachment (construction boom and poor land use planning) on wooded areas continues to constitute the main threat for the remaining forest areas, particularly in the mountainous and hilly areas of Lebanon. This is in addition to catastrophic events such as forest fires, flash floods, landslides etc. that are increasingly being exacerbated in intensity and frequency by climate change effects.

3. The services provided upstream and downstream to hilly areas and forest ecology and the potential impact of climate change on these services are poorly studied in Lebanon. A better understanding of these ecosystem services and their vulnerability to the natural disaster-climate change continuum could help inform the design and siting of rural infrastructure such as hill lakes and roads, particularly in the context of the SALMA project, in conjunction to the reforestation stance.

2. Objective

4. The objective of this assignment is to conduct a desk review of climate change projections and their potential impact on hillside ecology in Lebanon.

3. Scope of Work

5. The assignment will consist of reviewing the available literature focusing on the Mediterranean area in general and Lebanese context in particular to derive the typology of the mountainous and hilly areas ecosystem services and the actual and expected climate change impact.

4. Methodology, Limitations and Structure of the Review

6. The methodology consisted of performing a literature search of documents related to: (i) climate change in the region in general and in Lebanon in particular; and (b) ecological services of hill lakes in the region in general and Lebanon in particular. Also, more than 200 documents were reviewed out of which 45 were annotated in Annex I based on their relevance to the objective of this exercise. The annotated bibliography also includes the document pages that are relevant to the objective of this exercise.

7. In the process of fact finding it became clear that availability, accessibility and topicality of information relevant for the assignment posed problems. Information has been very scattered and not up-to-date. Moreover, the mapping of existing hill lakes exists in Lebanon, however, no documentation was found specifically analyzing these hill lakes.

8. The review includes 8 sections and an annex:
   - Section 1: Introduction
   - Section 2: Objective
   - Section 3: Scope of Work
   - Section 4: Methodology, Limitations and Structure of the Review
   - Section 5: Lebanon Physical and Environmental Background
   - Section 6: Hill Lake Ecosystem Services Review
   - Section 7: Climate Change Model Review
   - Section 8: Conclusions and Recommendations
   - Annex I: Annotated Bibliography

5. Lebanon Physical and Environmental Background

9. This Section builds notably on the Central Administration of Statistics website, on the Ministry of Environment publications (e.g., SOER 2010, website of the Ministry, etc.), Ministry of Agriculture publications, Ministry of Energy and Water 2012 Strategy, and Lebanon's CNRS publications.

5.1 Geomorphology and Geology

10. **Geomorphology.** Lebanon has 4 complex geomorphologic zones over a very narrow territory with a landbound area of 10.225 km^2. In addition to the seashore and coastal plain geomorphologic zone, Lebanon other geomorphologic zones consists of 3 units: 2 of them constitute the uplifted steep mountain ranges of Mount Lebanon and Anti-Lebanon that are separated by the Bekaa valley depression (Figure 5.1, first quadrant). Sub-geomorphologic zones are described in Box 5.1.

Box 5.1: Geomorphologic Zones of Lebanon

<table>
<tr><th colspan="2">Seashore and Coastal plain</th></tr>
<tr><td>Lebanese seashore</td><td>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).</td></tr>
<tr><td>Coastal plain</td><td>Varies in width beneath the Mount-Lebanon range:
• Very narrow along the majority of its length (7 km in average).
• Wider at the Akkar 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.</td></tr>
<tr><th colspan="2">Mount Lebanon: Western mountain range</th></tr>
<tr><td colspan="2">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.</td></tr>
<tr><td colspan="2">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.</td></tr>
<tr><td colspan="2">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.</td></tr>
<tr><th colspan="2">Bekaa valley: Interior plain</th></tr>
<tr><td colspan="2">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.</td></tr>
<tr><td>Northern and Central Bekaa</td><td>This agricultural area expands from the valley of Nahr el Aassi till Haouch el Nabi in the south. It contains Litani river water sources.</td></tr>
<tr><td>Southern Bekaa</td><td>This agricultural area spreads from Zahleh-Rayak region down to Marjeyoun in the South.</td></tr>
<tr><th colspan="2">Anti-Lebanon: Eastern mountain range</th></tr>
<tr><td colspan="2">High altitude consists of a dry plateau with a width of 30 km and an average elevation of 2,300 m (maximum is</td></tr>
</table>

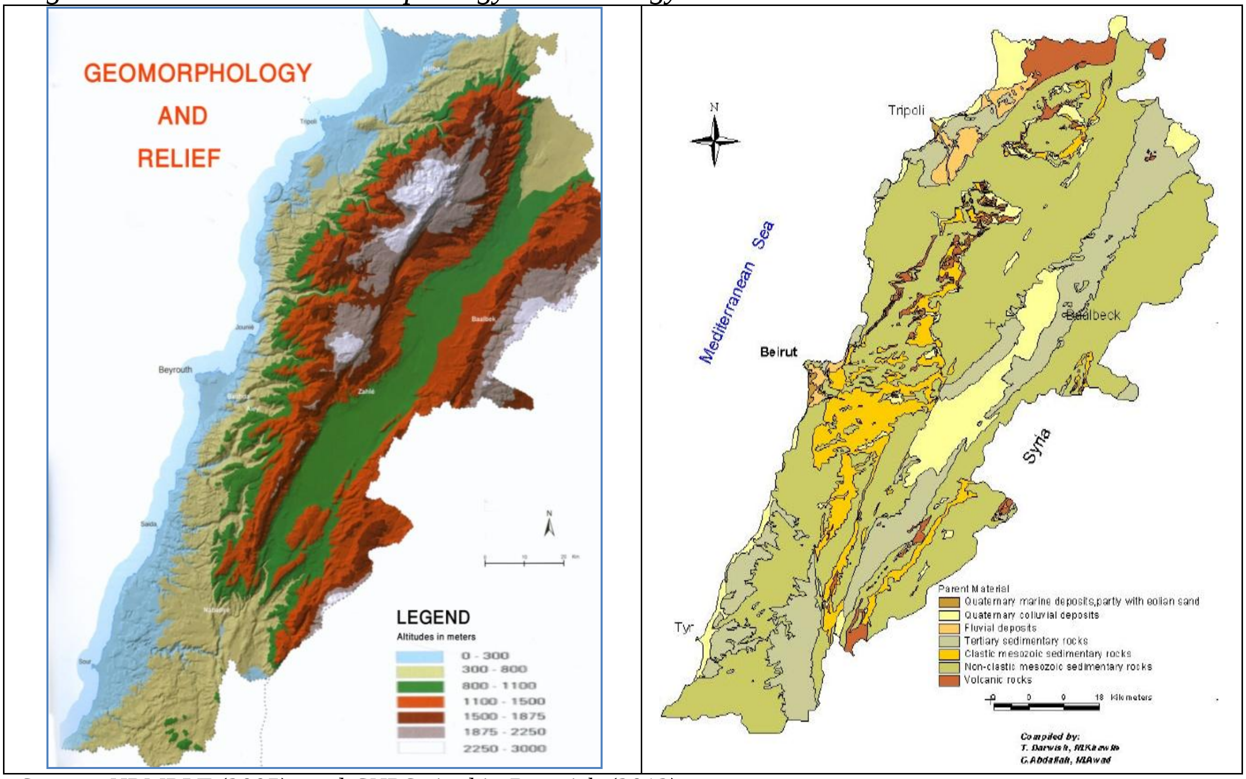
2,616 m at Tallet Moussa). The plateau inclines southward to reach an elevated plain (1,400 m). This creates a natural break-up between Eastern part and Mount Hermon. Anti-Lebanon has no deep valleys.

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 the Bekaa valley (west), the Houla Lake (southern border) and Aaouej plain (eastern border). Thus, Jabal el Cheikh intercepts and redistributes water resources in this arid region.

Source: CAS website: <www.cas.gov.lb>.

11. **Geology.** Lebanon geological formations include 7 groups: quaternary marine deposits; quaternary colluvial deposits; fluvial deposits; tertiary sedimentary rocks; clastic mesozoic rocks; non-clastic sedimentary rocks; and volcanic rocks. Yet, these can be combined into 3 groups and are formed mainly of sedimentary carbon rocks, limestone and dolomite. Locally, some volcanic rocks such as pyroclastic basalt may be found (mainly Akkar). Jurassic and cretaceous limestone represents the main feature (armature) of Lebanon topography. Apart from recent sediments within the plain of Akkar or the Bekaa valley, these are the core karstic formations that determine the landscape and water resources in Lebanon. Geologic formations are illustrated in the second quadrant of Figure 5.1

Figure 5.1 : Lebanon Geomorphology and Geology



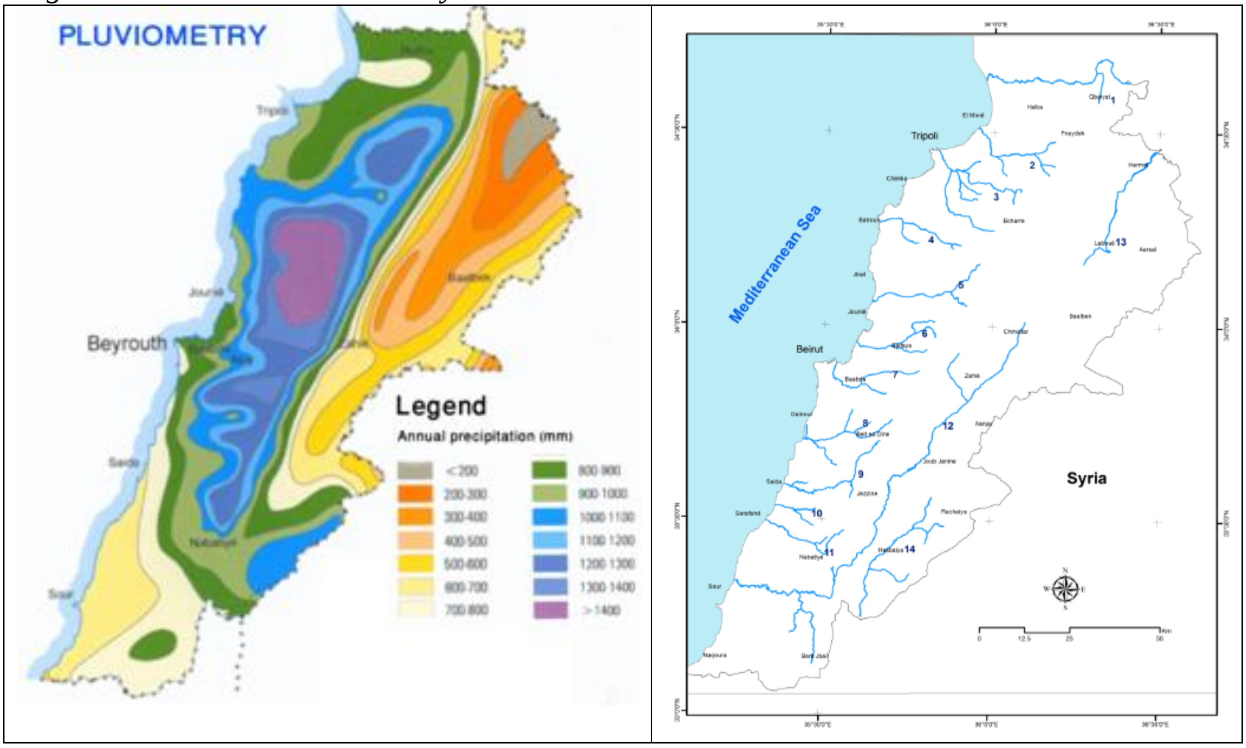
Source: NPMPLT (2005); and CNRS cited in Darwish (2012).

5.2 Weather

12. **Climate variability.** Lebanon complex geomorphology produces a great deal of diversity in 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.[1]

Figure 5.2 : Lebanon Pluviometry and Perenial Rivers



Source: General Directorate of Civil Aviation, Climatology Service data (2010); and NPMPLT (2005).

13. **Rainfall.** The average annual rainfall on the coastal zones varies between 700 and 1,000 mm and increases towards the North-South direction. Mount-Lebanon forms a barrier against the rain movement and the precipitations can reach more than 1,400 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 1,000 mm in Jabal el Cheikh (Figure 5.2, first quadrant). The global amount of precipitations is estimated at 8,600 millions of m^3 (MCM) per annum, to which it should be added the amount of snow, which is around 2,200 MCM. Rainy days varied between 45 and 59 days in 2010 with 0 days over 3 months and the maximum number of rainy days in January ranging from 12 to 15 days. The long term meteorological observations carried out for Beirut and Central Bekaa highlight the following characteristics:[2]

- 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.

[1] General Directorate of Civil Aviation, Climatology Service data (2010).
[2] General Directorate of Civil Aviation, Climatology Service data (2010).

14. **Temperature and humidity.** Lebanon general average temperature is 20.5° Celsius with a minimum average in January of 7° Celsius and a maximum average of 33° Celsius between July and August. January is in general the coldest month, while July and August are the warmest months. Coastal zones (Beirut 57.6%; and Tripoli 57.4%) are more humid than the interior zones (Bekaa).

15. **Wind.** Wind mean power varies between 2.1 and 3.0 m/s and reaches its peak in Beirut (up to 16.5 m/s in December), in Tripoli (20.0 m/s in April) and Zahleh (23.0 m/s in January) during different months.

5.3Water Resources

16. **Water Balance.** There are several citations for water resource flows in Lebanon (Table 5.2). When natural evapo-transpiration (-4.1 billion cubic meter --BCM), loss in surface waters to neighboring countries (-0.6 BMC), loss in underground water to neighboring countries (-0.3 BCM), and sub-marine sources (-0.4 BCM) are deducted from total annual precipitation of 8 BCM, it leaves Lebanon with a net annual water resources balance of about 2.8 BCM of which 2.2 BCM is surface water and 0.6 BCM is for groundwater[3] which falls between the 2009 MED EUWI range (Table 5.2).

Table 5.1: Lebanon Alternative Citations with Water Resource Flows

Description	**Unit**	**MED EUWI (2009)**	**MOEW (2004)**	**World Bank (2003)**	**Geadeah (2002)**	**Plassard (1971)**	**Nasr/UNDP (1970)**
Precipitation	mm	800-1,000	820	820			940
Evapo-transpiration	mm	500-600	430	380			
Precipitation	Mm^3	8,320-10,400	8,600	8,600	8,600	8,600	9,800
Evapo-transpiration	Mm^3	4,300-6,240	4,500	4,000	4,300	4,300	
Total flow: 40 streams	Mm^3	3,673-4,800	3,680	3,800	1,174	1,800	4,300
Surface water outflow	Mm^3	300-670	945	700	670	(north) 510 (south) 160	~680
Groundwater outflow	Mm^3	310		200	300	(south) 150	
Submarine flow	Mm^3	385-1,000	385	700	880	880	711
Total resources average	Mm^3	2,600-4,800					
Total resources dry season	Mm^3	*1,400-2,200*					
Exploitable: surface	Mm^3	1,500					
Exploitable: ground	Mm^3	700-1,165					
Exploitable: total	Mm^3	1,400-2,200			2,000	2,200	

Source: MOE (2011) where sources are cited in the Table.

17. **Hydrology.** Lebanon has more than 40 rivers of which 17 are *considered* perenial (Figure 5.2, second quadrant and Table 5.2). Most water courses are internal short rivers with an East-West lateral orientation spilling into the Mediterranean, except for the two transboundary rivers which are the Orontes River (Nahr el Aassi) crossing the northern border and the Hasbani River crossing the southern border. More specifically, the Litani River has the most important basin (2,181 km^2) and longest river of Lebanon (170 km) with an average water flow of more than 770 MCM/year. However, the river was split into two physiographically distinct basins where the Upper Litani Basin feeds into the artificial Qaraoun Lake. Its storage capacity of 220 MCM is used to notably produce hydroelectricity and supply irrigation

[3] Basil, G. 2010. Ministry of Energy and Water: National Water Sector Strategy, Baseline and Key findings. Beirut.

schemes, and any overflow during winter time is released into the Lower Litani Basin which has its own afluents.[4]

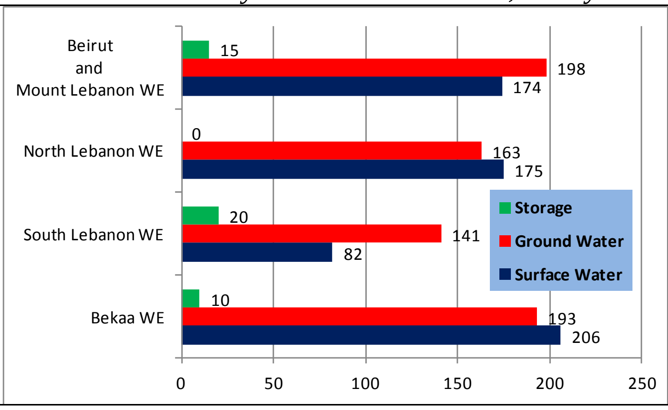
Table 5.2: Lebanon Perennial Rivers

River	Length km	Annual Volume Million m^3	Average Flow m^3/s	Maximum Flow m^3/s	Minimum Flow m^3/s
El Kabir	58	190	6.02	13.9	1.8
Ostuene	44	65	2.07	4.01	0.8
Aaraqa	27	59	2.06	6.27	0.8
El Bared	24	282	8.94	15.2	2.7
Abou Ali	45	262	15.17	37.3	1.6
El Jaouz	38	76	2.40	6.18	0.4
Ibrahim	30	508	16.1	27.6	1.9
El Kalb	38	254	8.04	18.1	2.4
Beirut	42	101	2.59	10	0.1
Damour	38	307	13.8	32.7	0.6
El Awali	48	299	9.71	26.2	3.9
Saitani	22	14	0.73	1.3	0
El Zahrani	25	38	1.59	3.4	0.3
Abou Assouad	15	11	0.35	NA	NA
Litani	170	793	12.5	30.8	4.3
El Aassi (Orontes)	46	480	16.4	20.9	11.5
Hasbani	21	151	4.8	11.3	1.6
Total	**731**	**3,890**	**123**	**265**	**35**

Source: MOE (2011).

18. **Water use.** Lebanon is currently using 2/3 of its available water resources which are poorly managed. The present annual demand is estimated at 1.5 BCM of which irrigation requires 0.8 BCM (53.4%), domestic water of 0.5 BCM (33.4%) and industry at about 0.2 million cubic meter (MCM --13.2%). Although well endowed, Lebanon's water resources are not evenly distributed among the different regions and are also affected by seasons. The 4 Water establishments exploits 1,377 MCM/year. Unfortunately, the storage capacity and water management leaves much to be desired (Figure 5.3). Moreover, groundwater is severely exploited where 42,824 public, private and informal wells are pumping 0.35 BCM annually leading to a drop in the aquifer levels (Figure 5.4).

Figure 5.3: Lebanon Water Resources Use by Water Establishment, Mm^3/year in 2010



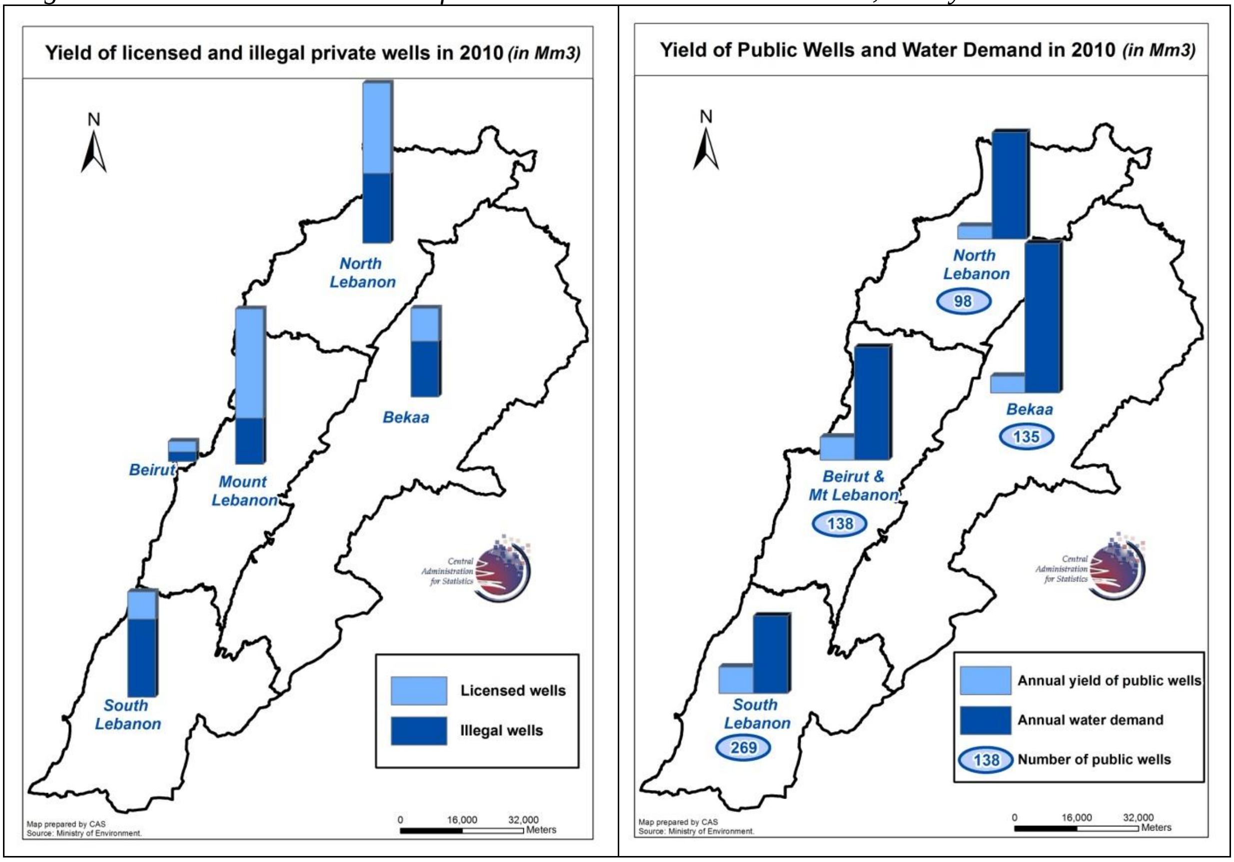
Source: CAS website: <www.cas.gov.lb>.

[4] Arif and Doumani (2013).

19. As a result, a new 10 year plan was developed by the Ministry of Energy and Water to meet the needs of water in Lebanon with the available quantities:

- Total water needs are 1,660 MCM.
- Expected storage volume is set at 806 MCM.
- Water shortage will be reduced to 854 MCM.

Figure 5.4: Lebanon Formal and Informal Well Yield vs. Water Demand, Mm^3/year in 2010



Source: CAS website: <www.cas.gov.lb>.

5.4 Land Use

20. **Vegetation cover.** Climate influences the vegetation cover in Lebanon. There are four major botanical levels, between the coastline, the mountain then the hinterland (Figure 5.5, first quadrant):[5]

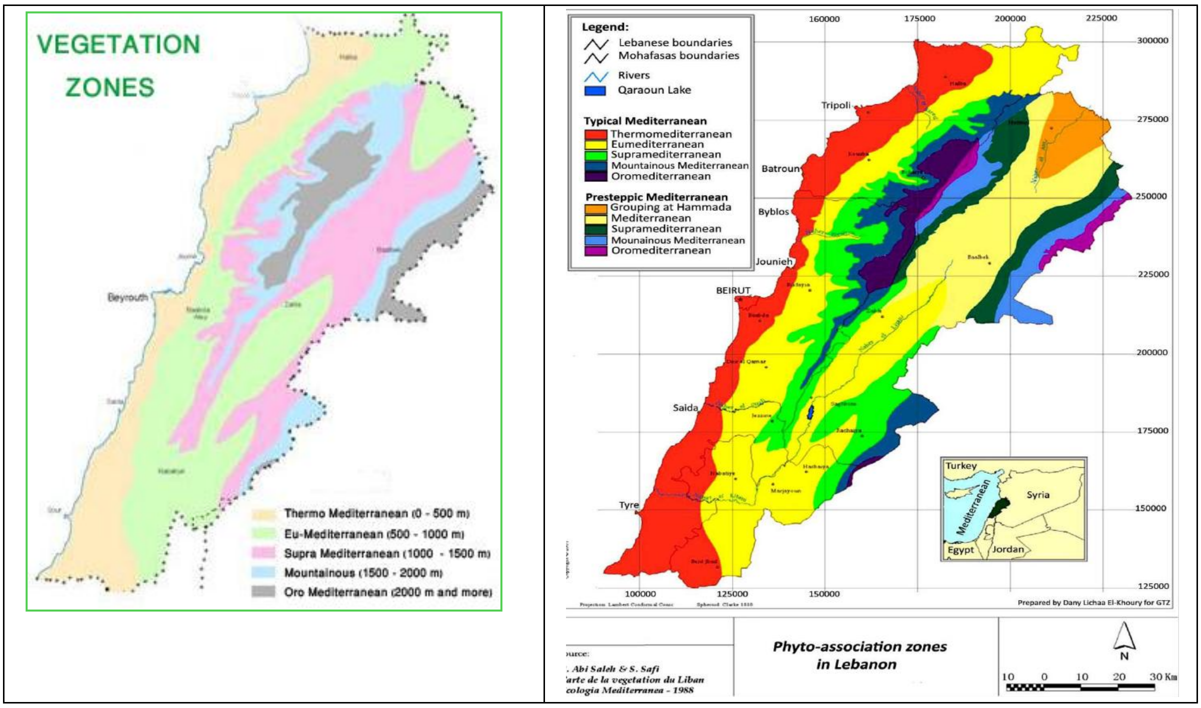
- Thermo-Mediterranean level (0-1,000 m): pines (Beirut and western slope of Mount-Lebanon), carob trees, storax, oak trees, willows (the slopes of Niha, Baruk Mountains, coastal zones, and the piedmonts of Mount Hermon in the hinterland).
- Supra-Mediterranean level (1,000-1,500 m): cypress, oak trees (Ehden, Sir ed-Dinniyeh, highlands of Qadisha, piedmonts of mount Mekmel, and Akkar).
- Mediterranean mountainous level (1,500-2,000 m): cedars, fir trees (Besharreh, Ehden, Qadisha, Hadath ej-Jebbeh, Tannourine, and Baruk).

[5] CAS website: <www.cas.gov.lb>.

- 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.).

21. **Biodiversity thematic areas.** Lebanon terrestrial biodiversity is distributed across 7 phyto-association zones as illustrated in Figure 5.5, second quadrant. The natural landscape of Lebanon is characterised by the gradual change from Mediterranean to continental Mediterranean and sub-desert conditions from west to east (MOE, 2009). The relevant thematic areas for biodiversity in Lebanon as addressed by the NBSAP, 1998 and its addendum (2005) are:
    - Terrestrial ecosystems and natural habitat;
    - Freshwater environment;
    - Marine environment; and
    - Agrobiodiversity.

Figure 5.5: Lebanon Vegetation Zones and Phyto-association Zones



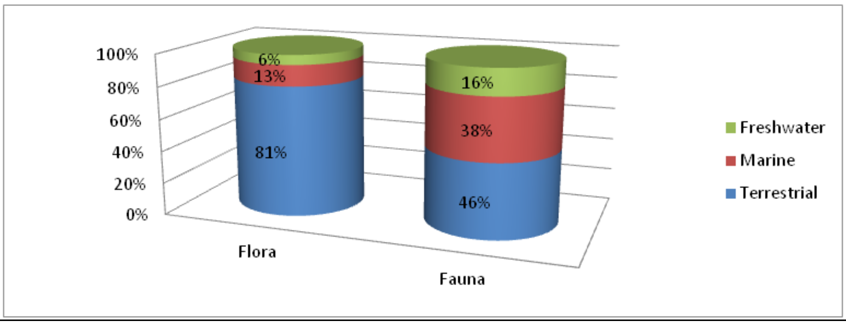
Source: Ministry of Agriculture's Atlas of Forests in Lebanon (2005); and Abi Saleh and Safi (1988) cited in Darwish (2012).

22. **Biodiversity species.** Lebanon enjoys a very rich biodiversity due to its wealth of habitats and varied topography; coastal stretches, high mountains and rivers, and extreme variability in climatic conditions across its landscape. There are 9,119 identified fauna (4,486) and flora species (4,633) in Lebanon (MOA, 1996), mostly in terrestrial ecosystems as illustrated in Figure 5.6. The flora and fauna densities of 0.25 and 0.028 species per km^2 respectively are considered high, especially when compared to neighbouring countries (MOE, 2009). More specifically, Lebanon is home to the following species: 3,835 invertebrates, 395 birds, 367 marine fish, 59 mammals, 54 reptiles, and 6 amphibians. Lebanon has no national biodiversity database and no national biodiversity monitoring program (MOE, 2009). Data from international reports[6] show that there are no threatened higher plant species, 10 threatened mammal species, 6

[6] IUCN website: <www.iucn.org>.

threatened bird species and 15 threatened fish species. The GEF benefits index for biodiversity,[7] which measures the potential global benefits that can be realized from biodiversity related activities in a country, is 0.17 for Lebanon. The number of species identified nationally as rare/endemic or nationally important varies between 92 (MOE, 2005) and 119 (Kew and LARI, 200-).

Figure 5.6 Breakdown of Flora and Fauna Species by Habitat – Lebanon



Source: MOA/UNEP/GEF (1996).

23. **Land use.** Lebanon covers a total land area of 10,225 km^2 (National Council for Scientific Research's Remote Sensing Department as territorial waters constitute the difference between the official area of 10,452 km^2 and the 10,225 km^2 land area). Although urban sprawl and encroachment are constantly changing the landscape in Lebanon, the distribution of some land use for the year 2009 is shown in Table 5.3.

Table 5.3: Lebanon Land Use, 2009

Indicator	**Area** (km^2)
Land area	10,225
Inland water	170
Agricultural area	6,871
Arable land	1,442
Permanent crops	1,429
Temporary crops	1,342
Permanent Meadows and Pastures	4,000
Total area equipped for irrigation	1,040
Irrigated area	519 of arable land 686 of permanently cropped land
Forest area	1,387
Other land	1,972

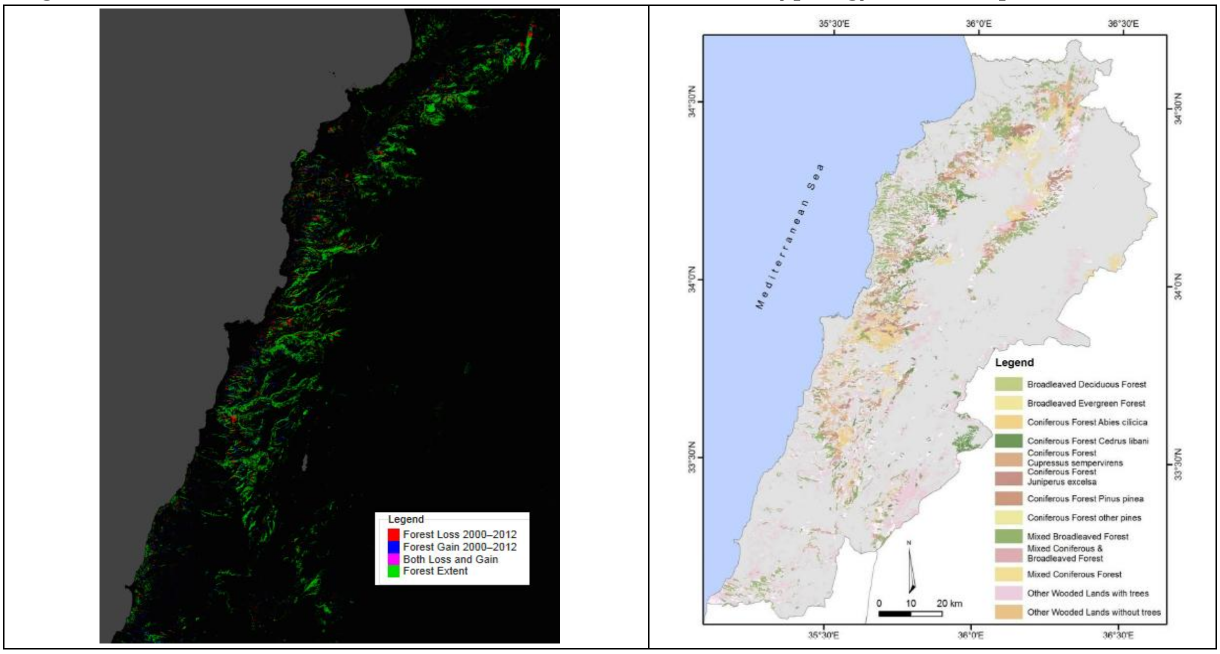
Source: FAO (2009).

24. **Forest.** Forests cover 13.6% of Lebanon area (FAO, 2009) equivalent to 1,387 km^2. Coniferous and deciduous forests cover 134,372 ha and other forested areas including woodlands with or without trees cover 120,574 ha (Figure 5.7, second quadrant). Forests' designated functions are mostly for multiple use (66%) and for protection of soil and water (25%), while 3% is for biodiversity protection with production at 6% (Table 5.4). Although 50% of the total forest was lost in 33 years, mainly affecting juniper sands (Jomaa et al., 2007), there has been a reforestation effort between 1990 and 2010 in Lebanon where forests gained 4.6% or 6,000 ha by the end of the period. There was an average gain of 0.25% per annum, or 6,000 ha. This "net" picture can hide the fact that

[7] GEF benefits index for biodiversity is a composite index of relative biodiversity potential for each country based on the species represented in each country, their threat status, and the diversity of habitat types in each country. The index has been normalized so that values run from 0 (no biodiversity potential) to 100 (maximum biodiversity potential).

deforestation and forest fragmentation occurred in some areas (Figure 5.7, first quadrant) and afforestation took place in others, so deforestation should not be seen as a non-issue, nor not a risk; deforestation looms as a threat if urban encroachment, increases in forest fires and insufficient protection of existing stocks continue (Tables 5.5 and 5.6). Moreover, the biodiversity and ecosystem services in old forests are much more complex than the ones found in new forests (reforestation). Measuring the total rate of habitat conversion (defined as change in forest area plus change in woodland area minus net plantation expansion) for the 1990-2010 intervals, Lebanon gained 0.23% per year.[8]

Figure 5.7: Lebanon Forest Continuum, Loss/Extent/Gain, and Typology Cover Map



Source: University of Maryland Global Forest Change 2000-2012 website: <http://earthenginepartners.appspot.com/science-2013-global-forest>;and Darwish (2012).

Table 5.4: Lebanon Forest Area Primary Designated Functions, 000' ha

Function Year	Production	Protection of soil and water	Conservation of biodiversity	Social services	Multiple use	Other	None or unknown	Total
2005	7.8	34.2	3.5	0	91	0	0	136.5
2010	8	34.4	3.5	0	91	0	0	136.9

Source: based on FAO (2010).

Table 5.5:Lebanon Trend in Total Net Forest Cover

Year	1990-2000	2000-2010
Total net forest cover end of decade (ha)	131,000	136,900
Annual Change Rate over the decade (±%)	+0.4%	+0.23%

Source: FAO website: <www.fao.org/docrep/013/i2000e/i2000e.pdf>; FAO (2010); and Doumani & Mucharrafiyeh (2011).

25. **Protected Areas.** Existing classification of protected areas exist since 1930 in Lebanon including international designations: 24 Natural sites/natural monuments, 5 Himas,[9] 12 Protected Forests, (Ministry of Agriculture), 10 nature reserves (of which 8 forests – Ministry of Environment), and 14 touristic sites. Nevertheless, some overlap exists between the mandates of the Ministry of Environment and the Ministry of Agriculture

[8] Doumani and Mucharrafiyeh (2011).
[9] Traditional Arab system of ecosystem's community-based management.

(Table 5.6). Actually, forests of cedar, fir, cypress and juniper are *de facto* protected. The Convention on Biological Diversity (CBD) Strategic Plan for 2011-2020 includes a target for protected areas that at least 17% of terrestrial and inland water, and 10% of coastal and marine areas (if applicable), are conserved through effective management practices. Lebanon has less than 2% of this land that falls under the protected area designation.

Table 5.6: Lebanon Selected Important Conservation Sites and International Designation

Legal Status	**National Designation**		**International Designation**					
Site	**Nature Reserve** **Under MOE**	**Protection of Sceneries and Natural Sites** **Under MOA**	**UNESCO World Heritage**	**UNESCO Biosphere Reserve**	**UNESCO depository of inter-gov. Ramsar Convention**	**NGO IBAs**	**UNEP Barcelona Convention Special Protected Area**	**UCN Cat.**
1. Bentael	**GAC**							**V**
2. Horsh Ehden	**GAC**							**V**
3. Palm Islands	**GAC**							**V**
4. Tannourine	**GAC**							**V**
5. Tyre Coast (Ramsar) and City	**GAC**		**(City)**		**(Coast)**			**V**
6. Karm Chbat Forest								**II**
7. Yammounneh								**V**
8. Wadi Al Hojaira								**V**
9. Shnaneer								**V**
10. Al-Shouf Cedar/Maaser as Shouf	**GAC**	**Hima**						**II**
11. Ammiq Wetlands								**V**
12. Ras Shakaa								**V**
13. Cedars of God and Qadisha Valley								**III**
14. Qammouah Park (Akkar-Dennieh)		**Hima**						**II**
15. Ras Baalbeck (semi desert area)								**V**
16. Rim Sannine mountain								**V**
17. Qaraoun lake (Beqaa)								**V**
18. Ramlieh valley (Shouf)								**V**
19. Anjar - Kfar Zabad		**Hima**						**II**
20. Ibl es Saqi (Marjayoun)								**V**
21. Beirut River valley								**V**
22. Jabal Moussa								**V**
23. Jabal Rihane								**V**
24. Swayse (Hermel)								**II**
25. Bezbina (Akkar)								**II**
26. Knat (Knat)								**II**
27. Qaryet Sfina (Akkar)								**II**
28. Merbine (Wadi Jhannam)								**II**
29. Shebaa (Hbaline)		**Hima**						**II**
30. Bkassine (Jezzine)								**II**

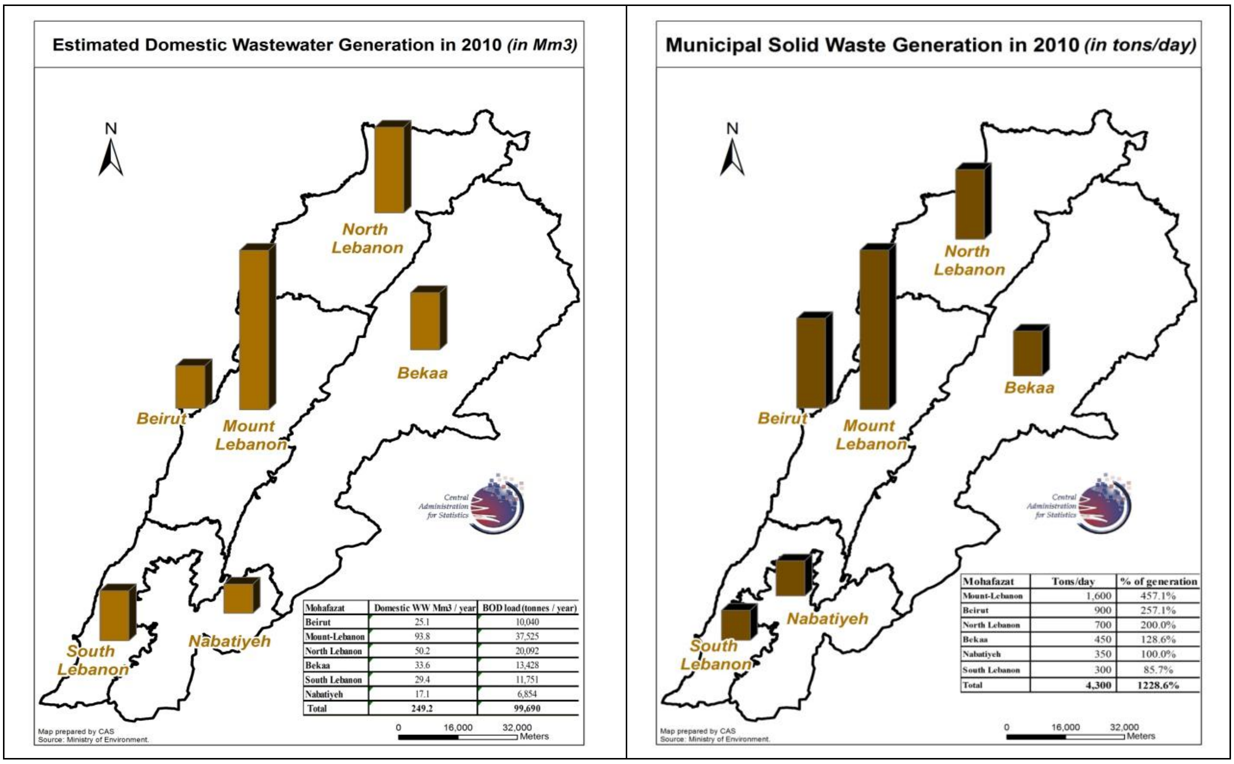
Note: Government Appointed Committee (GAC) management is overseen by the MOE and Hima by the municipalities. IUCN Categories are tentative.
Source: adapted from METAP (2009) based on the following websites: MOE <www.moe.gov.lb>; UNESCO <www.unesco.org>; Ramsar <www.ramsar.org>; IBA <www.birdlife.org>; and CAS <www.cas.gov.lb>..

5.5 Pressure on the Environment and Vulnerability

26. **Air.** Air pollution is becoming a dramatic issue in Lebanon in General and Greater Beirut in particular. Levels and PMx and NOx are increasingly exceeding WHO thresholds as ambient air pollution is increasing in most urban areas (sampling in Beirut resulted in 63

μg/m^3 of PM_{10} and 20 μg/m^3 of $PM_{2.5}$ in 2010)[10] and industrial zones (e.g., particulate concentrations and NO_3^- concentrations in the sites near Chekka's cement factories were higher when compared to 5 regional cement factory clusters).[11] Air pollution is not only affecting human health but also infrastructure (decaying), agricultural yield and ecosystem services. Indeed, pollutants can be washed into water bodies during winter and the smog could affect photosynthesis although these aspects are not thoroughly researched in Lebanon. Also, seasonal sandstorms emanating from the Sahara and the Arabic Peninsula equally affect human health, agricultural yields, the snow cap and ecosystem services.

Figure 5.8: Lebanon Liquid (Mm^3/year) and Solid Waste (ton/day) Generation



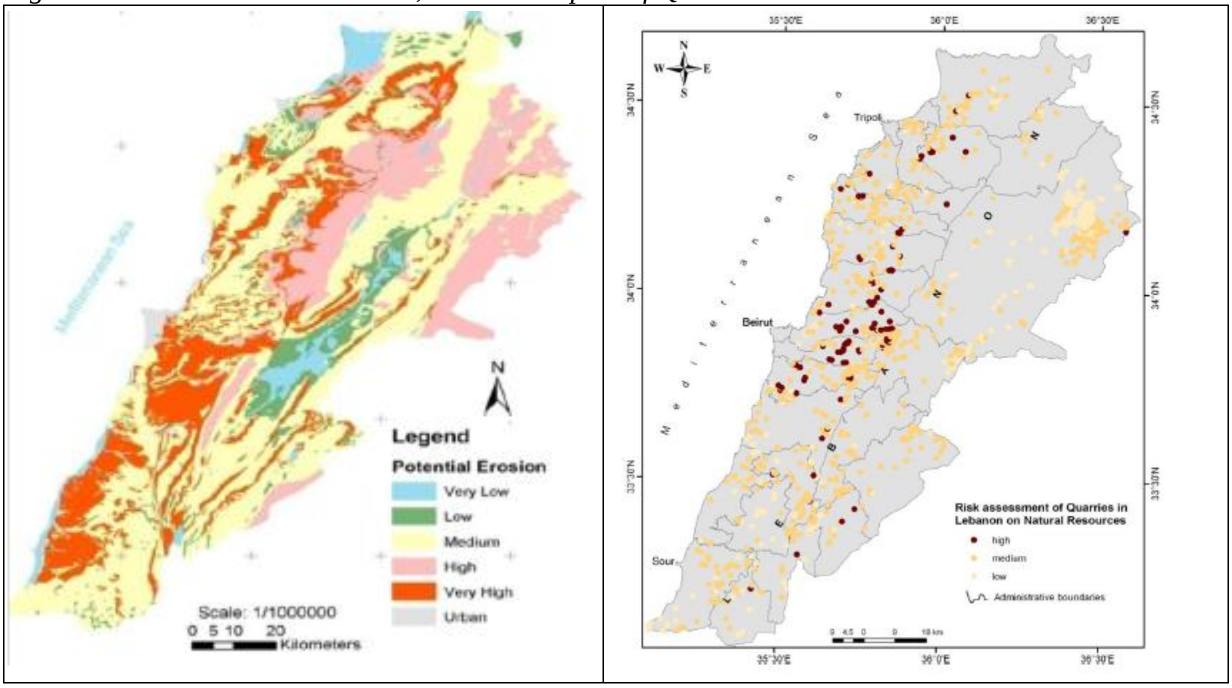
Source: CAS website: <www.cas.gov.lb>.

27. **Waste.** Municipal, industrial and hazardous liquid and solid wastes are affecting the environment in general and ecosystem services in particular as about 10% of liquid municipal and industrial waste is treated in Lebanon and only 2 sanitary landfills exist in Lebanon: Naameh that covers Beirut and Mount Lebanon and has already reached its full capacity; and Zahleh that covers the Casa of Zahleh. Also, Tripoli landfill and Saida dump are close to over capacity and represent a huge risk as they were constructed on the seashore. In the rest of Lebanon, waste is still released into unsanitary dumps, burnt and/or discharged into river basins. In term of volume, 4,300 tons of solid waste are generated per day whereas 249.2 Mm^3 of liquid waste is generated per year containing about 100,000 tons of BOD. Liquid and solid wastes could contaminate soils and water bodies with a tremendous effect on ecosystem services.

[10] Saliba et al. 2012. PM Levels in Beirut, Exposure and Health Effects.

[11] Kfoury et al. 2009. A Study of the Inorganic Chemical Composition of Atmospheric Particulate Matter in the Region of Chekka, North Lebanon.

Figure 5.9: Lebanon Land Erosion, and Risk Impact of Quarries on Natural Resources



Source: cited in Darwish (2012).

28. **Land erosion.** Land erosion effected by wind could occur in Lebanon but do not constitute an important risk as it is confined to spatial areas and temporal winds. However, land erosion induced by land use mismanagement and water runoff is an increasing issue in Lebanon. Most soils are calcareous and typically Mediterranean as the combined influence of weather, vegetation cover, and slope of the terrain have made a important part of Lebanon prone to erosion. Indeed, Lebanon soils are young, fragile and subject to erosion, especially in the mountains and hills that represent 73% of the country (Figure 5.9, first quadrant). 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. The 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.[12] Similarly, the negative impact of abandoned quarries include the fragmentation of the landscape, soil erosion, the deterioration of forest cover, land contamination, loss of biodiversity and decrease quality and quantity of water as the number of quarries increased from 711 with an area of 2,875 ha in 1996 to 1,278 with an area of 5,283 ha in 2005. Remote sensing showed that 21.5% were distributed on forested land and arable land while 32.4% of quarries were detected on scrubland and grassland and 3.2% of the quarries were distributed inside urban zones (Figure 5.9, second quadrant).[13] Modelling the risk of abandoned quarries and land resources in Lebanon using parameters like slope, climate, previous vegetation cover, land use, soil and rock types revealed large number of quarries having moderate (65.9%) and

[12] CAS website: <www.cas.gov.lb>.
[13] Darwish et al. (2008).

high (8.2%) impact on surrounding natural resources that was equally observed in Mount Lebanon and Anti-Lebanon.

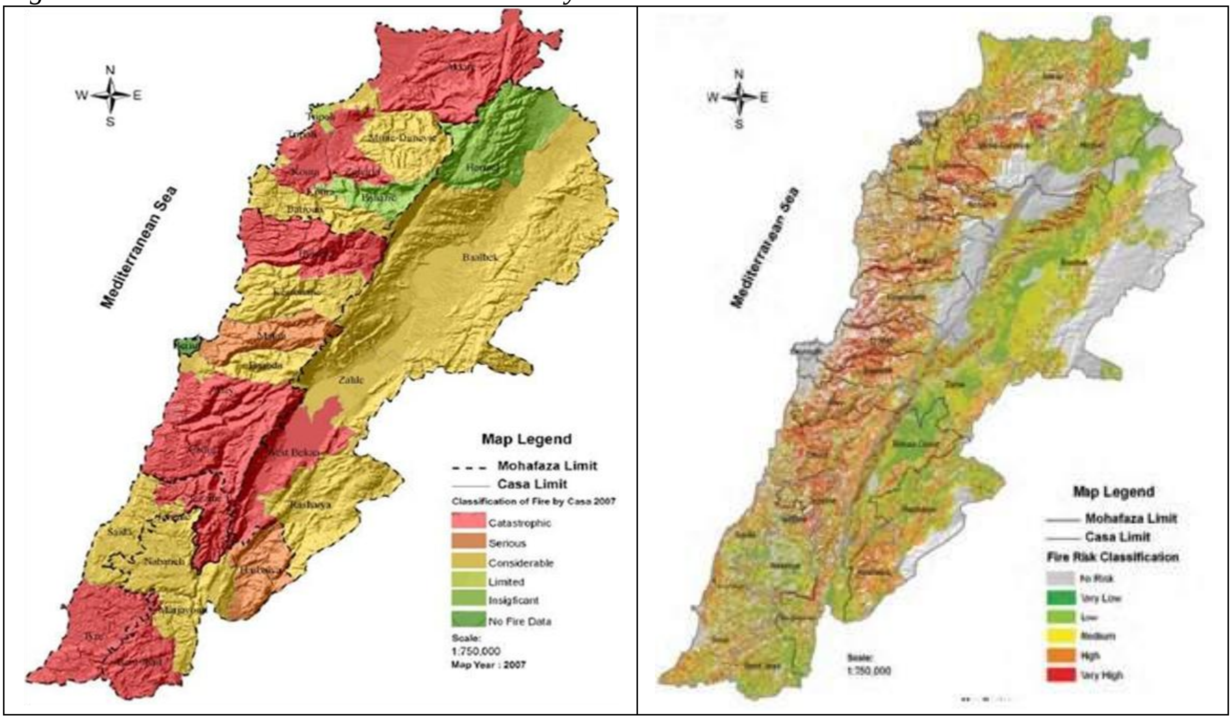
29. **Forest fire.** Forest fires are considered a major threat to terrestrial biodiversity in Lebanon as they have increased in frequency and intensity over the decade due notably to climate change. Forest fire risks are plotted in Figure 5.10, second quadrant. Reported forest and forested lands affected by fires between 2004 and 2012 are illustrated in Table 5.7 while the most damaging fires occurred in 2007 (Figure 5.10, first quadrant). The trend in terms of area affected is positive and forest fires are becoming more devastating by the year.

Table 5.7: Lebanon Forest Fires, 2004-13

Forest Fire	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Number	119	117	144	275	426	281	NA	NA	NA	NA
Area affected (ha)	585.3	440.0	874.6	4,031.0	1,860.5	2,644.0	NA	NA	NA	NA

Source: data provided by the MOE and compiled by CAS.

Figure 5.10: Lebanon 2007 Forest Fire Intensity Areas and Forest Fire Risk



Source: MOE (2011); and Darwish (2012).

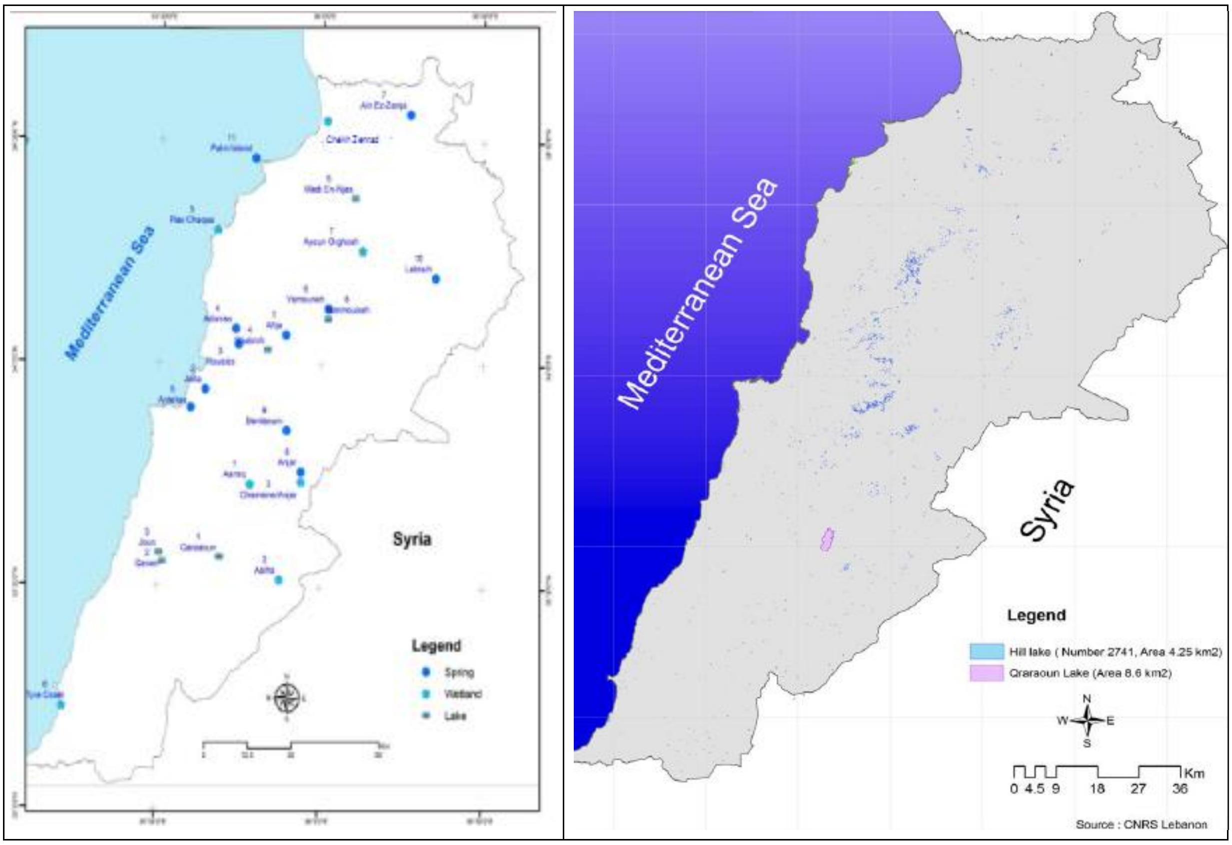
30. **Reforestation pressure.** A number of factors have impeded the reforestation efforts in Lebanon initiated by a number of actors (Ministries, public entities and NGO) with the help of development partners including notably: seed and seedling quality; lack of proper technical assistance; lack of adequate monitoring; lack of regulation, compliance and enforcement in open access reforested areas especially when it comes to grazing and hunting.

6. Hill Lake Ecosystem Services Review

6.1 Lebanon Lakes, Hill Lakes and Wetlands

31. **Lakes, hill lakes and wetlands.** There are no large-scale natural lakes in Lebanon. However, there are 6 artificial lakes and about 2,750 hill lakes, as compiled through spatial detection (CNRS). The Qaraoun Lake has by far the largest area spanning 8.52 km^2 or 65.3% of total combined lakes with a capacity of 225 Mm^3 or 93.2%. The combined hill lake area is about 4.25 km^2 with a storage capacity of 3.1 Mm^3. Yet, over the 1968-2008 periods, the Green Plan has implemented 6 km^2 of earth reservoirs and 0.365 km^2 of cement reservoirs which supposes that a large number of them was abandoned or decayed overtime. Interestingly, current hill lakes capacity over area ratio is the lowest with 3.1 m^3 stored per m^2 due to their small depth: 3 m depth on average. This ratio is 8.5 fold lower than the average artificial lakes in Lebanon. In other words, hill lake area represents 33% of Lebanon lakes' area but only represents 5.4% of Lebanon lakes' storage capacity (Table 6.1). Incidentally, the 2003 World Bank Irrigation Policy Note recommends limited construction of hill lakes to areas that urgently need potable water, as they are too expensive to use for irrigation. As for the 5 inland wetlands, their combined area is almost equal to the combined hill lake area and reaches 10.6 km^2 although they are constantly shrinking (see below). Conversely, the combined area of the 4 coastal wetland reaches 18.1 km^2.

Figure 6.1: Lebanon Lakes, Hill Lakes and Wetlands



Source: NPMPLT (2005); and CNRS cited in Darwish (2012).

Table 6.1: Lebanon Lakes, Hill Lakes and Wetlands

Category	Number	Area			Capacity			Efficiency
	#	Km^2	% of Category	% of Total	Mm^3	% of Category	% of Total	ratio m^3/m^2
Lakes								
Qaraoun	1	8.52	96.8%	65.3%	225	98.6%	93.2%	26.4
Anan	1	0.02	0.3%	0.2%	0.25	0.1%	0.1%	10.9
Joun	1	0.04	0.5%	0.3%	0.32	0.1%	0.1%	7.8
Shabrooh	1	0.17	1.9%	1.3%	2	0.9%	0.8%	12.1
Wadi en-Njas	1	0.05	0.5%	0.4%	0.7	0.3%	0.3%	15.2
Yammouneh	1	0.004	0.05%	0.03%	0.04	0.02%	0.02%	10.0
Subtotal	6	8.80	100.0%	67.4%	228.3	100.0%	94.6%	25.9
Hill Lakes								
Subtotal	2,741	4.25	100.0%	32.6%	13.0	100.0%	5.4%	3.1
Total	**2,747**	**13.05**		**100.0%**	**241.3**		**100.0%**	**18.5**
Inland Wetlands								
Aamiq	1	2.80	26.5%	9.8%				
Aaiha	1	3.20	30.2%	11.2%				
Chamsin/Anjar	1	0.85	8.0%	3.0%				
Kfar Zabad	1	3.26	30.8%	11.4%				
Ayoun Orghosh	1	0.47	4.4%	1.6%				
Subtotal	5	10.58	100%	36.9%				
Coastal Wetlands								
Ras Chaqaa	1	7.00	30.4%	19.2%				
Cheikh Zennad	1	4.85	4.0%	2.5%				
Palm Island	1	5.50	38.7%	24.4%				
Tyre Coast	1	0.72	26.8%	16.9%				
Subtotal	4	18.07	100.0%	63.1%				
Total	**9**	**28.65**		100.0%				

Source: Adapted from Darwish (2012); and Society for the Protection of Nature in Lebanon website: <www.spnl.org>.

6.2 Synthesis of Ecosystem Services and Anthropogenic Disturbances

32. **Hill lake ecosystem services.** There is little information on ecosystem services of Lebanon's hill lakes *per se* and few regional citations gave insightful information as most information is generic while hill lakes should be considered as part of an integrated water system that contributes to the provision of ecosystem services. The most interesting synthesis study on the Litani Ecosystem was produced by IDRC (2007), is reported in Box 6.1 and argues that the construction of dams has indeed increased the area of water surface but has changed the natural flow regime of the Litani: the previous drainage of certain areas of the Bekaa, urbanization along the river and agricultural expansion are all putting more pressure on the Litani ecosystem services; and floods and especially the one that occurred in 2003 have had a direct impact on the morphology of the river bed that resulted in biodiversity losses.

Box 6.1: Litani Ecosystem Assessment

The Upper Litani is divided into two sectors as follows:

- **The Upper Bekaa Valley**. This section of the Litani River has the worst water quality. The water here is hazardous to human health. The river is fed by source springs close to the natural divide of the Litani and the Orontes. Groundwater ponds are used in the headwater region for the year round supply of water for irrigation, municipal and domestic use. This results in a drawdown of the water table and a drying out of the upper reaches of the Litani River. Most of the irrigation water is lost by evaporation and evapo-transpiration and no evidence was seen of irrigation water return flow to the river. Groundwater after use for domestic and municipal purposes is largely collected by sewage systems and the untreated wastewater is returned to the river. From Location 28 downstream until the Beirut-Damascus highway, year round flow is observed increasing downstream due to the numerous wastewater out-falls along the river course.

- **The Lower Bekaa Valley.** Downstream of the Beirut-Damascus highway, the river receives the tributary waters of the Ghzayel, the Berdaouni and Chtoura Rivers. Each of these tributaries is fed year round by Karstic springs in the mountains on each side of the Bekaa Valley. High flow is therefore maintained year round. The high tributary loading of water to the Lower Bekaa results in dilution of most elements including the most important of all - bacterial concentrations. Despite this dilution, water quality remains extremely poor until the Qaraaoun Reservoir. Reduction in pollution in the Upper Bekaa would obviously improve the Lower Bekaa. However, the presence of towns and villages throughout the Valley will continue to result in extremely bad water quality unless all sources are subjected to remedial measures.

Fertilizers. The evaluation of Nitrate in the Litani indicates over-fertilization of agricultural soils as the major cause of very high nitrate concentrations throughout the Litani. Control of fertilizer application is needed (see below).

Solid Waste. Enrichment of the river waters with Nitrite indicates leaching of solid waste with exposure to rising water levels during higher flow conditions. Nitrite in itself may not be of immediate concern. However, it serves as a tracer indicating the probability that many other organic and inorganic materials are being leached from the solid wastes deposited throughout the basin.

The Qaraoun Reservoir. This reservoir has a dramatic effect on water quality from input to output to the generating station. There are clear reductions in bacterial concentrations and in nutrients. Seasonal levels of nutrients clearly reflect the limnology of the reservoir and indeed it can be postulated that phosphorus is the limiting nutrient to phytoplankton growth in the reservoir. An evaluation of nutrient cycling in the sluggish, inflowing waters of the Litani River indicate the nitrogen may be the limiting nutrient in the river system.

Diversion of Litani River water to the Awali Valley. The physical transfer of water by tunnel through the mountain range to the Awali River shows little change in water quality and only Phosphate and Ammonia show a statistically significant decline in concentration.

Impact of Litani Waters on the Awali River. The Litani River water discharge to the Awali has a significant impact. Bacterial levels are reduced whereas both nitrate and nitrite concentrations are increased. Phosphate both increases and declines relative to the concentration of the Litani diversionary water as compared to the Awali River phosphorus levels upstream of the point of discharge.

Lower Litani River. Most of the annual flow of the Lower Litani is derived from the many springs occurring along its course through the mountains. Discharge from the Upper Litani from the Qaraaoun Reservoir occurs only during periods when the water supply in the Reservoir exceeds that required for power generation. In general the water quality is good when compared to the Upper Litani. However, bacterial infection exceeds the guidelines for most human uses but is within the guideline for use as a supply of water for drinking water treatment. Nutrient water quality levels are good with only Nitrate showing cumulative increases downstream relative to increasing fertilizer application and the oxidation of ammonia and nitrite found in the discharged domestic wastewater to nitrate.

Source: IDRC (2007).

33. **Review of the annotated bibliography**. The citations were regrouped in main themes of reflection. The numbers [] correspond to the citation in Annex I.

34. **Rapid international take on biodiversity and ecosystem services.** [40] [41] [42] [43] [44] [45] The complexities of the concepts of biodiversity and ecosystems are highlighted and the relationships between biodiversity, ecosystem functioning and ecosystem services are examined. The ecosystem services are classified into: (i) Provisioning: provision of food, water, fuels and fibres, genetic resources, medicinal and other biochemical resources and ornamental resources; (ii) Regulating: air quality regulation, climate regulation, moderation of extreme events, erosion prevention, maintenance of soil quality, pollination services and biological control; (iii) Habitat: maintenance of life cycles of migratory species and genetic diversity; and (iv) Cultural: aesthetic information, opportunities for recreation and tourism, inspiration for culture, art and design, spiritual experience, and information for cognitive development. Lists the trade-offs (temporal, spatial, beneficiary and service) among ecosystem services. Physical changes affect and influence ecosystems. Illustrates the values of biodiversity in regulating different ecosystem services.

35. **Regional Mediterranean: Importance of integrated water systems.** [26] There is a need to pay more attention to terrestrial ecosystems (hydro-systems and wetlands) because they are very rich and very complex, both from a biological point of view (particularly in terms of biodiversity) sociological and global changes will affect all ecosystem functions, and consequently the goods and services that users derive. The disappearance of species affect ecosystems in their functioning and resilience to environmental change (such as climate change) and therefore lies in their ability to provide ecological services that benefit humans (food production, maintenance of soil fertility, carbon storage, nutrient cycling, etc.). An adaptation targeting ecosystems to future conditions is needed, so they can continue to provide the goods and the most important services requires improved knowledge of these goods and services (processes involved and their interactions, availability of tools to establish management options and different spatial scales considered). The development of ideas and approaches (biophysical modeling "process-based models", socioeconomic and optimization techniques) on the asset management of these goods and services must be considered. [25] Hydro systems are a natural capital generator of services, sewage services, dilution, cooling, hydro power, drinking water supply, recreational, ecological, navigation, irrigation, flora and fauna, authorization and protection against floods. Wetlands are valuable areas that must be preserved because they play an important role in terms of biodiversity, hydraulic term (operating like a sponge, they absorb water during floods and release it in period low water/drought) and after treatment. Water is an important condition for the development and a wealth that generates many services. [27] Reuse of treated wastewater (RTW) contributes to the integrated management of water resources and preservation of strategic environment in arid and semi-arid Mediterranean region (pressure on water resources is strong). Various recommendations to overcome obstacles and envisaging sustainable RTW (a holistic and multidisciplinary approach by linking the resource-use (top-down) approach with the used resource approach (bottom-up), choose a sanitation model while considering the separation of domestic and industrial flow, consider the irrigation system as part of the sanitation sector and recovery, etc.). In terms of Ecosystems-Wastewater: The disappearance of aquatic ecosystems is related to the overexploitation of aquifers which lowers groundwater levels and to human activity that tends to reduce indispensable resources that are key for the survival of ecosystems. Negative externalities such as release of untreated wastewater have an impact on the ecosystem and affect downstream users.

36. **National: Importance of integrated water systems.** [2] The Qaraoun Reservoir (1,000 ha) and the smaller Taanayel Lake (6 ha) are sufficiently large to attract numbers of migratory waterfowl and compensate for the shrinkage of the Aamiq wetland due to drainage for agriculture since the early 20th century. [7] Pumping of water from the Ammiq marshes for the irrigation of nearby cultivated lands has reduced the area of the wetland and shortened its life span and could disappear by 2020. [8] Detrimental changes in hydrology that Lebanese people have observed over recent decades such as the decrease in groundwater levels and the drying up of springs and wetlands whereas rivers mainly Litani, no longer flow in the dry season. Reduced infiltration rates, increased runoff and soil erosion, and a decline in groundwater recharge are all caused by deforestation, overgrazing, low rainfall, and poor surface management of cultivated lands. [17] Litani River calibration (upstream of Qaraoun Lake) was done in the 1970s to protect 1,500 ha

against flood damage and waterlogging. [14] Akkar's El Kabir River Integrated watershed assessment was established through remote sensing and GIS that helped quantify, model and predict changes in terms of impact of malpractices from excessive human interference that resulted in degradation of land and water quality while changes in the watershed were observed in decreased water resources, pollution by wastewater discharge, soil erosion, forest decline and socioeconomic imbalance. [18] Government should begin prioritizing "environmental water" in water sector planning defined as any water that achieves ecological benefits (protecting ecosystems as well as ecological processes and environmental needs of rivers and aquifers). [12] By prioritizing rural treatment plants, 35 environmental "hot spots" have been identified by the Ministries of Environment, and Energy and Water. In identifying "hot spots", special emphasis has been given to the following: the catchment areas of existing and proposed hill lakes; areas surrounding major springs and surface water sources; community clusters with no proposed sewage; and, Natural Reserves and other protected areas, wetlands, and areas of environmental sensitivity. [4] Medium-sized hill lakes are part of water and soil conservation strategies since they are used to store runoff rainwater and existing permanent sources of water such as springs for supplemental irrigation of nearby trees. Provides technical criteria for site selection and design of hill lakes; (i) When the water volume to be stored is higher than 50,000 m^3, it is more profitable to minimize the excavation works by constructing an earth compacted embankment; and (ii) The ratio: volume of stored water/earth moved and compacted should be around 4 as it is assumed that this ratio should not be less than 3 and not exceed 7. [22] World Bank in 2012 analyzes the factors contributing to seasonal water imbalance that include the very low water storage capacity and summarizes the Lebanese strategy for surface water storage that aims at constructing dams in Janneh, Bared, Aassi and Ibl Es Saki.

37. **Regional: Biodiversity at risk.** [28] Plant species (flora) are assessed in the Western Mediterranean Desert of Egypt according to their provision of goods (medicinal, grazing, human food, timber, fuel and other uses including mats, baskets, chairs, ornamental uses, beach beds, soap manufacture, and oil and dye extraction; assessed based on field observations and information collected from local inhabitants) and services (sand accumulation, wind breaking, aesthetic concerns, soil fertility, shading, water storage, refuge, salinity tolerance, bank retention, water invading, weed controlling and water purification), and identifying the threats (browsing and over grazing, over collecting and over cutting, clearance for agriculture, habitat loss, disturbance by cars or trampling, and mining and quarrying) that govern their gradual change in the study area. 548 species in Western Mediterranean Desert (56.6% of the total species) have at least one aspect of potential or actual goods arranged in descending order as follows: medicinal (important source of economic income in this region) > grazing > human food (vegetable dishes) > other goods > fuel > timber. Determines that 338 species (34.9% of the total species) have at least one environmental service including the following in descending order: sand accumulation > windbreaks > aesthetic concerns > soil fertility > shade plants > water storage > refuge > salinity tolerance > bank retention > water invading > weed controlling such as smother plants > water purification (ability to accumulate pollutants from contaminated water from agro-industrial activities). Services are related to the location and environment of the different species in the Western Mediterranean Desert of Egypt. 411 species (75% of the total economic species) suffer from at least one type of threat

arranged in descending order: over-collecting and over-cutting > habitat loss > browsing and over grazing > clearance for agriculture > mining and quarrying > disturbance by cars or trampling. [46] Water erosion processes have led to negative economic and environmental consequences in the a context of limited resources in Tunisian semiarid areas. These degradation phenomena were characterized and predicted by setting up a comprehensive high-resolution database on erosive rainfall, together with siltation records for 28 small reservoirs. The studied small reservoirs network displayed a general life-span of about 14 years and determined that average soil loss is 14.5 tons/ha/year. The complex relationship between the erosive rainfall events and the annual soil loss was explained by two important factors: (i) soil degradation cycle which determines the soil particle delivery potential of the catchment; and (ii) degradation front which presents a north-western/south-eastern direction. Rainfall disaggregation investigation was performed through a regionalization of fine timescale and daily rainfall and concluded that there are similarities between the maximum 15-minute and daily rainfall data. The multiplicative properties of a 4-year rainfall time series were explored and showed that scaling behavior for time scales up to 100-minutes coincides with the most active erosion process time scale. The potential of rain-fall scaling-based approaches to predict water erosion levels in semiarid areas proved promising and will help decision makers better manage soil erosion problems.

38. **National: Biodiversity at risk.** [1] Quarries and sand removal activities had for a long time a major impact on both the flora and fauna and the surrounding environment. States that the risk of extinction on fresh water fauna is very high for Plecoptera (81%), Coleptera (11.4%) and Ephemenoptera (8.7%). Crustaceans are 8.2% at risk, fish 4% and molluscs 3.0%. Mountain lakes have to be extended all over appropriate areas including protected areas and that research, building of capacities and studies on fresh water biodiversity should be expanded and supported. [4] A wide variety of organisms inhabit Lebanon’s freshwater ecosystems, including invertebrates, molluscs and fish. The faunal species in freshwater represent 16% of the total fauna biodiversity of the country and the floral species represent 6% of the flora species only; 5% of the country's freshwater fauna is threatened and 1.3% endemic including *Phoxinellus libani* (fish) considered extinct in the country but later observed in Yammouneh Lake, Litani River and Qaraoun Lake. [3] Drainage, pollution from wastewater, solid waste and runoff, and human interference have drastically changed the fresh water ecosystem and resulted in a high proportion of endangered species and the elimination of weak species especially those sensitive to pollution.

39. **National: Anthropogenic disturbances.** Most reviewed citations and some already reviewed above concur with regards to the impact of human-made damages in terms of physical alterations (deforestation, encroachment, sprawl, quarries, etc. leading to less recharge of aquifer and more erosion) and pollution loads (liquid and solid wastes as well as agricultural runoff leading to the deterioration of water quality and ecosystem services) affecting water resources. For instance: [6] Socio-economic factors and climate change have resulted in decrease in agricultural lands and an increase in deserted and barren land which affected the availability and the quality of water; [20] The analysis of the pollution status of the Litani River and Qaraoun lake has shown that the largest two pressures are agriculture (mainly nitrate, phosphorus, and pesticides) and municipal wastewater

(ammonia-nitrogen and nitrate-nitrogen concentrations); [9] Waste generation is severely affecting the upper Litani basin and the Qaraoun Lake itself which catches and contains many of the upstream pollutants, such that it is unfit for fishing, irrigation, or domestic use. The poor water quality has led to eutrophication, impeding drinking and agriculture water intakes. These impacts, in turn, lead to decreased agricultural output, increased water-related illnesses, and higher treatment costs to render water suitable for use.

6.3 Suitability of Abandoned Quarry Rehabilitation into Water Harvesting

40. **Synergy and arbitrage.** The Lebanese CNRS assessed the possibility of transforming the 1,278 abandoned quarries until 2005 (see Section 5.5 above) into either revegetation areas, water harvesting and/or sanitary landfills which could be a double whammy: repair a *fractured* land and notably providing water storage. Although the revegetation would require significant resources for remodelling and restoring the fractured land, water harvesting seems to be a more feasible alternative especially in light of the increase in forest fire events and recession of vegetation cover. Landfill feasibility ranking looks similar to water harvesting's. After combining the outputs of both groups, the rehabilitation success model used was effective at segregating quarries into clear rehabilitation alternatives (Table 6.2). There is no very highly feasible water harvesting for restoring abandoned quarries but the number of highly and medium feasible quarry restoration reaches 220 and 442 respectively with an area of 10.1 and 21.3 km^2 respectively (Table 6.3 and Figure 6.2). Potentially, the combined high and medium feasibility ranking which represents 2.4 fold Lebanon's existing hill lakes. Although it is difficult to determine initially the cost and potential water storage of these quarries, geographically, they are spread all over the territory. The water harvest quarries for reclamation should also consider the environmental impact of the quarry mitigation where a super-imposition of erosion risks, forestation and biodiversity index (not available yet in Lebanon) GIS maps could help refine the feasibility success ranking and therefore prioritize the rehabilitation of quarries based on hill lake needs after performing a quantitative analysis (cost-benefit analysis or cost-effectiveness analysis). Furthermore, water harvesting has a multi-purpose use such as revegetation, irrigation, underground water gradual recharge, water volumes used for forest fire preparedness, etc. Also, the optimization of water conservation could further call for exploring the use of flexible covers to reduce evapo-transpiration, etc.

Table 6.2: Lebanon Potential Quarry Rehabilitation: Revegetation vs. Water Harvesting Matrix

Alternative		**Revegetation**				
	Ranking Class	**Very High**	**High**	**Medium**	**Low**	**Total**
Water Harvesting	**High**	3	37	82	98	**220**
	Medium	15	77	188	162	**442**
	Low	2	30	333	251	**616**
	Total	**20**	**144**	**603**	**511**	**1,278**

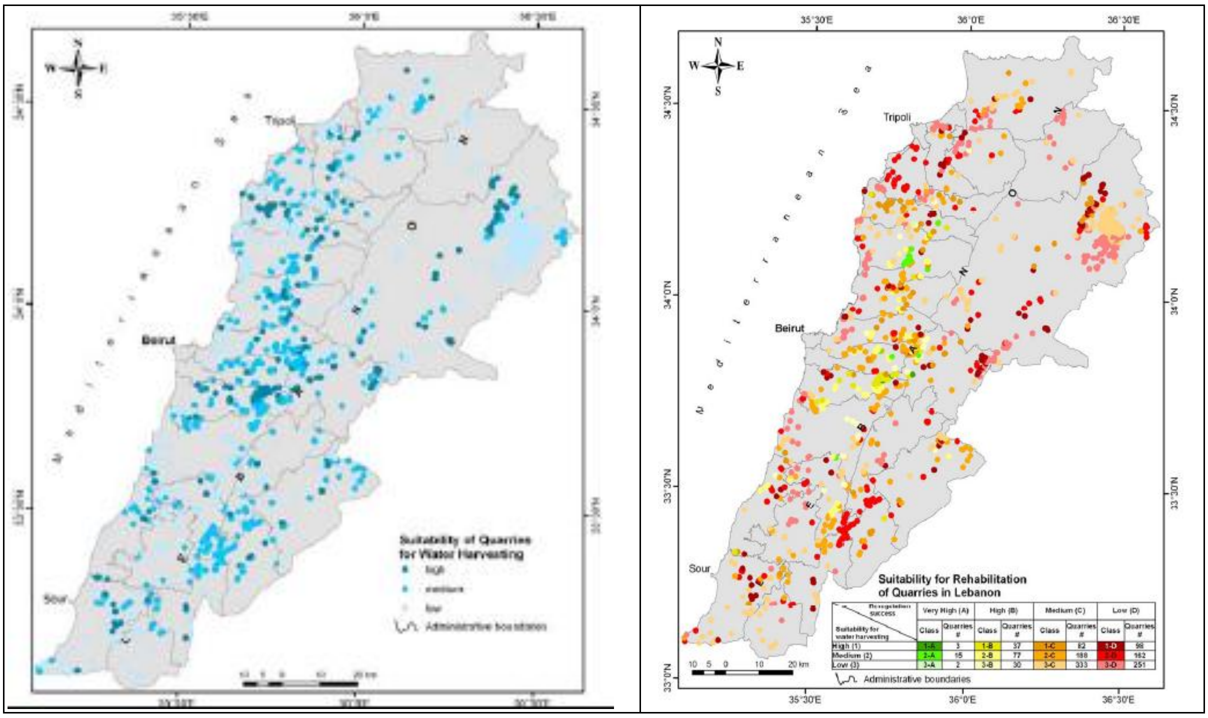
Source: Darwish et al. (2008).

Table 6.3: Lebanon Potential Quarry Rehabilitation: Revegetation vs. Water Harvesting

Feasibility Ranking	**Number**	**Area**	
	#	Km^2	ha
Potential revegetation success			
Very high	20	1.8	175.4
High	144	5.1	513.5
Medium	603	21.5	2,149.8
Low	511	24.3	2,427.8
Total	**1,278**	**52.7**	**5,266.5**
Potential water harvesting			
Very high	0	0.0	0.0
High	220	10.1	1,007.1
Medium	442	21.3	2,129.8
Low	616	21.3	2,129.6
Total	**1,278**	**52.7**	**5,266.5**

Source: Darwish et al. (2008).

Figure 6.2: Lebanon Potential Quarry Rehabilitation: Revegetation vs. Water Harvesting



Source: Darwish et al. (2008).

7. Climate Change Model Review

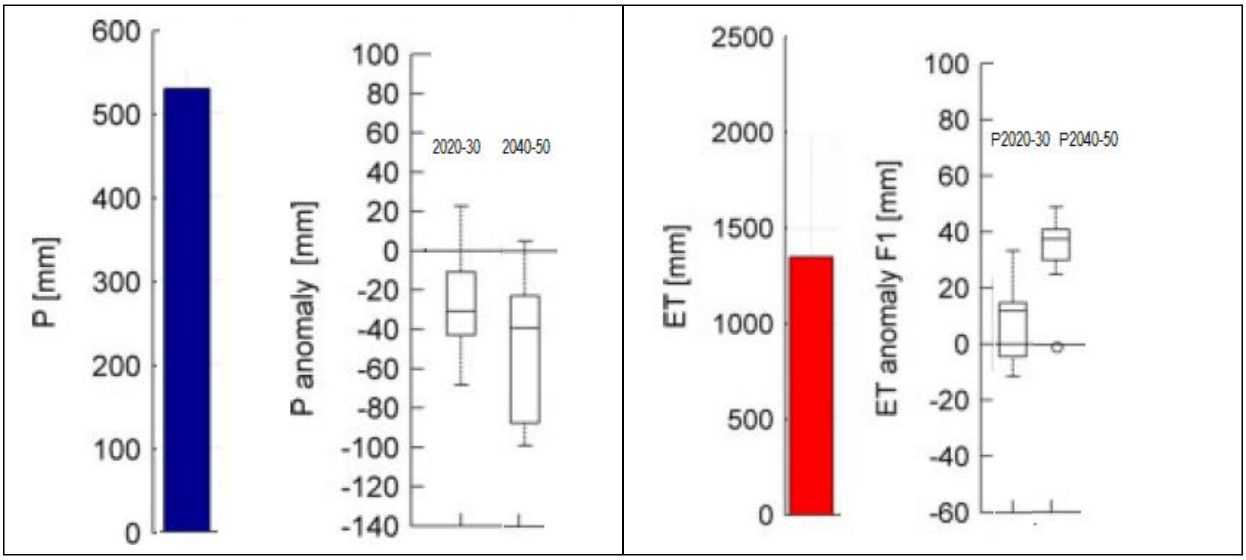
7.1 Regional IPCC Downscaling Models

41. **IPCC 5.** Similar to the IPCC 4 report, Lebanon falls between the cracks of downscaling models in the IPCC 5 report as the IPCC projections are made by continent or subcontinent. Whereas East Asia is not mentioned *per se*, the projection for Lebanon could be derived from the South Mediterranean and North Africa where the models concur that: annual rainfall is likely to decrease; largest warming and maximum summer temperatures are likely to increase; risk of summer drought is likely to increase; and the duration of the snow season is very likely to be shorten.[14]

7.2 Regional Downscaling Models with Emphasis on Lebanon

42. **Downscaling models for the 22 Middle Eastern and North African countries.** Nine global circulation models representing 2 futures (2020-2030 and 3040-2050) were compared to the 2000-09 period baseline to determine the precipitation and the water demand by vegetation reference evapo-transpration (ETref). It was found that: average annual precipitation decreases for period 1 and 2 for the majority of countries, with the largest decreases found for the second period (15-20%); an overall increase of ETref was found for both period 1 and 2, with the largest increase found in period 2 (Terink et al., 2013). In Lebanon, the precipitation anomaly could range between -10 and -42 mm in term of precipitation and -5 and 17 mm between 2020 and 2030. The anomalies are larger for the 2040-50 periods.

Figure 7.1: Lebanon Precipitation and ETref Projection, Reference, 2020-30 and 2040-50 Periods



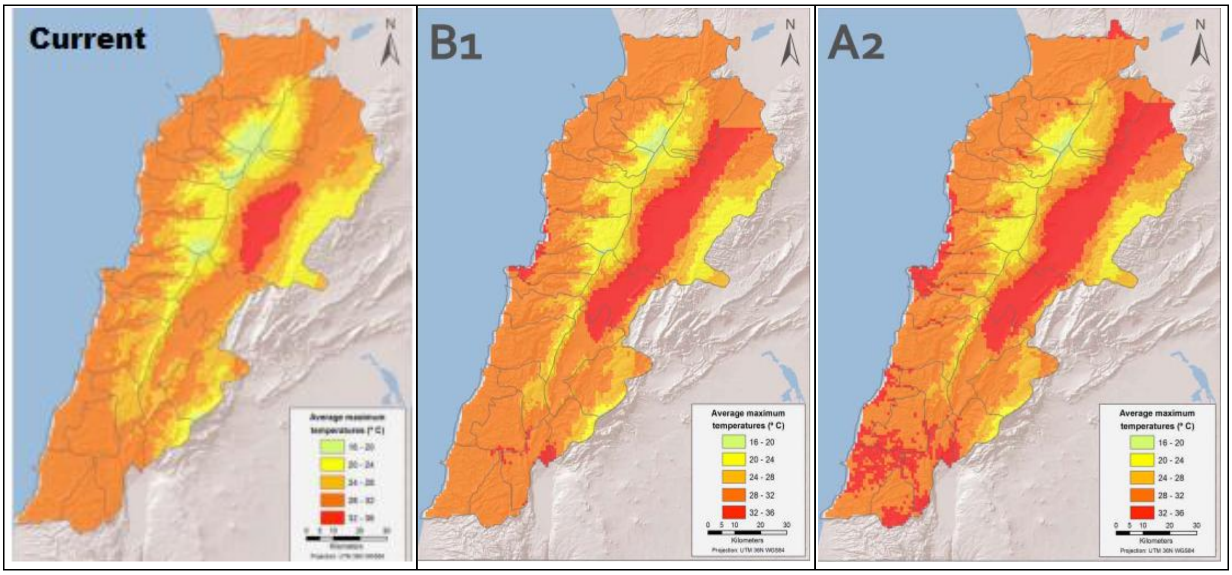
Source: Terink et al. (2013).

43. **Downscaling models for Lebanon.** Several downscaling models were run for Lebanon. In general, the most optimistic and most pessimistic models for Lebanon predict very large variations:

[14] Web site of the IPCC : <www.ipcc.ch>.

- Most Optimistic: There will be no changes in temperatures and precipitation in the future and climatic conditions will remain stable. As a matter of fact, climate change projections and modelling have large uncertainties and discrepancies and a given change in climate will produce different impacts in each region (could be positive: i.e., reducing floods). Lebanon will not be affected by climate variability and existing water shortages will not be exacerbated.
- Most Pessimistic: Climate change will manifest in increased temperatures (figure 6.3) and decreased precipitation (reduced rainfall and snowfall) leading to higher evapo-transpiration rates. Extreme weather conditions and changes in rainfall regimes will be observed. In Lebanon, water balance will be highly affected, water resources will be less available and water quality will deteriorate.

Figure 6.3: Current and 2050 Summer Temperature based on 2 IPCC Models



Source: USAID et al. (2013).

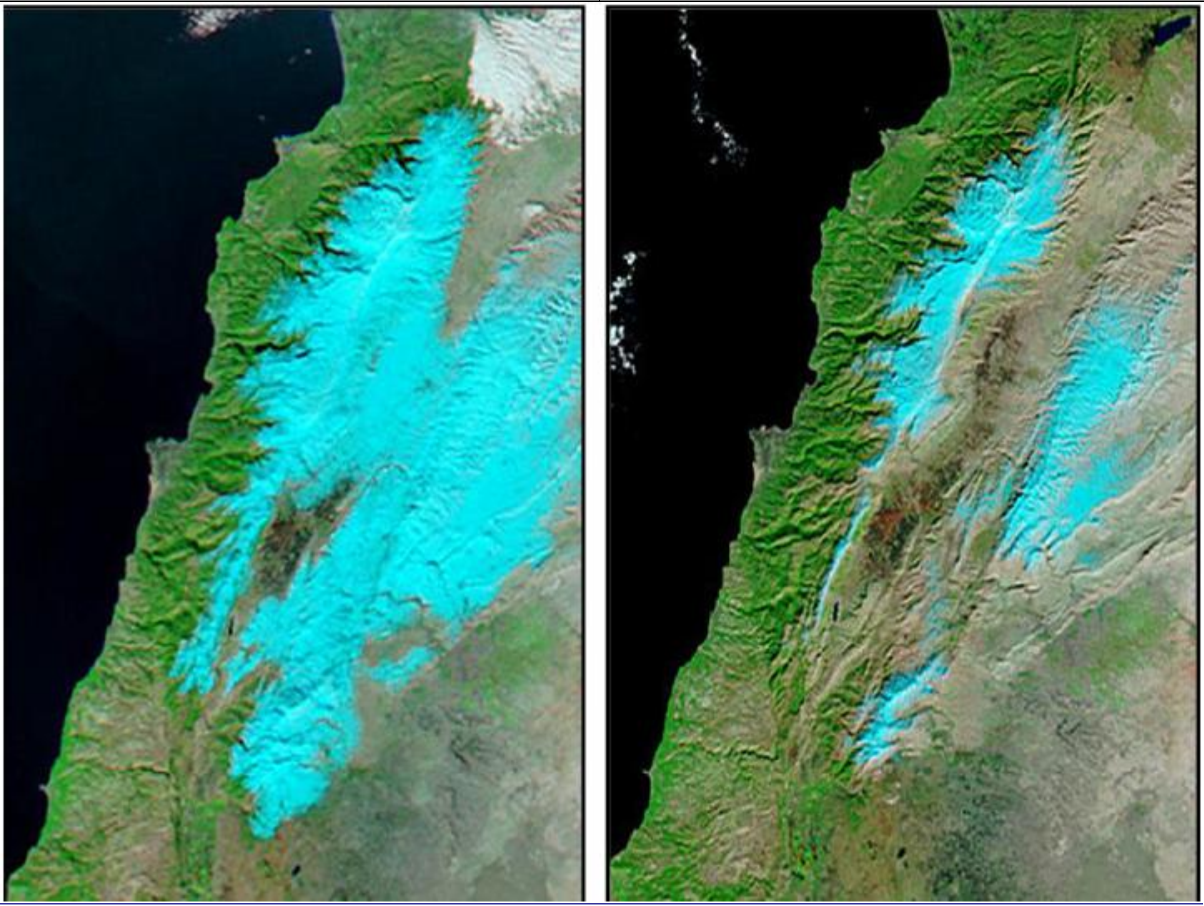
44. **More specifically when analyzing the effects of climate change on Lebanon.** The demand for water in Lebanon will have increased by more than 80 percent by 2025 as Lebanon's economic and population (from 3.8 in 2007 to 7.6 million in 2025) growth are, so far, more important drivers of the increasing water deficit than climate change.. In the same period, as a result of climate change, average summer temperatures in the country are predicted to increase by 1.2º Celsius. Rising temperatures mean more water lost to evapo-transpiration (from land to the atmosphere). This, in turn, could boost demand for irrigation in the Bekaa's rich agricultural farmlands by as much as 18 percent (LARI). Moreover, lower precipitations will reduce runoff, which will increase water stress. More specifically, despite the fact that snow represents the main source of water in Lebanon, recent observations showed very fast melting process and the reduction of the snow cover from 2,200 km^2 on December 15, 2010 to 1,700 km^2 on December 25, 2010 or 10 days later. This is threatening the normal recharge, increasing the risk of flooding and causing increasing risk of soil erosion (Figure 6.3).[15] Reduced water amounts and increased exploitation of less available water would cause water quality to deteriorate. This is especially applicable to groundwater that may contain higher concentrations of certain

[15] Darwish (2012).

undesirable metals and contaminants. Increases in water salinity would become inevitable with less water to dilute salt concentrations. Vegetation cover may be reduced, and increased water demand will lead to reduced soil moisture and enhanced desertification, thus affecting agricultural productivity. The growing intensity and frequency of droughts coupled with higher temperatures will increase the risk of forest fires. The pattern change of a number of species (mainly insects) has already been observed in Mount Lebanon.

Figure 6.4: Spatial and Temporal Change of Snow Cover in Lebanon

MODIS DECEMBER 15, 2010	MODIS DECEMBER 25, 2010

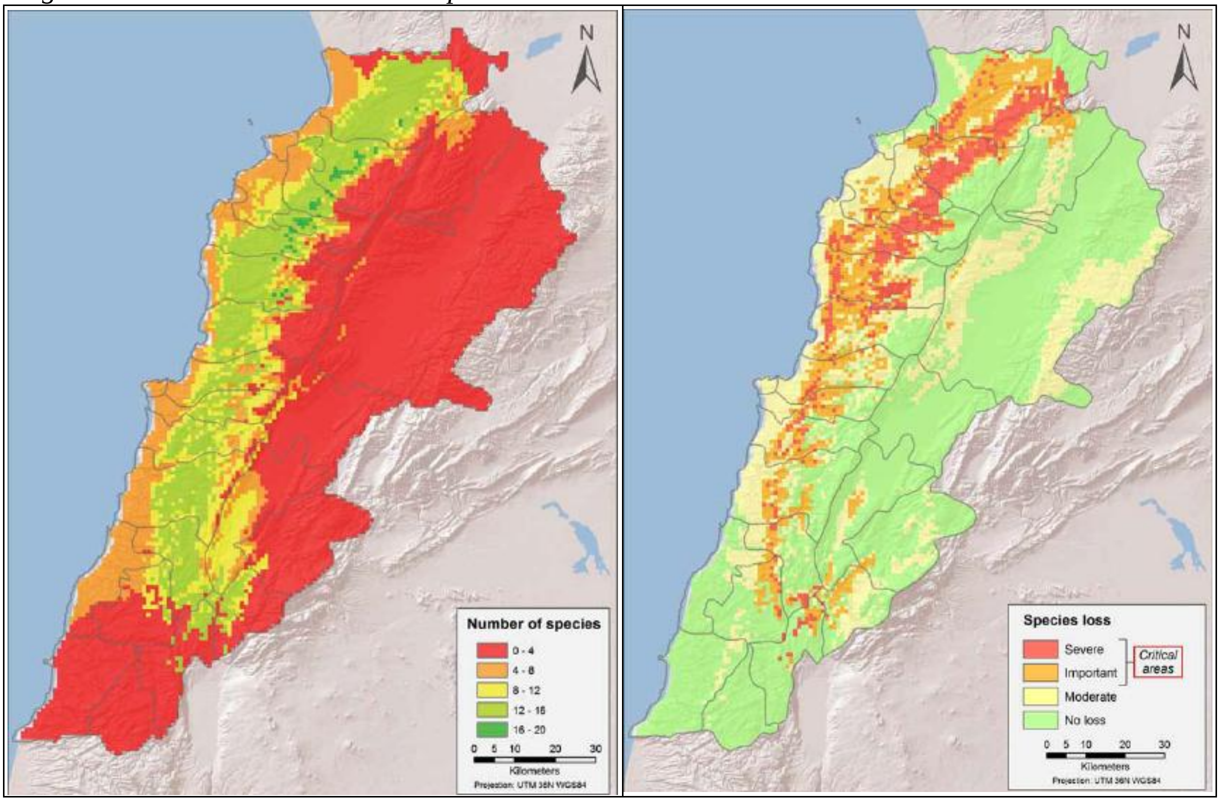


Source: Nasa and CNRS (2011) cited in Darwish (2012).

45. **Forest and Climate Change in Lebanon**. A recent report on forest and climate change in Lebanon shed new light on the possible impacts of climate change in the future and set general adaptation and mitigation guidelines for future management of tree species while specific actions are set for critical areas.[16] Hence, about 7,000 points of presence and 12,000 points of absence were identified and Species Distribution Model was run for 2050 for IPCC A2 and B1 scenarios (Figure 6.3). Vulnerability classification of Lebanese territories was conducted and plotted (Figure 6.5) in terms of species richness loss caused by climate change. This will help determine the critical areas to be restored and/or protected in terms of species diversity so that adaptation can be designed and integrated into policy planning and biodiversity management.[17]

[16] USAID et al. (2013).
[17] USAID et al. (2013).

Figure 6.5: Current Potential Tree Species Richness and 2050 Critical Areas



Source: USAID et al. (2013).

7.3 Synthesis of Climate Change

46. **Review of the annotated bibliography**. The citations were regrouped in main themes of reflection. The numbers [] correspond to the citation in Annex I.

47. **International experience of climate change and water resources**. [29] The current threats to freshwater ecosystems such as pollution, water diversion, invasive species and overexploitation are described. All anticipated and observed effects of climate change on freshwater ecosystems including the physical and the biological changes are explained. Lists the specific changes on lakes that include increased water temperatures and evaporation, acidification, reduction of bottom habitats, decrease in primary productivity, and alteration in fish communities. [30] Lakes are indicators of climate change since they are sensitive to climate, respond to change and integrate information about changes in the catchment. Indicators are affected by regional response to climate change, characteristics of the catchment, and lake mixing regimes. Thus, particular indicators or combinations of indicators are more effective for different lake types and geographic regions. Summarizes the indicators of climate change that include hydrology, temperature, ice phenology, transparency, chemistry, autecology, community structures and habitat structure. [31] All potential effects of climate change on lakes are described mainly the physical, chemical and biological effects. Changes in precipitation cause shifts in the connectivity of lakes and changes in the water balance. The hydraulic residence time of a lake affects its chemical composition whereas changes in landscape properties around the lake due to climate change have a strong influence on water quality and quantity. The biological

effects of climate change are summarized: (i) Extinction or alteration of aquatic biota; (ii) Changes in pelagic communities and their production; (iii) Alteration in species composition and diversity at the primary producer level; (iv) Shifts in the geographic distribution of many fish species; and (v) Changes in microbial processes. [39] It is expected that the global climate change will have serious impacts on the frequency, magnitude, location and duration of hydrologic extremes which will have implications on the design of hydraulic structures, floodplain development, and water resource management. A method of applying a bottom-up approach (determining the impacts first) on a study area, here the Upper Thames River Basin – UTRB- (Ontario, Canada), in hydrologic modelling could determine the meteorological parameters of climate change (Floods and droughts represent the main hydrologic hazards in the UTRB). The model results showed that under the increased temperature scenario the critical rainfall events which induced floods may occur less frequently and climate change may have beneficial impacts on the distribution of hydrologic extremes in the study area.

48. **Mediterranean experience of climate change and water resources**. [32] The Mediterranean region will witness a drop in water resources; more evapo-transpiration, less snow, less rain, therefore less surface runoff and less groundwater replenishment. Moreover, depletion of water resources will be particularly marked in the southern Mediterranean regions while the extension and worsening of water shortage situations will be unavoidable, particularly to the South and East. Affirms the importance of hydrological variation monitoring in the area. [33] The Mediterranean region is sensitive to global climate change and inland freshwater ecosystems and coastal lakes will be affected since heat and drought during summer and frost and wind during winter are hazardous to aquatic ecosystems. Changes in air temperature, precipitation and wind cause changes in evaporation, water balance, lake level, ice events, hydro-chemical and hydro-biological regimes and entire lake ecosystems. Under some climatic conditions, lakes may disappear entirely.

49. **Middle East and North Africa and climate change.** [37] Arab Countries coped with the challenges of climate variability for thousands of years by adapting their survival strategies to changes in rainfall and temperature. Climate change is happening now in Arab countries and over the next century the climate variability will increase in this water-scarce region through unprecedented extremes (High temperatures and reduced rainfalls). Without biodiversity and ecosystem services, life and human societies would not exist and that many countries have ecosystems that are of critical value for tourism, fisheries, and cultural heritage; thus incorporating risks of climate change in the management of these systems is essential. The importance of biodiversity and ecosystem services in livelihoods and economies is neither recognized nor included in national development planning and sectoral strategies in Arab Countries. Few studies have been conducted on the economic valuation of ecosystem services in the region, and even fewer on the impacts of climate change on these services.

50. **Middle East and North Africa and climate change with a focus on Lebanon.** [34] Higher temperatures and lower precipitation will add more pressure on natural and physical systems in Arab Countries. Climate change will have negative impacts on freshwater systems. Watersheds are facing drought and sudden intense rainfall causing

soil erosion and desertification and natural and artificial water bodies are facing evaporation leading to a decrease in their water supply. Lebanon has experienced varying conditions of water shortages in the last decade. [36] The impacts of climate change are quantified for agricultural and rural sectors in Jordan, Lebanon and Syria (both in physical and in economic terms). Over the eastern Mediterranean and Middle East potential climate change impacts are expected to be particularly acute; rates of 21st century warming are expected to be greater than the global average and annual precipitation could decline by more than 100 mm/year compared with present (reductions in winter precipitation in the range 24%-32%). States that the Middle East emerges as a “hot spot” of severe water stress by the 2050s in several global assessments. States that the agricultural economy and rural livelihoods of peoples in Lebanon, Jordan and Syria are particularly vulnerable to climate variability because of high dependency on natural resources and exposure to climate hazards. Improvements in water efficiency and protection of water sources from contamination are recommended. Observations of climate change in Lebanon over the last 40 years include: between the 1950s and 1980s precipitation in the Mount Lebanon basin dropped from 1295 to 1060 mm/year (Khair et al., 1994). Since the 1980s precipitation has decreased by 12% across Lebanon as a whole whilst the average number and intensity of peak rainfalls has increased (Shaban, 2009). The average discharge of Lebanese rivers is also falling (from 246 Mm^3/year in 1965 to 186 Mm^3/year in 2005) as is the number of springs (50-55% decrease) and volume of spring flows (53% decrease) (Shaban, 2009). Satellite measurements indicate that the area of dense snow cover in the Lebanese mountains has declined from 2280 km^2 before 1990, to an average of 1925 km^2 since (16% decrease). The average residence time of dense snow before melting has decreased too: from 110 days to less than 90 days over the same period (Shaban, 2009). Evaporation was found to increase. Extrapolates the 2050s mean temperatures and precipitations that could increase by ~1.5°C and reduce by 10-20% respectively. Largest reductions to annual rainfall are found for sites in the coastal zone, and within the Bekaa Valley, where changes could be in the range 10-30% by the 2050s and 20-50% by the 2080s. [35] Explains how climate change and increased temperatures in particular will aggravate existing water shortages in the Middle East and presents the potential negative impacts of climate change on water resources in Lebanon that mainly include increased agricultural water demands, water quality damage and ecosystems damage and species loss. Impacts with moderate socio-economic implications in Lebanon including increased industrial and domestic water demand and water resources distribution equity decline are also highlighted. The report summarizes some of the technical adaptation measures (conservation, use of surplus winter runoff and wastewater reclamation), their potential benefits and costs. [38] Due to the geographical locations of the Middle East North Africa (MENA) countries, the latter will be highly affected by the negative impacts of climate change including water loss, soil degradation, seawater intrusion and sea level rise due to an increase in average temperatures and fall in precipitation levels (larger in MENA than those estimated as a world average). An overview on the 2007 projections by the International Panel on Climate Change (IPCC) for the MENA region predicts: (i) an increase in temperature up to 2°C in the next 15-20 years and between 4°C and 6.5°C by the end of the 21st century; and (ii) a decrease of more than 20% in the level of precipitation exposing 80-100 million people in MENA countries to water stress by 2025. Climate change will have serious effects on agriculture sector and food security in MENA countries and a loss of 0.4 to 1.3% of GDP is estimated in MENA countries due to climate change effects, which could even rise to 14% if no mitigation and adaptation measures are undertaken. Particularly an increase in temperature by 1°C leads to a decrease in GDP per capita by 8% on average (close to results at worldwide level; the reduction in precipitations on GDP per capita is generally insignificant). The climate change impacts will affect all economic activities particularly agriculture and tourism as well as ecosystems and their related services, on which MENA societies depend. The MENA countries have already experienced a dramatic climate change over the past century (For Lebanon around +0.6°C were recorded from 1972 to 2008 and a decline of 45% in precipitation from 1900-2008). The MENA countries are encouraged to develop National Adaptation Programs of Action (NAPAs; simple and low cost adaptation measures building on traditional knowledge and local conditions), following the provisions of the United Nations Framework Convention on Climate Change (UNFCCC).

51. **Lebanon and climate change.** [5] Global warming is affecting precipitation and will be reflected in changes to "freshwater availability and quality, surface water runoff and groundwater recharge". due to reduced precipitation, river flows have regressed and the surface area of the Qaraoun Lake which was equal to 5.14 km^2 between 1965 and 1990, decreased to 4.35 km^2 between 1990 and 2005; a decrease of 15 percent. [23] The plan of the Lebanese government is described for surface water development through the construction of 18 dams and 23 lakes, as well as 2 regulation weir in the Beqaa that would serve as spillways, rather than storage work. This plan, if executed, would allow the mobilization of an annual volume of 1.1 billion m^3. Projected changes in climatic factors are of significance to the water sector including temperature, precipitation and evapo-transpiration. The impacts of climate change on indicators related to water demand, water quality, water availability and water supply are developed. [9] The effect of climate change on water resources in Lebanon is described since a reduction of 6 to 8% of the total volume of water resources is expected with an increase of 1°C and 12 to 16% for an increase of 2°C. The dry regions of Bekaa, Hermel and South Lebanon will be the most affected. Climate change will also induce a reduction in snow cover thus negatively impacting rivers and underground recharge and how snow will shift from 1,500 m to 1,700 m by 2050 and to 1,900 m by 2090, affecting the recharge of most springs. The change in rainfall regimes will increase the manifestation of extreme events such as winter floods and hot summer days. [16] The hydrologic properties of Al Kabir watershed is the largest in western Lebanon, shared between Lebanon and Syria, characterized by water flow throughout the year and fed mainly by springs. An obvious decline of ≈ 40% of the total river discharge has occurred over the last 50 years which could be explained by climate change and by water extraction associated with dramatic increases in population and associated land uses. Assessed the river flow characteristics and recommended erection of dams and hydropower plants on the river since ≈ 50% of the basin terrain is situated on elevations >560 m producing high energy flows. [13] Describes how climate change poses serious problems to water resources in Lebanon; temperature increases lead to both higher evapo-transpiration and shifting of snowfall to higher altitudes while decreases in precipitation lead to reduction in water resources. Biophysical impacts affect water quality mainly water temperature, water salinity, the amount of pollutant concentrations and the fauna and the flora. The report states that aquatic systems are affected by erosion and sedimentation, droughts and floods and the water levels in surface water bodies as well as in aquifers.

8. General Conclusions and Recommendations

52. The diagnosis and analysis developed in the previous sections helped reach the following conclusions:

- Lebanon has a complex geomorphology, young geology, various micro-climates with large spatial and temporal variations in terms of precipitation/temperatures (despite having the highest annual rainfall in the region), water resources that are not properly harnessed, a rich biological endowment, and a land use that is mismanaged with forest being increasingly prone to fires while reforestation efforts are mainly being poorly designed.
- Physically, urban sprawl, encroachment, forest fragmentation, forest fires and abandoned quarries have been increasing soil erosion especially during dilluvian rains showing increased intensity and frequency over the last years whereas the excessive and chaotic water use have affected water resources and ecosystem services.
- Pollution-wise, liquid and solid waste, and agricultural runoff are affecting water resources and ecosystem services.
- With regards to lakes, most are polluted from agricultural runoff and municipal discharge. Inland wetlands are shrinking due to excessive pumping for irrigation, e.g., Aamiq. As for the 2,741 hill lakes that were geo-referenced through remote sensing, there are poorly studied whereas their fauna and flora were never studied.
- The review of selected regional citations re-emphasized the need to consider hill lakes in the context of integrated water systems underpinned by their associated ecosystem services. The latter require the necessary water quality and quantity to maintain their health and productivity that however remains difficult to assess and value. Water augmentation through water reuse is also considered to bridge the growing water deficit in light of droughts exacerbated by climate change and population pressure. A case study in Egypt helped classify all the benefits derived from hill lakes whereas a study in Tunisia allowed to determine the precipitation scale (100 minutes) that effects erosion hence reducing the hill lake lifespan through excessive sedimentation.
- The review of selected national citations emphasized the effects of excessive water use in term of quantity and pollution discharge on water resources in general and ecosystem services in particular. Also, times series of several river revealed serious reduction of water flows over the years due to human pressure.
- An interesting citation gives guidance on hill lake construction whereas a CNRS study makes the case for rehabilitating abandoned quarries and use them as water harvesting reservoirs as suitable quarries are spread all over the Lebanese territories although it is not mentioned under which jurisdiction they fall: Central Government public domain (m'shaa); Local Government public domain (m'shaa); or private domain.
- With regards of climate change, higher temperatures, lower precipitation and higher evapo-transpiration are re-emphasized in the recent projections for Lebanon with more acute anomalies to be expected in 2040. The effects of

climate change on water resources and by extension on ecosystem services is underlined in all reviewed studies although there was no specific studies on the effect of climate change on hill lakes *per se*.

53. The following recommendations are suggested to move forward on better understanding the relationship between hill lakes and their environment in conjunction with climate change anomalies by:

- Improving data collection and validation

- Contribute to the unification of the statistical methods using both remote sensing and land based methods.
- Encourage the introduction of the monitoring of biodiversity index.

- Taking stock from previous experience

- Evaluate the Green Plan earth and cement reservoirs over the 2003-2013 periods to understand the reason for failure (abandoned, washed out, etc.), resilience and success.

- Seeking multi-layered modelling

- Develop and interpret with the help of CNRS and the recent USAID et al. (2013) report an overlay of several GIS maps: abandoned quarries, erosion risk, forest cover, forest fire risk, rangeland, etc.
- Consider using precipitation, temperature and evapo-transpiration projections based on downscaling models and confront them to the layers suggested above.

- Introducing the integrated water system approach

- Help regard hill lakes (catchment areas) and ecosystem services (spatial environment) as an integral part of the integrated water system strategy, policies and projects.

- Using quantitative analysis to optimize investments

- Acknowledge the need to optimize the spatial location of multi-purpose hill lakes that should be considered playing the “sponge” function of wetlands (absorb as much as possible water during winter time and release it during summertime).
- Use quantitative analyses to optimize the number of dams (whole sale) and hill lakes (retail) needed as hill lakes proved to be costly and sometimes inefficient.

- Piloting hill lakes and launching a case study

- Pilot the environmental assessment and implementation of 3 hill lakes located on Local Government land in an abandoned quarries to inform the SALMA project.
- Commission a hill lake case study on 3 locations to determine the relation of hill lakes with their upstream, local and downstream environments trying notably to better understand distal and proximal ecosystem services.

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10. Annex I Annotated Bibliography

National Level – Baseline

A - Lebanon's Biodiversity and Pollution issues

1-National Biodiversity Strategy and Action Plan, UNDP Lebanon CDB First Report, 1998

Explains how disturbances such as drainage, pollution and human interference have drastically changed the fresh water ecosystem, and resulted in a high proportion of endangered species; ecologically weak species are eliminated due to pollution. Describes how quarries and sand removal activities had for a long time a major impact on both the flora and fauna and the surrounding environment. States that the risk of extinction on fresh water fauna is very high for Plecoptera (81%), Coleptera (11.4%) and Ephemenoptera (8.7%). Crustaceans are 8.2% at risk, fish 4% and molluscs 3.0%. Affirms that mountain lakes have to be extended all over appropriate areas including protected areas and that research, building of capacities and studies on fresh water biodiversity should be expanded and supported (Page(s): 6,11,25,26 and 27).

2 - Third National Report of Lebanon to the Convention on Biological Diversity, 2005, Ministry of Environment

Explains that Lebanon reports to the Convention on Biological Diversity (CBD) signed in 1992. Reporting includes how the Government of Lebanon is achieving the goals and targets of the Convention. Goal 1 is about "Promoting the conservation of the biological diversity of ecosystems, habitats and biomes". States that Lebanon developed its National Biodiversity Strategy and Action Plan (NBSAP) in 1998 (GEF funded and MOE/UNDP implemented) and amended it in 2005. The strategy includes national objectives and remains the base reference for addressing CBD issues in the country.

Explains that under the CBD, Ramsar Convention and objective 4 of the NBSAP Lebanon implemented the five-year (2002-2006) Regional Project "Conservation of Wetlands and Coastal Zones in the Mediterranean" (MedWetCoast) which is a Mediterranean initiative covering Lebanon, Albania, Egypt, Morocco, the Palestinian Authority and Tunisia, and aims towards biodiversity conservation and proper management of coastal areas and wetlands. The project covered the conservation and management of two main sites in Lebanon: The Tyre Coast Nature Reserve and the Wetland of Aammiq.

The report stated clearly that:

- agriculture and urban expansion were the most important underlying cause of habitat loss/degradation.
- the once extensive swamps of the Beqaa Valley shrunk to 280 ha at Aammiq area in the early 20th century, due to drainage for agriculture. The only other significant inland wetlands are man-made lakes, notably Qaraoun Reservoir (1,000 ha), a large storage reservoir on the Litani River which is sufficiently large to attract numbers of migratory waterfowl, and the much smaller Taanayel Lake (6 ha) in the same valley.

B- State of Lebanon's Freshwater Biodiversity

3- State and Trends of the Lebanese Environment (SOER), MOE/UNDP/ECODIT, 2010 –

Chapter 5 – Biodiversity and Forests

Lebanon's freshwater fauna and flora: Clarifies that drainage, pollution and human interference have drastically changed the fresh water ecosystem and resulted in a high proportion of endangered species and the elimination of weak species especially those sensitive to pollution.
Pollution of Aquatic Ecosystems: Explains that major sources of pollution of surface and groundwater resources include untreated municipal wastewater discharge, industrial effluents, improper solid waste disposal and agricultural runoff. For inland freshwater protection from pollution, the construction of collector lines and treatment plants was undertaken in main cities (Zahleh, Baalbeck, Nabatieh, and others); and also in villages/towns close to water sources and springs (Labweh, Qaraoun Lake, Anjar, Hermel, Mechmech, Becharre, Bakhoun, Chabaa, Jbaa, Hasbaya, Chakra, Hrajel and Kartaba).

C - Lebanon's Biodiversity and Ecosystem services

4- Fourth National Report of Lebanon to the Convention on Biological Diversity, MOE/GEF/UNDP, 2009

Gives an overview of the status of biodiversity in Lebanon including the freshwater biodiversity. States that a wide variety of organisms inhabit Lebanon's freshwater ecosystems, including invertebrates, molluscs and fish. The faunal species in freshwater represent 16% of the total fauna biodiversity of the country and the floral species represent 6% of the flora species only; 5% of the country's freshwater fauna is threatened and 1.3% endemic (BCS, 1996) including *Phoxinellus libani* (Fish) considered extinct in the country (BCS, 1996) but later observed in Yammouneh Lake, Litani River and Qaraoun Lake (El Zein, 2001). States also that there are extensive pressures on Lebanon's inland aquatic ecosystems including water pumping, rivers channeling (changes in water flows), overfishing and pollution of various origin (i.e., agriculture).

Elaborates on the consequences of biodiversity loss including the decrease in ecological systems services. States that globally, the combined economic value of 17 ecosystem services has been estimated in the range of US$ 16-54 trillion per year (Costanza et al. 1997); in Lebanon the biodiversity resources as well as the ecological services that are provided by the various ecosystems are not valued due to gaps in knowledge about the direct and indirect services of biodiversity and the function of ecosystems, a matter which implicates insufficient awareness of decision makers of the value of biodiversity services and goods and subsequently absence of market values on ecological services (Sattout & Abboud, 2007) (Page(s): 37). Affirms that continued extensive loss of biodiversity and ecosystem health could have dire social and economic consequences. It is thus essential that sustainable biodiversity management is prioritized in the country. States that the Ecosystem Approach is considered as one of the most important principles of sustainable environmental management and adopted in Lebanon at Tyre Beach Nature Reserve (2007) and at Palm Islands Nature Reserve (2008).

D - State of and Impacts on Water Resources in Lebanon

5- State and Trends of the Lebanese Environment (SOER), MOE/UNDP/ECODIT, 2010 - Chapter 3 – Water Resources

Explains how water resources are being impacted by population growth, urbanization, economic growth and climate change. Defines the current situation of water resources (availability and demand) and selected government responses to water issues. States that global warming is affecting precipitation and will be reflected in changes to "freshwater availability and quality, surface water runoff and groundwater recharge" (GEO 4, UNEP, 2007). Reprints that Lebanon is witnessing signs of drought conditions and desertification (Shaban, 2009). Demonstrates that due to reduced precipitation, river flows have regressed and the surface area of the Qaroun Lake which was equal to 5.14 km^2 between 1965 and 1990, decreased to 4.35 km^2 between 1990 and 2005; a decrease of 15 percent (Shaban, 2009).

6-Land – Use/Cover Change, Water Resources and Driving Forces during 40 years in Lebanon, Talih Masri, Mohamad Khawlie and Ghaleb Faour, National Center for Remote Sensing, National Council for Scientific Research, 2001

Explains that socio-economic factors and climate change have negatively affected natural resources in Lebanon. The country witnessed a decrease in agricultural lands and an increase in deserted and barren land which affected the availability and the quality of water. In coastal areas, water resources are polluted by sea water intrusion and chaotic urban encroachment while in the mountains, the removal of the green cover has increased soil erosion thus easing up water run-off rather than infiltration. At the Nation level, changes in the water supply are not quantified and data on water balances at basin levels are not accurate while adaptive and mitigation measures are still at the planning phase. (Page(s): 1 and 5)

7-CCC Lebanon Report Vulnerability 1999, Chapter 4

Describes how pumping of water from the Ammiq marshes for the irrigation of nearby cultivated lands has reduced the area of the wetland and shortened its life span. States that climate change is expected to affect the marshes in two forms; 1) Spatial: leading to reduction in the total area of the marshes and 2) Temporal: shortening of the duration in which the marshes exist during each year meaning that there may be no marshland left for the migrating birds. Estimates that the total area of the marshes may undergo a decline at the rate of about 6% per year. At this rate, without climate change, the marshes may practically disappear in less than two decades. This will be exacerbated under climate change. (Page(s): 6)

8-Climate Change and Variability in Lebanon: Impact on Land Use and Sustainable Agriculture Development, Fadi Karam, 2002

States the detrimental changes in hydrology that Lebanese people have observed over recent decades such as the decrease in groundwater levels and the drying up of springs and wetlands whereas rivers mainly Litani, no longer flow in the dry season. Reduced infiltration rates, increased runoff and soil erosion, and a decline in groundwater recharge are all caused by deforestation, overgrazing, low rainfall, and poor surface management of cultivated lands. In addition, the report affirms the need of weather monitoring systems in Lebanon in order to improve the knowledge about climate change over the country. (Page(s): 1, 5, 9 and 12)

9- Second National Communication 2006-2011, Executive Summary

Describes the effect of climate change on water resources in Lebanon since a reduction of 6 to 8% of the total volume of water resources is expected with an increase of 1°C and 12 to 16% for an increase of 2°C. States that the dry regions of Bekaa, Hermel and South Lebanon will be the most affected. Explains how climate change will induce a reduction in snow cover thus negatively impacting rivers and underground recharge and how snow will shift from 1,500 m to 1,700 m by 2050 and to 1,900 m by 2090, affecting the recharge of most springs. Affirms that change in rainfall regimes will increase the manifestation of extreme events such as winter floods and hot summer days. (Page(s): 16 and 17)

10- Thematic Assessment Report on Climate Change, Dr. Farid Chaaban, January 2007

Describes how mismanagement of water and increasing demand on this resource in Lebanon are causing a shortage problem and how climate change is negatively affecting the water deficit that could possibly reach more than 800 MCM annually. States that river and riverbank habitats would be vulnerable to precipitation changes and are affected by pollution, soil erosion and pesticides and fertilizers runoff, while altitudinal and latitudinal shifts in these zones may influence the pattern of vegetation. Affirms that measures such as rationalization of water use and changes in land use should be adopted in order to protect wetlands and riparian habitats. (Page(s): 31, 32 and 33)

11- Vulnerability, Adaptation and Mitigation Chapters of Lebanon's Second National Communication, MOE/UNDP, Chap 4 : Water

Summarizes the different activities impacting water resources in Lebanon including agriculture, industry, transportation, energy and human settlements and the projected changes in climatic factors of significance to the water sector. States the different impacts under a climate change scenario; increase in water demand and consumption, decrease in renewable water resources, increase in water deficit, and increase in the salinity of groundwater. Lists the different names of dam projects (including one in Tannourine) that are part of the MOE's 10 year Water Plan 2000-2009 (project renewed from 2008-2018) and that would increase the storage capacity of water used for irrigation and drinking in Lebanon. Describes the investment priority of the proposed dams and lakes. (Page(s): 18, 27, 28, 32, 38 and 41)

12- National Environmental Action Plan, MOE, 2006
Water Chapter

Explains how water resources in Lebanon are under several pressures including growing population, an expanding economy, increased urbanization, agricultural, over exploitation and pollution. These pressures act on both the quantity aspect of the resources in terms of over exploitation and wasteful use; and on the quality of resources with polluting practices proliferating in all sectors. States that industrial establishments discharge their effluents into various water bodies without any prior treatment. "One of the critical areas is the industrial zone in the Litani watershed where untreated industrial effluents from sugar beet factories, paper factories, lead recovery plants, limestone crushers, agro-industries, poultry farms, tanneries, and slaughterhouses are discharged into the Litani River that flows into the Qaraoun Lake" (Page(s): 11). Explains that the 10 Year Plan prepared by the Ministry of Energy and Water focuses very strongly on the development of dams and lakes while very lightly addressing management and demand reduction practices (Page(s): 14). States that a national water registry must be created and should include an updated list of rivers, lakes, and other water bodies by their purpose of use, water quality, and sensitivity to pollution. (Page(s): 24)

Wastewater Chapter
Explains how the wastewater sector in Lebanon has long been neglected and practically all domestic and industrial wastewater, 250 million m^3 and 43 million m^3 respectively in 2001, is discharged without treatment into the Mediterranean Sea or to inland watercourses where it causes widespread pollution of marine and terrestrial environments, surface and ground water resources, aquatic flora and fauna, and endangers public health (Page(s): 1). States that the Ministry of Energy and Water have proposed the construction of 113 wastewater treatment plants before 2020 and defined the sequence in

which they will be constructed. To assist in prioritizing rural treatment plants, 35 environmental "hot spots" have been identified by the Ministries of Environment and Energy & Water. In identifying "hot spots", special emphasis has been given to the following: the catchment areas of existing and proposed hill lakes; areas surrounding major springs and surface water sources; community clusters with no proposed sewage; and, Natural Reserves and other protected areas, wetlands, and areas of environmental sensitivity. (Page(s): 10)

13- Social and Ecological Vulnerability Assessments of the Upper Akkar Watershed, Lebanon, SPNL and MADA, March 2013

Describes how climate change poses serious problems to water resources in Lebanon; temperature increases lead to both higher evapo-transpiration and shifting of snowfall to higher altitudes while decreases in precipitation lead to reduction in water resources. Biophysical impacts affect water quality mainly water temperature, water salinity, the amount of pollutant concentrations and the fauna and the flora. The report states that aquatic systems are affected by erosion and sedimentation, droughts and floods and the water levels in surface water bodies as well as in aquifers. (Page(s): 15, 16 and 17)

E - Pollution of Water Resources in Lebanon – The Case of Al Kabir River

14- Watershed characteristics, land use and fabric: The application of remote sensing and geographical information systems, Khawlie et al., 2005

Explains how based on remote sensing (RS) and geographical information systems (GIS) Integrated watershed assessment has been established for Akkar El Kabir River Watershed. RS and GIS quantify, model and predict changes. Techniques showed over the past 10 – 15 years the impact of malpractices from excessive human interference that resulted in degradation of land and water quality. Changes in the watershed were observed in decreased water resources, pollution by wastewater discharge, soil erosion, forest decline and socioeconomic imbalance.

15 - Phosphorus and nitrogen in the waters of the El-Kabir River watershed in Syria and Lebanon, Hassan et al., 2005

Proves the presence of phosphorus (P) and nitrogen (N) in the waters of the El-Kabir River watershed in Syria and Lebanon through the collection and analyses of 39 water samples (18 in Syria, 21 in Lebanon) collected from the main stem, three major tributaries (Nahr al-Arous and Nahr Nasrive in Syria, Chadra River in Lebanon) of the river as well as three major springs. Results showed that P concentrations were extremely high throughout the watershed, as were the ammonia-nitrogen and nitrate-nitrogen concentrations, indicating extensive pollution due to direct sewage discharges from settlements throughout the basin as well as agricultural fertilizer use and disposal of solid wastes into the river, on the stream banks and lands adjacent to the roads of the watershed.

16 - Hydrological and watershed characteristics of the El-Kabir River, North Lebanon, Amin Shaban et al., 2005

Analyzes the hydrologic properties of Al Kabir watershed which is the largest in western Lebanon, shared between Lebanon and Syria, characterized by water flow throughout the year and fed mainly by springs. States that an obvious decline of $\approx$ 40% of the total river discharge has occurred over the last 50 years which could be explained by climate change and by water extraction associated with dramatic increases in population and associated land uses. Assessed the river flow characteristics and recommended erection of dams and hydropower plants on the river since ≈ 50% of the basin terrain is situated on elevations > 560 m producing high energy flows.

F - Lebanon's Water Resources and the Idea of the Ecosystem Approach

17- Lebanon Water Resources, FAO, 2008

Gives an overview of the **climate** of Lebanon (temperatures range between 20°C on the coast and 10°C in mountain areas; average rainfall is estimated at 823 mm reaching 2000 mm in high altitudes), **the agriculture sector** (labor force – increased from 1967 to 1990; decreased from 1990 to 2005, areas - 23000 ha in 1956 to 54000 ha in 1966 and then went down to 48 000 ha in the early 1970s, irrigation methods – open canal, diversion from springs and rivers, and few sprinkler irrigation), **water resources in the country** (surface water & groundwater quantities - average annual water flowing 475 million m^3, exploitable groundwater ranges from 400 to 1000 million m^3, springs - 2000, rivers – 17 perennial, outflows), **water issues with neighboring countries** (Asi-Orontes; Al Kabir; & Wazzani), wastewater generated (310 million m^3), **irrigation water schemes** (Private and Public; 1963 -Public 5 large-scale schemes and 62 medium scale scheme (Page(s): 10)) and the **Ministry of Energy and Water 2000-2010 Plan** to satisfy Lebanon's water needs (including building 26 dams and 6 lakes, which will increase the storage capacity to 800 million m^3 by 2010). **Describes the Qaraoun Lake -** Constructed in the 1960s, it has a total capacity of about 220 million m^3 and effective storage of 160 million m^3 (60 million as the inter-annual reserve). It supplies in turn three hydroelectric plants generating about 7 to 10 percent (about 190 MW) of Lebanon's total annual power needs. It provides every year a total of 140 million m^3 for irrigation purposes (110 for South Lebanon and 30 for the Bekaa), and 20 million m^3 for domestic purposes to the South (Page(s): 5). Litani River calibration (upstream of Qaraoun Lake) was done in the 1970s to protect 1500 ha against flood damage and waterlogging (Page(s): 11). Emphasizes that water quality is adversely affected by agricultural, industrial and domestic wastewater and it is difficult to estimate accurately the pollution loads into water bodies from the different economic sectors (Page(s): 14). A study (2007) elaborated by IDRC, CNRS, DSA and LRA focused on an **ecosystem approach** f**or the sustainable management of the Litani Basin.** (Page(s): 14)

G - Lebanon's Current and Future Water Resources

18 - Lebanon's National Report to the United Nations Conference on Sustainable Development, Rio +20, MOE/UNDP, 2012

Describes Lebanon's position vis-à-vis sustainable development including achievements and failures in social development and poverty alleviation, environmental sustainability, green economy and environmental governance. Of importance in this document are aspirations towards sustainable development in the water sector. Summarizes the **National Water Sector Strategy (NWSS)** approved by the COM (March 9, 2012) and prepared to revamp the water sector in Lebanon: the NWSS presents procedures on how to augment water resources to meet future demand (1,800 million m^3 in 2035) by building dams and lakes and improving water supply, irrigation and sanitation services over the Lebanese territory. States that the GOL should begin prioritizing "environmental water" in water sector planning defined as any water that achieves ecological benefits (protecting ecosystems as well as ecological processes and environmental needs of rivers and aquifers). *A Strategic Environmental Assessment is currently being conducted to the NWSS.*

H - Qaraoun Lake, Sources of Pollution and Ecosystem Services

19- Water Quality Assessment of the Upper Litani River Basin and Lake Qaraoun Lebanon, USAID, 2003

Describes: 1) the Litani River Basin; 2) its water utilization for domestic, agriculture and industrial consumption, hydropower generation as well as tourism and recreation (Page(s): 12 to 16); 3) its major sources of impacts including domestic and industrial wastewater, solid waste and agriculture waste; and 4) actual and potential impacts and finally remediation measures and recommendations. Clarifies that waste generation is severely affecting the upper Litani basin (evidenced by measurements of various indicators including chemical oxygen demand, total organic carbon, heavy metals, chlorinated organic substances, fecal coliform, salmonella, and other microbiological parameters) and the Qaraoun Lake itself which catches and contains many of the upstream pollutants, such that it is unfit for fishing, irrigation, or domestic use. The poor water quality has led to eutrophication, impeding drinking and agriculture water intakes. These impacts, in turn, lead to decreased agricultural output, increased water-related illnesses, and higher treatment costs to render water suitable for use.

20 – Business Plan for Combating Pollution of the Qaraoun Lake, MOE/UNDP/ELARD, 2011

Gives an overview of the pollution status of the Litani River and Qaraoun lake based on previous studies (13) and water & sediment sampling events (catchment area, Litani River and Qaraoun lake divided into zones). Identifies the sources of pressure on the river and lake including solid waste (direct dump or leachate from existing landfills), domestic wastewater (direct discharge into the river), industrial effluents (direct discharge; detection of heavy metals in river and lake water as well as sediments) and agriculture and recommends appropriate mitigation measures to be implemented by the private and public sectors. The analysis has shown that the largest two pressures are agriculture and municipal wastewater. Of important recommendations: (1) swimming in the Litani River or drinking directly from the River's waters is not recommended due to the bacteriological counts in the waters; (2) irrigation using the Lake waters can be carried out with restrictions; adoption of (pre-)treatment technologies at industry-level is highly recommended (the MOE has been involved in the setup of a program that aims to assist Lebanese industrial companies to reduce pollution and comply with the Lebanese Environment Protection Law # 444 through providing them with technical assistance and subsidized loans to invest in end-of-pipe treatment and pollution prevention).

I - Irrigated Areas and Proposed Irrigation Schemes

21 - Lebanon World Bank Irrigation Policy Note, WB, 2003

Explains that the Policy Note has three main objectives: (1) to formulate strategic choices related to the sustainability of irrigated agriculture in Lebanon; (2) recommend institutional strengthening of water resource management in the irrigation sector in general, especially for operations and maintenance (O&M); and (3) possible WB future involvement in the irrigated agriculture sector. Specifically, describes that Lebanon has two water reservoirs serving the agriculture sector, Qaraoun lake in the Bekaa valley, with a storage capacity of 220 MCM and another hill lake with a storage capacity of 2 MCM. Describes also proposed irrigation projects (total estimated cost of the programs of both the MOEW and the LRA is about US$ 1,350 million) for future implementation up until 2030 including 17 irrigation and 18 hill lakes projects (to harness part of runoff rain water lost annually to the sea) with an irrigation area of about 80,000 ha (expanding the current schemed areas by 50,000 ha and rehabilitating and/or modernizing 30,000 ha of existing irrigation schemes). Gives an overview of MOEW investment program 2002-2030 divided into 2 phases (Phase I – 2002 -2015 – Construction of hill lakes serving 1250 ha of agricultural areas and providing 10 MCM; Phase II – 2016 – 2030 – Construction of Younine and Yammouneh lakes providing, respectively, 7 MCM and 1.5 MCM of water for irrigation). Provides recommendations to the GOL, "the Bank recommends limited construction of hill lakes to areas that urgently need potable water, as they are too expensive to use for irrigation. MOEW should prioritize their investment programs based on technical and economic/financial feasibility studies, as well as the social priorities in beneficiary areas".

22- Lebanon Country Water Sector Assistance, World Bank, 2012

States that Lebanon is on the threshold of water scarcity, that annual surface water diversions and groundwater extraction total about 1.6 BCM against theoretical availability of 2.7 BCM and groundwater is over-extracted (0.7 BCM against total recharge of 0.5 BCM). Explains the factors contributing to seasonal water imbalance that include the very low water storage capacity, the consequent high rate of losses to the sea, combined with the deficiency of water supply networks and, the fast rising demand from the municipal and industrial sectors. Summarizes the Lebanese strategy for surface water storage that aims at constructing dams in Janneh, Bared, Aassi and Ibl Es Saki. (Page(s): 1, 4 and 30)

23- SCN Adaptation Consultation, Water Booklet

Describes the plan of the Lebanese government for surface water development through the construction of 18 dams and 23 lakes, as well as 2 regulation weir in the Beqaa that would serve as spillways, rather than storage work. This plan, if executed, would allow the mobilization of an annual volume of 1.1 billion m^3. Summarizes projected changes in climatic factors that are of significance to the water sector including temperature, precipitation and evapo-transpiration. Displays the impacts of climate change on indicators related to water demand, water quality, water availability and water supply. (Page(s): 14, 17 and 28)

24 -Lebanon Hasad Work Paper 2: Water and Soil Conservation Development Component, January 2008

States that medium-sized hill lakes are part of water and soil conservation strategies since they are used to store runoff rainwater and existing permanent sources of water such as springs for supplemental irrigation of nearby trees. Provides technical criteria for site selection and design of hill lakes; 1) When the water volume to be stored is higher than 50,000 m^3, it is more profitable to minimize the excavation works by constructing an earth compacted embankment 2) The ratio: volume of stored water / earth moved and compacted should be around 4 as it is assumed that this ratio should not be less than 3 and not exceed 7. (Page(s): 22, 23 and 24)

Regional and Global Level - including Climate Change Scenarios

J - Water Resources and Ecosystem Services in the Mediterranean Region

25 -Bassin Rhône Méditerranée Corse, Guide Technique No.8, Eau et Aménagement du Territoire en RMC, 2003

Reconnait que les hydro-systèmes sont un capital naturel générateur de services; les services d'épuration, dilution, réfrigération, énergie motrice, alimentation en eau potable, récréatif, écologique, navigation, arrosage, faunistique et floristique, agrément et de protection contre les crues (Page(s): 22). Indique que chaque service a une valeur d'usage qui peut être: 1) Valeur d'usage réel ; 2) Valeur d'option ; 3) Valeur d'usage pour les autres habitants ; 4) et Valeurs de non-usage (Page(s): 23). Explique que les zones humides sont des zones utiles qui doivent être préservées parce qu'elles jouent un rôle important en terme de biodiversité, en terme hydraulique (fonctionnant comme une éponge, elles absorbent l'eau en période de crue et la restitue en période d'étiage) et en terme d'épuration (vis-à-vis des nutriments notamment) (Page(s): 31). Signale que l'eau est une condition importante pour le développement et un patrimoine générateur de nombreux services. Donne l'exemple du Projet « Grand Lac » en Savoie qui consiste à préserver la qualité de l'écosystème du lac du Bourget afin d'assurer sa valeur touristique (Page(s): 32). Affirme que l'environnement (dont la gestion de l'eau et les milieux aquatiques) ne doit pas être perçu comme un "obstacle" ou une "formalité" puisque c'est une "donnée" essentielle correspondant à de véritables "enjeux" pour les politiques d'aménagement du territoire; en témoignent notamment les questions liées aux risques d'inondation, à l'alimentation en eau potable et à la préservation des zones humides. (Page(s): 53)

26 - Quelles recherches et quels partenariats pour la Méditerranée ? Atelier de Réflexion Prospective PARME, RAPPORT FINAL, Juillet 2011

Signale les principales préoccupations de l'atelier de réflexion prospective (ARP) PARME (Partenariats et Recherche en Méditerranée) dans le domaine des ressources naturelles et qui sont : (1) la gestion adaptative des anthropo-écosystèmes ; (2) l'amélioration de la connaissance des ressources en eau et de leurs usages ainsi que ; (3) la recherche d'une sécurité énergétique régionale minimisant l'empreinte environnementale. Informe que la région méditerranéenne possède des milieux naturels terrestres et aquatiques très originaux, ce qui en fait l'un des 34 points chauds de la biodiversité mondiale (le taux d'endémisme y est très élevé). Annone que la Méditerranée (surtout les ressources en eau) est aujourd'hui considérée comme l'une des régions du globe les plus vulnérables au changement climatique, avec, en moyenne une diminution de la pluviométrie et une hausse importante des températures, associées à une augmentation de la récurrence et de l'intensité des évènements météorologiques extrêmes (Page(s): 67). Offre des solutions impliquant un renforcement de la coopération régionale, une mobilisation et une reconnaissance des savoirs locaux, notamment en matière de gestion de l'eau et des cultures avec une hybridation avec les avancées techniques.

Avertit que les écosystèmes terrestres (hydro-systèmes et milieux humides) doivent faire l'objet d'une attention plus particulière étant donné que ceux-ci sont d'une très grande richesse et d'une très grande complexité, tant du point de vue biologique (notamment en termes de biodiversité) que sociologique et que les changements globaux vont affecter l'ensemble des fonctions des écosystèmes, et en conséquence les biens et services que les sociétés en retirent (Page(s): 68). Alerte que les disparitions d'espèces affectent les écosystèmes dans leur fonctionnement et leur capacité de résistance aux changements environnementaux (tel que le changement climatique) et en conséquence dans leur aptitude à fournir les services écologiques dont bénéficient les êtres humains (production de nourriture, maintien de la fertilité du sol, stockage du carbone, cycle des éléments minéraux, etc.) (Page(s): 68). Informe qu'une adaptation des écosystèmes aux conditions futures, afin qu'ils puissent continuer à fournir les biens et services les plus importants, exige une connaissance améliorée de ces biens et services (processus impliqués et leurs interactions, disponibilité d'outils permettant de fonder les options de gestion et différentes échelles spatiales considérées). Indique que le développement de réflexions et d'approches (modélisation biophysique « process-based models », socioéconomique et techniques d'optimisation) sur la gestion patrimoniale de ces biens et services doit être considérer. (Page(s): 71)

27 - La réutilisation des eaux usées traitées en Méditerranée: Retour d'expériences et aide à l'élaboration de projets, Plan Bleu, 2012

Signale que la réutilisation des eaux usées traitées (REUT) contribuent à la gestion intégrée des ressources en eau et à la préservation de l'environnement stratégique dans les pays arides et semi-arides de la région méditerranéenne (pression sur les ressources en eau est forte). Souligne que l'irrigation par REUT reste l'usage prépondérant et en fort développement car le secteur agricole dans cette région prélève une part très importante des ressources en eau conventionnelles (plus de 80% dans les pays du Sud et de l'Est). Annonce que les moteurs (drivers) pour les projets REUT sont relatifs à des évolutions structurelles lourdes impliquant l'aggravation du déficit hydrique, l'urbanisation ou le développement de l'agriculture irriguée et freinés par plusieurs facteurs (réglementations inadaptées au contexte local, difficulté de combiner l'offre de la ressource et la demande des usages dans l'espace et le temps; filières d'assainissement inadaptées ou incomplètes; politique tarifaire inadaptée; changement climatique, etc. (Page(s): 19) Propose différentes recommandations pour dépasser les obstacles et envisager des projets de REUT durables (adopter une démarche holistique et pluridisciplinaire en articulant l'approche ressource-usage 'top-down' avec l'approche usage-ressource 'bottom-up', choisir un modèle d'assainissement en envisageant la séparation des flux -notamment domestiques et industriels, considérer le système irrigué comme faisant partie intégrante de la filière d'assainissement et de valorisation, etc.).

En terme d'Ecosystèmes – Eaux Usées : Note que la disparition des écosystèmes aquatiques est liée à la surexploitation des nappes qui abaisse les niveaux piézométriques[18] et à l'activité humaine en général qui tend à soustraire la part de la ressource indispensable à la survie des écosystèmes (Page(s): 20). Indique que l'une des externalités négatives qui peuvent avoir un impact sur l'écosystème est par exemple le rejet d'eaux usées non traitées dans une rivière par une usine qui peut entraîner un impact direct sur l'écosystème et un autre indirect sur les usagers en aval (agriculteurs irrigant à partir de l'eau de la rivière). (Page(s): 61)

28 - Ecosystem Services of the Flora of Southern Mediterranean Desert of Egypt, K. Shaltout and Dalia Abd El-Azeem Ahmed, 2012

Assesses the plant species (Flora) in the Western Mediterranean Desert of Egypt according to the goods[19] (medicinal, grazing, human food, timber, fuel and other uses including mats, baskets, chairs, ornamental uses, beach beds, soap manufacture, and oil and dye extraction; assessed based on field observations and information collected from local inhabitants), and services[20] (sand accumulation, wind breaking, aesthetic concerns, soil fertility, shading, water storage, refuge, salinity tolerance, bank retention, water invading, weed controlling and water purification) that they offer and identifying the threats (browsing and over grazing, over collecting and over cutting, clearance for agriculture, habitat loss, disturbance by cars or trampling, and mining and quarrying) that govern their gradual change in the study area. Demonstrates that 548 species in Western Mediterranean Desert (56.6% of the total species) have at least one aspect of potential or actual goods arranged in descending order as follows:

[18] En Espagne, 60% des zones humides ont disparu en 40 ans (EVREN, 2011)

[19] Goods of the natural flora in the ecosystem include species and their parts and products that grow in the wild and are used directly for human benefit (Daily et al. 1997). (Page(s): 4)

[20] Services of the natural flora are those valuable, ongoing streams of benefits provided by these plants (Turner & Daily 2008). (Page(s): 4)

medicinal (important source of economic income in this region) > grazing > human food (vegetable dishes) > other goods > fuel > timber. Determines that 338 species (34.9% of the total species) have at least one environmental service including the following in descending order: sand accumulation > windbreaks > aesthetic concerns > soil fertility > shade plants > water storage > refuge > salinity tolerance > bank retention > water invading > weed controlling such as smother plants > water purification (ability to accumulate pollutants from contaminated water from agro-industrial activities). Proves that services are related to the location and environment of the different species in the Western Mediterranean Desert of Egypt. 411 species (75% of the total economic species), suffer from at least one type of threat arranged in descending order: over-collecting and over-cutting > habitat loss > browsing and over grazing > clearance for agriculture > mining and quarrying > disturbance by cars or trampling.

K - Climate Change and Water Resources

29- Protecting Freshwater Ecosystems in the Face of Global Climate Change, Stacy Combes, University of Washington

Describes the current threats to freshwater ecosystems such as pollution, water diversion, invasive species and overexploitation. Explains in details all anticipated and observed effects of climate change on freshwater ecosystems including the physical and the biological changes. Lists the specific changes on lakes that include increased water temperatures and evaporation, acidification, reduction of bottom habitats, decrease in primary productivity, and alteration in fish communities. (Page(s): 216 to 219)

30 - Lakes as Sentinels of Climate Change, Limnol Oceanogr, 2009 November; 54(6): 2283–2297

Explains how lakes are indicators of climate change since they are sensitive to climate, respond to change and integrate information about changes in the catchment. States that indicators are affected by regional response to climate change, characteristics of the catchment, and lake mixing regimes. Thus, particular indicators or combinations of indicators are more effective for different lake types and geographic regions. Summarizes the indicators of climate change that include hydrology, temperature, ice phenology, transparency, chemistry, autecology, community structures and habitat structure. (Page(s): 1 and 19)

31 - Effects of Climate Change on Lakes, W F Vincent, 2009

Describes all potential effects of climate change on lakes mainly the physical, chemical and biological effects. Explains how changes in precipitation cause shifts in the connectivity of lakes and changes in the water balance. States that the hydraulic residence time of a lake affects its chemical composition whereas changes in landscape properties around the lake due to climate change have a strong influence on water quality and quantity. Summarizes the biological effects of climate change: 1) Extinction or alteration of aquatic biota; 2) Changes in pelagic communities and their production; 3) Alteration in species composition and diversity at the primary producer level; 4) Shifts in the geographic distribution of many fish species and ; 5) Changes in microbial processes. (Page(s): 1 to 6)

32 - The Foreseeable Impacts of Climate Change on the Water Resources of Four Major Mediterranean Catchment Basins, Plan Bleu; Regional Activity Center, January 2010

Sates that the Mediterranean region will witness a drop in water resources; more evapo-transpiration, less snow, less rain, therefore less surface runoff and less groundwater replenishment. Moreover, depletion of water resources will be particularly marked in the southern Mediterranean regions while the extension and worsening of water shortage situations will be unavoidable, particularly to the South and East. Affirms the importance of hydrological variation monitoring in the area. (Page(s): 3, 4 and 5)

33 -Climate Change Impacts on Lake Bafa in Mediterranean Climate Region Turkey, BALWOIS 2008 - Ohrid, Republic of Macedonia - 27, 31 May 2003

States that the Mediterranean region is sensitive to global climate change and inland freshwater ecosystems and coastal lakes will be affected since heat and drought during summer and frost and wind during winter are hazardous to aquatic ecosystems. Changes in air temperature, precipitation and wind cause changes in evaporation, water balance, lake level, ice events, hydro-chemical and hydro-biological regimes and entire lake ecosystems. Under some climatic conditions, lakes may disappear entirely. (Page(s): 1 and 4)

34 -Impact of Climate Change on Arab Countries, Mahmoud Medany

Explains that higher temperatures and lower precipitation will add more pressure on natural and physical systems in Arab Countries. States that climate change will have negative impacts on freshwater systems. Describes how watersheds are facing drought and sudden intense rainfall causing soil erosion and desertification and how natural and artificial water bodies are facing evaporation leading to a decrease in their water supply. States that Lebanon has experienced varying conditions of water shortages in the last decade. (Page(s): 129 and 134)

35- Climate Change and Water Resources in the Middle East: Vulnerability, Socio-Economic Impacts, and Adaptation, M. El-Fadel and E. Bou-Zeid, NOTA DI LAVORO 46.2001

Explains how climate change and increased temperatures in particular will aggravate existing water shortages in the Middle East and presents the potential negative impacts of climate change on water resources in Lebanon that mainly include increased agricultural water demands, water quality damage and ecosystems damage and species loss. Impacts with moderate socio-economic implications in Lebanon including increased industrial and domestic water demand and water resources distribution equity decline are also highlighted. The report summarizes some of the technical adaptation measures (conservation, use of surplus winter runoff and wastewater reclamation), their potential benefits and costs. (Page(s): 1, 2, 5, 10 and 11)

36 – Climate Change Projections and Downscaling for Jordan, Lebanon and Syria, Draft Synthesis Report, 27 September 2010, Rob Wilby, Climate Change Science Advisor on behalf of the World Bank

Quantifies the impacts of climate change on agricultural and rural sectors in Jordan, Lebanon and Syria (both in physical and in economic terms). States that over the eastern Mediterranean and Middle East potential climate change impacts are expected to be particularly acute; rates of 21st century warming are expected to be greater than the global average and annual precipitation could decline by more than 100 mm/year compared with present (reductions in winter precipitation in the range 24%-32%) (Page(s): 15). States that he Middle East emerges as a "hot spot" of severe water stress by the 2050s in several global assessments. States that the agricultural economy and rural livelihoods of peoples in Lebanon, Jordan and Syria are particularly vulnerable to climate variability because of high dependency on natural resources and exposure to climate hazards. Recommends improvements in water efficiency and protection of water sources from contamination. Describes observations of climate change in Lebanon over the last 40 years: between the 1950s and 1980s precipitation in the Mount Lebanon basin dropped from 1295 to 1060 mm/year (Khair et al., 1994). Since the 1980s precipitation has decreased by 12% across Lebanon as a whole whilst the average number and intensity of peak rainfalls has increased (Shaban, 2009). The average discharge of Lebanese rivers is also falling (from 246 Mm^3/year in 1965 to 186 Mm^3/year in 2005) as is the number of springs (50-55% decrease) and volume of spring flows (53% decrease) (Shaban, 2009). Satellite measurements indicate that the area of dense snow cover in the Lebanese mountains has declined from 2280 km^2 before 1990, to an average of 1925 km^2 since (16% decrease). The average residence time of dense snow before melting has decreased too: from 110 days to less than 90 days over the same period (Shaban, 2009). Evaporation was found to increase. Extrapolates the 2050s mean temperatures and precipitations that could increase by ~1.5°C and reduce by 10-20% respectively. Highlights that the largest reductions to annual rainfall are found for sites in the coastal zone, and within the Bekaa Valley, where changes could be in the range 10-30% by the 2050s and 20-50% by the 2080s.

37 - Adaptation to a Changing Climate in the Arab Countries; A case for Adaptation Governance and Leadership in Building Climate Resilience, World Bank, 2012

Explains how Arab Countries coped with the challenges of climate variability for thousands of years by adapting their survival strategies to changes in rainfall and temperature. States that climate change is happening now in Arab countries and over the next century the climate variability will increase in this water-scarce region through unprecedented extremes (High temperatures and reduced rainfalls). Affirms that without biodiversity and ecosystem services, life and human societies would not exist (Page(s): 152) and that many countries have ecosystems that are of critical value for tourism, fisheries, and cultural heritage; thus incorporating risks of climate change in the management of these systems is essential. Confirms that the importance of biodiversity and ecosystem services in livelihoods and economies is neither recognized nor included in national development planning and sectoral strategies in Arab Countries. States that few studies have been conducted on the economic valuation of ecosystem services in the region, and even fewer on the impacts of climate change on these services.

38 - The Economic Costs of Climate Change in MENA countries: A Micro-Spatial Quantitative Assessment and a Survey of Policies, Femise Research Program, 2010-2011

Explains that Middle East North Africa (MENA) countries, due to their geographical positions, will be highly affected by the negative impacts of climate change including water loss, soil degradation, seawater intrusion and sea level rise due to an increase in average temperatures and fall in precipitation levels (larger in MENA than those estimated as a world average). Gives an overview on the 2007 projections by the International Panel on Climate Change (IPCC) for the MENA region which predicts (1) an increase in temperature up to 2°C in the next 15-20 years and between 4°C and 6.5°C by the end of the 21st century and (2) a decrease of more than 20% in the level of precipitation exposing 80-100 million people in MENA countries to water stress by 2025. States that climate change will have serious effects on agriculture sector and food security in MENA countries and a loss of 0.4 to 1.3% of GDP is estimated in MENA countries due to climate change effects, which could even rise to 14% if no mitigation and adaptation measures are undertaken. Particularly an increase in temperature by 1°C leads to a decrease in GDP per capita by 8% on average (close to results at worldwide level; the reduction in precipitations on GDP per capita is generally insignificant). Clarifies that CC impacts will affect all economic activities particularly agriculture and tourism as well as ecosystems and their related services, on which MENA societies depend (Page(s): 29). Demonstrates that MENA countries have already experienced a dramatic climate change over the past century (For Lebanon around +0.6°C were recorded from 1972 to 2008 and a decline of 45% in precipitation from 1900-2008). Encourages MENA countries to develop National Adaptation Programs of Action (NAPAs; simple and low cost adaptation measures building on traditional knowledge and local conditions), following the provisions of the United Nations Framework Convention on Climate Change (UNFCCC).

L - Inverse Climate Change Model (Global)

39 - Hydrologic Models for Inverse Climate Change Impact Modeling, Juraj M. et al, 2007

States that it is expected that the global climate change will have serious impacts on the frequency, magnitude, location and duration of hydrologic extremes which will have implications on the design of hydraulic structures, floodplain development, and water resource management. Describes that a method of applying a bottom-up approach (determining the impacts first) on a study area, here the Upper Thames River Basin – UTRB- (Ontario, Canada), in hydrologic modelling could determine the meteorological parameters of climate change (Floods and droughts represent the main hydrologic hazards in the UTRB). The model results showed that under the increased temperature scenario the critical rainfall events which induced floods may occur less frequently and climate change may have beneficial impacts on the distribution of hydrologic extremes in the study area.

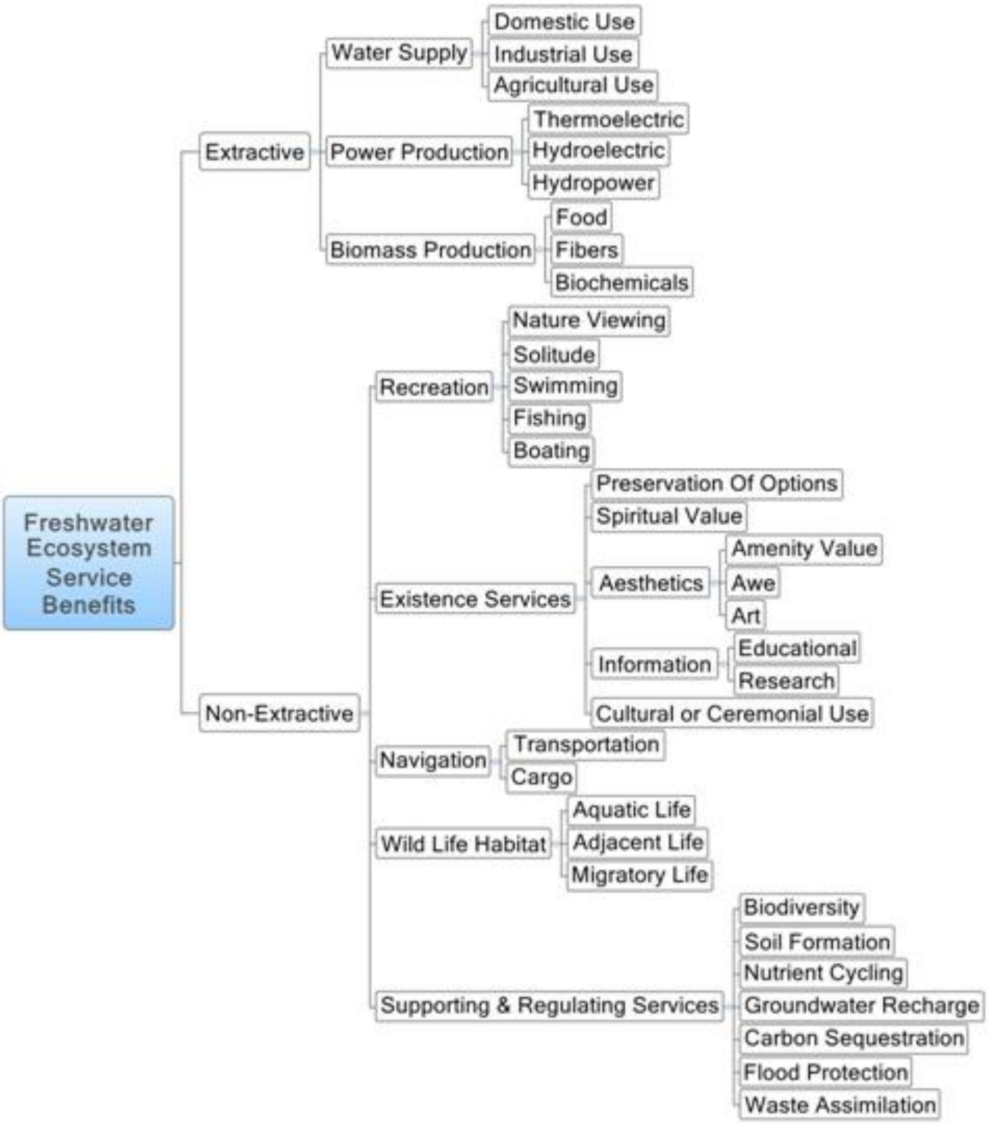
General Information – Ecosystem Services

L - Ecosystem Services

40 - Biodiversity, ecosystems and ecosystem services, Chapter 2, Thomas Elmqvist and Edward Maltby, 2010

Highlights the complexities of the concepts of biodiversity and ecosystems, and examines the relationships between biodiversity, ecosystem functioning and ecosystem services (Page(s): 7 and 8). Classifies the ecosystem services into: 1) Provisioning: provision of food, water, fuels and fibres, genetic resources, medicinal and other biochemical resources and ornamental resources; 2) Regulating: air quality regulation, climate regulation, moderation of extreme events, erosion prevention, maintenance of soil quality, pollination services and biological control; 3) Habitat: maintenance of life cycles of migratory species and genetic diversity; and 4) Cultural: aesthetic information, opportunities for recreation and tourism, inspiration for culture, art and design, spiritual experience, and information for cognitive development (Page(s): 18). Lists the trade-offs (temporal, spatial, beneficiary and service) among ecosystem services (Page(s): 46). Describes the physical changes that affect and influence ecosystems (Page(s): 49). Illustrates the values of biodiversity in regulating different ecosystem services. (Page(s): 59)

41 - Freshwater Ecosystem Services, EPA



Source: EPA website : <www.epa.gov/aed/lakesecoservices/ecosl.html>

States that every lake can provide a multitude of ecosystem service benefits simultaneously but the actual output of each will depend on the physical characteristics of the basin and the quantity, quality, and timing of water flow. As anthropogenic influences increase ecosystem services and benefits will be affected. Can present significant challenges to managers interested in maintaining multiple ecosystem service benefits while ensuring overall lake health is maintained.

42 -Freshwater Ecosystem Services by Bruce A. et al.

Describes the impacts of human activity on ecosystems and lists all ecosystem services provided by freshwater as follow;

- Provisioning Services: Water for consumptive use (drinking and irrigation) and non-consumptive use (power generation and navigation) and aquatic organisms for food and medicines.
- Regulatory Services: Maintenance of water quality, buffering of flood flows and erosion control.
- Cultural Services: Recreation, tourism and existence values.
- Supporting Services: Role in nutrient cycling and primary production and predator/prey relationships and ecosystem resilience. (Page(s): 216 and 217)

43 - Water Security and Ecosystem Services, The Critical Connection, UNEP, 2009

States that all ecosystems are impacted in one way or another when they are utilized to meet human needs (e.g., water supply, food production). The concern is whether or not these impacts are sufficient to overwhelm the ability of an ecosystem to continue to provide such services in a sustainable and balanced manner, or to provide different ecosystem services as communities and countries continue to change and develop (Page(s): 21). Presents different case studies of Lake Ecosystem Services (*none in the Mediterranean*) which highlight: (i) the ecosystem being addressed and the services they provide; (ii) the constraints to their sustainable use and the impacts of these constraints; (iii) the actions taken to ensure ecosystem structure and functioning; and (iv) the results of the actions taken within the context of sustainable ecosystem services and water security (Page(s): 21). Case studies are grouped based on lessons learned including Habitat rehabilitation, Pollution Control, Environmental Flows, Stakeholder Involvement and Integrated Watershed Management.

44 - Biodiversity Regulation of Ecosystem Services – UNEP
http://www.unep.org/maweb/documents/document.280.aspx.pdf

Explains how biodiversity including the number, abundance and composition of genotypes, population, species, functional types, communities and landscape units strongly influence the provision of ecosystem services. States that the loss of biodiversity can reduce the provision of ecosystem services essential for human well-being. Conserving and managing biodiversity sustainably can maintain a number of ecosystem services. (Page(s): 26)

45 – Valuing Ecosystem Services toward better Environmental Decision-Making, The National Research Council, 2004 - Copyright 2004 The National Academy of Sciences

Explains that both, the value of the ecosystem services that could be compromised as well as the value of the human activity should be considered to assess environmental policy alternatives and the decisions that follow. Gives an example on the 1996 water pollution (due housing developments, septic systems, and agriculture) of the Catskills/Delaware watershed which provides 90% of the drinking water for the New York City and the choices of policymakers to build a water filtration system at an estimated cost of up to $6 billion or protect its major watershed. New York City water managers chose to protect the watershed by limiting further development, improving sewage systems, and reducing the impact of agriculture by using less fertilizers and building up riparian zones along river banks at a total projected investment of about $1 to $1.5 billion. Describes the benefits of a lake ecosystem including clean drinking water, food production, and recreation. States that measuring the value of each benefit is not easy to measure and therefore many economists use the Total Economic

Valuation (TEV) Framework to incorporate the multiple ways that individuals or groups could value an ecosystem. Figure 1 in the report shows the multiple types of values from ecosystem goods and services that are considered within a total economic valuation (TEV) framework. (Page(s): 2)

46 - Jebari, S., Berndtsson, R., Lebdi, F., and Bahri, A., 2012. "Historical aspects of soil erosion in the Mejerda catchment." Hydrological Sciences Journal, 57 (5), 1–12.

Argues that in the Tunisian semiarid area, water erosion processes have led to negative economic and environmental consequences in the a context of limited resources. Characterizes and predicts these degradation phenomena by setting up a comprehensive high-resolution database on erosive rainfall, together with siltation records for 28 small reservoirs. Showed that studied small reservoirs network displayed a general life-span of about 14 years. Determines that average soil loss is 14.5 tonnes/ha/year. Explains the complex relationship between the erosive rainfall events and the annual soil loss by two important factors: (i) soil degradation cycle which determines the soil particle delivery potential of the catchment; and (ii) degradation front which presents a north-western/south-eastern direction. Argues after rainfall disaggregation investigation through a regionalization of fine timescale and daily rainfall that there are similarities between the maximum 15-minute and daily rainfall data. Explores the multiplicative properties of a 4-year rainfall time series that showed that scaling behavior for time scales up to 100 minutes coincides with the most active erosion process time scale. Proves that the potential of rain-fall scaling-based approaches to predict water erosion levels in semiarid areas seems promising and will help decision makers better manage soil erosion problems.