CLIMATE CHANGE VULNERABILITY AND ADAPTATION

FORESTRY

Lebanon's Second National Communication
Ministry of Environment/UNDP

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1. VULNERABILITY AND ADAPTATION OF THE FORESTRY SECTOR

1.1. VULNERABILITY ASSESSMENT

1.1.1. Background

Lebanon is a highly mountainous country (highest peak at 3,090 m), with extreme variability in climatic conditions, soils and socio-economic status. Forests in Lebanon are very particular in their variation and characteristics. They represent a unique feature in the arid environment of the Eastern Mediterranean.

In 2002, Forests covered 139,376 ha while Other Wooded Lands (OWLs) covered 108,378 ha, 13.3 percent and 10.37 percent of the surface area of the country respectively[1]. Other lands with trees (including fruit and olive trees) covered a surface of 116,210 ha (11.1%) of the surface of the country (MoA/FAO, 2005). Figure 1-1 below shows forest cover in Lebanon as illustrated by the derived forest map of Lebanon (MoA/ FAO, 2005).

The forest cover is broadly divided into three main classes: Mixed Forests (15,610 ha), Broadleaves (78, 887 ha) and Coniferous (44,879 ha). On the other hand, OWLs are divided into the following classes: coniferous shrubs, broadleaved shrubs, mixed shrublands and grassland with trees (MoA/FAO, 2005).

The main forests widespread in Lebanon are Quercus calliprinos, Quercus infectoria, Quercus cerris (mostly referred to as Quercus spp), Juniperus excelsa, Cedrus libani, Abies cilicica, Pinus pinea, Pinus halepensis, Pinus brutia and Cupressus sempervirens. In addition, Lebanese forests contain a wide range of aromatic, wild and medicinal plants (Asmar, 2005 a). Table 1-1 shows the percent distribution of the different forest types. Oak woodlands (Quercus spp) constitute the major parts of Lebanese forests with 41.61 percent, while.pine forests (Pinus spp) occupy 20.28 percent (MOA/FAO, 2005).

1 See Appendix A

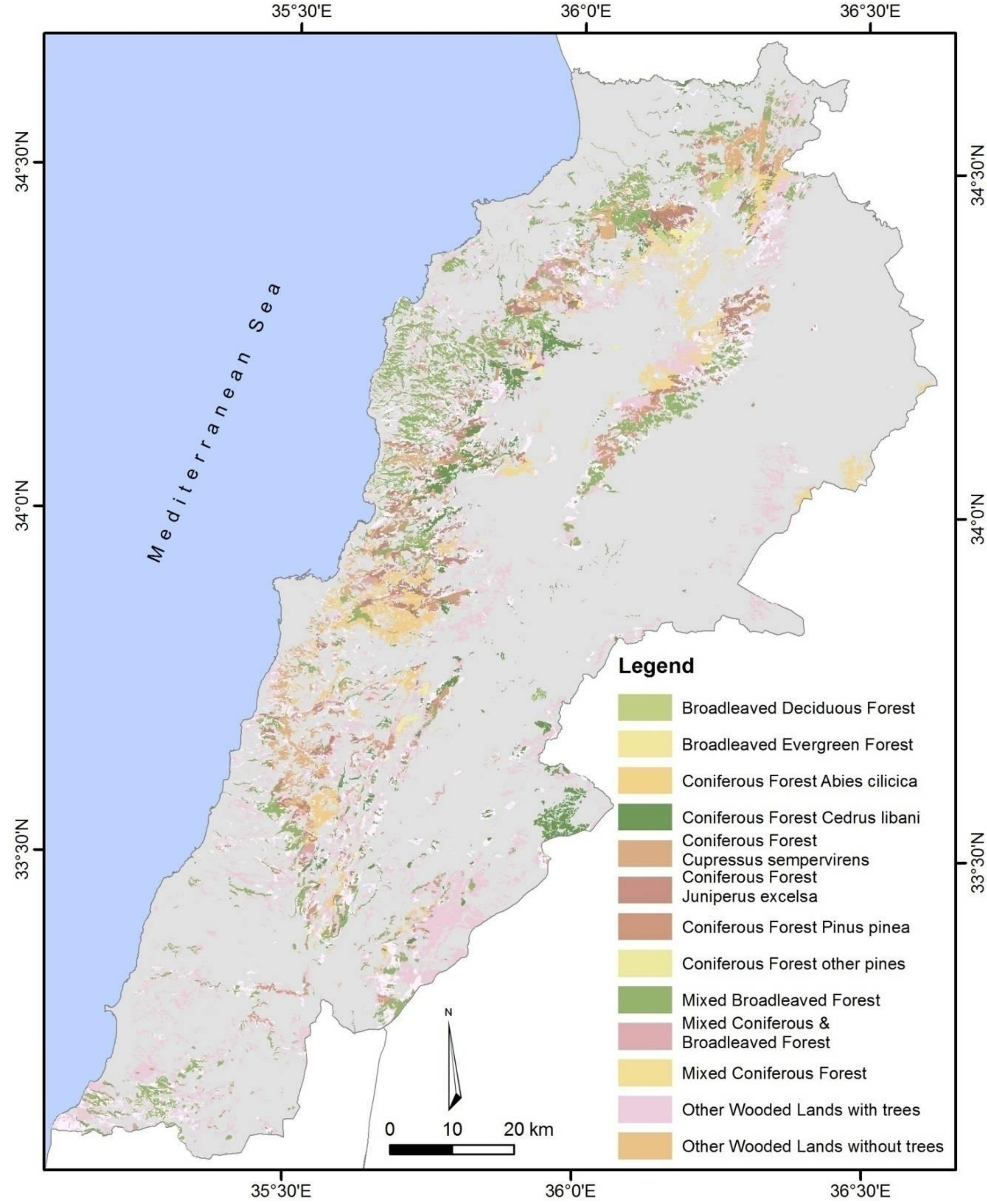

Figure 1-1 Lebanon's derived forest map (MOA/FAO, 2005)

Table 1-1 Distribution of Lebanese forests by type

FOREST TYPE	AREAS IN HA	PERCENTAGE OF TOTAL FOREST COVER
Cedrus libani	2,125	1.58 %
Abies cilicica	1,613	1.2 %
Cupressus sempervirens	318.75	0.23 %
Juniperus excelsa	11,318	8.47 %
Pinus spp	27,273	20.28 %
Quercus spp.	61,325	41.61 %
Mixed forests	30,398	22.61 %
Riparian forests	58	0.04 %
Total forest cover	134,430	100 %

Source: MOA/FAO, 2005

As a result of unsustainable forest practices and neglect of forested lands, and as a result of the decline of controlled grazing in forest understory, oak and pine forests have become highly susceptible to fire events. In contrast, cedar forests have received national, regional and international attention due to their historic, symbolic and biological value (Sattout et al., 2005) even if they just constitute 1.58 percent of the total forest cover (MOA/FAO, 2005).

In Lebanon 9,119 species have been documented (4,633 flora and 4,486 fauna species). 81 percent of the floral species are terrestrial, of which 96 species are listed as rare or threatened. Due to Lebanon's geomorphologic diversity and the isolation effect of its diverse topography, 12 percent of plant species are endemic. Lebanon has 8 nature reserves, 3 biosphere reserves, 16 protected forests, 16 protected natural sites/ landscapes, 4 Ramsar sites and 5 World heritage sites (MoE, 2009). Species are distributed and divided into vegetation level zones according to altitude and climatic conditions (Table 1-2).

Table 1-2 Distribution of vegetation in Lebanon on the different vegetation levels

FLORISTIC ENSEMBLE	VEGETATION LEVEL	MOTHER-ROCK		
		LIMESTONE	MARL AND MARLY LIMESTONE	SANDSTONE
MEDITERRANEAN	Thermomediterranean (0-500 m)	Ceratonia siliqua & Pistacia lentiscus series Thermophilic series of *Quercus calliprinos*	Thermomediterranean series of *Pinus brutia* & *Cupressus sempervirens*	Thermomediterranean series of *Pinus pinea*
	Eumediterranean (500m – 1000 m)	Mediterranean series of *Quercus calliprinos* Mediterranean series of *Quercus infectoria*	Mediterranean series of Pinus brutia & Cupressus sempervirens	Mediterranean series of *Pinus pinea*
	Supramediterranean (1000 m – 1500 m)	Supramediterranean series of Quercus Calliprinos, normal series of Quercus. Calliprinos, Series of Ostrya carpinifolia & Fraxinus ornus, Series of Quercus cerris		Supramediterranean series of *Pinus pinea*, Series of *Quercus infectoria* sandstone variety, Series of *Quercus cerris* sandstone variety
	Mountainous Mediterranean (1500 m – 2000 m)	Series of Cedrus libani & Abies cilicica Mountainous Mediterranean series of *Quercus cedrorum* & *Quercus brantii* ssp. *Look* Mountainous series of *Juniperus excelsa*		
	Oromediterranean (> 2000 m)	Oromediterranean series of *Juniperus excelsa*		
MEDITERRANEAN PRESTEPPIC		Formation of *Hammada eigii*		
	Mediterranean presteppic (1000m-1500 m)	Presteppic series of *Quercus calliprinos*		
	Presteppic supramediterranean(1400m-1800m)	Mixed presteppic series of Quercus calliprinos & Quercus infectoria		
	Presteppic mountainous Mediterranean (1800 m – 2400m)	Mountainous presteppic series of *Juniperus excelsa*		
	Presteppic oromediterranean (>2400 m)	Presteppic oromediterranean series of *J. excelsa*		

Source: Abi Saleh & Safi, 1998

Economic Importance of the Forestry Sector

The forestry sector remains a relatively small employer nationwide; it contributes to 0.02 percent of the total labor force. Lebanese people have traditionally benefited from forest resources in various ways: forest flora exploitation, beekeeping, pine nuts production, wood collection and charcoal production (AFDC, 2007). The economic value of the different forest ecosystems in Lebanon is estimated at about 131.5 million USD. The contribution of the forest sector to Lebanon's gross domestic product (GDP) was 0.93 percent in 2001 (Sattout E. et al., 2005).

Wood Products:

Despite the fact that some of the Lebanese tree species like the cedars, the junipers and some oaks could produce wood of good quality, wood production is a minor activity of the forestry sector in Lebanon as in most Mediterranean countries. The present structure, cover and distribution of forests do not allow for such a production. Wood is only exploited as fuel and charcoal by some rural communities that use it as a source of energy for cooking and heating (Asmar, 2005 a).

Non-wood products:

Non-wood forest products are the main income-generating activity from forests as several rural communities depend on these products for their living. The main wild products collected are:

- Pine nuts collected from pine forests (Pinus pinea) on the coastal slopes of Mount Lebanon from sea level up to 1,500 m. According to the Ministry of Agriculture (MoA, 2007), the production of pine seeds was 1,200 tons for the year 2004. With reference to Masri et al. (2006) as well as values adopted by the "Syndicate of pine growers in Lebanon", each 100 kg of seeds results in 22 kg of edible nuts; the price of 1 kg of edible nuts is equivalent to US$ 22. Consequently the potential revenues generated by the 1,200 tons would be of 5,808,000 USD.
- Carob pods collected from carob trees (Ceratonia siliqua) found on the coastal slopes up to 800 m. According to MoA, the production of pods (for the production of molasses or row carob pods) was 3,300 tonnes 2for the year 2004 (MoA, 2007).
- Medicinal and aromatic plants are estimated at more than 365 species (MoE, 2009). Plants like the wild Origanum syriacum, Salvia sp. Rosa canina, Ferrula hermonis (known as the Zallouh root) and many others are extracted from forests for culinary, medicinal or aromatic use (MoA, 2005). The potential estimated market value of medicinal and aromatic plants assessed by market analysis (sales of herbs and teas) and not by direct estimate of forest ecosystems production, was US$ 29,600,000/ year (MoE, 2009).

Other Economic activities and services:

The appropriate management of forests and other wooded lands would play a very important economic role, allowing the provision of services with a high market value such as eco-tourism, agri-tourism and rural tourism. Over the last decade, ecotourism activities have been expanding in Lebanese forests, attracting local and foreign tourists (MoA, 2005).

Grazing has always been considered not only as an interesting economic activity related to forested lands, but also a powerful management tool that has shaped and defined the structure of Mediterranean forests. Grazing activities in and around forests occur in Lebanon during summer. Shepherds traditionally move their sheep and goats to the coast in winter (AFDC, 2007). Unfortunately, little data is available in Lebanon on grazing as an economic activity and the common figure given by

2 No market value available.

the MoA reflects that goat herds are more important than sheep herds. In 2004, the goats' population was estimated at around 432,100 heads while the sheep population was estimated at around 150,558 animals.

Honey production is a significant trade in Lebanon, whereby the number of beehives is 131,000 distributed throughout the country. These beehives produced 1,070 tonnes of honey evaluated at around 14.67 million USD (MoA, 2007). The common practice in honeybee management in Lebanon consists of transporting beehives in winter to lower elevations, where they are usually placed in fruits orchards and other cultivated lands (Sattout E. et al., 2005).

As for hunting, it is an important socio-economic activity in the region, particularly in rural areas. Hunting in Lebanon involves hundreds of thousands of population and hectares, and supports a variety of groups. Sport hunting has become particularly widespread in the region in recent years (AFDC, 2007). The overall value of hunting based on the number of legal and illegal hunters is estimated at around €12 million (Sattout E. et al., 2005).

1.1.2. Methodology

1.1.2.1. Scope of assessment

Unit of Study

Based on the project scoping phase, it was agreed that the assessment would focus on the forestry sector, particularly forest types that are most sensitive to climate change and identified in the scoping report, as well as associated problems such as pest and disease spread and invasion by alien species.

Spatial Frame

The assessment covers the entire country with focus on forest areas, particularly those that are most vulnerable to climate change.

Temporal Frame

The temporal scope of the assessment extends over the entire year, since forest vulnerability depends on both temperature increase (summer) and precipitation (winter). 2004 was taken as a baseline year, and projections were made until 2030, i.e., over a time frame of around 25 years.

1.1.2.2. Climate factors

Temperature increase is an important factor affecting forest growth and survival. In addition, water availability which results from rainfall, snowfall in mountains and the soil's capacity to store water are considered as the most relevant parameters to the forestry sector, especially during critical phases such as spring and early autumn.

Mediterranean vegetation and specifically Mediterranean forests have adapted to prevailing climatic constraints and are typically represented by clear altitudinal leveling: the vegetation levels. In Lebanon, vegetation levels have been described by Abi Saleh et al. (1978) and illustrated in the phyto-association map published by Abi Saleh & Safi in 1988, in which 10 vegetation levels can be clearly distinguished with respect to altitude (Figure 1-2).

Those vegetation levels derive from the computation of a single indicator defined by Quezel (1976) with respect to the "Quotient pluviothermique" (Q) of Emberger that delimits for the Mediterranean region six climatic types: Inframediterranean, Thermomediterranean, Eumediterranean, Supramediterranean, Mountainous Mediterranean and Oromediterranean.

$$Q = \frac{1000 \times P}{0.5 \times (M + m) \times (M - m)}$$

This precipitation/temperature ratio) accounts for the ecological needs (valence ecologique) of the Mediterranean type species and reflects the tolerance of each species within a range of P, M and m (where P is the annual precipitation in mm, M the mean maximum temperature of the hottest month expressed in °K, and m the mean minimum temperature of the coldest month expressed in °K).

In order to estimate the vulnerability of the forest sector in Lebanon to the projected changes in climatic conditions, the Q (quotient of Emberger) parameter was considered and evaluated.

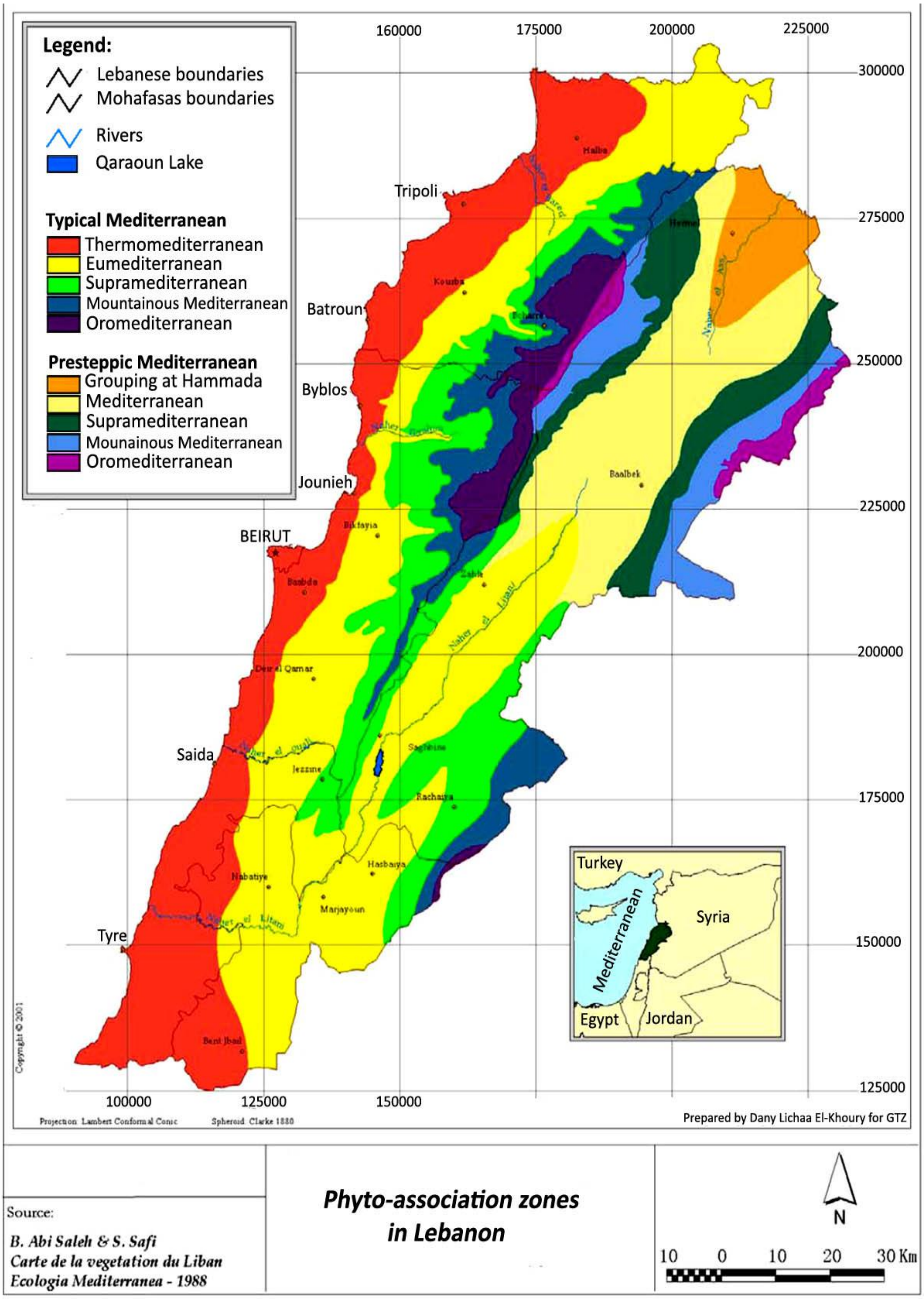

Figure 1-2 Phyto-association zones in Lebanon (Abi Saleh & Safi, 1988)

1.1.2.3. Methods of Assessment

In order to assess the vulnerability of the forest sector to the expected increase in temperature and decrease in annual rainfall, this chapter has followed the following methodology:

- Overlaying the derived forest map (MoA, 2005) on the grid map of Lebanon (25 km x 25 km)
- Identifying for each grid: the dominant forest type (current- for the period 1960- 2000), and the Quotient of Emberger (Q), for the periods 1961-1980; 2025- 2044; and 2080-2098.
- Selecting the most vulnerable forest types with respect to Quotient of Emberger (Q), and their ability to withstand future climate change; i.e the forest types were designed as "most vulnerable" when the shift in bioclimatic level (Q) will overbear the tolerance of the forest type with reference to climagramme of Emberger for Lebanon (Abi Saleh & Safi, 1996)
- Assessing the impact on vulnerable forest types with respect to the expected change in Q and therefore in the bioclimatic condition and the ability of the ecosystem (valence écologique) to the projected change (Figure 1-3).
- In order to represent a geophysical continuous distribution for the Q factor over Lebanon, a GIS spatial prediction method (Kriging) was used. The Kriging methodology interpolates point values on a grid of raster cells that are spatially continuous based on a weighted average that is given for each point. Nearby points are weighted more heavily than more distant ones during spatial computation. The statistical spatial variations and spatial prediction of values over different distances produce minimum error in its estimation using the Kriging methodology as compared to relying only on point data.
- Accordingly, the future potential presence of forest types with regard to the projected changes in climatic factors was mapped using Arc GIS facilities.

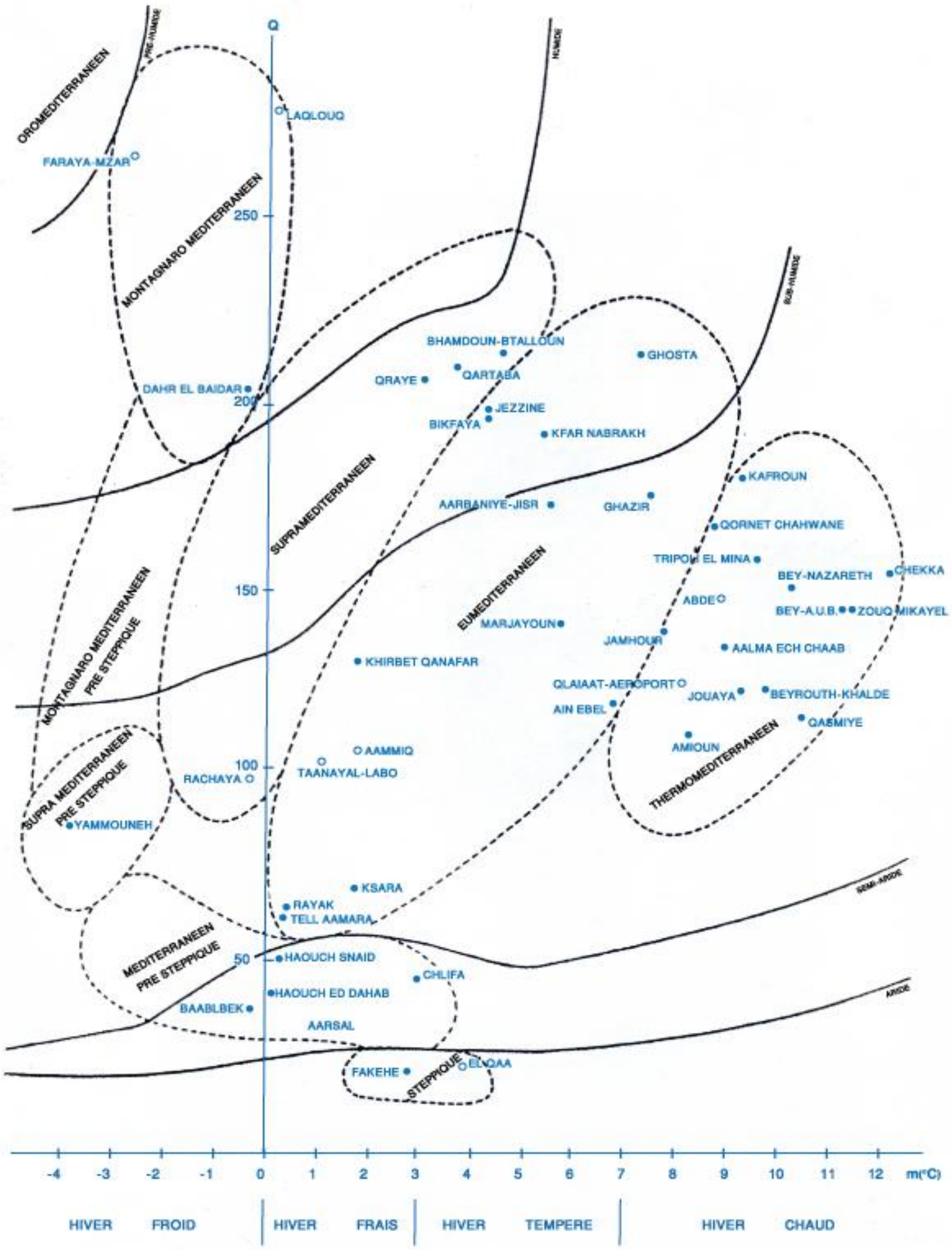

Figure 1-3 Distribution of bioclimatic levels in Lebanon with respect to Emberger Quotient (Abi Saleh & Safi, 1996)

1.1.2.4. Data Sources and Gaps

In this chapter the main data sources used in the analysis are reports generated by the:

- Ministry of Agriculture (MoA):
  - National Forest and Tree Assessment and Inventory
  - Agricultural statistics
- Ministry of Environment:
  - Fourth National Report of Lebanon to the Convention on Biological Diversity.

- State of the Environment report (SOER)
- Database of fires in Lebanon
- Council for Development and Reconstruction (CDR)

- Other sources include: Plan Bleu, UNEP, IPCC Millennium Ecosystem Assessment, the Economic Accounts Mission of the Presidency of the Council of Ministers and the International Monetary Fund for National Accounts data, and the UN Population Division's World Population Prospects for population growth data and scientific journals.

In this chapter the major data gaps were the:

- The need for field studies to validate and update existing figures and studies; such studies are limited since they require intensive time, human and financial resources;
- Heavy reliance on secondary sources of information instead of using primary sources, the latter being very limited;
- The complexity of forest ecosystems, which calls for expert judgment and assumptions regarding potential impacts, with the associated limitations.

1.1.2.5. Assumptions and limitations

In addition to global assumptions related to modeling and forecasting the response of the earth's atmospheric, terrestrial and marine ecosystems, assessing future response of Mediterranean forest to expected climate change holds an important number of uncertainties and assumptions because:

- Mediterranean forests are adapted (used) to adverse climatic conditions and sustained human pressure.
- Climatic models have included many parameters but they still are unable to properly describe future conditions with accuracy. Parameters such as albedo, cloud behaviour and microclimatic conditions are sometimes much more important as local factors to explain forest response rather than global factors such as temperature or precipitation.
- The response of natural ecosystems is multi-factorial and does not only respond to climatic parameters, but to a number of factors such as soil, topography, human interaction, pressures, site history, biotic and abiotic interactions, etc., to which climate comes as an additional stress. Thus, forest ecosystems are complex ecosystems whose response to the expected climatic variability cannot be assessed without integrating a multitude of factors.
- Lebanon has a very complex topography and is characterized by a great number of micro-ecosystems justifying the development of complex landscapes inter-representing forests, woodlands, agriculture and human presence. The global approach undermining downscaling global model to regional models can hardly account for this complexity and the available grids (25km x 25 km) are too rough to give an accurate prediction of the response of forests to projected climate change.

Other uncertainties arise from the fact that:

- The assessment is based on experts' judgment rather than on field experimental measures;
- Forests need a very long term to react to climate variability (more than 50 -100 years); and
- Most simulations are made with a time frame of 20 – 100 years.

Wherever a forest grows within a given climatic belt (bioclimatic level), it is assumed that a change in this bioclimatic level that overbears the climatic limits of the forest type would result in a shift in the forest's geographical extent. While the climatic simulations are based on a lot of assumptions and uncertainties, the major assumption is to state that the forest might shift to adapt with climatic variation.

The analysis of future vulnerability takes into account the current vulnerability, and assumes that the policies and strategies currently in place will be on the course of implementation by 2030. Moreover, the analysis does not account for internal and external security shocks which would severely impact growth, the population's livelihoods and vulnerability, hence intensifying any natural shocks from the projected climatic changes.

Assumptions made in the formulation of the socio-economic scenarios were based on an examination of national statistics on GDP growth trends from national accounts and IMF's World Economic Outlook, and population growth prospects as projected by the UN Population Division.

1.1.3. Scenarios

Several public institutions are involved in forestry-related activities, namely the Ministry of Agriculture (MoA), Ministry of Environment (MoE), Ministry of Energy and Water (MEW), the Council for Reconstruction and Development (CDR), the Directorate of Antiquities (when forests are considered as a cultural heritage) and the National Center for Remote Sensing (NCRS). Both the MoA and MoE are launching initiatives to save the natural patrimony and promote protection and proper management of natural resources (AFDC, 2007). MoA is responsible for managing all forest areas, except for nature reserves which fall under the responsibility of MoE (Sattout E. et al., 2005).

Since the end of the civil war (around 1990), MoA achieved some efforts in combating deforestation and increasing the forest cover in terms of afforestation and reforestation activities, as the main concern was in restructuring and building new capacities, and as a result of the very limited budged allocated to the Ministry (Asmar, 2005 a).

Nevertheless, MoA has been distributing forest seedlings on a yearly basis to municipalities, community-based organizations, NGOs and individuals in order to plant trees along road sides or on communal plots. The RDNRD[3] has undertaken the implementation of public gardens in villages and towns, as well as a trans-boundary afforestation project between Lebanon and Syria since 2002.

Despite the fact that there is no official forest policy in Lebanon, MoA has developed laws, legislations and projects within a certain framework, aiming at the conservation, promotion and management of the forest and tree resources.

In 2001, MoE launched a reforestation/ afforestation plan for abandoned land in Lebanon: the National Reforestation Plan (NRP). The plan, which aimed at increasing the forest cover by 20% and combating desertification, took into consideration environmental and socio-economic aspects and emphasized the importance of coordination with MoA, MoI&M, the Lebanese Army, and NGOs. In 2003, a total of 305 hectares distributed over the five Mohafazas (23 sites) were replanted by MoE with indigenous species such as cedar, fir, juniper, pine, carob… The second phase of the project was launched in 2004, with twenty-four localities assigned for reforestation, constituting a total area of 361.5 hectares (MoE, 2009). However, even if lots of efforts are invested in the initial phase (planting of seedlings) and follow up contracts are signed with municipalities to ensure regular irrigation and protection of those seedlings from grazing and damage, little is being done in terms of monitoring the success of those

3 The Rural Development and Natural Resources Directorate (RDNRD) at the Ministry of Agriculture is the official body in charge of the forestry sector, including rangelands and protected forests in Lebanon.

reforestation campaigns. Therefore, no data is available to assess the achievement of the project's targets.

In 2003, MoA developed a National Action Plan to Combat Desertification in Lebanon as part of the commitment of Lebanon to the United Nations Convention to Combat Desertification. This plan has briefly tackled the constraints facing the forestry sector and proposed an action plan for the development and conservation of forests in Lebanon.

In 2005, MoA defined the priorities and strategies for forests and forestry until the year 2020, which consist of the following (Asmar, 2005):

- Application of a "natural management" approach through the adaptation of techniques already developed and used over time to face forest challenges and constraints, or even through the introduction of new techniques.
- Integration in a global sustainable development plan through forest plantation on abandoned lands and taking measures for reducing the exploitation of forests and OWL.
- Participation and involvement of civil society groups (NGOs, municipalities, local community …) in the decision making process related to legislations, and in the preparation of the forest policy.
- Evolution of the institutional and economical systems through the implementation of modern multidisciplinary management tools, decentralization, integration and collaboration of all planning authorities, development of economical tools aiming at a better valorisation of the resources and the creation of an independent forest authority.
- Creating a forest research institute for the development of the sector, as well as a forest and natural resources training center.
- Strengthening the cooperation with the different international partners through different forms (Technical Cooperation Projects (TCP) approach developed by FAO, or any other approach involving large budgets).
- Developing and implementing an independent forest authority that will be in charge of all the aspects related to the forestry sector.

The project "Safeguarding and Restoring Lebanon's Woodland Resources" launched in 2009 by UNDP/MoE, aims at complementing the on-the ground investments undertaken through the National Reforestation Program. The project initially planned to 2013 will attempt to remove the institutional, economic and technical barriers to Sustainable Land Management in order to enable the National Reforestation Plan to meet its targets. The immediate objective of the project is to develop a strategy for safeguarding and restoring Lebanon's woodland resources and assist its implementation through capacity building and execution of appropriate SLM policies and practices.

1.1.3.1. Socio-economic scenarios

Two socio-economic scenarios were developed for the possible evolution of forestry in Lebanon. They were proposed as a result of the combination of the different scenarios presented by the MoA (Asmar, 2005) for the forestry sector in Lebanon with Lebanon's main challenges defined in the National Physical Master Plan for the Lebanese Territory (NPMPLT) published by the CDR. The two socio-economic scenarios – scenario A (optimistic/ status quo scenario) and scenario B (home nature pessimistic scenario/ cement bloom) – are presented below; the development of the forestry sector until 2030 is outlined next to each scenario in the right hand side column.

Scenario A	
▪ Low population growth: Population will grow, however at a decreasing rate – average of 0.35%[4] between 2010 and 2030 ▪ GDP grows at an annual average rate of 4.2%[5] ▪ Total urbanized area will slightly increase ▪ Rural migration ▪ Loss of interest in agriculture in some parts of the country ▪ Same standard of living ▪ Improved cooperation between government agencies and authorities ▪ Progressive adoption of forest management policies ▪ Law enforcement ▪ Increased awareness of the recreational value of forests, and participation of civil society in forest protection. ▪ Lack of agro-forestry policies.	This scenario entails forest development over abandoned agricultural lands due to the loss of interest in agriculture. With regard to current practices within rural areas (unsustainable relationships), expected rural migration under this scenario might benefit forest stands as pressure (illegal logging, over grazing/ undergrazing, unsustainable harvesting, collection of medicinal and aromatic plants) on existing forests will be reduced. Non-wood forest products resulting from agro-forestry products (such as pine nuts, carob pods and honey…) might be negatively affected due to the lack of labor, open market strategies and absence of agro-forestry policies. Law enforcement and the increased awareness of the recreational value of forests will lead to a better interest in eco-tourism and nature-based activities, as well as in the value and associated services such as landscape, biodiversity. The risk from forest fires will probably decrease with the adoption of improved and innovative integrated management practices (improved fire fighting techniques, pre- and post-fire management, sustainable grazing within forest areas…)
Scenario B	
▪ High population growth - Population will grow at a modest increasing rate with an average of 0.96%[6] between 2010 and 2030 ▪ Considerable GDP growth - GDP is assumed to grow at an annual average rate of 8.6% between 2010 and 2030[7] ▪ Total urbanized area will increase with population, growth of 284 km^2 of urbanized	Under this scenario, an increase in forest fragmentation is expected due to urban sprawl. Degradation of forest resources will result from an increase in the demand for fuel wood. The potential lack of new personnel (guards, technicians and engineers) might lead to Inappropriate management of forest resources.

4 This an average of the population growth rate in a **low-fertility scenario** as projected in the World Population Prospects: The 2008 Revision (UN, 2009).

5 This is an average of the actual GDP growth rate, at constant 1990 prices, between 2000 and 2004 (IMF, 2009).

6 This an average of the population growth rate in a **high-fertility scenario** as projected in the World Population Prospects: The 2008 Revision (UN, 2009).

7 An assumption, whereby the annual average GDP growth rate would grow by double the IMF-projected average annual growth rate of 4.3%, for the period between 2010 and 2014 (IMF, 2009).

areas ▪ Urbanization of some rural areas ▪ Higher standards of living ~ 2.4 times higher ▪ Increase in intensive agricultural production and development of new agricultural fields at the expense of forests and OWL ▪ Increased demand on fuel wood ▪ Absence of land-use planning at a regional and local level ▪ Little investment in human resources dedicated to the forestry sector. ▪ Lack of awareness of recreational and other values of forests.	Soil degradation, desertification, loss of biodiversity and a severe decrease in land's productivity will result from unsustainable practices such as intensive agricultural production, absence of land use planning, urbanization of rural areas… Due to the loss of interest in the forestry sector, forest fires are expected to increase, and pests and insects will outbreak. The loss of economic value of existing forests (non-wood forest products) will probably result from the lack of awareness of the value of forests and the lack of labor.

1.1.3.2. Climatic Scenarios

The IPCC fourth assessment report (2007) forecasts for the Mediterranean region a number of assumptions that are very likely to be prevailing within the coming century. In particular and with relevance to the forestry sector:

- The warming is likely to be largest in summer, with an important decrease in annual precipitation as well as in the total number of rainy days, which will have important repercussions on the drought period;
- The risk of summer drought will be increased, and it is estimated that by 2080-2098 almost one year out of two would be considered as dry;
- The average temperature in the Middle East region will increase by 1-2 °C by 2030-2050, with expected maximum warming up to 2.7- 6.5°C in summer and 1.7 and 4.6°C in winter, and this increase in temperature would lead to increased evaporation that will most likely outweigh any projected slight increase in precipitation. Consequently the higher evaporation rates would cause soil degradation in wide areas of the region.
- Under the A1B scenario (IPCC, 2007), the annual mean warming from the period 1980 - 1999 to 2080 - 2099 varies from 2.2°C to 5.1°C in the Mediterranean region; and the annual area mean change in precipitation from 1980 - 1999 to 2080 - 2099 varies from –4 to –27% in the Mediterranean region (up to 53% in summer and spring), mostly occurring in summer (with a decrease in mean precipitation in other seasons). This decline is expected to result in a considerable decrease in water availability, especially on the southern shore of the Mediterranean.

In Lebanon, the simulations of climatic parameters have forecasted the following on an annual average basis, in relation to the present climate (2000-2010): by 2040 temperatures will increase from around 0.8°C on the coast to 1.8°C in the mainland, and by 2090 they will be 3.5°C to 5°C higher. Comparison with the historical temperature (LMS record from the early 20th century) indicates that the expected warming has no precedent. Rainfall is also projected to decrease by 10-20% by 2040 and by 25-45% by the year 2090, compared to the present.

1.1.4. Vulnerability Assessment

1.1.4.1. Sensitivity to Climatic Factors

Natural ecosystems in Lebanon and particularly forests are under various pressures most of which are landscape and habitat fragmentation, changes in land use and land tenure conflicts, unorganized urban sprawl, forest fires, pest outbreaks encroachment of cultivated lands and unsustainable practices such as logging, over and undergrazing, and the massive collection of medicinal and aromatic plants. Many species have either disappeared or are endangered because of the different threats on their habitats (Asmar, 2005; AFDC, 2007).

Those threats and in particular landscape fragmentation, have increased vulnerability of natural patches to various pressures and are seriously challenging their resilience (adaptive capacity). In view of existing pressure on natural ecosystems (whether forested or non- forested) future expected climate change will mainly exacerbate their consequences. Some of the major threats on terrestrial biodiversity can be summarized as follows:

Pests and diseases

Lebanon has witnessed a proliferation of forest pests over the past years that have caused extensive damage to several forests. The most serious and recent infestation was by the pine processionary moth that infested pine forests, and the *Cephalcia tannourinensis*, the Cedar web-spinning sawfly that infested and devastated cedar forests in Tannourine and Hadath El Jebbe (one of the largest cedar forests in Lebanon). Table 1-3 below presents a tentative list of the most harmful pests that have affected several forests in Lebanon.

Table 1-3 Most common pests affecting Lebanese forests

FOREST TYPE	TREE LATIN NAME	PESTS AND INSECTS
Stone pine	Pinus pinea	*Emobius gigas, Ernobius sp., Chalcophora detrita, Phytocecia sp., Pitophtorus pubescens, Tomicus destruens, Rhyacionia buoliana*
Aleppo and brutia pine	Pinus halepensis, Pinus brutia	*Thaumetopoea pityocampa; Thaumetopoea wilkinsoni, Tomicus destruens*
Cedar of Lebanon	Cedrus libani	*Cephalcia tannourinensis, Dichelia cedricola, Cedrobium laportei, Cinara cedri, Thaumetopoea libanotica, Ernobius libanesis, Dasineura cedri, Megastigmus schimitscheki, Phloeosinus cedri*
Oak	Quercus spp.	*Lymantria dispar, the processionary moth: Thaumetopoea processionae, Erigaster philipps, Cerambyx cerdo*
Pistacia	Pistachia palaestinia	*Thaumetopoea solitaria*

Source: Abdo et al.; 2008; Abou-Jawdah et al., 2008; Personal communication Dr. Nabil Nemer

Forest fires

Forest fires constitute a serious threat on the vegetation cover and influence the decline of Lebanese forests. The frequency and intensity of these fires are a real threat to the sustainability of the forest ecosystems. They usually occur at the end of summer and are followed a few weeks later by heavy showers of rain, which cause severe soil erosion. Forest fire prone areas in Lebanon are usually near urban complexes and below an altitude of 1,200 m. They encompass three main forest types: broadleaved forests (mainly *Quercus spp*.), *P. pinea* and *P. brutia* pine forests (Masri et al., 2006). Figure 1-4 shows the burnt forest area for different years between 1998 and 2007. According to the MoE's forest fires database, 129 fires occurred in 2004 resulting in 585 ha of burned forest areas (MoE, 2007). It has been stated that 5.6% of forests are at high risk of fires, and 25% are at medium risk (AFDC, 2007). The neglect and the lack of management of forests and other wooded lands play the main role in forest fire occurrence. Furthermore, the general public through its lifestyle or livelihood activities represents an important initiator of forest fires, mainly due to the lack of understanding of the importance and value of forests and of the negative impacts of fire (AFDC, 2007).

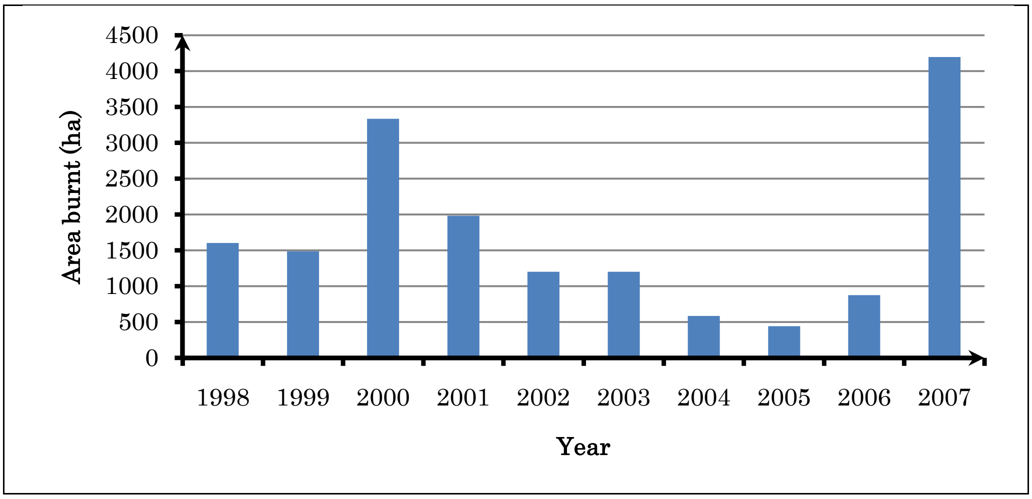

Figure 1-4 **Forest burnt area in hectares per year**

Source: (MoE/LEDO, 2001; AFDC, 2007; MoE, 2007)

Ecosystem fragmentation and land use changes

Urban expansion and road network development, human intervention by logging and overgrazing activities are the serious causes behind biodiversity depletion and ecosystem fragmentation in Lebanon. Forests have been broken into isolated small pieces that are more susceptible to external disturbances than larger ones. The number of forest patches on the eastern flank of Mount Lebanon has increased from 131 to 730 patches between 1965 and 1998. With the disappearance of the forest cover, rock outcrops have appeared within patches due to soil erosion. Almost 50 percent of the total forest cover has been lost in 33 years, mainly affecting juniper stands (Jomaa et al., 2007). Figure 1-5 shows the severe forest changes between 1965 and 1998 and Figure 1-6 shows the forest fire risk map.

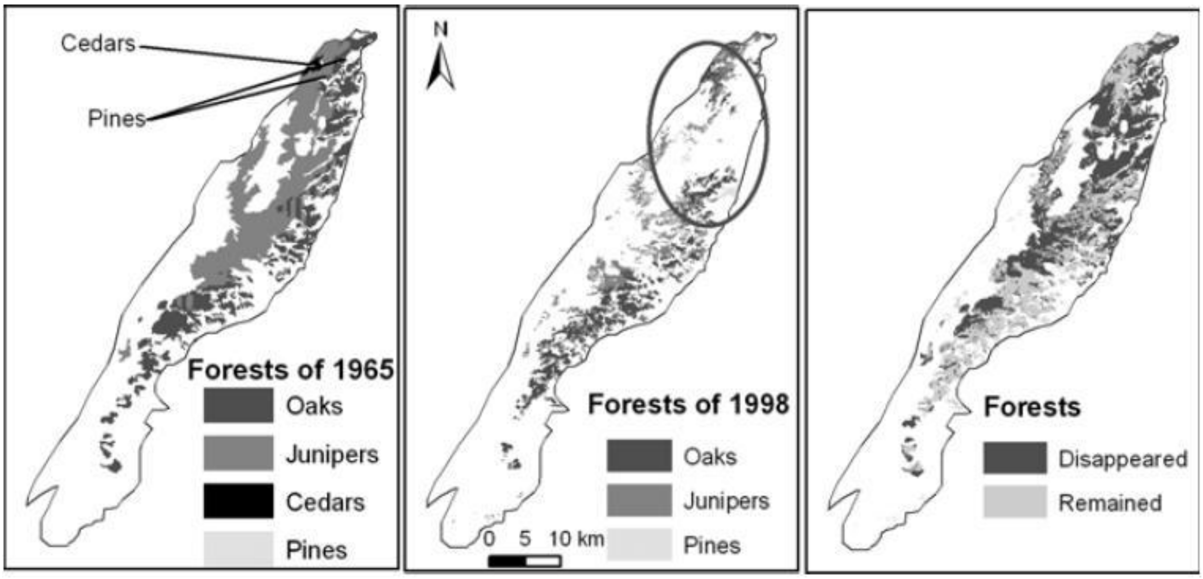

Figure 1-5 **Spatial forest changes on the eastern flank of Mount Lebanon between 1965 and 1998**

Source: Jomaa. et al., 2007

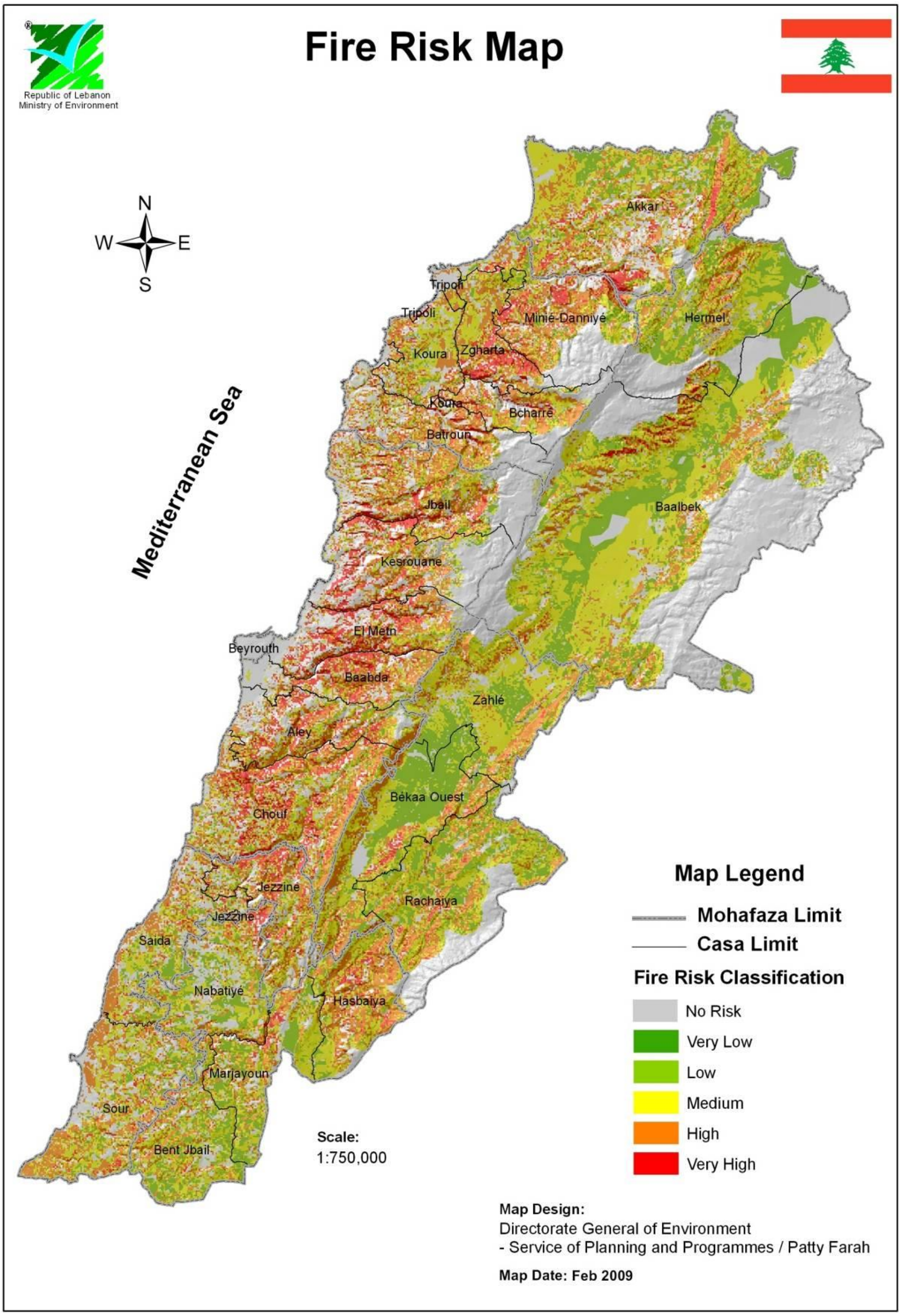

Figure 1-6 Forest risk map 2003

Quarries

Between 1996 and 2005, the number of quarries increased from 711 to 1,278 with a simultaneous increase of quarried land from 2,875 to 195,283 ha. The interpretation of Satellite imagery confirms that in 2005, 25% of existing quarries developed within forested land (forest and OWL) (Darwish et al, 2008).

While 32.5 % of quarries were concentrated in Mount Lebanon before 1989, more and more exploitations were expanding in 2005 towards the North (15.5%) and the South of Lebanon (16 %), and notably towards the Bekaa and the Anti Lebanon Mountain chain (44 %). Quarrying operations are characterized by significant environmental impacts occurring both during operation and post closure phases (Darwish et al. 2010). The majority of quarries in Lebanon followed the rapid urban expansion and were developed with no consideration for their environmental impact, thus causing the destruction of vegetation and important natural habitats, the permanent loss of biodiversity and natural resources, negative impacts on soil stability, and many others (AFDC, 2007).

Grazing (over and undergrazing)

Grazing is one of the most controversial forest uses in Lebanon as it lacks organization and sustainable management. Nevertheless, the decline of grazing activities during the past decades has favored uncontrolled development of forest understory which in turn has resulted in an increased fire risk on forests. The conservative policies (Law 558/1997: Forest code) aggravated the situation as grazing has been prohibited in forested areas, which increased the overgrazing pressure on OWL.

1.1.4.2. Adaptive Capacity

Species migration as a response to climate change is not "new". Analysis of pollen deposits in sediments as well as vegetation macrorests (such as charcoal or imprints, e.g., leaves, cones...), have shown pronounced and sometimes rapid response (sometimes in less than 20 years) of terrestrial vegetation to past climatic changes, with sudden collapse of a number of species and the rapid expansion of others. The ability of tree species to spread after changes in environmental conditions have been evaluated for European forest species but a number of authors (Tinner & Lotter, 2001) believe that species migration may not be fast enough to cover dispersal requirements under the predicted rate of climate change, in spite of the paleobotanical indications of rapid migration speed (>100 m/yr) for several tree genera. On the other hand, a number of authors highlight the fact that future climate change projections on species range shifts and/ or extinction result from over-simplified species-based models and, therefore, they should be interpreted with care.

Analyses of past climate changes also provide valuable information about the ability demonstrated by certain species to persist in situ under adverse and unpredictable conditions. This seems to be the case of plant species adapted to extreme environments, such as the Mediterranean climate. Studies from the Mediterranean region show that the current tree flora is made up of very resilient old taxa that have already experienced many abrupt and intense climate changes in the past (Petit et al, 2008; Hajar et al. 2008), being able to maintain quite stable populations through periods where climate conditions have changed.

Mediterranean ecosystems are among the most heavily utilized by man and for the longest periods of time. As a result, they are frequently severely impacted. Because of these anthropogenic perturbations as well as strong ecological constraints like long summer drought, Mediterranean-type ecosystems are predicted to be especially responsive to management practices and environmental conditions. The interaction of human disturbance and environmental changes will affect vegetation boundaries, water yield and stand productivity.

The resilience of a forest ecosystem to changing environmental conditions is determined by its biological and ecological resources, in particular:

- The diversity of the species, including micro-organisms;

- The genetic variability within species (i.e., the diversity of genetic traits within populations of species);
- The regional pool of species and ecosystems.

Resilience is also influenced by the size of forest ecosystems (generally, the larger and less fragmented, the better), and by the condition and character of the surrounding landscape.

Resilience to Forest Fires

The forest sector will have to face the impact of increased frequency of fire events due to increased drought periods and the replacement of forest stands with fire prone shrub communities. Forest fires are part of the natural disturbance of the dynamics of Mediterranean vegetation. However, it is rather difficult to understand and/or characterize natural forest fire regimes in Lebanon, and to determine whether fire or any other natural or anthropogenic disturbance acted as the major selective force in the environmental adaptation of forests: *Pinus halepensis* stands can be considered as rather very fire tolerant ecosystems (Masri et al. 2006); this could be explained by an adaptation of the species' reproductive features by a self seed delaying technique described as serotony (Ne'eman et al., 2004). Similarly, Arbutus unedo's behave as fire tolerant species which could be explained by their resprouting ability after fires or intensive grazing (Regato, 2008). *Quercus calliprinos* has also been noted by Masri et al. (2006) as a fire tolerant species.

However, the increased frequency of forest fires and higher periodicity with repetition of fire events in consecutive years might seriously affect the reproductive ability of stands. This is particularly true in the case of *Pinus pinea* stands and *Pinus halepensis*, whenever fire events occur during the maturation period of cones. High mountain forest stands (*Cedrus libani, Abies cilicica and Juniperus excelsa*) are considered little vulnerable to fire occurrence (humid bioclimates). However, as most *Pinus halepensis* stands are on sloping lands and usually develop dense understory, their vulnerability to fire has been considered as moderate potentially tending to high with respect to future climate change, and inversely their potential resilience to fire events, which varies from low to Moderate. The *Juniperus* stands are already very vulnerable stands because of various pressures occurring in their habitats (drought, overgrazing), and consequently any shift in bioclimatic level might seriously jeopardize the ability of the individuals to face any eventual fire event.

Ability to shift upward or northward

Upward shifting of the life zone belts is considered as an adaptation mechanism of forests; for example, the *Pinus halepensis* in southern France is expected to shift 200 m upward (Vennetier et al., 2005) and *Fagus sylvatica* by ca. 70m upward by 2100. This upward shift should be interpreted with care as sometimes, as in the case of alpine pine in northern Europe (Walther et al., 2002), this dynamic was rather the result of a recolonization potential for pine trees over abandoned pasture lands. The use of tree lines as indicators of climate change must also be approached with care: although tree lines are considered to be thermally controlled, historical and biotic factors can confound the interpretations of climate change effects on the upslope spreading of trees, apparently strengthening or minimizing the expected impacts of climate change (Cairns et al., 2004). Besides, it should be noted that current species distribution ranges may be significantly different from the potential species' climate envelope. This may imply that a number of species may have larger margins for in-situ adaptation to climate change before reaching the migration threshold.

Migration capability is dependent on each species' seed production and dispersal strategies. Nevertheless, predicting the distance that seeds can travel depends on a great variety of processes

(Higgings et al., 2003). The ability of forest stands in Lebanon to move upwards or northwards was not assessed in the scientific literature at the exception of Hajar et al. (2010) who modeled the potential future distribution of Cedars forests in Lebanon in response to climate change, and who concluded that existing Cedar forests are seriously threatened by future changes as most of existing stands are already present at the mountain peak line and will face impossible challenge moving upwards at the exception of the Bcharre forest. Their migration northward is also seriously challenged by the important fragmentation of forests and natural habitats in Lebanon.

Resilience to pest attacks

Increased levels of CO_2 in the atmosphere prompt an increase in the C/N balance of plant tissues, which in turn results in a lower food quality for many defoliating insects. Some insects respond by increasing the level of leaf consumption and consequently the damage to the tree, whereas others show higher mortality and lower performance. An increase in temperature may alter the mechanism by which the insects adjust their cycles to the local climate (diapause), resulting in faster development and a higher feeding rate – a technique to overcome some adverse effects of climate change (Battisti, 2004). This has already been witnessed in Lebanon with the attack of Cedar stands in Tannourine forest by *Cephalcia tannourinensis*, an outbreak that has been closely correlated to the length of the snow cover period over the last decade (Nemer 2004). While pests on Cedar forests have been studied (Nemer 2004), little is known about the pest attacks on junipers and firs.

Table 1-4 and Table 1-5 present a comparative assessment of the adaptive capacity of different forest types in Lebanon as a combination of several criteria such as the impact of climate variability, their socio economic importance and the resources needed to adapt to climate change.

Table 1-4 Evaluation of the contribution of the different criteria in the assessment of the adaptive capacity of forest ecosystems

	FOREST TYPE					
Criteria	Laurifoliar sclerophyll forests (Quercus calliprinos; Ceratonia siliqua; Pistacia lentiscus)	Mediterranean deciduous forests (Q. infectoria, Q. cerris var. pseudo-cerris…)	Sub-Mediterranean deciduous forests (Ostrya carpinifolia & Fraxinus ornus)	Lower and middle zone coniferous forests (Pinus halepensis and Pinus brutia; Pinus pinea; Cupressus sempervirens)	Upper zone coniferous forests (*Cedrus libani; Abies cilicica*)	High mountain formations (*Juniperus excelsa*)
Impacts from climate variations	1	2	3	2	3	3
Socio-economic importance (contribution to GDP, population affected)	2	2	1	3	3	3
Resources needed to adapt with climate change	2	2	3	2	3	3
Total	5	6	7	7	9	9

Table 1-5 Comparison matrix of resilience to climate change impacts estimated with relevance to current situation and expected future situation.

FOREST TYPE	NATURAL ADAPTIVE CAPACITY				
	RESILIENCE TO FOREST FIRES	ABILITY TO MIGRATE UPWARD/ NORTHWARD	RESILIENCE TO PEST ATTACKS RELEVANT TO CC	RESILIENCE TO OTHER IMPACTS (DIE BACK, INVASIVE SPECIES....)	OVERALL RESILIENCE TO IMPACTS OF CLIMATE CHANGE
Pinus halepensis/ P. brutia	Moderate (2)	High (3)	Low (1)	High (3)	High (9)
Quercus calliprinos	High (3)	High (3)	High (3)	High (3)	High (12)
Pinus pinea	Low (1)	Moderate (2)	Moderate (2)	Moderate (2)	Moderate (7)
Cedrus libani	Moderate (2)	Low (1)	low (1)	Moderate (2)	Low (6)
Abies cilicica	Low (1)	Low (1)	Moderate (2)	Low (1)	Low (5)
Juniperus excelsa	Low (1)	Low (1)	Moderate (2)	Low (1)	Low (5)
Quercus cerris, Fraxinus ormus & Ostrya carpinifolia	High (3)	Low (1)	Low (1)	Low (1)	Low (6)

1.1.4.3. *Vulnerability Assessment Results*

Given the numerous pressures on forests in Lebanon, the sensitivity of these ecosystems to climate change would likely increase. In addition, *Cedrus libani*, *Abies cilicica*, *Quercus cerris* and *Juniperus excelsa* stands have been identified as those having the lowest natural adaptive capacity to current and future trends (Table 1-5).

Considering that the vulnerability of a system is determined by the combination of sensitivity and adaptive capacity, Table 1-6 summarizes these forests' vulnerability to climate change.

Table 1-6 Vulnerable hotspots in the Forestry sector

SYSTEM	SENSITIVITY TO CLIMATE CHANGE	ROOT CAUSE	NATURAL ADAPTIVE CAPACITY		OVERALL VULNERABILITY
Juniperus excelsa	Very high	Absence of effective protection, pressure of overgrazing and the demanding physiological requirements for regeneration	Scenario A	Low	Very High
			Scenario B	Low	Very High
Cedrus libani	High	Forest fragmentation and the location of forest stands on mountain crestline, which limits their ability the migrate upwards	Scenario A	Moderate	High
			Scenario B	Low	High
Abies cilicica	High	Absence of pure fir stands, forest fragmentation and illegal logging	Scenario A	Low	High
			Scenario B	Low	High
Quercus cerris, Fraxinus ornus & Ostrya carpinifolia	High	Limited geographical extent and forest fragmentation	Scenario A	Low	High
			Scenario B	Low	High

1.1.5. *Impact Assessment*

Climate change is rapidly increasing the stress on ecosystems and can exacerbate the effects of other stresses, including from habitat fragmentation, loss and conversion, over-exploitation, invasive alien species, and pollution.

Past changes in the climate and in atmospheric CO_2 levels have already had impacts on natural ecosystems and species, and the IPCC report (2007) states that 10% of species assessed so far will be at an increasingly high risk of extinction for every 1°C rise in global mean temperature. However, even if Mediterranean type ecosystems have shown a natural capacity to adapt (resilience) to past and current changes (0.75°C rise in global mean surface temperature), while other species and ecosystems have already demonstrated adverse response, the expected temperature increase of 2.0 - 7.5°C by 2100 according to the IPCC (2007); 1 - 2 °C by 2040, and 3.5 - 5 °C by 2090 on climate simulations, if no mitigation is effectively implemented, can hardly be assessed in terms of response of natural vegetation. There are indeed a lot of uncertainties about the extent and speed at which climate change will impact biodiversity and ecosystem services, as well as the thresholds of climate change above which ecosystems are irreversibly changed and no longer function in their current form.

As previously stated, and since Mediterranean ecosystems are heterogeneous and complex, there is a strong need to measure and model adequately land surface fluxes, soil moisture and vegetation dynamics for a sufficiently long time, including years characterized by different hydro-meteorological conditions, before being able to properly assess the effects of climate change on forest ecosystems. Montaldo et al. (2008) have demonstrated that vegetation dynamics are strongly influenced by the inter-annual variability of atmospheric forcing, with grass leaf area index changing significantly each spring season according to seasonal rainfall amount.

However, global understanding of potential trends in the response of forest ecosystems to future climate change might be useful in terms of management and conservation adaptation strategies.

1.1.5.1. Selected Impact Indicators

During the past century, species migration upward and northward have already been noted in the Mediterranean basin with respect to their own ecological niche (margin of ecological tolerance), as well as a perturbation of most biological cycles related to pest outbreaks and reproductive cycles (Abou Samra et al., 2009).

The expected modifications in temperature and rainfall are expected to be accompanied by a significant change in bioclimatic levels in Lebanon, particularly the geographical extent of bioclimatic levels in Lebanon, in terms of % of total cover. The Oromediterranean level is projected to have totally disappeared from Lebanon by 2080, while the Arid bioclimatic level is expected to have increased from 5 to 15 % in area (Safi In Abou Samra et al., 2009).

In addition to the stress resulting from the shift in bioclimatic levels and the subsequent need for the species to migrate upward/ northward, other impacts on forests in Lebanon related to climate change could be expected as follows:

- The need for trees to physiologically adapt to pollinators' appearance and adequacy with their blooming period
- Reduced migration and dispersal opportunities with increased landscape fragmentation
- Slower tree growth increments
- Increased forest dieback as a result of temperature rise and reduction of precipitation rate, which might severely limit the gross primary production of forests. During dry periods with extremely low annual rainfall, the respiratory cost is compensated by using the mobile carbohydrates stored in the plants. Once this pool has been used up, the visible symptoms of dieback become evident (Gracia, 2006).
- Invasive species as climate change will certainly increase the invasiveness of alien species. The number of alien species in the Mediterranean region has grown considerably during the last decades, but to date no relevant study has been conducted in Lebanon to assess the risk related to invasive species.
- New pests or increased recrudescence of pest outbreaks

In order to better evaluate the impact of climate change on the forestry sector in Lebanon on the different forest types previously identified as vulnerable systems, Table 1-7 presents a number of indicators adopted.

Table 1-7 Indicators for analysis of climate change impacts on vulnerable systems in forestry

VULNERABLE SYSTEM	INDICATOR	RELEVANCE
Juniperus excelsa	Regeneration rate Population density	The major threat to existing stands is the very low capability of regeneration
Cedrus libani	Overall area Population density	As the existing cedar forests are protected, the challenge will be their ability to colonize new areas beyond protection boundaries.
Abies cilicica	Population density Regeneration rate Age of mature individuals	The capacity of forests to sustain depends on mature individuals and regeneration rate
Quercus cerris, Fraxinus ormus & Ostrya carpinifolia	Overall area Population density	Pure stands are very limited in their geographical extent, therefore monitoring overall area and density will inform on potential impact

1.1.5.2. Impacts due to non-climatic factors

Non climatic factors that may affect forests in Lebanon are mainly socio-economic parameters such as population dynamics, urban development and rural migration, in addition to the non-enforcement of laws and regulations related to the protection of forests, which will directly impact forest development and well being.

As detailed above in the sensitivity section (Sensitivity to Climatic Factors), stress on forests in Lebanon results from various sources, the most important being fragmentation and urban encroachment as well as unsustainable management practices. Consequently, the resilience of forests is seriously challenged by those various pressures exerted on the forestry sector, to which climatic variability will be added and considered as an additional stress to cope with.

The non climatic factors most relevant to vulnerable forests systems are the absence of effective protection on existing forests, illegal lodging and over/undergrazing, as well as forest fragmentation. Their impacts on *Cedrus libani, Abies cilicica Juniperus excelsa* and *Quercus cerris* (fraxinus and ostry…) were evaluated with respect to both scenarios adopted. Those stands, mostly fragmented in Lebanon will face additional challenge in their migration upward or northward in response to climatic pressures.

In addition, non climatic pressures will have differential impacts on forests and are expected to be most pressing on forest types such as *Quercus spp, Pinus spp*. and *Ceratonia siliqua* located in geographical locations most vulnerable to urban development and subsequent fragmentation.

1.1.5.3. Impacts from climatic factors

In order to better assess the expected impact of climate variability on vulnerable forest hot spots in Lebanon, the following approach was adopted:

- Overlaying the derived forest map of Lebanon and the grid map (25 x 25 km), as well as the bioclimatic levels in Lebanon (Figure 1-7)
- Computing for every grid a Q (Emberger) for the current period (1981-2000)
- Computing for every grid a Q' (for the period 2020-2044) and a Q'' (for the period 2080-2098)
- Evaluating the change in bioclimatic levels with respect to the change in Q for each grid
- Assessing for each forest type the margin of tolerance with respect to temperature and rainfall in reference to Table 1-8 adapted from Quezel 1976; Abi Saleh 1978 and M'Hirit, 1999

- Highlighting grids where the shift in bioclimatic level (Table 1-8) will surpass the ecological tolerance of the dominant forest type. In this case, the selected grids show the location of the most vulnerable forest types that would be most impacted by climate change. They represent grids where the shift in bioclimatic level will be from humid or sub-humid to semi-arid, and subsequently areas where the survival of the species will be challenged (Figure 1-7). These grids were obtained by overlaying the grid map over the derived forest map of Lebanon.

Table 1-8 Forest types' tolerance to precipitation variability in Lebanon

BIOCLIMATIC LEVEL	CLIMATE AND VEGETATION LEVEL		
	Precipitation (mm)	**Variability tolerated (%)**	**Dominant forest type**
Semi-arid (Thermomediterranean)	300 <P<600	25-50%	*Pinus halepensis, Quercus calliprinos; Ceratonia siliqua; Pistacia lentiscus*
Subhumid (Eumediterranean)	600<P<800	10-25%	*Pinus pinea ; Pinus brutia ; Quercus calliprinos, Cupressus sempervirens*
Humid (Supramediterranean Mountainous Mediterranean)	P>800	10-25%	*Quercus spp. ; Cedrus libani, Abies cilicica*
Perhumid (Oromediterranean)	P>500	10-25%	*Juniperus excelsa*

Source: adapted from Quezel 1976; Abi Saleh 1978 and M'Hirit, 1999

Table 1-9 Changes in Q (quotient of Emberger) and in bioclimatic levels for the different forest types in Lebanon from 1960 – 1981 to 2080 – 2098.

GRID BOX	DOMINANT FOREST TYPE[8]	AV Q1 1960-1981	BIOCLIMATIC LEVEL	AV Q2 2020-2044	BIOCLIMATIC LEVEL	AV Q3 2080-2098	BIOCLIMATIC LEVEL
148	Quercus spp.	150	Humid	120	Humid	105	Humid
269	Quercus, mixed pinus	165	Humid	150	Humid	90	Sub-humid
380	Querucs, Pinus pinea and Pinus brutia	240	Humid	150	Humid	90	Sub-humid
487	Juniperus, Quercus	90	Sub-humid	90	Sub-humid	60	Sub-humid
837	Juniperus, Cedrus, Abies, Mixed Quercus/ Pinus	75	Sub-humid	75	Sub-humid	45	Semi-arid
951	Juniperus, Quercus and Pinus brutia	345	Perhumid	195	Humid	120	Humid
1001	Quercus, Pinus brutia	225	Humid	120	Humid	90	Sub-humid
1112	Quercus	404	Perhumid	330	Perhumid	180	Humid
1208	Juniperus	75	Sub-humid	49	Semi-arid	34	Semi-arid
1368	Cedrus, mixed Juniperus and Quercus	315	Perhumid	255	Perhumid	135	Humid
1526	Juniperus	240	Humid	195	Humid	120	Humid

8 Highlighted rows (grid box 837 and 1208) indicate the grid boxes where the shift in bioclimatic level is mostly significant for species survival.

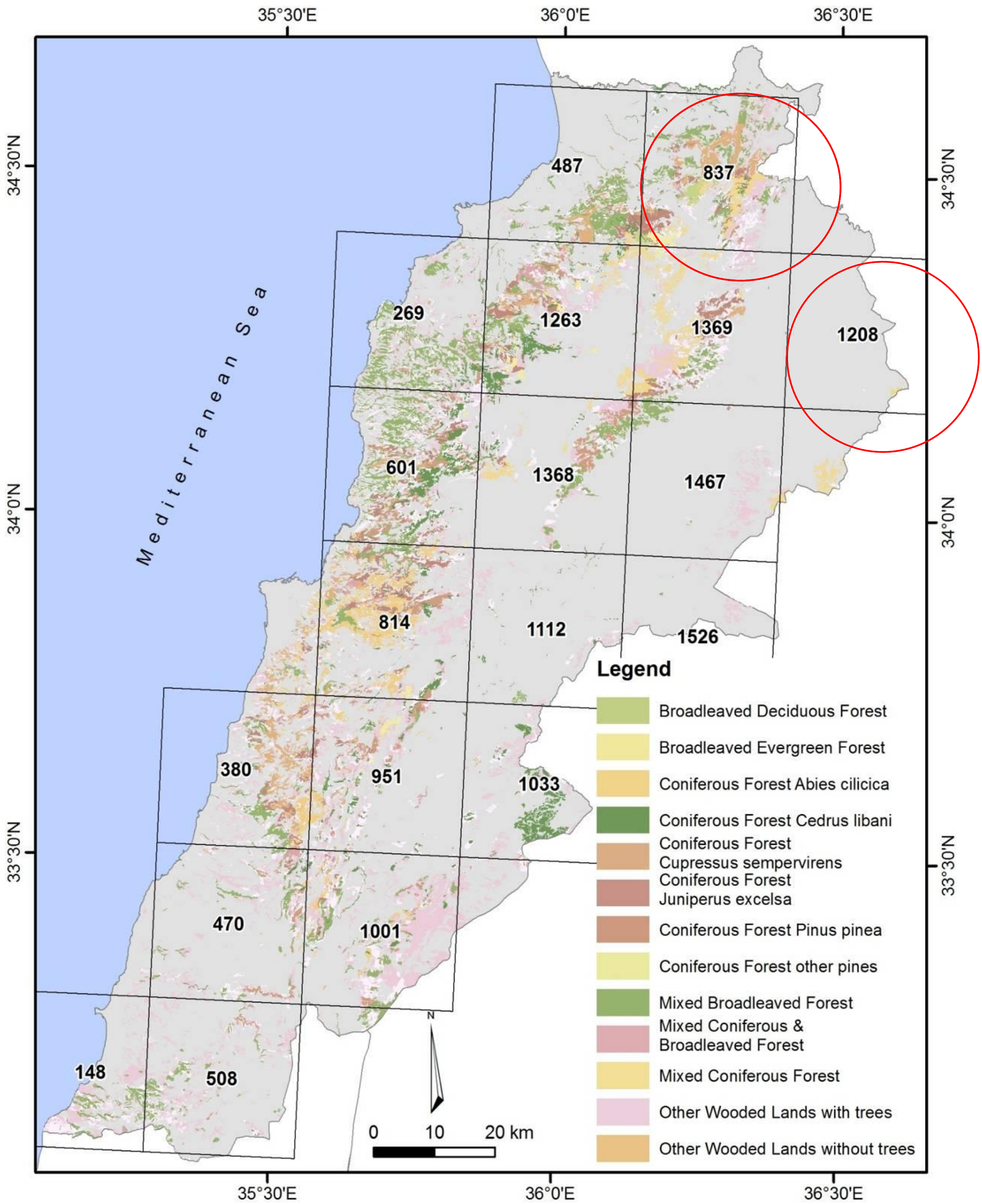

Figure 1-7 Areas (circles) expected to be most impacted by climatic factors

All forests in Lebanon deserve attention and investment; however, based on the above analysis, Figure 1-7 confirms that the most vulnerable forest stands that are expected to be most impacted by climate change are located in north Lebanon (Akkar) and in Hermel areas, where they are expected to experience a shift in bioclimatic level from sub-humid to semi-arid (Table 1-9), which will potentially challenge their survival. Adaptation efforts should therefore target those areas in priority.

Impact of Climate change on nature reserves and protected areas

Climate change impact on forests has been described as the need for species to migrate, especially cedar, fir and juniper; and as the increased risk from pest attacks such as the increased and more frequent outbreak of *Cephalcia tannourinensis*.

As *Cedrus libani* was highlighted as one of the most vulnerable species to climate change in Lebanon and as Tannourine and Arz el Chouf nature reserves are mainly composed of cedar forests, it is expected that both of these nature reserves will severely be impacted by climate change. As for Horsh Ehden, which hosts diverse tree communities, the most important of which are *Cedrus libani*, *Abies cilicica* and *Juniperus Excelsa*, it will also be impacted by climate change, but the presence of other species such as *Malus Trilobata* make it less vulnerable than Tannourine and Horsh Ehden nature reserves.

1.1.5.4. Summary of Impact Assessment Results

The results presented in this chapter are in agreement with the literature (Hajar,L. et al., 2010; Awad, L. 2009) with respect to the vulnerability of *Cedrus libani, Abies cilicica, Juniperus excelsa* stands in Lebanon, and stress the fact that the resilience of other forest types is somehow challenged by the various pressures exerted on natural ecosystems, to which climatic variability will be added and considered as an additional stress to cope with.

The impact assessment is summarized in Table 1-10 and illustrates the eventual impact of non-climatic pressures considered as the potential consequences of any or a combination of situations happening under a defined scenario, as well as the impact of climate change on forest ecosystems illustrated using the indicators identified above.

Those impacts are expected to be more significant under scenario B where they will be complicated by non-climatic and anthropogenic pressures; while under scenario A, with increased awareness of the value of forests and the participation of civil society in forest protection, the impacts would be attenuated.

Table 1-10 Impact of climate change on specific indicators

VULNERABLE HOTSPOTS	INDICATORS	CHANGES IN INDICATORS UNDER NON-CLIMATIC (BUSINESS-AS-USUAL) SCENARIOS		CHANGE IN CLIMATIC FACTORS	CHANGES IN INDICATORS UNDER A CLIMATE CHANGE SCENARIO	OVERALL CHANGE IN INDICATORS	
Juniperus excelsa	Regeneration rate and population density	Scenario A	Moderate increase	Higher temperature and decrease in precipitation will lead to shift in bioclimatic level to semi-arid, which might seriously affect regeneration capability	Moderate decrease	Scenario A	Moderate decrease
		Scenario B	High decrease			Scenario B	High decrease
Cedrus libani	Overall area and population density	Scenario A	Slight increase	Shorter snow cover residence time might enhance pest outbreaks, mainly Cephalcia tannourinensis	Slight decrease	Scenario A	Slight decrease
		Scenario B	Stable			Scenario B	Slight decrease
Abies cilicica	Number of mature individuals and population density	Scenario A	Slight increase	Higher temperature and decrease in precipitation will induce a need for existing stands to shift northwards	Moderate decrease	Scenario A	Slight decrease
		Scenario B	High decrease			Scenario B	High decrease
Quercus cerris, Fraxinus ornus & Ostrya carpinofolia	Overall area and population density	Scenario A	Stable	Higher temperature and decrease in precipitation will induce a need for existing stands to shift northward	Moderate decrease	Scenario A	Slight decrease
		Scenario B	Moderate decrease			Scenario B	Moderate decrease

In conclusion, forests in Lebanon like other sectors will be affected by climate change. However, the climate change impacts are exacerbating factors since the most prevailing risks on forest stands lie in fragmentation and unsustainable practices, and are most seriously challenging the capacity of those already very vulnerable ecosystems to survive and develop.

It is of ultimate importance that forests in general, and not only vulnerable forests with respect to climate change, are protected and sustained in order to increase the resilience of the vulnerable systems and ultimately counter the consequences of the global climate change.

1.2. ADAPTATION MEASURES

Lebanon's biological diversity in species and ecosystems is considered to be under threat from many factors as well as from climate change. Climate change effects on forests will be exacerbated by unsustainable land use changes. Forest ecosystems and especially Mediterranean forests have always adapted to climate variability. The purpose of initiating an oriented strategy for adaptation is to influence the barriers and the time direction of those natural processes, mainly in order to mitigate the socio-economic and environmental cost of degradation which will be exacerbated by climate pressure.

As forest resilience refers to the capacity of a forest to withstand and absorb changes in the environment, adaptation will imply understanding and influencing these conditions to increase forest resilience (Regato, 2008), with the overall perspective of increasing and conserving forest ecosystem services (Millennium Ecosystem Assessment, 2005). Consequently, a number of adaptive forest management strategies (Table 1-12) could be recommended in order to satisfy the below detailed objectives:

1.2.1. Assist the natural resilience of forests:

This adaptation measure should be implemented in order to facilitate In situ conservation of forests with high phenotypic plasticity through the following activities:

- Organize and monitor activities and human interaction within forested ecosystems: grazing, wood collection, non wood forest products.
- Promote and inform on forest ecosystems services.
- Encourage private initiatives promoting forest protection and sustainable use of forest resources.
- Reduce habitat fragmentation through controlled monitoring of urban expansion with respect to forested ecosystems, and through planning of natural corridors.
- Explore and cultivate drought-tolerant ecotypes (when/where needed).
- Adopt an ecosystem/ community philosophy for reforestation activities: tree and understory species should be reintroduced on carefully planned sites.
- Devote and finance intensive studies of species and ecosystems.
- Reduce non-climatic stresses on forests: fragmentation, pollution, habitat loss.

1.2.2. Anticipate future changes:

This adaptation measure should be implemented in order to anticipate biome shifts for species within the margin of their ecological valence and to address reduced growth and eventually extinction of more vulnerable species. This can be done through the following activities:

- Rationalize water use and changes in land use.

- Mainstream biodiversity conservation and ecosystem management in all policy making and development of laws.
- Expand protected areas (in number and surfaces) to include more sensitive habitats and more vegetation / bioclimatic zones.
- Promote protected areas networks though the establishment of natural corridors.
- Increase buffer zones around protected areas to minimize impact of future climate changes.
- Build on the potential of protected areas and forests as carbon sinks to involve into carbon trading.
- Plan reforestation activities including future migration anticipation
- Establish collections of seeds for the main forest tree species and understory species (seed/gene banks).
- Conserve and/or restore biotic dispersal vectors: birds, insects, and migratory species.
- Adopt effective land management practices, such as sustainable grazing, to prevent large reductions in ground cover.
- Promote soil conservation, as soil carbon not only constitutes a carbon sink, but also improves site productivity.
- Implement effective fire management strategies through forest management.
- Encourage close to nature forestry management practices.

1.2.3. Promote landscape scale in the adaptation options:

This adaptation measure should be implemented in order to plan for ex-situ measures for the maintenance of genetic diversity through the following activities:

- Plan for fire smart landscapes: more efficient ways to deal with increased fire intensity.
- Enhance the ability of species to move and migrate within their climatic envelops.
- Emulate long distance dispersal through habitat restoration.
- Diversify habitat type, forest types and land uses at landscape level.
- Increase genetic, species and landscape diversity within the limits of ecological composition (vegetation series)
- Maintain and restore connectivity within the landscape.
- Collect, conserve and disseminate traditional and local knowledge, innovations and practices related to biodiversity conservation

In order to be able to effectively implement the above recommendations, legal and regulatory measures are well needed such as revising the forest code law and existing regulations as well as adopting the national forest program. Moreover, financial and economic measures are required such as the promotion of reforestation and conservation of forest resources, as well as the adoption of economic incentives.

In view of the specific threats relevant to each forest type, Table 1-11 presents adaptation measures for each of the vulnerable subsectors within the forestry sector.

Table 1-11 Appropriate actions to increase resilience of vulnerable ecosystems

VULNERABLE ECOSYSTEMS	MAJOR THREATS/CHALLENGES	RECOMMENDED ACTIONS TO INCREASE RESILIENCE
Juniperus excelsa	▪ Unregulated grazing, hunting, junipers regeneration capabilities, poor forest management	▪ Improve forest conservation economics and social involvement ▪ Adopt and implement forest management plans accounting for regeneration capability, stress reduction, and shifting to sustainable integrated practices (grazing & hunting)
Cedrus libani	▪ Outbreak of Cephalcia tannourinensis and other pests ▪ Sensitivity of Cedars and the specific conditions affecting their regeneration capability. ▪ Urban expansion over mountainous areas	▪ Adopt and implement an integrated action plan for forest health control targeting pest management
Abies cilicica	▪ Illegal logging ▪ Unregulated grazing in forest understory ▪ Urban expansion over mountainous areas ▪ Poor forest management	▪ Improve forest conservation, economics and social involvement ▪ Adopt and implement forest management plans accounting for regeneration capability, stress reduction, and shifting to sustainable integrated practices (grazing & hunting)
Quercus cerris	▪ Forest fragmentation ▪ Land use changes (urban encroachment) ▪ Unregulated grazing in forests understory ▪ Risk of Pest outbreaks	▪ Improve forest conservation, economics and social involvement ▪ Adopt and implement forest management plans accounting for regeneration capability, stress reduction, and shifting to sustainable integrated practices (grazing & hunting)

The cost of vulnerability and adaptation in natural ecosystems is inherently problematic. The Lebanese government spends on nature conservation around 300,000 USD per year, mainly dedicated for the management of nature reserves, while the action plan for protected areas has foreseen a sum of US$ 4,685,000 over 5 years (NAPPA, 2006) to encompass ecological conservation, extension of protected areas, diversification of protected area types as well as awareness, institutional capacity building and ecotourism promotion. This action plan aims to reduce the threat form habitat fragmentation and the vulnerability of ecosystems and species to the pressures of climate change.

This cost, considered as vulnerability and adaptation costs, is underestimated as the adaptation activities adopted to reduce the vulnerability of species and ecosystems should account for different extra actions needed such as land acquisition for corridors and the fluctuation of land prices with time. It should also include the costs of pest management to fight pest infestation resulting from climate change implications on nature reserves in Lebanon.

Table 1-12 below shows the major physical impacts corresponding to the vulnerable hotspots and the proposed adaptation action plan for the Forestry sector. It should be noted that the indicative budget is a rough estimate based on professional judgment, and sometimes reflects the cost of studies that need to be carried out prior to the implementation of the proposed activities. Each of the mentioned activities requires an in-depth assessment to determine its actual cost at the time of planning and implementation.

Table 1-12 Adaptation Action Plan

IMPACT	PROPOSED ADAPTATION STRATEGY	ACTIVITIES	RESPONSIBILITY	PRIORITY (ST/ MT/ LT)	INDICATIVE BUDGET (USD)	SOURCES OF FINANCING/ IMPLEMENTATION PARTNERS
Decrease in the regeneration rate, population rate and overall area for the most vulnerable species identified: Juniperus excelsa Cedrus libani Abies cilicica Quercus cerris Fraxinus ornus, Ostrya carpinifolia	Strengthen the legal and institutional framework to integrate climate change needs	▪ Revise protected areas legislation: To broaden the classification system to account for and orient existing land use practices related to natural resources use, grazing, wood cutting... To include natural parks and protected landscapes To base local classification systems on international systems (e.g., cultural heritage sites…). ▪ Amend the forest code to allow controlled pruning, wood harvesting and grazing as means of conservation in forest ecosystems. ▪ Revise construction law to ensure protection of sensitive ecosystems. ▪ Revise Urban Development Code to require a SEA study on every development plan, which should properly take into consideration the sensitivity of vulnerable ecosystems. ▪ Expand protected areas (in number and areas) to include more sensitive habitats and more vegetation / bioclimatic zones. ▪ Mainstream biodiversity conservation and ecosystem management in policy making and legislation development related to quarrying, construction, water use, education, etc. ▪ Revise relevant legislation to reduce non-climatic stresses on forests: fragmentation, pollution, habitat loss. ▪ Encourage private initiatives promoting forest protection and sustainable use of forest resources. ▪ Reduce habitat fragmentation through controlled monitoring of urban expansion with respect to forested ecosystems, and through planning of natural corridors, especially towards promoting the development of OWL into forested cover. ▪ Initiate the creation of an official forest body as an independent and unique unit with special mandates on forest conservation and sustainable use. This body should coordinate with MoA and MoE.	MoA MoE DGUP OEA Council of Ministers Parliament	ST	USD 300,000	MoE budget GEF EU Neighborhood policy Bi-lateral cooperation
	Integration of climate change and landscape levels planning in local/regional development plans in Lebanon	▪ Higher Council for Urban Planning should endorse urban planning guidelines that require due consideration of climate change and landscape levels in urban planning, including the following requirements: Maintain and restore connectivity within the landscape. Plan for fire smart landscapes, i.e., include easier access to forests with water points; water pipes around and across vulnerable fire spots, fires breaks across vulnerable forest spots, in order to deal more efficiently with increased fire intensity and frequency. ▪ Enhance the ability of species to move and migrate within their climatic envelops. through: Planning the extension of existing protected areas to cover higher altitudes in order to facilitate tree line	MoE MoA CDR HCUP/DGUP OEA	ST	USD 100,000	MoE budget DGUP budget Bi-lateral cooperation

IMPACT	PROPOSED ADAPTATION STRATEGY	ACTIVITIES	RESPONSIBILITY	PRIORITY (ST/ MT/ LT)	INDICATIVE BUDGET (USD)	SOURCES OF FINANCING/ IMPLEMENTATION PARTNERS
		migration Promoting the protection of existing OWL to enable their future development into forest cover Promoting landscape connectivity in terms of natural corridors between forests and OWL. ▪ Emulate long distance dispersal through habitat restoration. ▪ Diversify habitat type, forest types and land uses at landscape level. ▪ Modify existing legislation to increase buffer zones around protected areas and to minimize the impact of future climate change.				
	Strengthen the awareness and education and support research	▪ Increase awareness on ecosystem services and climate change to key target groups such as government agencies, order of engineers and architects, universities (introduction of related courses), schools (revision of curriculum). ▪ Collect, conserve and disseminate traditional and local knowledge, innovations and practices related to biodiversity conservation. ▪ Promote research and implementation of soil conservation, as soil carbon not only constitutes a carbon sink, but also improves site productivity. ▪ Promote and inform on forest ecosystems services.	MoA MoE NGOs CNRS Ministry of Education	ST-MT	1,000,000 to 5,000,000 USD	Technical assistance programs from multi-lateral and bi-lateral agencies

IMPACT	PROPOSED ADAPTATION STRATEGY	ACTIVITIES	RESPONSIBILITY	PRIORITY (ST/ MT/ LT)	INDICATIVE BUDGET (USD)	SOURCES OF FINANCING/ IMPLEMENTATION PARTNERS
	Develop forest management plans	Prepare management plans for the most vulnerable ecosystems to climate change, with due consideration to the following needs: ▪ Implement effective fire management strategies through forest management. ▪ Adopt an ecosystem/ community philosophy for reforestation activities: tree and understory species should be reintroduced on carefully planned sites ▪ Explore and cultivate drought tolerant ecotypes (when needed). ▪ Increase genetic, species and landscape diversity within the limits of ecological composition (vegetation series) ▪ Establish collections of seeds for the main forest tree species and understory species (seed/gene banks). ▪ Establish natural and ecological corridors to promote protected areas networks. ▪ Adopt effective land management practices, such as sustainable grazing, to prevent large reductions in ground cover. ▪ Conserve and/or restore biotic dispersal vectors: birds, insects, and migratory species ▪ Plan reforestation activities including future migration anticipation	MoA MoE	ST	100,000 to 500,000 USD per vulnerable site	MoE budget International agencies/bi-lateral cooperation ESCWA

1.3. RECOMMENDATIONS FOR FURTHER WORK

Recommendations for further work in the forestry sector comprise:

- Improving the collection of climatic data such as rainfall, temperature, wind speed and direction, cloud density through higher resolution geographical networks of meteorological stations for data collection to obtain monthly long term series with high spatial resolution.
- Ensuring proper collection, archiving and accessibility of climatic data (temperature, rainfall, snow fall, wind speed...)
- Refining climate simulation tools to take into consideration elevation and topographic features while downscaling climatic data to Lebanon, which was not possible in the current assessment,
- Developing growth models for different forest types in Lebanon
- Updating the forest map on a scale of 1/20,000 showing distribution per forest type, based on 2009 satellite images
- Improving access to data and information relevant to forestry through creating and maintaining an online portal to resources: website and data sharing.

APPENDIX A

FRA Categories and Definition

CATEGORY	DEFINITION
Forest	Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds *in situ*. It does not include land that is predominantly under agricultural or urban land use.
Other wooded land (OWL)	Land not classified as "Forest", spanning more than 0.5 hectares; with trees higher than 5 meters and a canopy cover of 5-10 percent, or trees able to reach these thresholds *in situ*; or with a combined cover of shrubs, bushes and trees above 10 percent. It does not include land that is predominantly under agricultural or urban land use.
Other land	All land that is not classified as "Forest" or "Other wooded land".
Other land with tree cover (Subordinated to "Other land")	Land classified as "Other land", spanning more than 0.5 hectares with a canopy cover of more than 10 percent of trees able to reach a height of 5 meters at maturity.

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