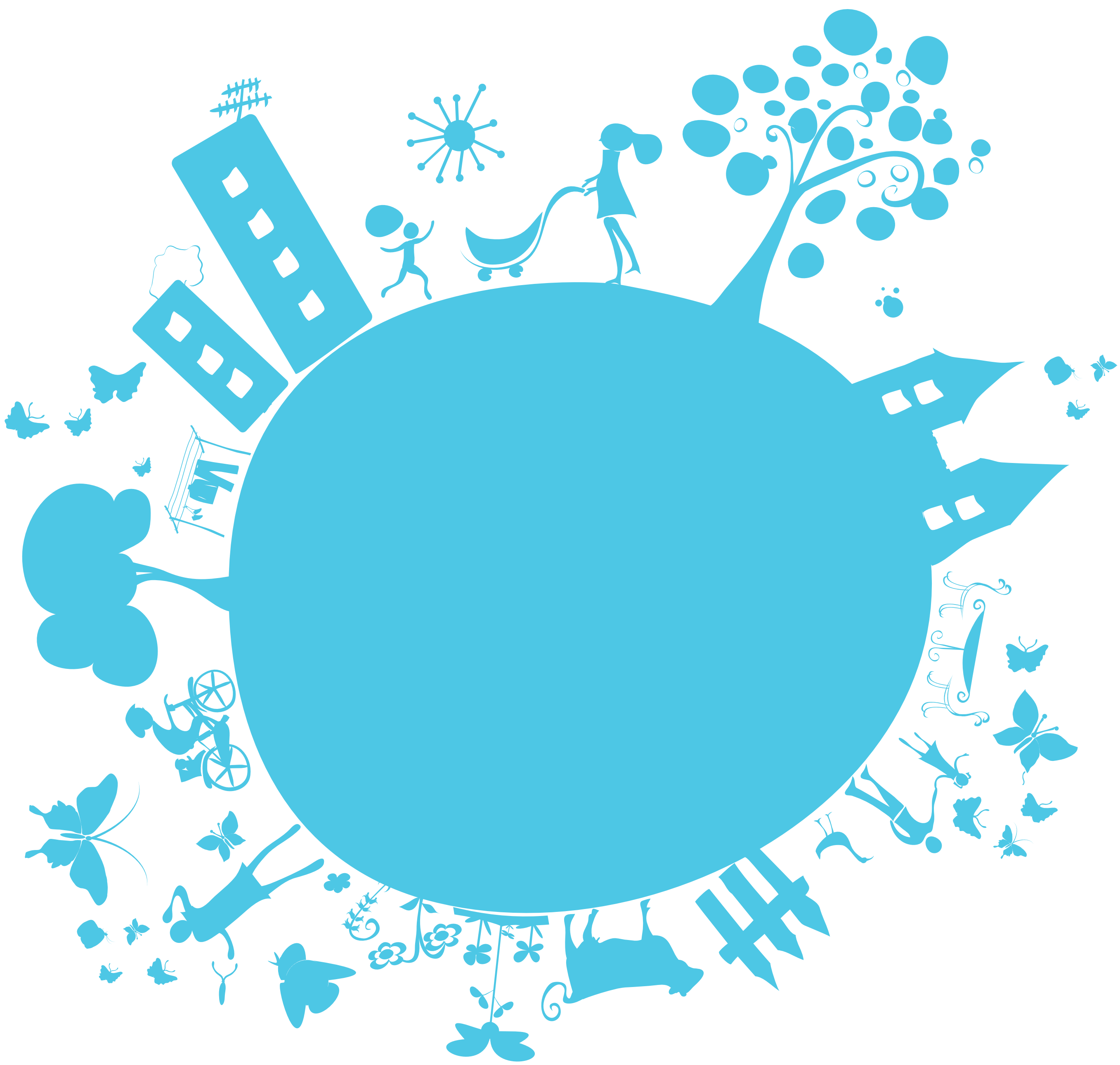
Climate Risks, Vulnerability & Adaptation Assessment



4. Future climate risks

4.1 Future climate risks

This section presents climate model predictions that provide national climatological information and enables the assessment of vulnerability and impacts relating to climate change in Lebanon. Data for the future state of the climate are generated from state-of-the-art, high-resolution Regional Climate Model (RCM) simulations. RCMs dynamically downscale the Global Climate Model (GCM) projections and, due to their increased resolution, achieve more detailed simulation of the regional climate responses and of the representation of surface topography (Laprise, 2008), thus allowing for more refined estimates of future climate extremes and their impacts.

4.1.1 Methodology

The PRECIS (Providing REgional Climates for Impacts Studies) regional climate model, developed at the Hadley Centre and based on the HadCM3 GCM, is applied in a 25 km x 25 km horizontal resolution whereby Eastern Mediterranean and Lebanon particularly are at the centre of the model domain, ensuring optimal dynamical downscaling (Figure 4-1). The driving emissions scenario adopted is A1B, assuming a world with rapid economic growth, a global population that reaches 9 billion in 2050 and then gradually declines, and a quick spread of new and efficient technologies with a balanced emphasis on all energy sources. PRECIS was integrated from 1980 throughout the end of the 21th century and the periods considered were the near (2025-2044) and distant future (2080-2098), assessed as changes from the control simulation period of the recent past/present (1980-2000/2010). For that purpose, meteorological historical data from observations are obtained for the latter period in order to validate the model's results, an exercise that should be taken into account when assessing the future predictions.

The model outputs' key meteorological variables, maximum temperature (T_{max}), minimum temperature (T_{min}), and precipitation (P) are evaluated using measurements of the Lebanon Meteorological Service (LMS). Multi-year daily time-series of these variables have been obtained for the stations of Beirut, Tripoli and Cedars while monthly climatological data for the period 1971-2000 are obtained for Beirut, Tripoli, Zahleh and Daher-el-Baydar (referred to as "Daher" for brevity). The data are checked for continuity and outlying values, and only the time-

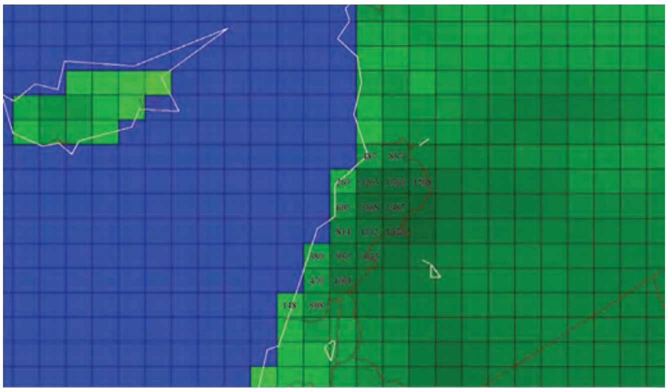


Figure 4-1 Elevation (in m) of the PRECIS model grid-boxes covering Lebanon.

series with complete daily/monthly coverage for several years are used. Accordingly, only the Beirut and Zahleh datasets are used in the model evaluation and output correction for the daily time-series. The Cedars data has large gaps with entire months missing for several years, and only 14 years from 1960 to 1981 are used to construct monthly climatologies. Daher-el-Baydar has only monthly climatological data for the period 1971-2000. Since the scarce data is unsuitable for homogenization, highly correlated neighboring station daily series are used to correct candidate station values, and are therefore applicable only in areas with high station density (Kuglitsch et al., 2009). The provided daily temperature time series could not be corrected due to (1) too short measuring periods, (2) too many missing or non reliable data, and (3) unavailability of highly correlated neighboring time series.

Indices of extremes are also calculated using RclimDex and are expressed as annual occurrence of a parameter exceeding a fixed threshold. They are applied to the observed data for Beirut, as continuous, long-term daily data to satisfy the statistical robustness of the results are available only for this station.

4.1.2 Projections uncertainties and limitations

The model presents several uncertainties, due to the uncertainty from the anthropogenic emissions scenario and the resulting GHG concentrations. The A1B emissions scenario that is used lies in the middle of various emission pathways – such as the more "pessimistic" A2 and the more "optimistic" B1, considered in the Fourth Assessment Report of IPCC (AR4) (Christensen et al., 2007). AR4 also reveals that until the 2040s the global warming associated with this emissions scenario is very similar to the A2 and B1 (up to 1^{o}C) so the choice of A1B instead of other scenarios is not crucial for the projected climate change by this period, which most of this assessment focuses on.

Two additional uncertainties arise from 1) the driving global climate model formulation and accuracy and from 2) the regional climate model's ability to downscale the global model projections. A simple measure of the global models' climate response to a specific perturbation is the equilibrium climate sensitivity, defined as the change in global mean surface temperature that would result from a sustained doubling of atmospheric CO_2 and depends on key physical processes simulated by the models, like water vapour, cloud feedbacks and radiative forcing. The HadCM3 global model that is downscaled here has a climate sensitivity of 3.4°C, very close to the 3.2°C mean value of all the AR4 GCMs (Randall et al., 2007), thus rendering it a representative modeling tool of the earth's climate response (relative to other GCMs).

The RCM's uncertainty that ultimately provides the local climate projections can be quantified by taking an "ensembles" approach by averaging the projections from different models, something that is not possible to achieve in this assessment due to the lack of resources and scarcity of regional climate modeling initiatives in the region. It is envisaged that in the future, more results from RCM simulations that focus on the Eastern Mediterranean and the Middle East can be obtained through cross-national collaborative efforts. By then, the RCM's horizontal resolution will be more refined than the current 25 x 25 km used here, thus allowing for a much more realistic representation of the local topography, which is considered a limitation for contemporary regional climate model projections.

Some grid-boxes in the model fail to catch the real elevation of the selected stations, which results in overestimating or underestimating results. Such biases are common in regional climate models, and although progress is made and the RCM representation of the past climate comes as an improvement to output from the GCMs, horizontal resolution, and subsequently orography, are still limiting factors (among others) in the accurate climate simulation in local scale.

4.1.3 Model Evaluation- Recent Past Changes

The PRECIS output was evaluated with LMS observations mainly for the years from 1980 to 2000 for Beirut, Zahleh, Cedars and Daher-el-Baydar where model data of T_{max}, T_{min} and P are extracted. From these observations, it is evident that all locations exhibit the typical Mediterranean climate with the hot, dry summers from May to October and the wet season in the remaining months, which is reproduced satisfactorily by the model. The main differences are the model underestimation of observed precipitation (especially in the months from October to November) and the slightly higher temperatures arising from the differences in elevation between model and reality. Error! Reference source not found. presetns the climatological (1981-2000 average) annual cycle of T_{max}, T_{min} and P for Beirut as modelled in four PRECIS grid-boxes and observed by LMS. It shows the respective model monthly biases from the LMS observations and the numbers of respective annual average biases.

The long-term daily records measured by LMS in Beirut for the period 1980 to 2000 are used to calculate climatic indices using the RclimDex software, For the recent past (1981-2000) the main outcome is shown in Figure 4-2 and Figure 4-3. In Figure 4-2a the temperature-related indices are presented and they all reveal important warming. The hot "Summer Days", defined as the number of days per year when T_{max} is greater than 30°C (SU30) or 35°C (SU35) and the "Tropical Nights", defined as the number of days per year when T_{min} is greater than 20°C (TR20) or 25°C (TR25), both exhibit a clear upward trend. This faster increase of hot nights versus hot days is confirmed by the large negative trend in the diurnal temperature range (DTR), which the monthly mean difference between T_{max} and T_{min}. In addition, T_{xx}, the absolute extreme of T_{max} within a year also increases sharply from 1981-2000 (Figure 4-2b). The precipitation-related indices in Figure 4-3 (a and b) indicate an overall decrease in total annual rainfall, a decrease in the amount of rain falling in a 5-days period and a large enhancement of the Consecutive Dry Days (CDD index, a measure of the drought conditions), while a simple measure of the daily intensity of rainfall (SDI index) shows no change.

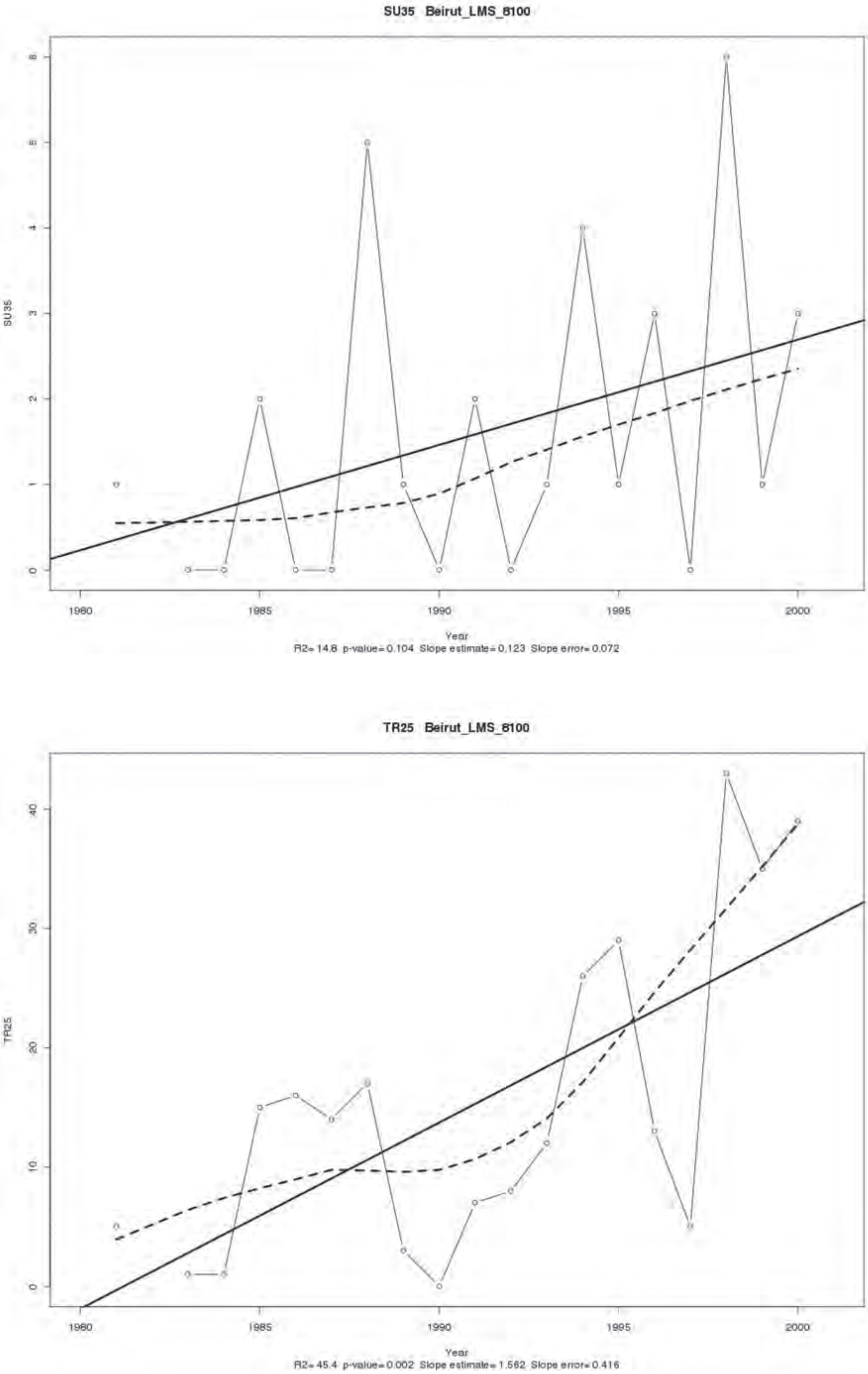
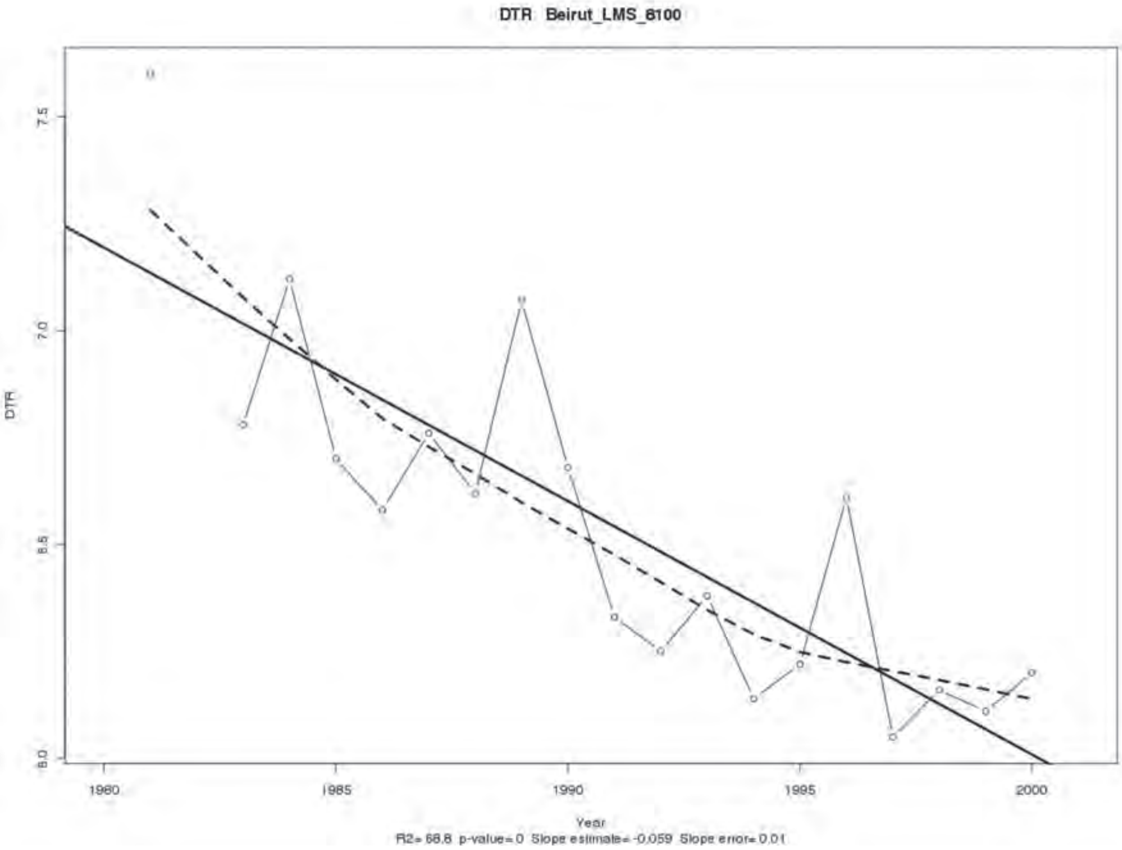


Figure 4-2a Temperature-related indices for Beirut for 1981-2000 derived from RClimDex



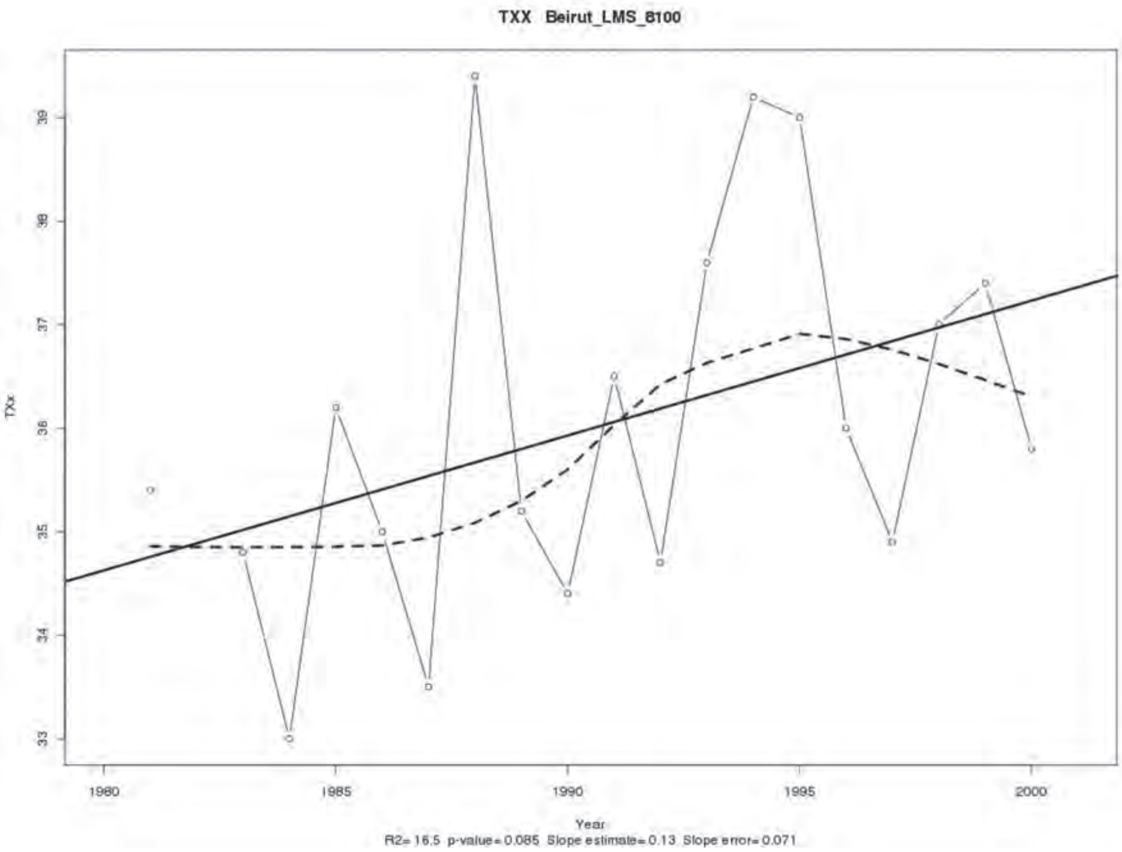
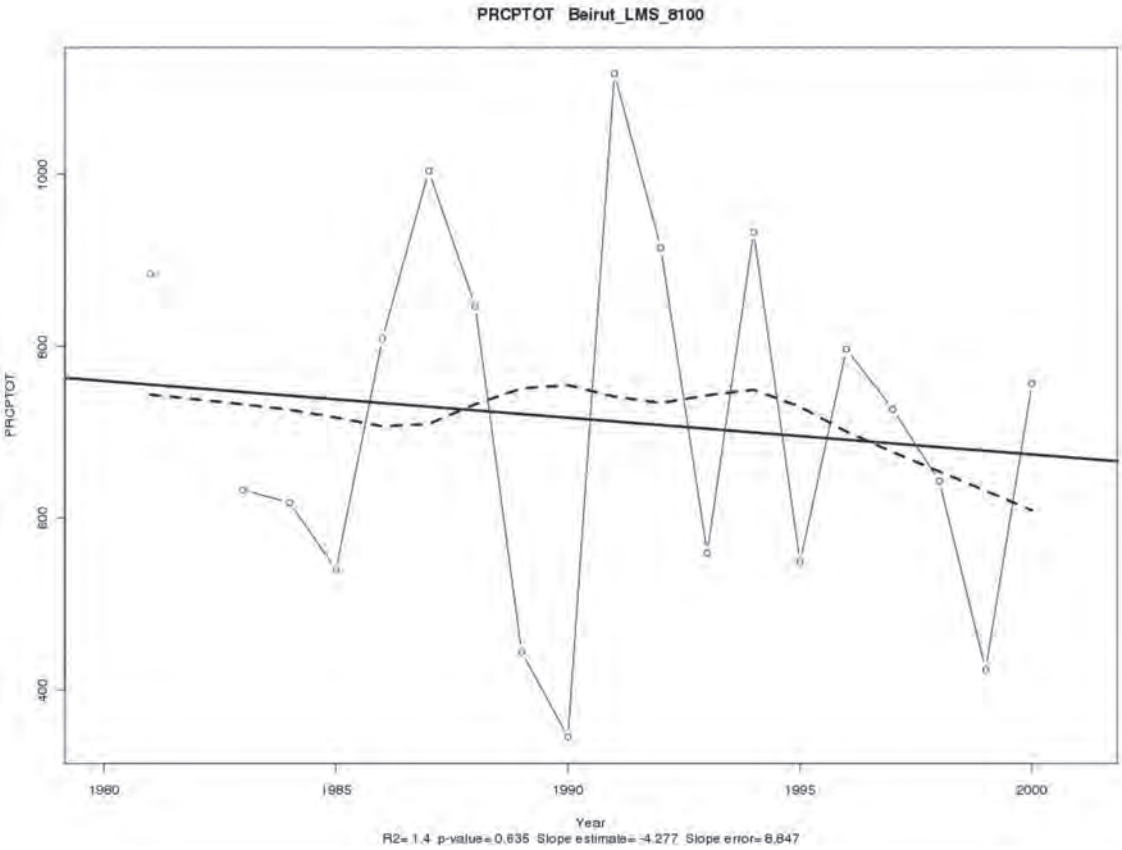


Figure 4-2b Temperature-related indices for Beirut for 1981-2000 derived from RClimDex



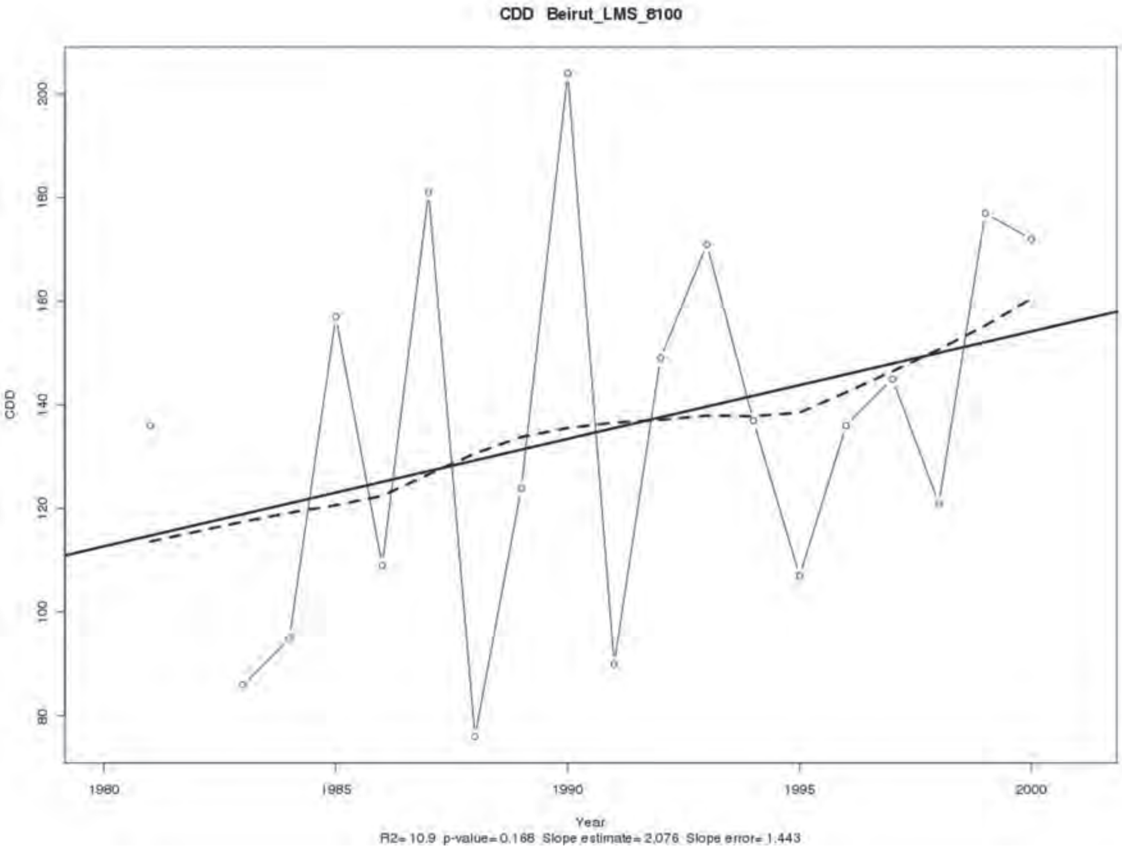
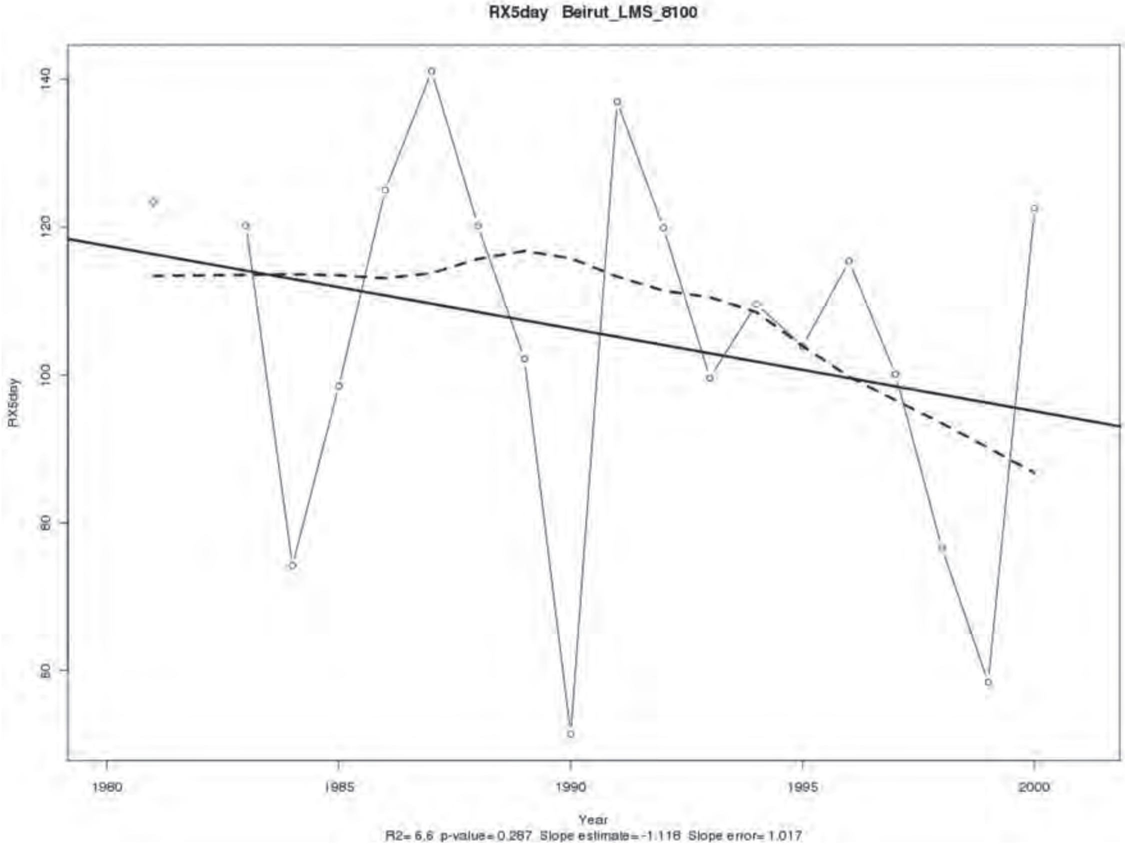


Figure 4-3a Precipitation-related indices for Beirut for 1981-2000 derived from RClimDex



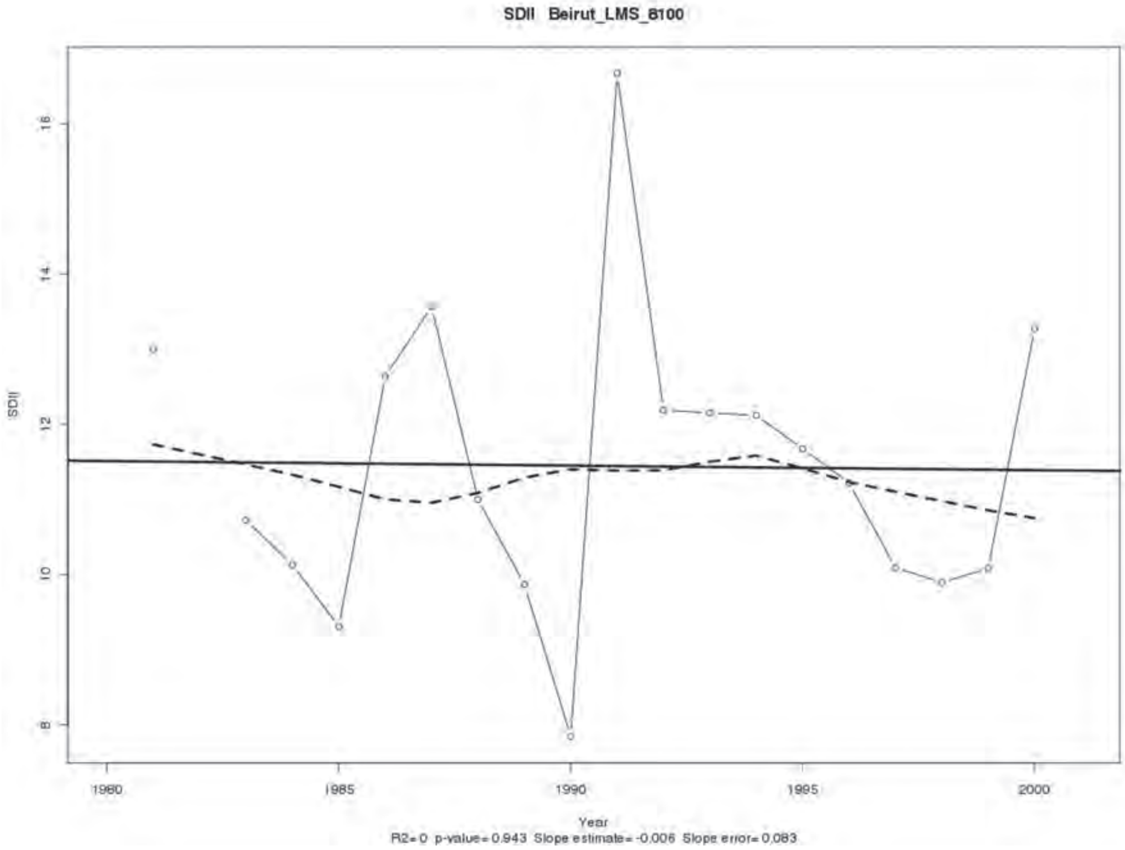


Figure 4-3b Precipitation-related indices for Beirut for 1981-2000 derived from RClimDex

4.1.4 Future Climate Projections

The main results of key climate variables in Lebanon as simulated by PRECIS are presented as changes of the respective periods of the near and distant future compared to the "control" period of the last 20-30 years or the "recent past/ present". Figure 4-4 puts the projected climate change over Lebanon into historical context by looking at observed and modeled annually averaged T_{max} from the beginning of the 20th century until 2100. During the previous century, the observed temperatures fluctuated between 23°C and 25°C without any discernible trend. The PRECIS model temperature (adjusted for a ~ -1.5°C climatological bias from the observed) also looks stable in the recent past; it starts to evidently take off after 2025 and by the end of the 21st century is at around 4°C higher, reaching unprecedented levels.

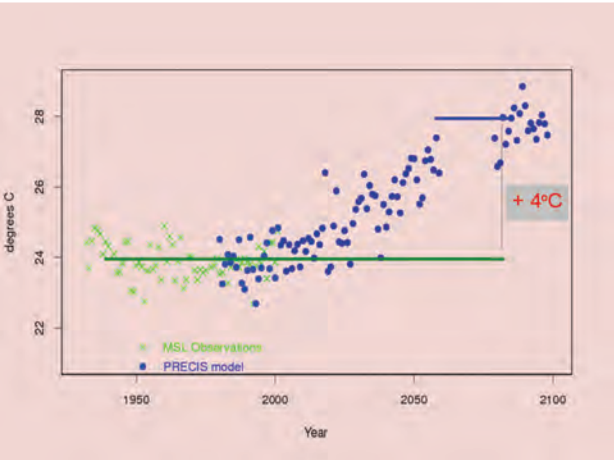


Figure 4-4 Long-term time-series of annual T_{max} over Beirut as observed by LMS and projected by PRECIS (adjusted)

Figure 4-5 to Figure 4-7 present the country-wide modeled changes for the near and distant future of the three key climate variables (The PRECIS data have been adjusted with the climatological bias from the observations). By 2040, maximum temperatures are predicted to increase between 1°C around the coast of Lebanon up to 2°C in the mountainous inland; by 2090 the increases are from 3 to 5°C respectively. Minimum temperatures will evolve similarly, but the end of century increases will not exceed 4°C within the country domain. Significant reductions are projected for rainfall, which will be more severe from the coastal to the inland areas, ranging from -10% to -20% for 2040 and -25% to -45% for 2090.

As for other parameters, the changes in annual average relative humidity are very small in 2040 but reductions up to -10% in the eastern part are projected for the 2080s. Wind speed and cloud fraction are not projected to change significantly in the two future periods studied. Annual average wind speeds in the model do not exceed 4 m/s in the recent past and the future values changes are less than ±0.3 m/s. The cloud cover is modeled to decrease over the Lebanon mainland by about 5%.

In terms of seasonal changes by 2040, temperatures will increase more in summer and precipitation will decrease more in winter, while positive changes are predicted for autumn as it appears in the Walter and Lieth Climate diagrams (Figure 4-8, Figure 4-9 and Figure 4-10). These diagrams are brief summaries of average climatic variables and display monthly averages for temperature and precipitation over a year. When the precipitation curve undercuts the temperature curve, the area in between them is dotted, indicating dry season. When the precipitation curve is above the temperature curve, vertical lines are plotted for each month, indicating moist season (WAZA, 2010). The area shaped under the temperature and precipitation, which represents the warm and dry conditions, shows a progressive increase from 2000 to 2040 and 2090, highlighting the extension of the summer season stress In Lebanon. The PRECIS data have been adjusted with the climatological bias from the observations.

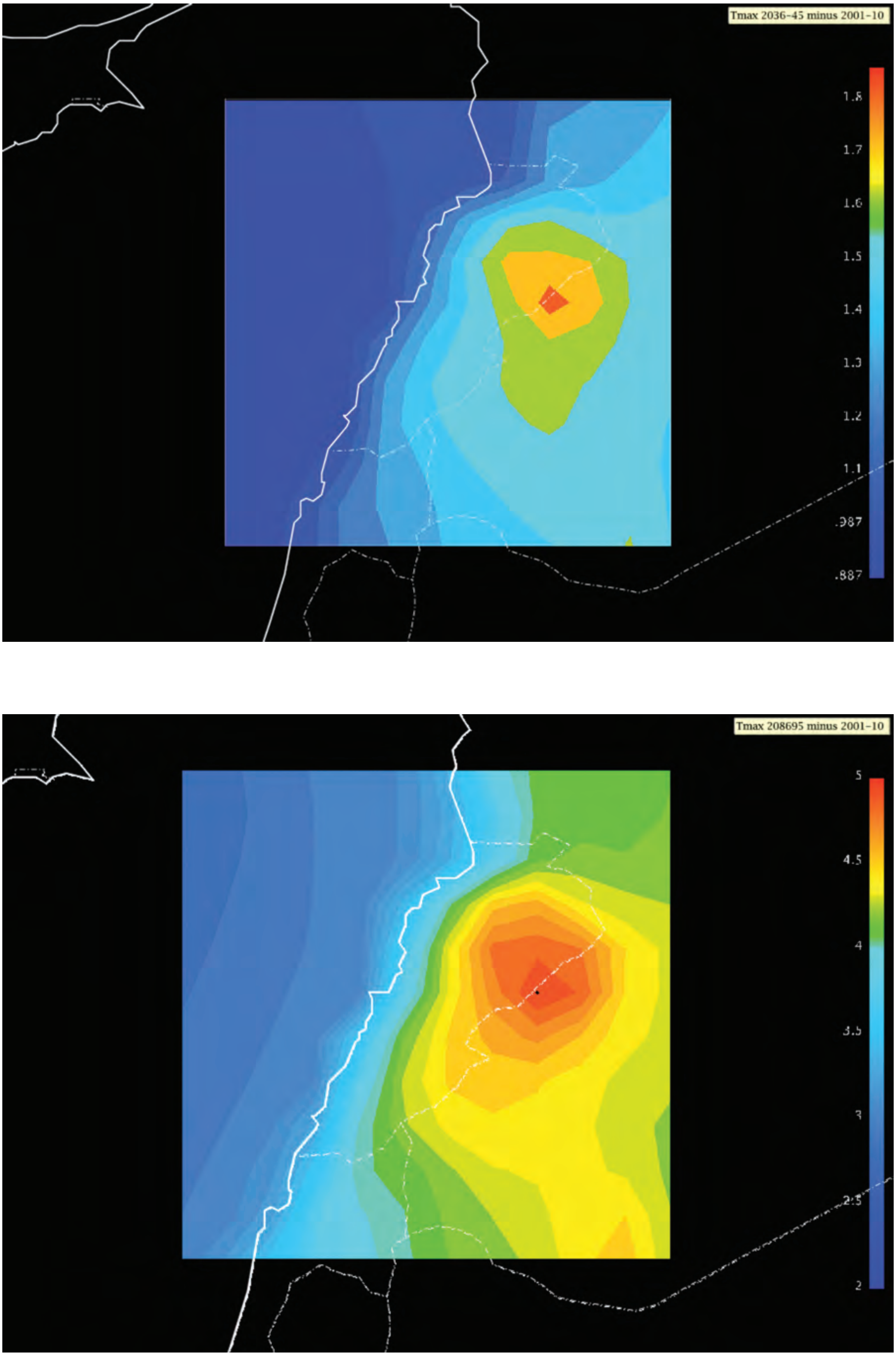
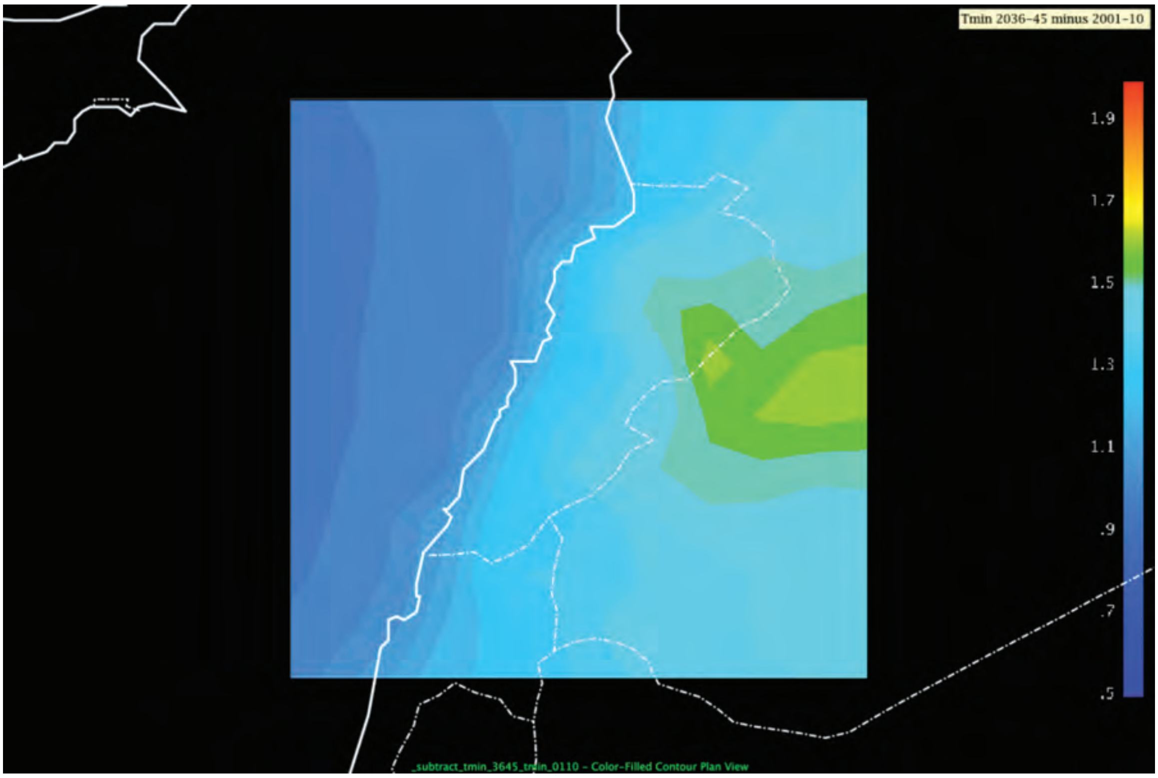


Figure 4-5 PRECIS projections of annual T_{max} over Lebanon as changes from the 2001-2010 average for 2036-45 (Top) and 2086-95 (Bottom)



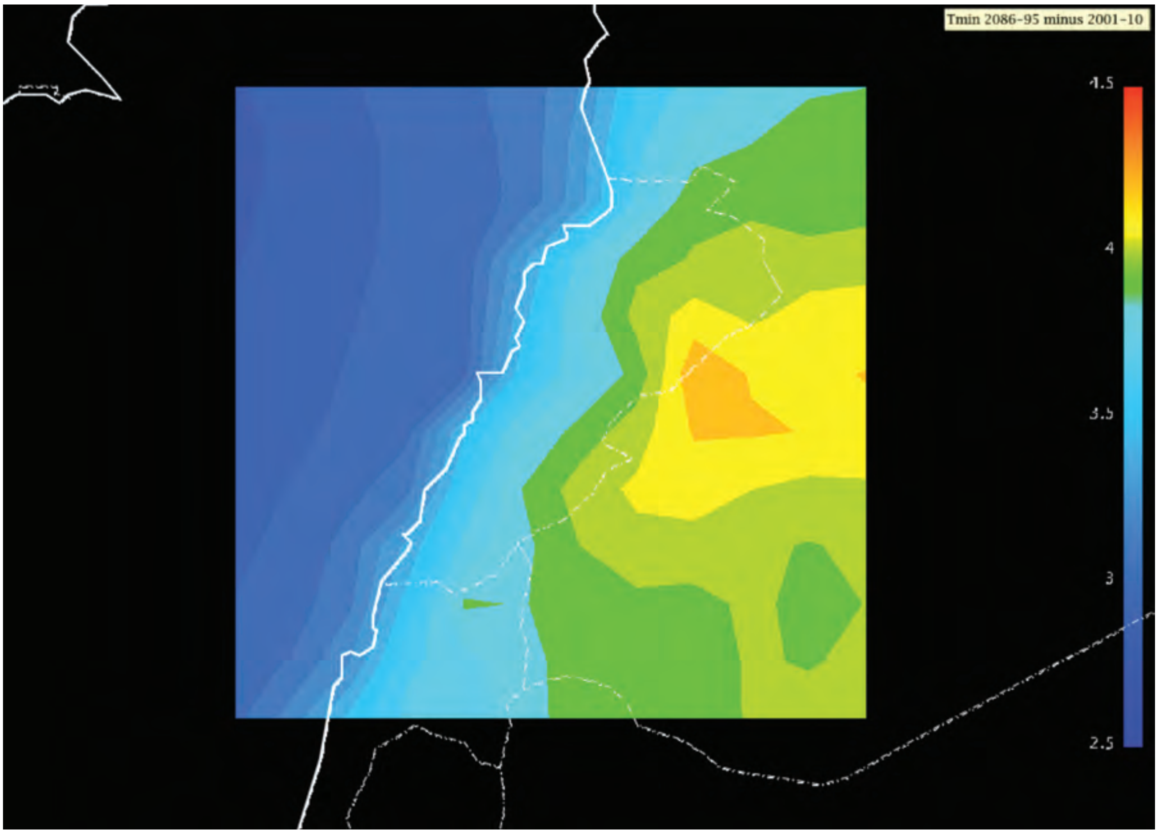


Figure 4-6 PRECIS projections of annual T_{min} over Lebanon as changes from the 2001-2010 average for 2036-45 (Top) and 2086-95 (Bottom)

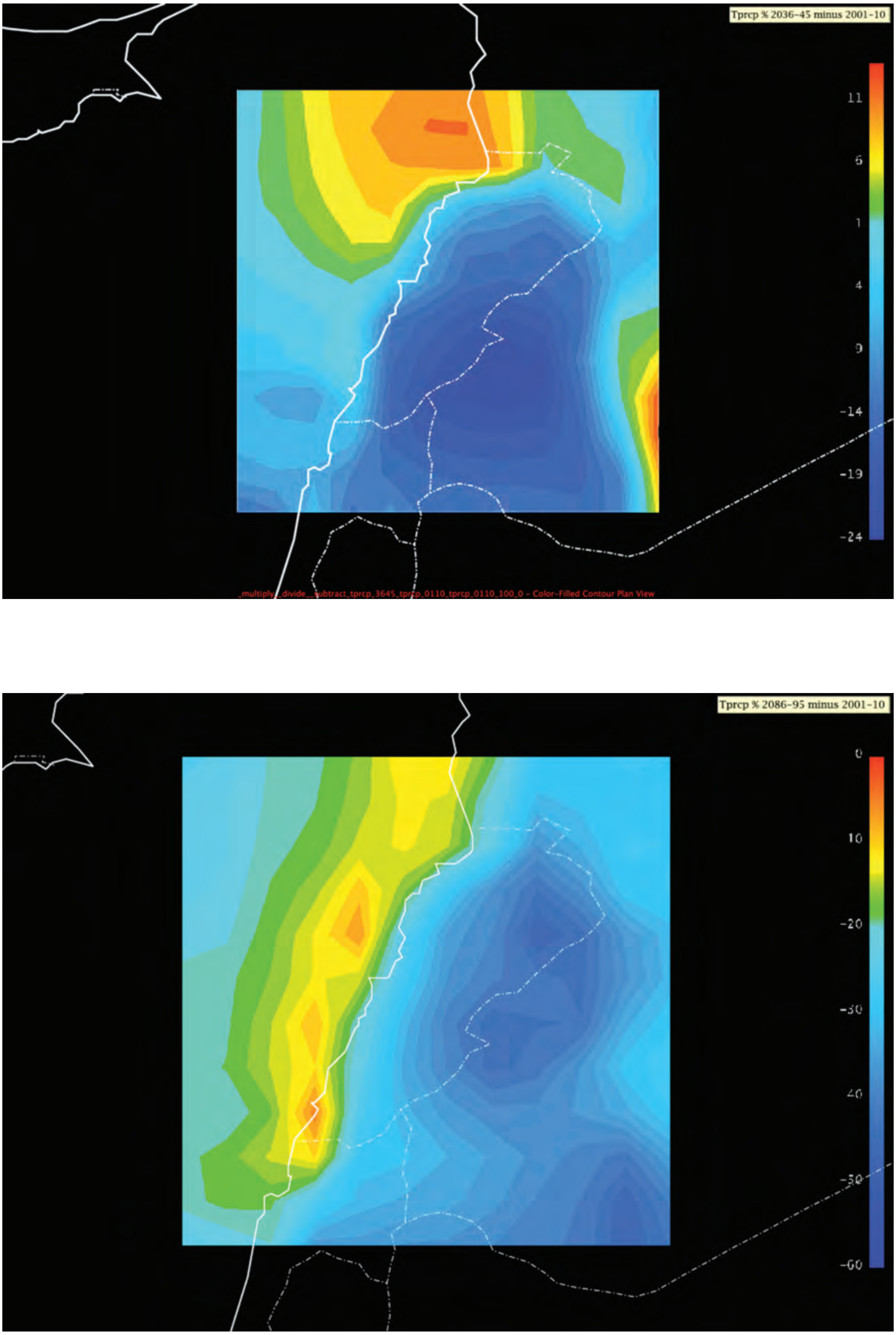


Figure 4-7 PRECIS projections of annual Precipitation over Lebanon as changes from the 2001-2010 average for 2036-45 (Top) and 2086-95 (Bottom)

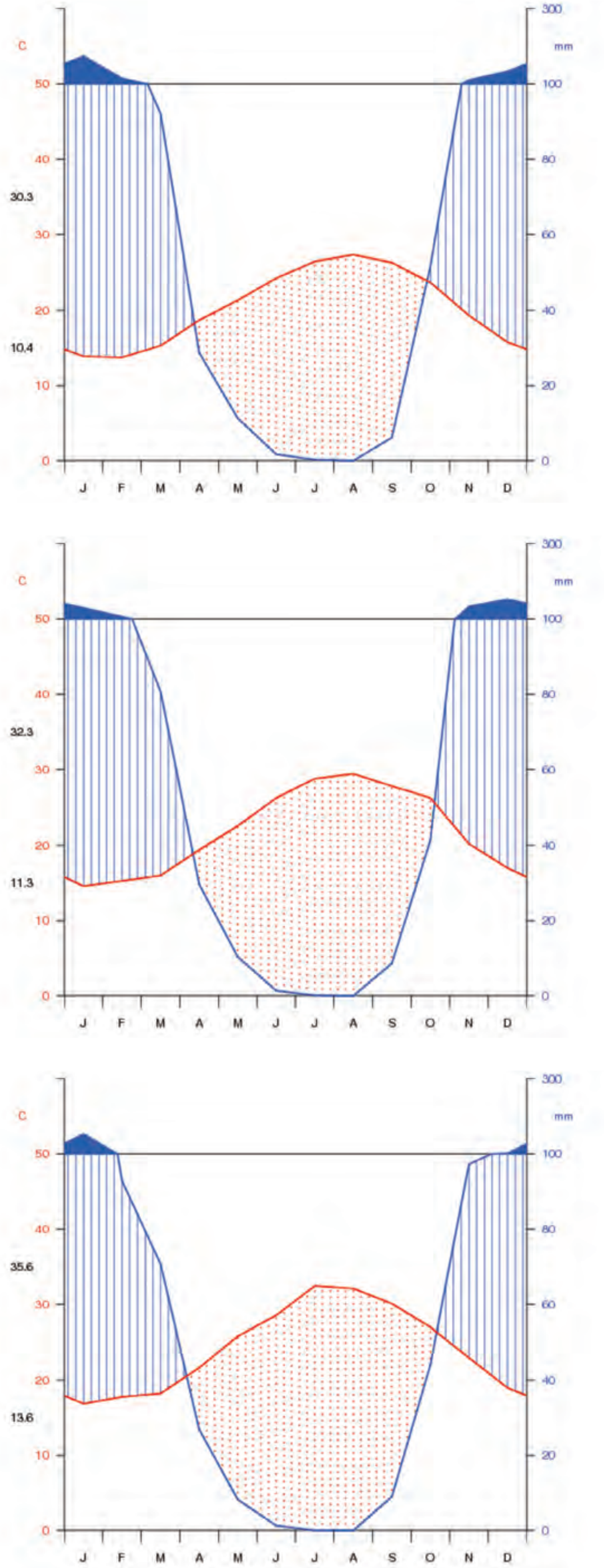


Figure 4-8 Walter & Lieth climate diagrams for Beirut observed by LMS in 1980-2000 and projected by PRECIS for 2025-2044 and 2080-2098

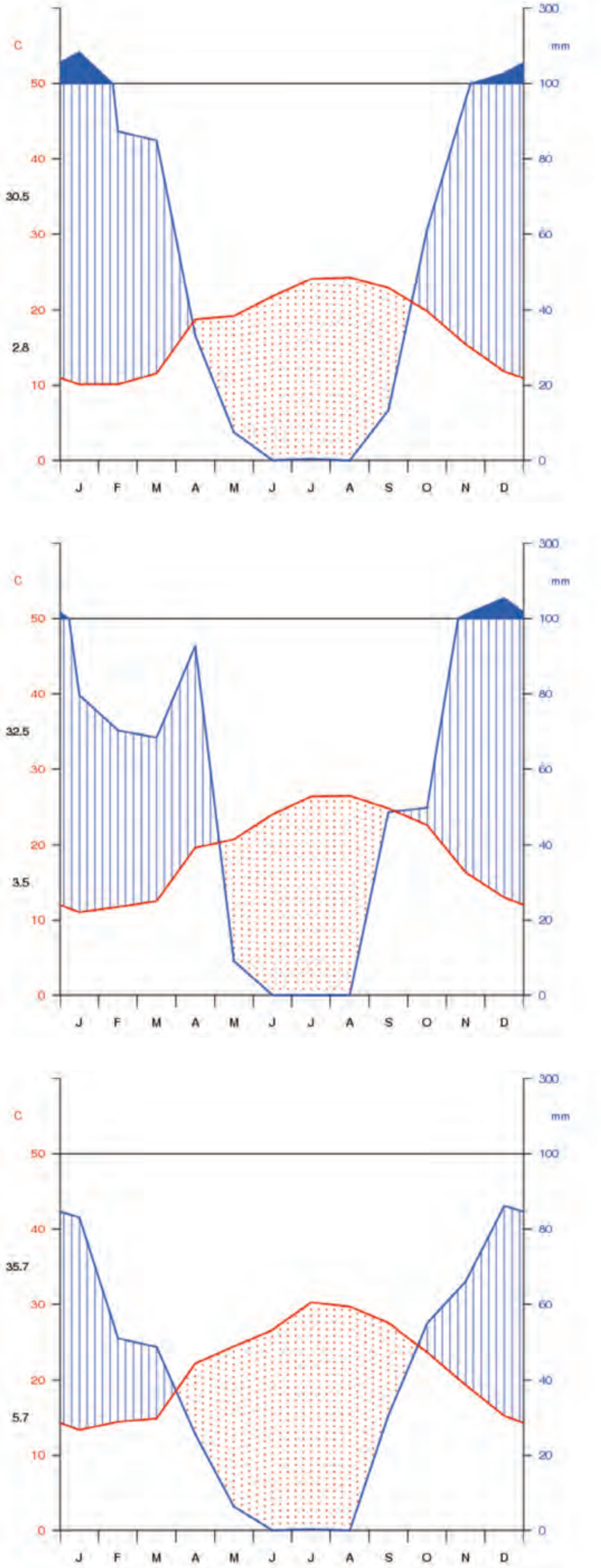


Figure 4-9 Walter & Lieth climate diagrams for Zahleh observed by LMS in 1980-2000 and projected by PRECIS for 2025-2044 and 2080-2098

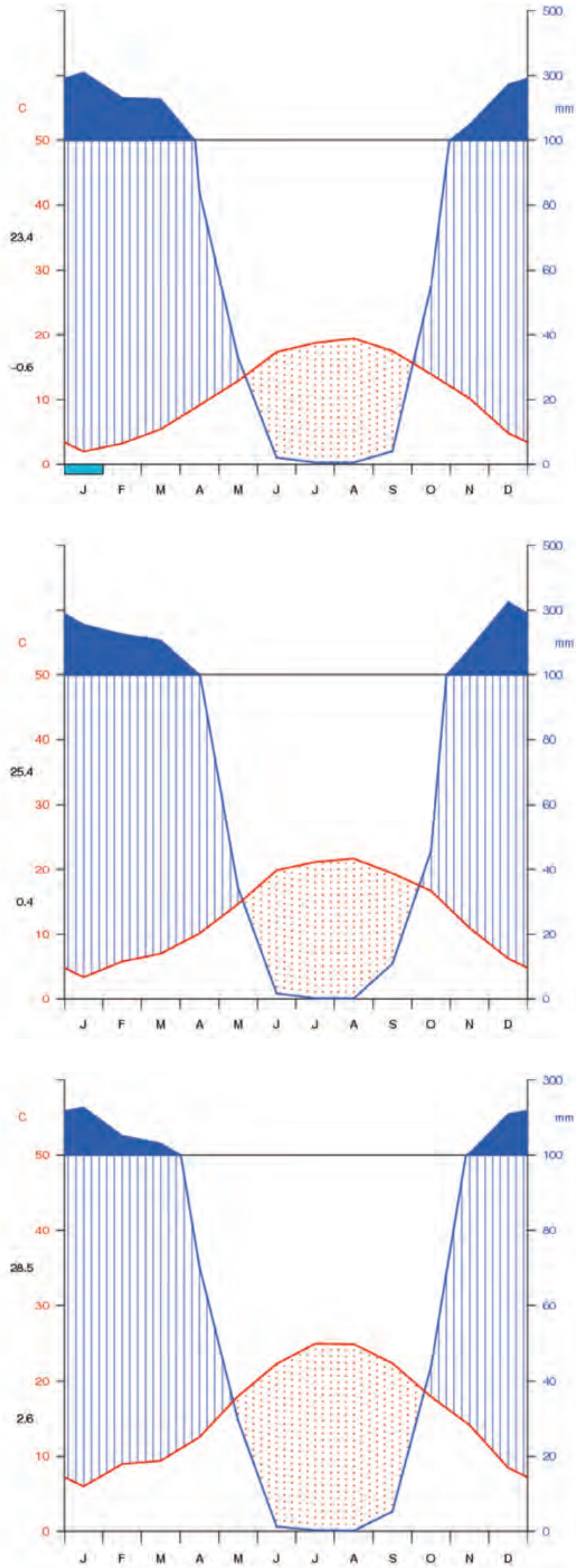


Figure 4-10 Walter & Lieth climate diagrams for Daher observed by LMS in 1980-2000 and projected by PRECIS for 2025-2044 and 2080-2098.

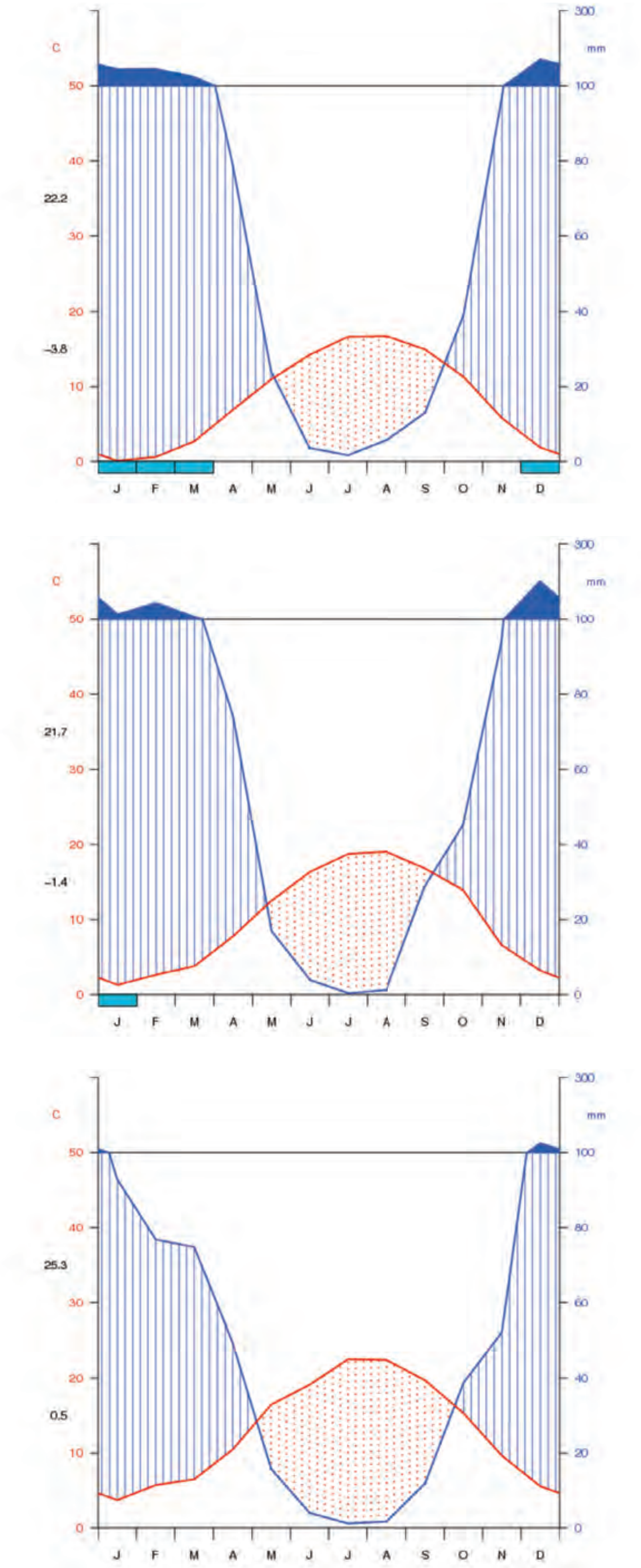


Figure 4-11 Walter & Lieth climate diagrams for Cedars observed by LMS in 1980-2000 and projected by PRECIS for 2025-2044 and 2080-2098

4.1.5 Indices of extremes

Large increases in the temperature related extremes are projected for all stations by the end of the century, and modest ones for the next 30 years. For the period 2080-98, the hot "Summer Days (SU30) will increase by 50-60 days, while the hot "Tropical Nights" (TR20) will increase by 1-2 months (less uniformly across the locations). The absolute extremes of maximum and minimum temperatures will increase by several degrees with the largest increase, between 5-6°C, predicted for the maximum extreme of the minimum temperatures (Tn_x). In Beirut, for example, Tn_x will almost reach 30°C, implying very hot night-time conditions. In the mountainous stations, the diurnal temperature range (DTR) is expected to increase up to 0.6°C, while in Beirut it will decrease slightly.

Precipitation (P) over the four locations will decrease between 18% and 38%, with the largest reduction in the mountainous stations and less in Beirut. The amount of rain falling within 5 consecutive days (RX5day) will decrease similarly, as well as the rainfall intensity (SDII). The consecutive dry days (CDD) are projected to increase between 15-20 days, exacerbating the hydrological stress (Table 4-1).

4.1.6 Comparison to Lebanon's Initial National Communication and other regional studies

The current climate assessment comes as an improvement to Lebanon's Initial National Communication (INC). Although both studies use global climate models from the Hadley Centre and similar emission scenarios, the PRECIS RCM 25 x 25 km resolution used here allows for the country to be represented by 17 grid-boxes and relevant climatic information, while the INC used a GCM with only 4 grid-boxes. Due to the different model resolution and study periods, a detailed comparison of the projected changes from the initial and the second national communication is not possible. However, the general findings of both communications regarding the projected warming are not far apart, since in both studies, by the end of this century, T_{max} and T_{min} are shown to increase more in the summer (~ +5°C) than in winter (~ +3°C). A notable difference is the spatial variation of the simulated warming that is located in the northern part of Lebanon in the current study, while in the INC it is higher in the south.

In comparison with other climate studies on the patterns of climate changes over the Middle East and the Eastern Mediterranean region, results indicate that the important warming and drying predicted from the PRECIS model simulation are in broad agreement with other published studies, using different modeling systems. Kitoh et al. (2008), who used a high-resolution (20 km) GCM from the Japan Meteorological Agency to simulate future precipitation changes in the Fertile Crescent region, predicts an end-of 21st century reduction of around 15% of rainfall over Lebanon under a moderate warming scenario. Evans (2010), who used the MM5 model to study the impacts on the dominant precipitation processes in the Middle East, reveals an increase in temperature over Lebanon by 2100 of about 2 °C in winter and 6 °C in the summer, and a decrease in rainfall by around 30%. Similar changes of the mean climate are also projected for neighboring countries such as Cyprus, where maximum and minimum temperatures will increase by the end of the century by an annual average of 4°C (up to +5°C in the summer and +3°C in winter) and precipitation will decrease by an annual average of 27% (Hadjinicolaou et al., 2010).

4.1.7 Further Work – Recommendations

The results of this study are those of a single-model experiment and they are in general agreement with GCM

Table 4-1 Changes in temperature and rainfall indices of extremes for 2080-2098 compared to the modeled 1981-200 mean

Index	Beirut	Cedars	Daher-el-Baidar	Zahleh
SU30 (days)	+50	+62	+60	+53
TR20 (days)	+34	+53	+18	+62
P (mm)	-116	-205	-312	-191
RX_5day (%)	-14	-39	-26	-30
SDII (%)	-6	-14	-8	-15
CDD (days)	19	21	15	19
DTR (°C)	-0.02	+0.61	+0.64	+0.27
Tn_x (°C)	+5.21	+5.47	+6.18	+6.26

predictions for the region. Simulations in higher horizontal resolution than the current 25 x 25 km must be explored for follow-up studies. Resolving the steep orography of the Lebanese terrain adequately would require a grid-box size less than 10 km, which is a very challenging effort for integrations in climatic time-scales. Another step forward would be a probabilistic approach which can be applied from multi-model simulations in order to quantify prediction uncertainty; however this requires extensive computational and human resources and collective efforts comparable to large EU project consortia.

Subsequent revision of this or similar dynamical downscaling experiments can benefit from empirical and statistical downscaling and bias correction methods (e.g. Déqué, 2007), in order to provide more accurate data input for sector impact studies. These were not applied in the current study because the observed meteorological data obtained were insufficient spatially (not dense) and temporally (not long-term). More effort is required for improving observational data availability and quality, as well as retrieval and digitization of older data from a larger number of stations that involves collaboration between the relevant national departments and international experts with experience in data rescue and homogenization.

4.2 Vulnerability and impact assessment

4.2.1 Method of assessment

The vulnerability and impact assessment of all sectors is conducted based on:

- Developing two baseline socio-economic scenarios that show and characterize the current and future possible variations in the demographic, socio-economic and technological driving forces in the country;
- Developing a climate change scenario to indicate how climatic and climate related factors could possibly change;
- Identifying vulnerable hotspots to climate change based on their social and biophysical exposure, their sensitivity and their adaptive capacity to climate change. This identification was based on maps, professional judgment and literature review;
- Setting out indicators to study the sensitivity, adaptive capacity and vulnerability of vulnerable hotspots under socio-economic and climate change scenarios;
- Determining the likely climate change impacts through a literature review and further analysis;
- Additional sectoral-specific tools and methods used for vulnerability and impact assessment are described in their respective sections below.

4.2.2 Socio-economic scenarios

The National Physical Master Plan for the Lebanese Territory (NPMPLT) defined by the CDR sets out the main principles and strategic vision of development, and identifies the different challenges that Lebanon faces today and the ones that it might face in the future (CDR, 2005). According to those challenges, two possible scenarios are proposed for the development of all sectors by the year 2030. These two scenarios are detailed in Table 4-2.

In addition, the NPMPLT draws several sectoral plans, regulations and operational measures and recommendations as described below:

- Agriculture: Considering large agricultural entities with high flood risk unsuitable for construction, establish a national strategy for agricultural development including irrigation projects, agricultural land consolidation, access to the lands and modernizing the processes and means of production, avoiding opening new agricultural roads or asphalting existing ones before the classification of agricultural lands, and locating waste treatment facilities and landfill sites on agricultural lands with the least agricultural value.

- Urban planning and development: Dividing the territory into three categories: urban regions mixed with rural regions, agricultural domain of national interest and natural sites of national interest; elaborating local land use plans in urban areas, building around 400,000 new dwellings and destroying 50,000 old ones as well as constructing hundreds of kilometers of new roads, streets, avenues, boulevards and expressways; protecting and conserving heritage; launching legislative and legal reforms that define the principles of land use; launching strategic urban planning operations, and creating an urban development agency for the management of extension zones of the agglomerations.

-Coastal zones: Managing and maintaining sandy beaches; underlining the high ecological value of certain seashores, preserving and developing the seashore promenades and corniches, preserving the picturesque ports for their important touristic value; adopting several legislative steps against illegal constructions; decreeing

Table 4-2 Socio-Economic scenario

Scenario A	Scenario B
- Growing integration of international trade, Lebanese prodtuction of exchangeable products would not be significantly developed - Less balanced economic development - GDP grows at an annual average rate of 4.2%[1] - Low population growth: Population will grow, however at a decreasing rate – average of 0.35%[2] between 2010 and 2030 - Total urbanized area will slightly increase with rural migration - Loss of interest in agriculture in some parts of the country - The migration balance[3], between 2001 and 2030 will be around (- 27,000) persons yearly - Improved cooperation between government agencies and authorities - Progressive adoption of management policies - Law enforcement - Lack of agro-forestry policies - Same standard of living	- Growing integration of international trade, local production could better resist the competition induced by imported products - Balanced economic development - Considerable GDP growth - GDP is assumed to grow at an annual average rate of 8.6% between 2010 and 2030[4] - High population growth - Population will grow at a modest increasing rate with an average of 0.96%[5] between 2010 and 2030 - Total urbanized area will increase with population, growth of 284 km^2 in urbanized areas - Urbanization of some rural areas - The migration balance, between 2001 and 2030, will be around (-6,000) persons per year. - Increase in intensive agricultural production and development of new agricultural fields at the expense of forests and other wooded lands - Absence of land-use planning at a regional and local level - Better standards of living ~ 2.4 times higher

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

[2] 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).

[3] The migration balance is the difference between the number of persons having entered the territory and the number of persons having left the territory in the course of the year. This concept is independent of nationality (INSEE, 2010).

[4] 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).

[5] 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).

the administrative, juridical and operational delineation of the Lebanese coastal zone; establishing the National Agency for Coastal Zone Management; restricting land reclamation to strategic projects of public utility; halting sand extraction; restricting seafront dumps; and reducing intensive agricultural practices and monoculture in the coastal areas.

- Transport: Rehabilitation of secondary airports and improvement of the quality of the ports' services; securing strong transport links and infrastructure between cities, towns and villages and establishing an integrated transport system for the entire Central Urban Area (GBA and the agglomerations of Bikfaya, Broumana, Jounieh, Aley and Damour) through widening and improving major roads and increasing the transport capacities of other roads.

- Waste: Attaining a total coverage of the entire territory of sewage networks and wastewater treatment services provision; constructing controlled dumpsite, transfer stations and treatment plants where it is needed and rehabilitating uncontrolled dump sites in the major cities as in Tripoli, Sidon, Baalbek and Tyre.

4.2.3 Climatic scenarios

Table 4-3 summarizes the projections of the climatic factors of relevance for the Mediterranean region and for Lebanon as they figure in the IPCC AR4, regional studies and the modeled climate simulations of PRECIS.

4.2.4 Data Sources and Gaps

The main data and information used in the assessment are based on government publications and official databases. However, when the required data are unavailable or inaccessible and when faced with contradicting figures, scientific literature and expert judgments are considered in order to select the value used in the analysis. In the assessment of some sectors where quantitative analysis was difficult, a qualitative analysis was prepared. In addition, the limited availability of data and maps hindered the used of GIS techniques and other tools to improve the assessment.

Table 4-3 Projected change in climatic factors of significance to the agriculture sector

Climate Factor	Projections for the Mediterranean region	Projections for Lebanon
Temperature	The annual mean warming from the period 1980-1999 to 2080-2099 varies from 2.2°C to 5.1°C. The warming in the Mediterranean area is likely to be largest in summer The risk of summer drought will be increased, and almost one year out of two would be considered dry by 2080-2098 (Christensen et al., 2007)	Increases in T_{max} are projected to be between 1°C on the coast of Lebanon and 2°C inland by 2040, and between 3°C on the coast and 5°C inland by 2090 The SDII is expected to decrease by 6 to 15 percent over three locations (Beirut, Zahleh, Daher-el-Baydar) by 2098 after an increase of 6% in Daher-el-Baydar region by 2044 Hot summer days are expected to increase by 12 to 29 days in 2040 and by approximately two months by the end of the century in 2090
Precipitation	The annual area-mean change from the period 1980 -1999 to 2080 - 2099 varies from –4% to –27% in the Mediterranean region (Christensen et al., 2007)	Rainfall reduction is projected to be between -10 and -20% by 2040, and between -25% and -50% by 2090
Relative humidity		Annual average relative humidity changes will be very small by 2040, but reductions up to -10% in the eastern part are projected for the 2080s
Wind speed	The northward shift in cyclone activity tends to reduce windiness in the Mediterranean area (Christensen et al., 2007)	Less than ±0.3 m/s change for 2025-2044 and 2080-2098
Cloud cover		Decrease by about 5% inland
ETP (results obtained from the model developed in the impact assessment of the water sector)		Beirut: 1% increase by 2044, and 2% increase from 2044 to 2098 Cedars: 5% increase by 2044, and 8% increase from 2044 to 2098 Zahleh: 26% increase by 2044, and 10% increase from 2044 to 2098 Daher el Baydar: 5% increase by 2044, and 6% increase from 2044 to 2098
Sea Level Rise	Sea level rise in the order of 45-50 cm between 2004 and 2050 (Margat, 2004) Sea level rise in the Eastern Mediterranean Basin is in the order of 20 mm/yr (Cazenave et al., 2001) Sea level rise in Lebanon in the order of 5 -10 mm/yr (Tourre et al., 2008) will reach 12-25 cm by 2030 and 22-45 cm by 2050	
Sea Surface Temperature	Regional temperature increases have been reported in the Mediterranean Sea, where SSTs have been rising about twice as much as those of the global oceans. (Rhoads et al., 2009)A rise in SST induces a likely increase in the frequency and intensity of storms and hurricane (Jäger and Kok., 2008)	
Frequency and intensity of storms	Contradictory projections: - Extreme phenomena such as storms and violent winds are expected to increase over the Mediterranean basin, (Tourre et al., 2008) - Storm track over the Mediterranean is expected to weaken due to a large scale hemispheric change (Bengtsson et al., 2005)	

4.2.5 Main assumptions

The vulnerability and impact assessment assumes that the policies and strategies currently in place will be on the course to implementation by 2030. It is assumed that the decreed NPMPLT and future changes to occur under its umbrella are part of the future baseline scenario without climate change.

However, 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.

4.3 Vulnerability & Adaptation of the Agriculture Sector

Due to the topography of the Lebanese territories that allows for a distribution of precipitation ranging widely from less than 200 mm to more than 1,400 mm of rain per year, five distinct agro-climatic zones are present. The varied elevation offers Lebanon the possibility of extending to an extremely diversified agriculture; from quasi-tropical products on coastal plains to orchards in high-altitude mountains. The main crop production regions are the coastal strip, the Akkar plains, the central Bekaa valley, the mountainous region, the western slopes of the Mount Hermon and Anti-Lebanon range and the hills in the South (Saade, 1994).

Population growth exerts pressure on agricultural production where the higher demand for food leads to more intensive agricultural practices that are characterized by the excessive use of fertilizers and increase in the use of water for irrigation. Projections through 2030 show an increase of 41% in total domestic demand for water (from 296 Mm^3 in 2000 to 418 Mm^3 in 2030), and estimate the need for irrigation water at 1,600 Mm^3 (CDR, 2005). According to the Ministry of Environment (2001), 32% of water resources available for exploitation in 2015 will be directed towards domestic use (as compared to 16% in 1994), leaving 60% of water resources to agricultural use (as compared to 74% in 1994). It is worth noting that water withdrawal figures for 2005 show that the share of agriculture had already dropped below 60% (FAO, 2010). Other projections elaborated in the National Integrated Water Resources Management Plan for Lebanon (Hreiche, 2009) forecast a 47% increase in the irrigated surface area by 2030 (2005 as a base year), and a 10% increase in the demand for irrigation water. The total need is estimated at 1,410 Mm^3 in 2030, versus 1,600 Mm^3 estimated by CDR (2005).

4.3.1 Methodology

Scope of assessment

The overall vulnerability of crops and sub-sectors was evaluated according to their economic importance, their exposure and sensitivity to the changing climatic conditions projected for Lebanon and the adaptive capacity of the farming system (land, labor, irrigation systems, etc.) in the two baseline socio-economic scenarios. Livestock and crops that are totally dependent on the amount of rainfall such as grazing small ruminants, rainfed crops (olives, grapes and wheat), crops whose production is highly vulnerable to temperature changes (stone and pome fruits) and crops that require a large initial investment with long payback periods (perennial crops), are prioritized. Water demanding crops, such as bananas, tomatoes and potatoes are also selected for vulnerability assessment. Citrus crops as well as avocado were not considered since they are less vulnerable to climate change, given that they are tropical crops.

References on crop climatic needs were linked to projected climatic conditions in order to predict the vulnerability and impact on specific crops. Climatic simulations were adjusted according to the agro-climatic zones where specific crops are grown. Eventual impacts of climate change on specific crops were retrieved from available studies on Mediterranean countries, namely Italy, Tunisia and Greece, or countries with similar climatic conditions, namely Australia, South Africa and the state of California of the USA, whenever possible.

The assessment covers the entire country with focus on the areas where the target crops and fruit trees are produced. The analysis is done on a yearly basis for annual crops such as cereals and vegetables, and on a two-year basis for perennial crops, such as olives. The impact of climate change on the vitality and survival of young non-productive seedlings and trees is also important, especially during the first four years after planting. A period of 25 years with 2005 as baseline year is adopted for the analysis of vulnerability.

Development of the sector under socio-economic scenarios

Under Scenario A, population remains almost the same meaning that overall food demand remains the same corresponding to a low increase in local consumption needs. Local agricultural production might slightly decrease as more land and water are allocated for urban areas. The cost of production might increase due to low investment in agricultural capital. Looking at the figures of Scenario A, assumptions are that the future situation will follow current trends. The growth in international trade, increased globalization and increased competition coupled with a weak development of export-oriented crops signal a slight growth in agricultural and food exports.

Under scenario B, population growth will exert more pressure on agriculture in two ways; (1) more intensive production, and (2) more expansion of residential areas over agricultural lands. Although local production will be better positioned to resist rising food import levels, imports especially for non-essential food needs will grow, while the demand of essential food products will be increasingly met from local production (e.g. dairy and meat products, vegetable oil, sugar and cereals). More pressure will be exerted to satisfy the local consumption needs; and with increasing demographic pressure, the stress is mainly on water demand which means that farmers will have to adopt drip irrigation systems to increase water use efficiency. However, improvement in yields will not correspond to the rising demand of a larger population growth but to the increased adoption of technology. Land prices will increase in tandem with population growth, which would disfavor agricultural land use. Despite the projected rise in yields; local production will continue to face increasing competition, and the high local production costs are expected to render local produce uncompetitive.

4.3.2 Vulnerability and Impact Assessment

Sensitivity and adaptive capacity are examined for the most vulnerable crops, and an analysis of the vulnerability is presented for each of the crops and agricultural sub-sectors. The impacts of projected changes in climatic conditions and changes in socio-economic conditions use indicators of productivity, cultivated area, need and cost of irrigation, and volume and value of export in order to provide a targeted impact assessment that could potentially be measured in the future. The impact assessment is carried out in light of the socio-economic scenarios A and B, and is based on expert judgment and supported by a review of the scientific literature.

Wheat

The overall vulnerability of wheat and cereals in general to projected changes in relevant climatic factors is considered moderate since wheat yield is mostly correlated to rainfall amount (minimum annual rainfall should be above 400 mm), T_{max} in November and T_{min} in March (Ventrella, 2006). The most vulnerable areas in Lebanon are in the Bekaa where extreme conditions such as reduced precipitation and frost are more frequent. Since spring rainfall is more prejudicial than annual overall rain amount, areas where rainfall attains more 800 mm/yr are still considered with moderate risk.

Changes in temperature and precipitation patterns do not show a significant effect on the production of wheat in Lebanon. Higher spring temperatures and higher evapotranspiration (ETP) will decrease soil moisture and increase aridity that will reduce yields in the second half of the century, especially if rain or complementing irrigation does not occur in spring. Since the onset of the rainy season defines sowing date, all areas of production will be facing a shorter period of growth. All areas of wheat production are subject to yield variation, but yield variation is very controversial and difficult to assess.

Potato

Potato is cultivated all year round, mainly in the Bekaa (during spring/summer) and in Akkar (in winter). It is 100% irrigated in the Bekaa while irrigation is complementary to rainfall in Akkar (MoA and LARI, 2008). Production is affected when temperature is outside the range of 10-30°C. Hence, winter cropping of potato in Akkar is vulnerable, with higher frequency of disease due to higher humidity and milder temperatures. On the other hand, spring and autumn cropping in the Bekaa are mostly affected by water availability and temperature extremes, while summer cropping is highly vulnerable as tuber formation could be jeopardized, and irrigation lacking. Figure 4-12 illustrates the cultivation areas and vulnerability of the potato crops to projected changes in climatic factors with a ranking of vulnerability by area. The overall vulnerability of the potato crop is considered high.

Currenlty, potato is tolerating summer heat and slight winter frost in the Bekaa, as cool, summer nights are enough for starch accumulation, and winter sunny days are suitable for plant growth. Projected changes in climate will decrease the risk of frost to less than 1 day per month for the three winter months, and increase the average T_{max} to above 30°C starting May. This could be seen as an opportunity to plant potatoes as a winter crop, rapidly increase canopy, save water for irrigation, harvest earlier and increase yield (Haverkort, 2008). Nevertheless, potato cultivation in spring and summer will be unsound as T_{min} in summer nights will increase (T_{min} above 20˚C), and water for irrigation will be scarce, while plant demands will be higher. It would become possible though to plant a second autumnal crop from September to December. Potato growers will see their profits increase from early cropping, but might lose if they plant later in the spring/summer season. Winter potato growers will be facing nematodes and aphids infestation and more fungi and bacterial diseases, such as late blight, brown rot and erwinia due to the combined relative humidity and temperature increase (Haverkort, 2008).

Tomato

Tomato is as an annual crop cultivated, mainly in the Bekaa valley, Akkar plain, Zahrani plain, as well as coastal areas and mountain villages of Mount Lebanon and North Lebanon. It is grown either in greenhouses or in fields, mostly as an irrigated crop and requires a warm and cool climate. The tomato plant cannot withstand frost and high humidity hence requires temperatures between 10˚C and 30˚C. Field tomato is grown in 2 rounds in the Bekaa and on medium altitudes (500 - 1,200 m) between April and August and on higher altitudes (1,200 - 2,000 m) between May and the first frost in autumn while it can be gown for up to 3 rounds per year in greenhouses. The overall vulnerability of the tomato crop is considered moderate where the vulnerable areas of production are in medium altitudes including the Bekaa and Marjayoun plains and in coastal areas where tomato production could be relocated.

Tomato production would be slightly affected by temperature rises by the 2030s, but yield decrease could be significant by the end of the century. The growing period would be shorter, with less fruit set in summer due to temperature extremes, and water shortage, especially in the Bekaa and mid-range altitudes. On higher altitudes, the diminishing production in summer could be counterbalanced by a delayed autumn frost. Water demand of plants would increase and water availability for irrigation is likely to decrease especially on coastal areas that are highly affected by seawater intrusion in groundwater. Increasing carbon concentration in the air would offset eventual production losses in tomato crops grown in plastic greenhouses due to higher temperatures and relative humidity during the spring and summer/ autumn growing seasons. Under Scenario A, overall productivity is not expected to change, despite the regional differences, while under Scenario B, productivity might actually increase due to increased adoption of technology which would counter effect the expected slight decrease in productivity.

Cherries

Cherries are grown in Lebanon in temperate regions, mostly in Mount Lebanon and the Bekaa. Orchards are mainly irrigated except in Aarsal where they are rainfed. Due to several problems in cherry production on lower altitude areas such as wood insect outbreaks, spring frost, and deficient chilling requirements, the more drought tolerant rootstock Prunus mahaleb is currently being used to enable the production of rainfed or complementary irrigated cherries. Cherry blossom is sufficiently robust against short spring frost, however due to its high chilling requirements (700 hours of chilling which is equivalent to 70 days with $0˚C < T_{min} < 7.2˚C$), it is likely to be more sensitive to high temperatures (over 21˚C) in winter and during blossom as well as early hail and rain. The overall vulnerability of the crop is considered moderate, with the central Bekaa being highly vulnerable.

With the expected increases in minimum temperature, chilling needs of cherries will barely be met by 2024 (630 hours), and would be below requirements by the end of the century (444 hours). Increases in maximum temperature will increase the risk of failure of blossom pollination and fecundation by 30% in Mount Lebanon and up to 50% in the Bekaa valley and will increase the rate of infestation by the cherry fly especially with high spring temperatures. These risks are lower at altitudes higher than 1,300 - 1500 m. The changes in precipitation amount and number of rainy days in spring will not affect significantly rainfed orchards even if soil moisture is slightly reduced. If irrigated orchards are to face a shortage in water due to higher demand in other sectors and higher ETP, the production will be slightly affected. As for the drought-resistant Mahaleb rootstock, the growth of its fruit occurs in spring when the soil is still moist; hence, it will not be affected by the decrease in irrigation water resources. Overall, cherry crops grown in central Bekaa at altitudes below 1,300 m will be less productive with time.

Apples

Apple is the most cultivated fruit species by area, and is the second highest agricultural product marked for export (MoA, 2007). Apple plantations are located mainly in North Lebanon, Mount Lebanon and the Bekaa, in altitudes between 900 m and 1,900 m. Production is sensitive to spring

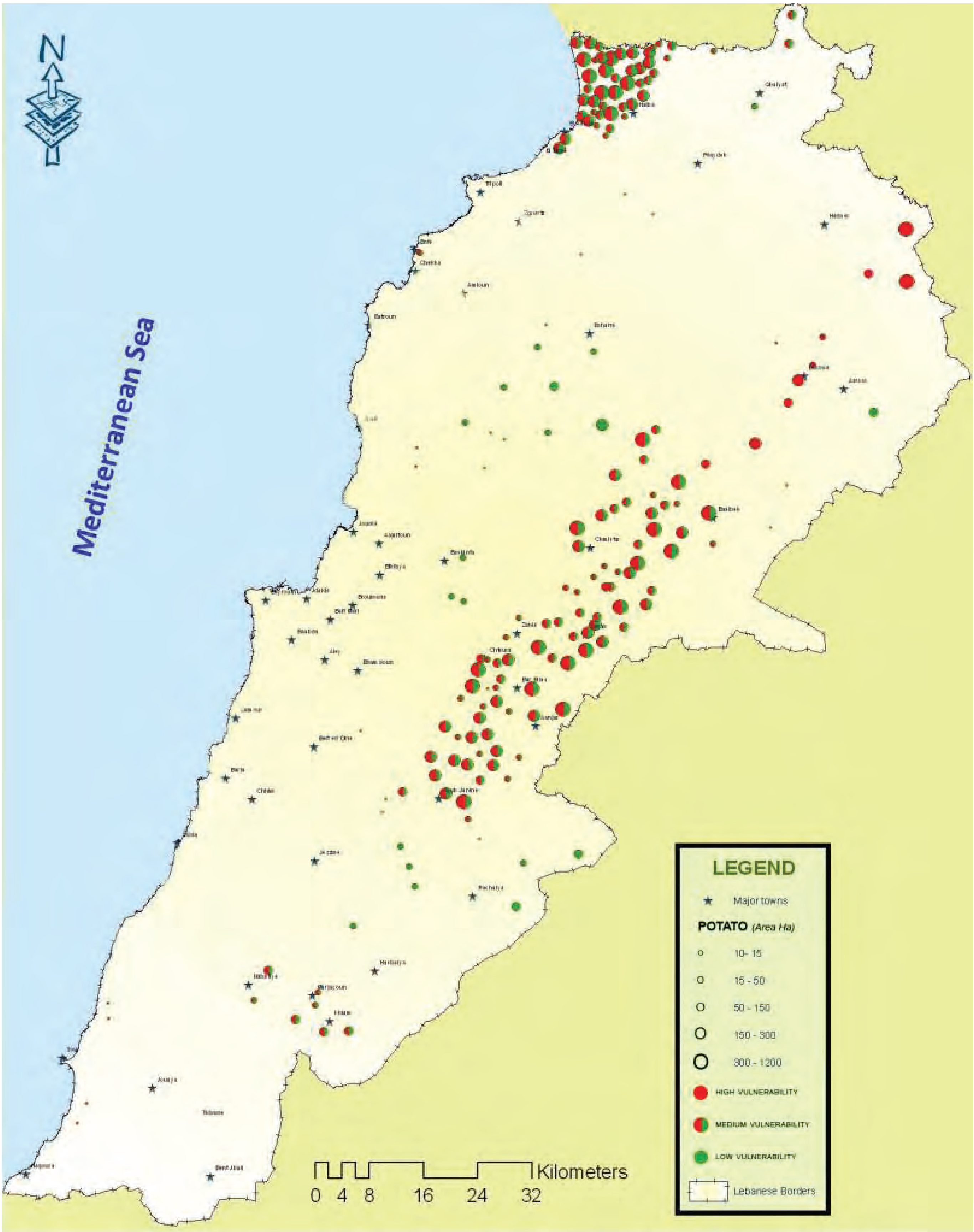


Figure 4-12 Potato cultivation areas and crop vulnerability

frost, hot and dry winds, and hail and rain that come late in May or June or later in October, as well as high temperatures (>40˚C) accompanied with drought conditions, and less cloud cover, all increase the risk of sunburn to fruits (Trillot et al., 2002) that affect the apples' chilling requirements (400 to 900 hours) (Steffens and Stutte, 1989). In Addition, demographic pressure in Akkar, the Bekaa and some other areas combined with water scarcity for irrigation will intensely affect the production. Figure 4-13 illustrates the cultivation areas and vulnerability of apple trees to the projected changes in climatic factors with a ranking of vulnerability by area. The overall vulnerability of the apple trees is considered high.

Increases in temperature are expected to reduce the chilling requirements of apple cultivars at 1,000 m elevation from 678 hours to 444 hours by the end of the century. Changes in precipitation patterns will not directly affect production since in general apple orchards are irrigated. If a shortage in irrigation water occurs with increase in ETP and water demand, production will be affected. Since water needs for apples are mostly during the fruit growth period between May and July, it is estimated that reduced irrigation supply will increase the rate of fruit drop and reduce fruit caliber. A shortage in water later in August or September would slightly affect fruit quality. If water flow is to decrease by 20%, the yield (or area) of apple trees will drop by 10 to 15% at least. As cloud cover and relative humidity do not show a significant change, fruit quality, consisting of fruit color, russet and sunburn among others would not face additional risks. Nevertheless, late varieties planted in the Bekaa valley are more prone to sunburn due to excessive sun radiation, lower relative humidity, higher temperatures and higher frequency of heat waves.

Grapevine

Most of the area of production of grapevine is located in the Bekaa valley and Akkar, with few vineyards in Mount Lebanon and the South. Vineyards for table grape production are irrigated in general, while industrial production is rainfed (MoA and LARI, 2008). Most varieties are local and area specific. For instance, the Maghdoushi variety is better adapted to warm areas, while the Tfeifihi and Baitamuni varieties thrive better in cooler regions. However, in general, grapevine requires a long warm summer and a mild winter, tolerates drought and can survive rainfall of no more than 300 mm a year. Humid spring and summer seasons would negatively affect yields and the quality of the crop. Table vines can tolerate high T_{max} over 40˚C, yet heat waves should not last days as fruit quality will be altered when T_{max} is over 30˚C. Vines can stand winter frost too, but are sensitive to spring frost. Humidity and cool temperatures (below 15˚C) negatively affect fruit set (Schultz et al., 2005; Vidaud et al., 1993). The overall vulnerability of the grapevines crop is considered moderate.

Climatic projections show that T_{max} will be the major limiting factor for table grapes in both the Bekaa and Akkar, where higher temperatures may lead to 1) early bud burst thus increasing the vulnerability of to eventual spring frosts (Quirk, 2007) 2) early Véraison stage thus exposing fruits to sunburn and causing early ripening. For rainfed table grapes and industrial grapevines, changes in precipitation will affect production and quality of grapes especially in low altitude areas, leading to an eventual decrease in yields and a change in wine quality. Since there is no information about the capacity of the actual system of production, such as rootstock, variety, distance of plantation, training system and soil cover, to cope with climate change, losses in terms of production are not evident, except that quality will certainly be affected. In general, grapevine production could face several problems in terms of water availability for irrigation and in terms of quality, especially for industrial grapes, due to temperature rise. Thus, all the areas of production are vulnerable.

Banana

Production of banana is concentrated mainly on the coast of South Lebanon and to a lesser extent in Mount Lebanon (MoA, 2007), on altitudes rarely exceeding 150 m mostly due to the lack of water availability at higher altitudes. Banana is usually planted for a two-year growth period and requires heat, humidity and large amounts of irrigation water to ensure its needs during the arid season. It cannot withstand frost. Banana production may be hindered by a reduced land and water availability due to urbanization, demographic pressure and seawater intrusion in coastal aquifers. Nevertheless, the climatic conditions will be favorable for banana growth and even expansion further north to its actual limits in latitude and even in altitude, which will counterbalance the losses. Therefore, the overall vulnerability of the crop is considered lowThe climate conditions predicted for the near and distant future are likely to be favorable for banana production. Increases in temperature, humidity and carbon fertilization would have a positive impact on yields and fruit quality. Banana plantations could be expanded to higher altitudes (by 150 m at least) and further north in latitude to the Syrian coastal plain.

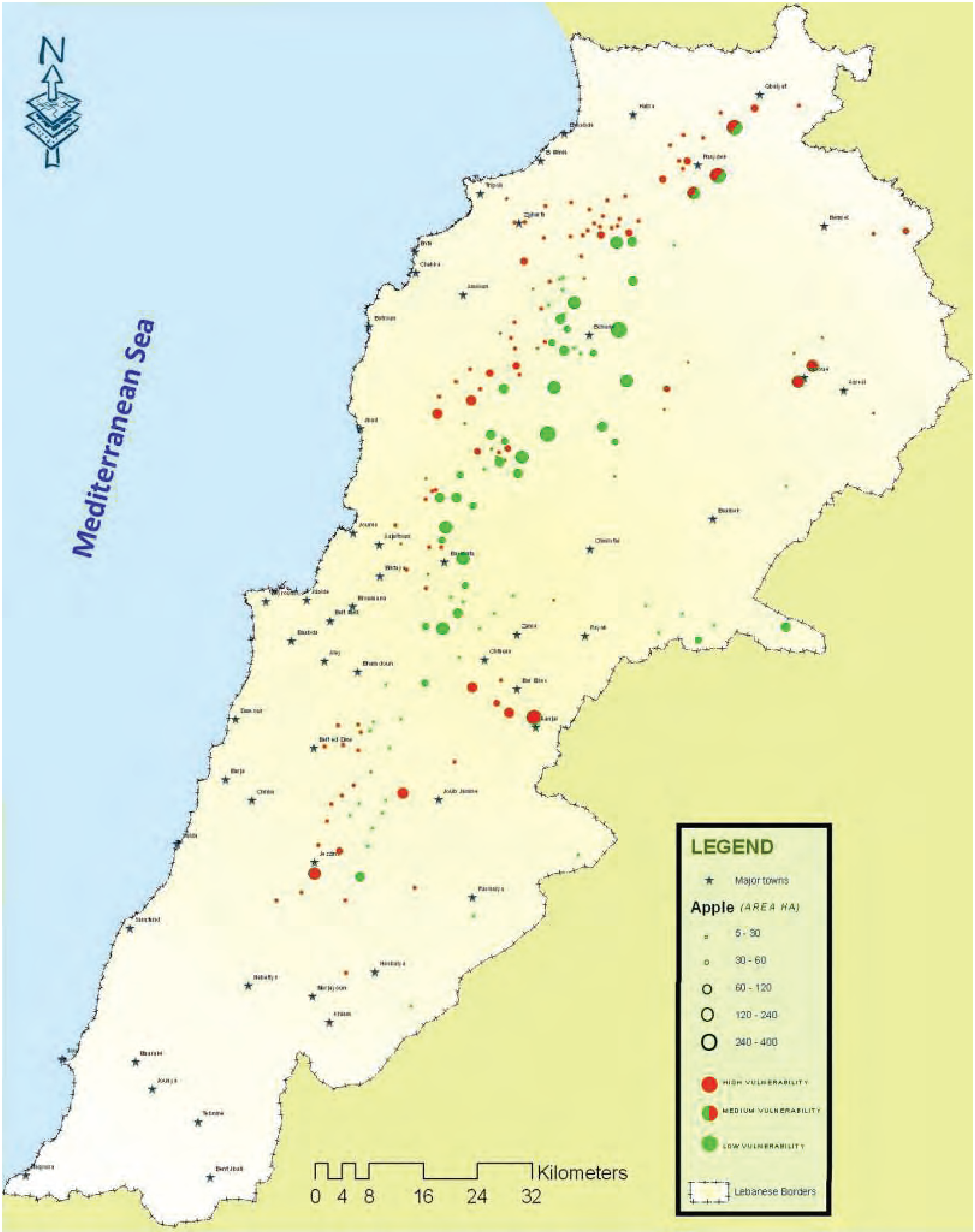


Figure 4-13 Apple cultivation area and crop vulnerability

However, water demand in addition to the frequency of nematodes, viruses and fungal diseases is expected to concurrently increase.

Olive

Olive tree orchards are generally found on the western slopes of Mount Lebanon and Mount Hermon below 1,000 m. They are mostly rainfed, except in areas that receive less than 300 mm of annual rainfall, such as in Hermel. Since Lebanon is a major importer of vegetable oils, it is important to consider the olive crop grown for oil production as an important crop for food security that helps the population meet its fat intake. The olive tree can withstand long drought periods, high temperatures (above 40˚C) and low precipitation thus water needs in the summer time are minimal, and can be secured through the tree's high performing rooting system. Olives are sensitive to long cold waves, freezing winter temperatures (below -5˚C), spring frosts and hot dry winds (MoA and LARI, 2008; Loussert and Brousse, 1978). The major climatic factors that would eventually affect olive production are the amount of precipitation and to a lesser extend chilling requirements. Some pests and disease will be reduced with higher temperatures and drier weather, which leaves most areas of production at low risk. In areas at altitudes higher than 500 m, the olive groves will always receive enough precipitation for proper yields and ensure their chilling needs. The area of cultivation could even expand to higher altitudes of up to 1,300 m as warmer temperatures set in. The overall vulnerability of the olive crop is considered low with plantations on costal zones and in northern Bekaa being the most vulnerable due to persisting humidity, decrease in chilling hours, demographic pressure and decrease in water availability where olive groves are irrigated.

The impact of climate change on olive production is limited to 1) a slight reduction in yield by the end of the century in areas with minimal precipitation rates due to a decrease in rainfall and decrease in the chilling period (from 37 days to 4 days) which will however be partially offset by carbon fertilization and 2) proliferation of the olive fly and olive moth. In general, olive tree cultivation will be slightly affected. The vulnerable areas of production in the Bekaa do not constitute more than 5% of the total olive cultivated area, and are mostly irrigated. Large olive groves in areas below 500 m, specifically Akkar, Zgharta, Koura, Batroun, Saida, Tyre and Nabatiyeh, will face reductions in yields.

Small ruminants

Small ruminants include sheep and goats in Lebanon which are concentrated in the Bekaa valley, and in summer migrate between the valley and the surrounding mountain chains. Rangelands provide the bulk of livestock food needs in Lebanon. However with the absence of natural permanent pastures, shepherds invest in forests, other wooded lands and in agriculture areas, specifically post-harvest fields and fallows. The degradation of vegetation cover in many rangelands in Lebanon is an evidence of overgrazing. In other areas, forest biomass is increasing and forests and woodlands are invading grasslands, as there is a lack, and even an absence, of herds in these areas. Since grasslands are scarce, shepherds are increasingly relying on feed blocks and feed supplements to complete the nutrient ratio of the ruminants, hence decreasing the vulnerability of animal production to climate change, since the feed is provided regardless of the availability of grazing (Enne et al., 2002). Some ruminants such as local Awassi sheep and Black goat can adapt to these extreme conditions in terms of temperatures and drought and can still produce milk and meat although with reduced productivity (Gintzburger et al., 2006). However the overall vulnerability of small ruminants and rangelands is considered high.

The expected decrease in amount and distribution of precipitation coupled with an increase in temperatures may affect the length of the grazing period and the quality of pastures by increasing ETP and reducing soil moisture content and the viability of grass (Fleischer and Sternberg, 2006). Temperatures below 10˚C will slow down grass growth, and stop it when frost occurs. Higher levels of CO_2 will worsen conditions for grazing across the country as this will increase the carbon to nitrogen ratio in forage, thus reducing its food value and the carrying capacity of pastures. Moreover, a reduction in moisture availability would change the species composition in favor of woody, less palatable plants. A further effect of a shift of carbon storage from soil to biomass may adversely affect soil stability and increase erosion. Moreover, the shorter pasture season on the lower altitudes (below 1,000 m) would be partially compensated by an increase in herbaceous biomass due to optimal temperature and humidity conditions, coupled with carbon fertilization and an extension to medium altitudes. On higher altitudes (>2,000 m), herders would benefit from a longer pasture season caused by reduced thickness and a lower residence time of snow cover, but with a decreasing herbaceous biomass. By the 2080s, areas having an annual precipitation below 400 mm in the Bekaa will be facing additional reduction in rainfall (up to 35%), which would hamper the development of agriculture and grasslands would move southward in the northern Bekaa plain to invade abandoned agriculture areas.

Adaptive Capacity: agriculture resilience and food security

Several studies show that a better adaptation and resilience to climate change can be obtained through farm product diversity and small scale farming (Reidsma and Ewert, 2008; Oxfam, 2009). The Lebanese agricultural production is very diverse at both country and regional levels, due to the diversity of agro-climatic zones. Even at farm level, diversity is illustrated by the variety of grown crops (mainly for fruits and vegetables) and the range of cultivars within the same crop (namely fruit trees). The average surface of exploitations does not exceed one hectare. Although most farmers do not grow crops for their subsistence, at least one-third of the production is auto-consumed in small exploitations (MoA and FAO, 2005b). No cash crops are grown exclusively for export, which induces a more resilient market against international prices fluctuation. Most farmers do not count exclusively on agriculture for their livelihood. If this activity remains a primary source of income for most farmers, their livelihood is in most cases sustained by other income-generating activities.

In terms of food security, Lebanon produces half of the population's consumption in terms of value. The value of exported commodities such as fruits and vegetables partially covers the value of imports (namely cereals, meat and dairy products, sugar and vegetable oils). The food security balance tends to show more disequilibrium with increasing imports and demographic growth that cannot be covered by a notable increase in exports (MoE and AUB, 2009). Strategic crops for food security in Lebanon can be reduced to wheat, potato, poultry and red meat, milk and olive oil. While Lebanon is close to self-sufficiency in poultry meat, olive oil and potato, the country imports half of its needs of milk, and most of its consumption of red meat and vegetable oils. The production of exportable crops such as citrus crops, banana, apple, potato and tomato as well as some other fruits and vegetables are expected to decrease for multiple reasons including demographic pressure and climate change.

4.3.3 Adaptation measures

The key adaptation measure for climate change is setting and implementing a sustainable agriculture policy to sustain the viability of the agriculture sector, and maintain an acceptable level of food security. Although adaptation measures vary horizontally according to the agricultural sub-sectors and their vulnerability to climate change and vertically according to the different actors involved, they should be coherent and synergic to ensure a proper policy development and implementation. In addition, since the agricultural sector is considered as an emitter and a vulnerable sector, many measures proposed for mitigation can be applied for adaptation.

4.3.3.1 Field level measures

- Change planting dates and cropping pattern, according to precipitation and temperature variations and irrigation water availability;
- Shift to less water consuming crops, e.g. barley instead of wheat, snake cucumber instead of cucumber, figs instead of kaki, grapes instead of peaches; and drought and heat tolerant e.g. industrial hemp, avocado and citrus instead of banana;
- Adopt adequate plantation schemes and greenhouse systems in order to facilitate air circulation between plants in areas where atmospheric humidity is expected to increase, e.g. coastal plains;
- Introduce crops that would be tolerant to higher levels of humidity and temperature (i.e. citrus, tropical fruit trees), and to higher salinity concentrations (i.e. legumes, cucurbits and solanaceous rootstocks), especially in coastal zones;
- Shift to perennial crops (apple, cherry, and to a lesser extent other stone fruits, olive and grape) with low chilling requirements in lower altitude areas of cultivation of each crop;
- Shift to irrigation systems that are more efficient such as drip irrigation or sprinklers, and adjust irrigation schedules as well as water quantities according to the increasing crop water demand;
- Adopt sustainable agriculture practices such as conservation agriculture, adequate crop rotations (including fodder species) and organic farming;
- Adopt integrated pest management techniques, and good agricultural practices when organic farming is not an option, to decrease chemical use and lower the cost of production;

Table 4-4 Specific field level adaptations measures

Crop	Measures
Potato	Shift to winter cropping (plantation: December-February) and to a lesser extent autumn late cropping in the Bekaa (plantation: September) if water is available. In Akkar, plantation can be made earlier (December-January)
	Introduce early varieties that would have smaller vegetative period (Binnella, Charlotte, Samba, etc.). Late varieties could be kept if they are grown as winter crops and resistant to blight (Agria), or to drought (Remarka). Spunta which is the major grown cultivar should not comprise the bulk of the production
	Promote potato growing at higher altitudes (above 1,400 m) in small irrigated plains inland (Marjhine, Jbab el Homr, Oyoun Orghosh, Ainata, Yammouneh, Bakka, Yanta, etc.) and in the western chain of Mount Lebanon (Mrebbine, Laqlouq, Bakish)
	Adopt biotechnology to produce potato seeds locally
Cherry	Introduce Cristobalina, Brooks cultivars and maintain the early local cultivars (Nouwari, Telyani) at altitudes between 1,000 m and 1,300 m
	Select high performing clones of Prunus mahaleb or other equivalent rootstock
Apple	Introduce varieties such as Mollie's Delicious, Anna, Ein Shemer, and Dorsett at altitudes below 1,200 m and Gala, Granny Smith, Pink Lady, at altitudes between 1,200 m and 1,500 m
	Research on products inducing bud break and blossom to substitute for chilling requirement (i.e. Thidiazuron) in years with warm winters (Austin & Hall, 2001)
Grapevine	Promote early varieties of table grapes especially in lower altitudes (Early Superior seedless, Maghdoushi) instead of standard varieties (Baitamuni, Tfeifihi)
	Select drought and heat tolerant rootstocks (R110, 140Ru, P1103) and varieties from local and imported genetic resources, and disseminate to farmers
	Shift vineyards of Western Bekaa to higher altitudes (above 1,200 m) in potential areas such as Rashaya, Bhamdoun, higher Akkar, etc., for both table and industrial grapes
Olive	Promote new methods of harvesting to reduce bud alteration by traditional harvesting methods, and to reduce labor cost
	Upgrade post-harvest techniques (olive and oil storage, pressing)
	Undertake a policy based on the cost efficiency analysis of irrigation of olive orchards
Banana	Promote the use of shade nets to reduce transpiration and extreme climatic effects (hail, wind)

- Adapting the number of livestock according to the carrying capacity of a rangeland;
- Elaborating a national rangeland program in collaboration with all concerned actors, which would include concise specific rangeland management plans, with the eventual actions to be undertaken (grazing period, number of ruminants, etc.);
- Enhancing genetic selection of local breeds so they are adapted to local extreme climatic conditions and crossing them with breeds that have a higher potential of milk or meat production;
- Diversifying animal production through expanding into milk, dairy products, meat, leather, wool and honey;
- Promote mixed exploitations, e.g. animal and vegetable production;
- Promote controlled grazing in forests, namely in ecosystems that are prone to fires.

Specific adaptation measures for some crops are summarized hereafter in Table 4-4.

4.3.3.2 Research and infrastructure measures

Research measures

Some topics to be studied include conservation of agro-biodiversity by the creation of a gene bank; models tackling the potential agriculture production systems that could adapt to climate change; water consumption and needs of various crops and cultivars, and their variability with climate change, agriculture production systems and regions; socio-economic models that would engage water price efficiency according to the cultivated irrigated crops, i.e., virtual water price; tree training and pruning techniques to reduce alternate bearing between years; the nutritional value and the carrying capacity of different types of rangeland at different climatic conditions; and monitoring of meat and milk productivity of small ruminants according to the animal pedigree, type of rangeland and climatic conditions.

Infrastructure measures

Public institutions should rehabilitate their infrastructure to address operational inefficiencies (quarantines, laboratories, frontier posts, etc). Infrastructure related to the agriculture sector, which mostly occurs at farm level, includes water harvesting and distribution systems (dams, hill lakes, reservoirs and channels), terraces, greenhouses, agricultural machinery, agro-processing plants, storage and packaging units, hives, farm constructions, etc. The Green Plan at MoA, which is the mandated authority to provide such services to farmers on a demand-driven basis, should be reinforced.

An adaptation action plan for the agriculture sector is proposed in Table 4-5.

4.3.4 Cost of adaptation

The cost of adaptation at farm level would be impossible to address since measures are not limited in time, and the number of exploitations and actors involved are tremendous and heterogeneous. Some measures (such as changing planting dates, shifting varieties, no-tillage, crop diversification) are costless and comprise mainly operations that do not necessarily pose an additional cost to farmers. Other measures require additional investments such as irrigation systems, new rootstocks, adapted greenhouses and farm infrastructures, adapted machinery for seeding, weed control and harvesting in no-tillage systems, etc. The costs of these inputs, with the necessary labor needs are unpredictable because they depend on the scale of investments and baseline conditions at the farm level. However some of these measures are already being implemented regardless of climate change, to improve yields and product quality, or to decrease the cost of production.

The cost of adaptation at the level of public institutions, notably education, research and assistance, public infrastructure and institutional measures, is seen as an integral part of the national agriculture strategy. The budget line of adaptation is thus already included within the strategy, which means that only additional budgetary requirements should be addressed.

4.4 Vulnerability and Adaptation of the Electricity Sector

Although Lebanon figures among the countries with high coverage of electric power in the region (IEA, 2006), self-generation still plays a large role in electricity supply and demand due to the inability of EDL to meet demand effectively (World Bank, 2008). Expected changes in weather pattern due to climate change are only expected to exacerbate the already existing problems affecting the electricity sector in Lebanon.

4.4.1 Methodology

Scope of Assessment

The main aspects of vulnerability of the electricity sector focuses on 1) the increased pressure on the energy production system as a result of increased cooling demand during summer, increase in oil/gas prices and potential disruption of hydroelectric power plants as a result of reduced precipitation and 2) the increased pressure on the power supply chain as a result of increased demand, and possibly storm surges.

The assessment covers the entire country during summer and winter, since cooling and heating demands, hydropower generation, and power supply cover the whole territory and all seasons. The year 2004 is used as the baseline year and the analysis extends until 2030.

Methods of Assessment

The expected increase in temperature estimated by the climate model is used to calculate the increased energy demand in summer. Assuming an average Coefficient of Performance (COP) of 2.8, an average outside temperature between 13.6°C for January to 28.7°C for August (MoPWT, 1971) and an inside temperature of 22°C, an increase of 1 to 3°C in temperature by 2040 is estimated to lead to an annual increase in electrical cooling consumption of 9.04% to 28.55%. No projections are made for the 5°C increase in temperature by 2080-2098 since it is difficult to predict energy demand by then.

The increase in demand from natural and economic growth from 2004 to 2030 is estimated using expert judgment in the absence of data on activity level, energy intensity, etc. to make a disaggregated end-use oriented demand analysis and projections using LEAP. The additional growth in energy consumption resulting from increased cooling demand in summer is calculated for 2004 to 2030 and superimposed on the business-as-

Table 4-5 Adaptation action plan for the agriculture sector

Impact	Proposed Adaptation Strategy	Activities
Reduction of water availability for irrigation	Shifting from surface to drip irrigation	Survey on water sources Topology-hydrology-water needs study Design of irrigation schemes Installation of systems Training for farmers
Increase in pest outbreaks	Adopting Integrated Pest Management (IPM) or organic farming	Assess the cropping pattern of the concerned areas, define the key pests and diseases that are a major problem Define the number of traps, pheromones to be distributed as well as the closest meteorological station to be linked to import the required material Distribute the necessary material (traps, pheromones, etc.) Training for farmers and installation of material
Chilling requirements not met for some cultivars at specific locations, and rootstocks not tolerating drought	Renovating orchards with low chilling requiring cultivars grafted on drought tolerant rootstocks	Survey on cropping pattern (cultivar/ rootstock) per altitude Identify vulnerable orchards and quantify trees to be replaced Propose a plan of orchard renovation with adapted cultivars and rootstocks Renovate orchards with a rate of 20% of trees over 5 years Training farmers on new plantations management
Increase in water demand in annual plants with low tolerance to higher temperatures	Shifting in planting date Shifting to adapted cultivars Shifting to conservation agriculture	Conduct trials for new cultivars and plantation systems Conservation agriculture for potato, cereals and tomato Disseminate results to engineers (public/private) Propose Good Agricultural Practices to concerned farmers Import necessary plant material and equipment Select appropriate cultivation dates for each crop Develop a system to alert farmers on the occurrence of extreme weather events (early hail, frost, etc.)

usual scenario. These estimates are entered in LEAP just to draw a curve on the growth in consumption under the baseline scenario and the two warming scenarios (+1°C and +3°C). Data gaps related to energy consumption on household equipments, sectoral breakdown of demand and consumption figures, demand, supply, capacity and efficiency of power plants, and proportion of electricity self-generation prevented the use of LEAP in conducting a disaggregated end-use oriented demand analysis with projections. Assumptions based on expert judgment are used when necessary.

Moreover, the expected decline in precipitation levels was taken into consideration to assess the potential impact on hydropower given the government plan to build over 20 dams and hydropower plants along major rivers. Finally, the assessment of the sector's overall vulnerability land impact is based on the baseline socio-economic scenarios (A and B) and the climate change scenario.

Development of the sector under socio-economic scenarios

The NPMPLT projections put Lebanon's energy demand in 2030 at 4,200 MW, based on a 3% in consumption per capita by 2015 and a 1% increase by 2030, which was planned to be met through the addition of 3,000 MW by 2030 (CDR, 2005). However, current projections give a higher estimate of increase in demand, and recent government plans consider the rehabilitation of the Zouk and Jiyeh plants rather than their retirement. Therefore, a 4-5% yearly increase in demand was assumed until 2020, followed by a 2-3% increase from 2020 until 2030, knowing that in middle income countries, demand for electricity grows at a factor above the GDP growth, as reported by the World Bank (2008). Based on a peak load of 2,575 MW in 2004 including self-generation, these rates yield a projected demand of around 4,820-7,555 MW by 2030. These figures are in line with the World Bank's projection of demand by 2015 of 4,000 MW, necessitating an additional 1,500 MW from EDL and self-generation by that date (World Bank, 2008). In terms of energy consumption, projections using the same growth rates give a range of 25,530 - 40,000 GWh by 2030, based on 13,631 GWh in 2004.

Under Scenario A, the power sector and energy security will not really be at a disadvantage since the scenario estimates a slow increase in energy consumption and total demand, a limited need for the expansion of the distribution network and a higher interest in renewable energy sources.

However, under Scenario B, high population and GDP growth combined with higher standards of living will have a double edge impact on energy consumption and total energy demand, which are expected to increase considerably. Additionally, the increase in urbanized area will put additional pressure on the power distribution system that will require expansion. In spite of the relative affluence and more balanced economic development that will enable EDL to cope with this increase in demand, energy security will still be threatened.

Successive governments have suggested numerous master plans for the electricity sector throughout the years. However, none of these plans and strategies has been implemented so far. The current government proposed in June 2010 a policy paper for ensuring 24-hour supply, improving security and reducing costs and losses in the electricity sector by 2014. The proposed plan tackles the addition of generation capacity to cover the existing gap, the required reserve margin, as well as the necessary improvement in transmission and distribution infrastructure (MoEW, 2010).

4.4.2 Vulnerability and Impact Assessment

Energy demand and consumption

Electricity demand is sensitive to fluctuations in ambient temperature, decrease on precipitation and increases in oil prices. The overall vulnerability of the electricity sector is estimated to be moderate to high due to increase in energy demand, power production and supply chain. The forecasted rise in ambient temperatures coupled with a natural growth in population and consumption rates, would lead to higher cooling demand in summer, pushing the peak load up. This would in turn put pressure on the power production and supply system to meet the additional increase in demand and consequently drive the cost of power production up. In addition, the adaptive capacity of the power sector is generally low as a result of the already existing shortages and rationing, the slow expansion in power generation capacity and the deficit in EDL's budget. Figure 4-14 shows the increase in energy consumption (GWh) for the period 2004 - 2030 based on 3 scenarios.

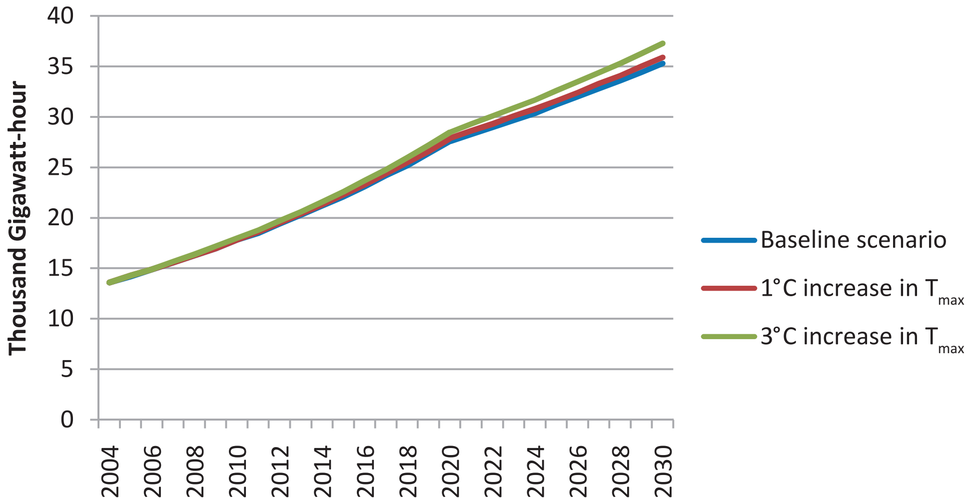


Figure 4-14 Forecasted increase in energy consumption resulting from a 1°C to 3°C increase in ambient temperature

The 1-3°C increase will incur an additional 635 GWh to 2,047 GWh on energy consumption. Given that cooling consumption constitutes 20% of total energy consumption, and that temperature increases of 1°C to 3°C lead to 9.04% and 28.55% increase in cooling consumption respectively, the increase in total consumption from increased cooling consumption will be 1.8% for a 1°C increase in temperature, and 5.8% for a 3°C increase in temperature. This will consequently necessitates an expansion of installed capacity between 87 and 438 MW, based on a forecasted demand of around 4,820-7,555 MW by 2030. The demand increase will surely be higher under Scenario B with the high population growth and improvement in standards of living that will bring about an increase in per capita energy consumption regardless of climate change. On the other hand, the global increase in energy demand, coupled with the gradual depletion of oil reserves, is expected to lead to an increase in oil prices, which will drive the cost of energy production higher.

Hydropower generation

The forecasted 10 to 20% decrease in precipitation by 2040, together with the increase in temperature, leading to higher ETP, will eventually lead to a decrease in river flows, which will decrease the hydropower generation potential. The availability of hydropower plants is also expected to decrease given the forecasted shortening of the winter season and the increase in the length of drought periods. By the end of the century, with more severe reduction in precipitation, hydropower generation potential will drop further, which would jeopardize the government's plans to increase energy capacity.

Renewable energy

The predicted insignificant changes in wind speed and cloud cover are not likely to lead to any potential change in solar and wind energy, thus making renewable energy sources slightly vulnerable to climate change. The governmental plans to invest in wind energy might not be affected and the potential for solar energy might be positively affected, especially inland, where a 5% decrease in cloud cover is forecasted by the end of the century.

4.4.3 Adaptation Measures

Efforts of the power sector to adapt to the potential adverse impacts of climate change converge and complement mitigation measures that entail ensuring a 24-hour supply of electricity, reducing budget deficit, reducing dependence on exported oil consumption as well as accounting for the expected additional generation capacity needed to meet the increasing cooling demand. Therefore, adaptation efforts should mainly be directed at implementing the Policy Paper for the Electricity sector (MoEW, 2010), in addition to the application of the thermal standards for buildings proposed by DGUP (MoPWT et al., 2005).

4.5 Vulnerability and Adaptation of the Water Sector

Lebanon faces significant challenges in meeting the country's water demand in terms of quantity and quality. Unsustainable water management practices, environmental risks and water governance shortcomings are among the main obstacles facing the sector (MED EUWI, 2009). Extensive aquifer over-abstraction and years of mismanagement have contributed to causing the hydraulic gradient to reverse, encouraging seawater encroachment in coastal areas in Lebanon. This has been further exacerbated by the continuous urban growth and repeated natural drought conditions.

4.5.1 Methodology

Scope of Assessment

The water sector is the hardest sector to assess due to the lack of data such as non-consistent measurement of river flows, lack of metering systems to measure withdrawals from each sector, etc. and the significant amount of losses resulting from leakages and widespread unlicensed wells where pumping is not monitored.

This assessment looks at the combined effect of precipitation and temperature variation on evapotranspiration, and consequently on the reduction of water availability throughout the country. To that is added the effect of population and economic growth. Potential impacts of temperature increases on snow cover are also addressed based on existing studies as a result of limited relevant data and measurements in Lebanon.

The study area extends from Hadath in the South-West to the Cedars in the North East, spreading over an area of 2,500 km^2. This area comprises most of lebanon's topographic features as well as the Jurassic aquifers of Kesrwan, the totality of the Kneisseh and Hadath Cennomanian aquifers, the majority of Chekka springs recharge area, the majority of Berdawni spring recharge area, as well as four major catchment areas (Beirut river, Dog river, Ibrahim river and Jawz river) and several major springs (Figure4-15). It also contains the largest snow coverage zone of the Mount-Lebanon, and is an important area from a socio-economic point of view, with a wide range of activities.

The study area, like the entire Lebanese territory, can be divided into 4 pluviometric zones and 5 temperature zones. The superposition of these two sets thus yields 13 subzones. Four of these subzones are represented by meteorological stations as follows (Figure 4-16):

- 800 - 1,000 mm (interior zone) and 15°C, represented by Zahleh's meteorological station;
- 1,000 - 1,400 mm, and 7.5°C, represented by the Cedars meteorological station;
- >1,400 mm, and 12.5°C, represented by Daher-el-Baydar's meteorological station;
- <200 mm, and 20°C, represented by the Beirut Airport meteorological station.

Given that almost all subzones resulting from the above combinations of precipitation isohyets and isotherms throughout the Lebanese territory are represented in the study area, the results can be extrapolated to the entire territory.

The assessment covers the entire year to account for precipitation (winter season) including snow cover, and losses through ETP that are increased by temperature increases (summer season).

Methods of assessment

It is important to clarify that the term precipitation figuring in this section excludes water equivalents from snowfall.

Active precipitation is used as the main parameter for the assessment of the water sector since it is directly affected by the decrease in precipitation and increase in temperature. In fact, a reduction of 10% to 20% in precipitation coupled with an increase of 0.5 to 1°C in temperature would result in about 1% to 4% decrease in net ETP respectively (Bakalowicz, 2009). Accordingly, a mathematical model is built to simulate the variability of active precipitation in the absence of data on spring and river flows needed to simulate the impact of climate change on these flows. The purpose of the model is to derive active precipitation out of total precipitation by calculating the potential ETP taking into consideration relative humidity, which is a function of temperature. Using the relations defined by Catafago and Jaber (2001) between geographical exposure (western slope vs. interior areas), precipitation, temperature and altitude, real ETP and active precipitation are calculated.

Several simulations are conducted for the precipitation and temperature series set for 4 climatological stations (Beirut, Dahr-el-Baydar, Cedars and Zahleh). Monthly series of active precipitation for the recent past, the near future and the distant future are computed and compared. Each data series derived from the model is considered representative of the subzone corresponding to the location of the station, and the ratio of active precipitation out of total precipitation indicated the varying extent of vulnerability of different subzones. For subzones that do not have a match among the 8 series, a simple linear interpolation is used to draw an intermediate ratio between the ratios of adjacent subzones.

As for the potential impacts on snow cover, the direct effect of temperature increase on snow area and residence time is assessed based on existing studies, given the lack of continuous data and measurements relating to snow in Lebanon.

Policies, plans and prospects

The MoEW published the 10-year Water Plan 2000–2009 for water and wastewater management in 1999, defining the strategy to satisfy Lebanon's future water needs. The strategy mainly consisted in increasing the water supply by building dams and lakes, extending the drinking water projects, increasing the quantity of irrigation water, building wastewater treatment plants, cleaning river courses, etc. (FAO, 2008; Hreiche, 2009). However, this plan has not been achieved by 2010, and has been renewed to 2018 (Hreiche, 2009). Only three dams (Shabrouh in Kesrwan-Mount Lebanon; Barissa in Donnieh-North Lebanon; and Yammouneh spring in Baalbeck) have been built so far. The MoEW has also developed a long-term plan of surface water development (with 2030 as a horizon), through the construction of 18 dams and 23 lakes, as well as 2 regulation weir in the Beqaa. This plan, if executed, would allow the mobilization of an annual volume of 1,100 Mm^3, bringing the exploited amounts (current and future) up to 2,000 Mm^3, which is very close to the maximum volume possible. Such a perspective could obviously resolve the problem of domestic water supply and irrigation of the effectively irrigable lands of Lebanon. Nevertheless, it is unlikely that the Lebanese administration and public finance could accomplish this project in less than 30 years. Hence, this project should be

Figure 4-15 Geographic location of springs and rivers in the study area

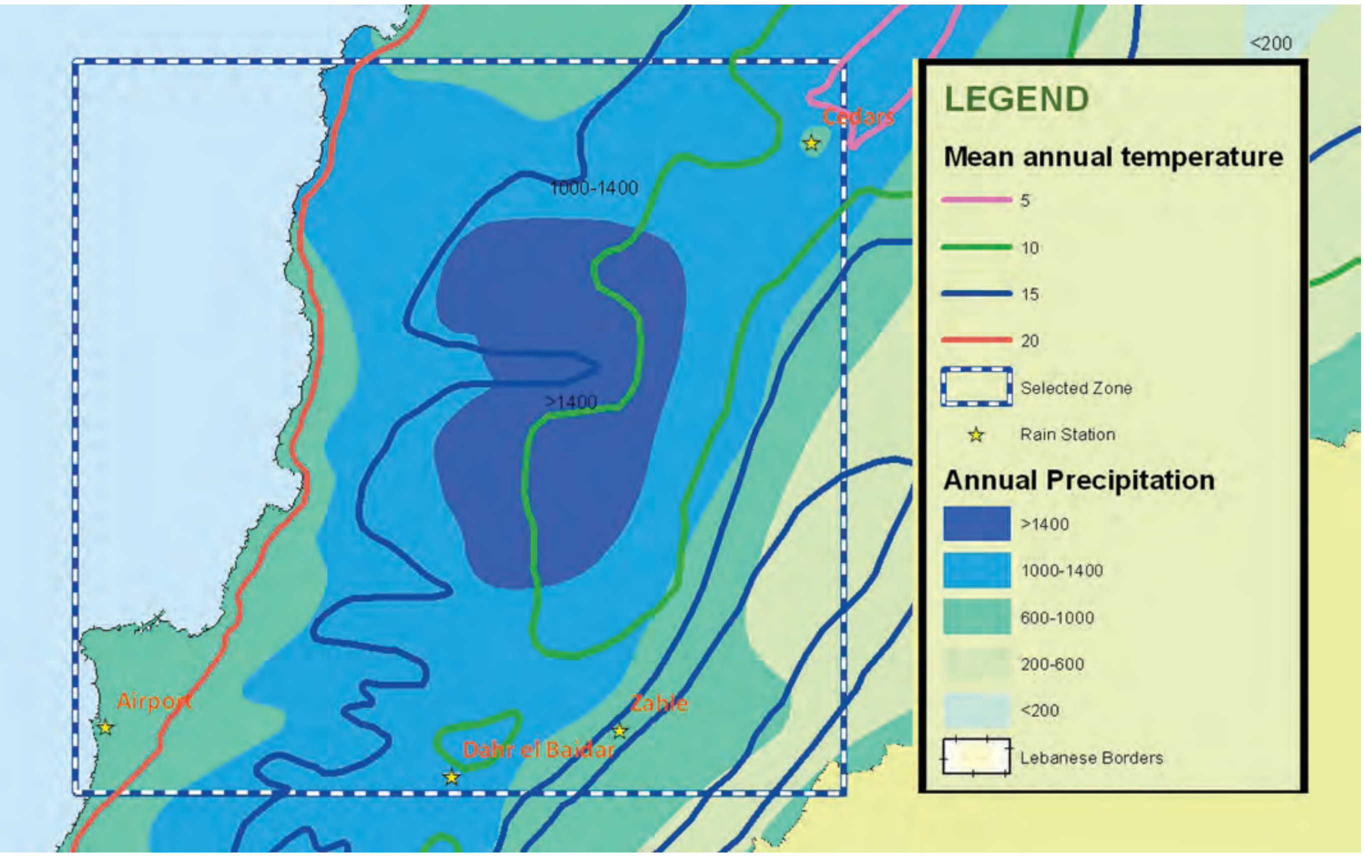


Figure 4-16 Temperature and precipitation isohyets in the study area

perceived more as a development scheme, rather than a finalized and scheduled program (CDR, 2005).

The CDR is coordinating with the MoEW in executing the 10-year plan by following the priorities set by the latter and subcontracting the execution of projects. Accordingly, the NPMPLT looks at the 2030 horizon, and gives the priority for domestic supply, given the critical situation of this part of the demand. The satisfaction of domestic water demands in Lebanon in 2030 under a middle scenario (between scenarios A and B defined below) will require around 418 Mm^3, namely an annual volume of 525 Mm^3 to pump and distribute (Table 4-6), considering a system loss rate of 20%. This volume represents roughly 24% of the maximum exploitable resources. This perspective constitutes a major challenge to the country, because the total volume actually distributed by the Water Authorities is around 280 Mm^3, only half of which reaches consumers (due to network losses), who have consequently developed their own means of water provision (wells and tankers). The reduction of losses and leakages alone will not be enough to cover the demand and a simultaneous increase of 86% of the current distributed quantities by the authorities should be reached. Without this double effort, private and uncontrolled groundwater extraction would reach dangerous levels and lead to a high risk of water shortage in many regions of the country, especially in large agglomerations (CDR, 2005).

As for agriculture, the use of available water resources for irrigation, after satisfying the domestic and industrial demands, would mean the activation of around 1,600 Mm^3 in 2030. This would allow the irrigation of practically all the exploitable lands of Lebanon. However, this objective will be very difficult to reach before 2030, given the constraints of public finance (CDR, 2005).

In addition to an increase in water demand in all sectors (Table 4-7), a decline in annual renewable water resources are projected in Lebanon regardless of climate change impacts (Table 4-8). Lebanon falls below 1,000 m^3/capita/yr, and is therefore considered a water poor country. The projections made in Lebanon's Initial National Communication, as illustrated in Figure 4-17, forecast a water deficit of 140 Mm^3 by 2015 under a low scenario (characterized by a lower growth in demand), and 800 Mm^3 under a high scenario (characterized by a higher growth in demand) (MoE et al., 1999).

Table 4-6 Projections for domestic water demand by 2030

	2000	2030	Growth
Daily domestic water demand / person	200 liters	220 liters	+10%
Total domestic water demand / year	296 Mm³	418 Mm³	+41%

Source: CDR, 2005

Table 4-7 Annual water demand, 2010-2030 by water use category

	Hajjar (1992)	Bou-Zeid and El-Fadel (2002)	World Bank (2010)	CDR (2005)
Domestic water demand, Mm³/year (%)				
2010	-	425 (23)	467 (30)	-
2020	850 (32)	641 (25)	767 (37)	-
2030	-	876 (27)	1,258 (45)	525 (23)
Industrial water demand, Mm³/year (%)				
2010	-	445 (24)	163 (11)	-
2020	240 (9)	598 (23)	268 (13)	-
2030	-	804 (24)	440 (15)	140 (6)
Irrigation water demand, Mm³/year (%)				
2010	-	1,000 (53)	900 (59)	-
2020	1600 (59)	1,350 (52)	1,020 (50)	-
2030	-	1,600 (49)	1,120 (40)	1,600 (71)
Total water demand, Mm³/year (%)				
2010	-	1,897	1,530	-
2020	2,690	2,589	2,055	-
2030	-	3,280	2,818	2,265

Table 4-8 Projections for annual renewable water resources in Lebanon

	Yearly renewable water resources (m³/capita)	Total yearly renewable water resources (billion m³)
1997	766–1,287	
2015	336–979	
2025	262–809	2.00 – 3.94

Source: Bou-Zeid and El-Fadel (2002)

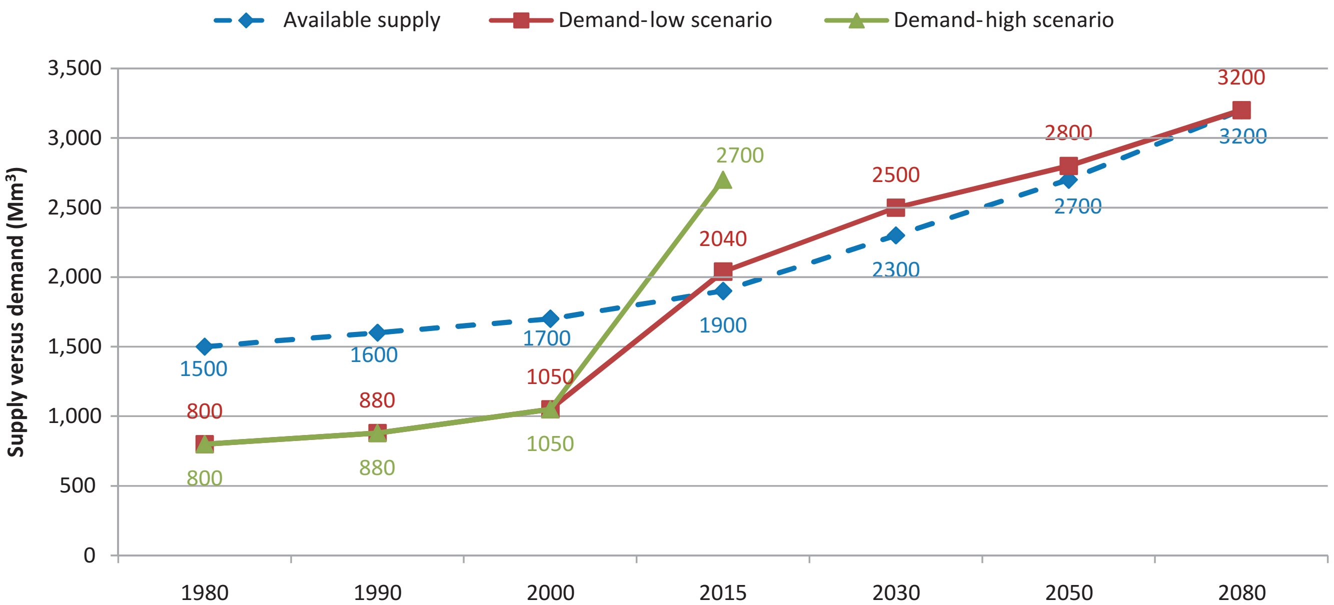


Figure 4-17 Baseline projections of supply and demand

Development of the sector under socio-economic scenarios

Under the scenario A, total water demand will not increase much, given the low increase in population size and the same standard of living. However, increased urbanization entails higher water demand in urban areas, with potentially higher seawater intrusion into groundwater aquifers, leading to groundwater quality degradation. In addition, water demand for the tourism sector will increase with the expected growth in this sector, especially during summer, which will put pressure on the supply system and lead to shortages. Nevertheless, the gradual implementation of government plans in the water sector is expected to relieve some of this pressure.

Under scenario B, total water demand will increase with the high population growth rate, the high economic growth, and the expected improvement in standards of living. The latter will lead to a higher per capita consumption, decrease in water resources per capita and an increase in the average water deficit. Water will continue to be extracted from new private wells; under such conditions, the risk of seawater intrusion and aquifer salinization will increase despite the implementation of governmental plans for the development and expansion of water supply. Since, under this scenario, the CDR envisions relieving the pressure by developing inland cities (Zahleh-Chtaura, Nabatiyeh and Baalbeck), the water supply infrastructure will need expansion to cover those areas which will put great pressure on the supply system. Even though the improved economic situation is expected to improve public finance, and thus allow a better execution of water plans, the supply system – and thus water security – will be at a disadvantage and will not keep up with the expected growth, resulting in unmet demand. In general, vulnerability of water resources is expected to be higher under scenario B. Nevertheless, the higher GDP growth and more balanced economic development can incur a higher adaptive capacity through faster implementation of water projects.

4.5.2 Vulnerability assessment

Water resources are sensitive to changes in temperature and precipitation. The expected rise in average annual temperature and reduction in rainfall will have both quantitative and qualitative consequences on water resources, mainly consisting of a reduction in water reserves and a change of the seasonal distribution of discharged volumes.

The adaptive capacity to any reduction in water resources is low due to the limited capacity for storage of rainwater, excessive reliance on groundwater resources, seawater intrusion, losses in the distribution network, inefficient irrigation methods and the lack of measures that promote water conservation (including metering systems, tiered pricing, awareness efforts, etc.). Vulnerability of water resources is assessed in terms of water demand, availability, supply, and quality.

Water demand: Per capita consumption, as well as domestic, industrial and agricultural water demand, identified as key indicators of water demand, will increase with increased temperatures, potential heat waves and longer dry periods, coupled with the low adaptive capacity. These increases are more significant under scenario B.

Water availability: Water demand will increase with increased temperatures, potential heat waves and longer dry periods, coupled with the low adaptive capacity.

Water supply: The water supply system will be under pressure as a result of increasing demand and decreasing water availability, coupled with low storage capacity. The unmet demand identified as an indicator of water supply will moderately increase under scenario B.

Water quality: Water quality will deteriorate as a result of increasing demand on water resources. Salinity of groundwater would increase due to lower recharge rates of aquifers coupled with potentially higher rates of abstraction, in addition to rising sea level that is projected to reach 12 to 25 cm by 2030 and 22 to 45 cm by 2050 (calculations based on measurements by Cazenave and Cabanes, 2001). Salt water intrusion poses a serious threat to the quality of freshwater, particularly that in some locations such as the Choueifat-Rmeileh region, seawater has actually intruded several kilometers inland into coastal aquifers (El Moujabber and Bou Samra, 2002; El Moujabber et al., 2004). With the gradual implementation of the water plan, groundwater abstraction is expected to decline, thus alleviating seawater intrusion.

4.5.3 Impact assessment

Although available data and analytical means clearly demonstrate that precipitations over the Eastern Mediterranean Basin have not experienced any particular increasing or decreasing trends or a major shift in the rainy season over the past century (Najem et al., 2006; Zeinoun, 2004), long-term rainfall series, however, do reveal wide multiannual variations, where lengthy humid periods follow lengthy dryer periods (Bakalowicz, 2009).

By analyzing monthly average precipitation data for the recent past over four major meteorological stations, and comparing them to near future and distant future predictions generated by the PRECIS model, differential seasonal change in the trends of precipitation and temperature are detected (Figure 4-18 to Figure 2-21). While the predictions show a decrease in precipitation for some months, increases in other months are forecasted, modifying the direction of the trend. This occurrence implies a potential modification in the annual distribution of rainfall.

The main precipitation decrease occurs in December for Beirut, Dahr-el-Baydar and Cedars, and in January and February for Zahleh. The main temperature increase is noticed in July, February and May for the four analyzed stations. Moreover, an increase in precipitation is noted in November for the near future in Beirut, in November and December for Daher-el-Baydar, in September and December for the Cedars, and in September, November and April for Zahleh, which implies an extension of the wet season until early spring in the Central Bekaa area. As for the distant future, the only expected increase in precipitation is noticed in September in Zahleh (Figure 4-18 to Figure 2-21).

The expected decrease in precipitation until the end of the century is of 120 mm in Beirut, 390 mm in Daher-el-Baydar, 316 mm in the Cedars and 242 mm in Zahleh.

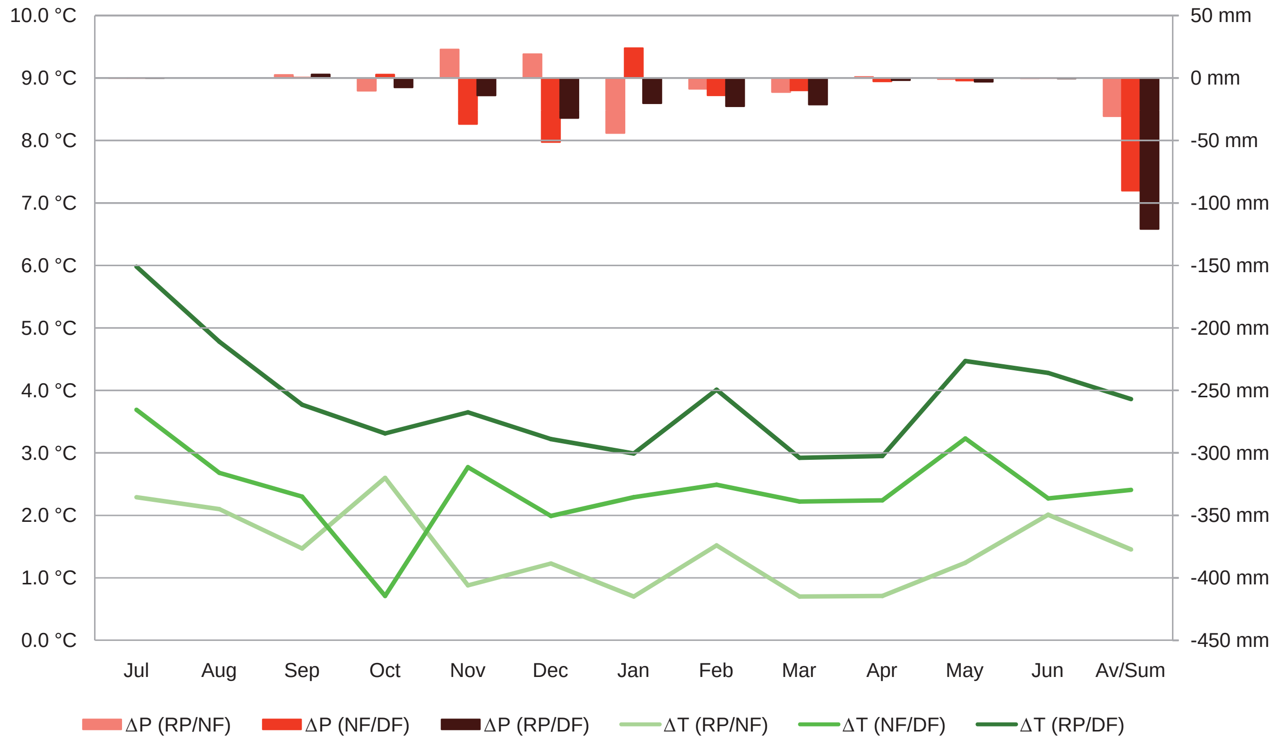


Figure 4-18 Projected changes in precipitation and average temperature – Beirut station

RP: Recent Past - NF: Near Future - DF: Distant Future - ΔP: Variation in Total Precipitation - ΔT: Variation in Temperature

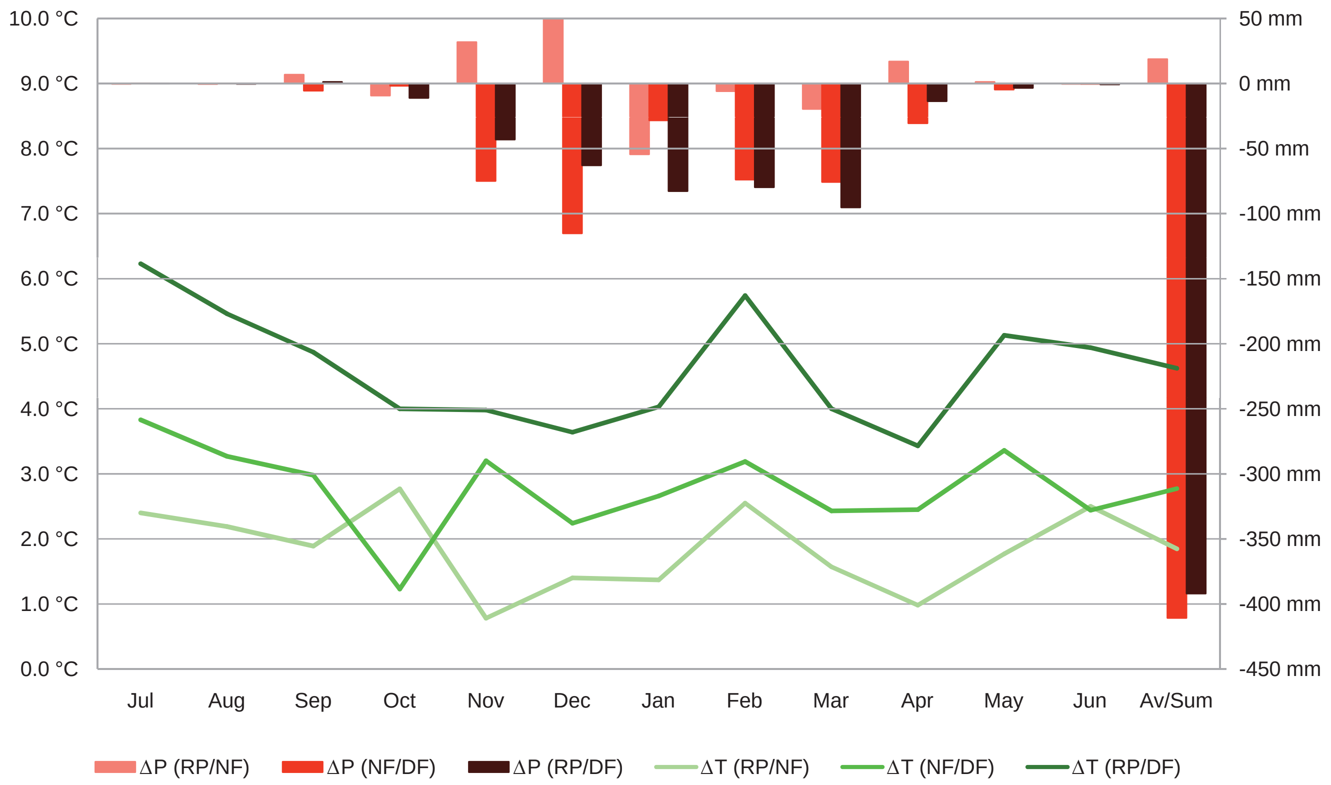


Figure 4-19 Projected changes in precipitation and average temperature – Daher-el-Baydar station

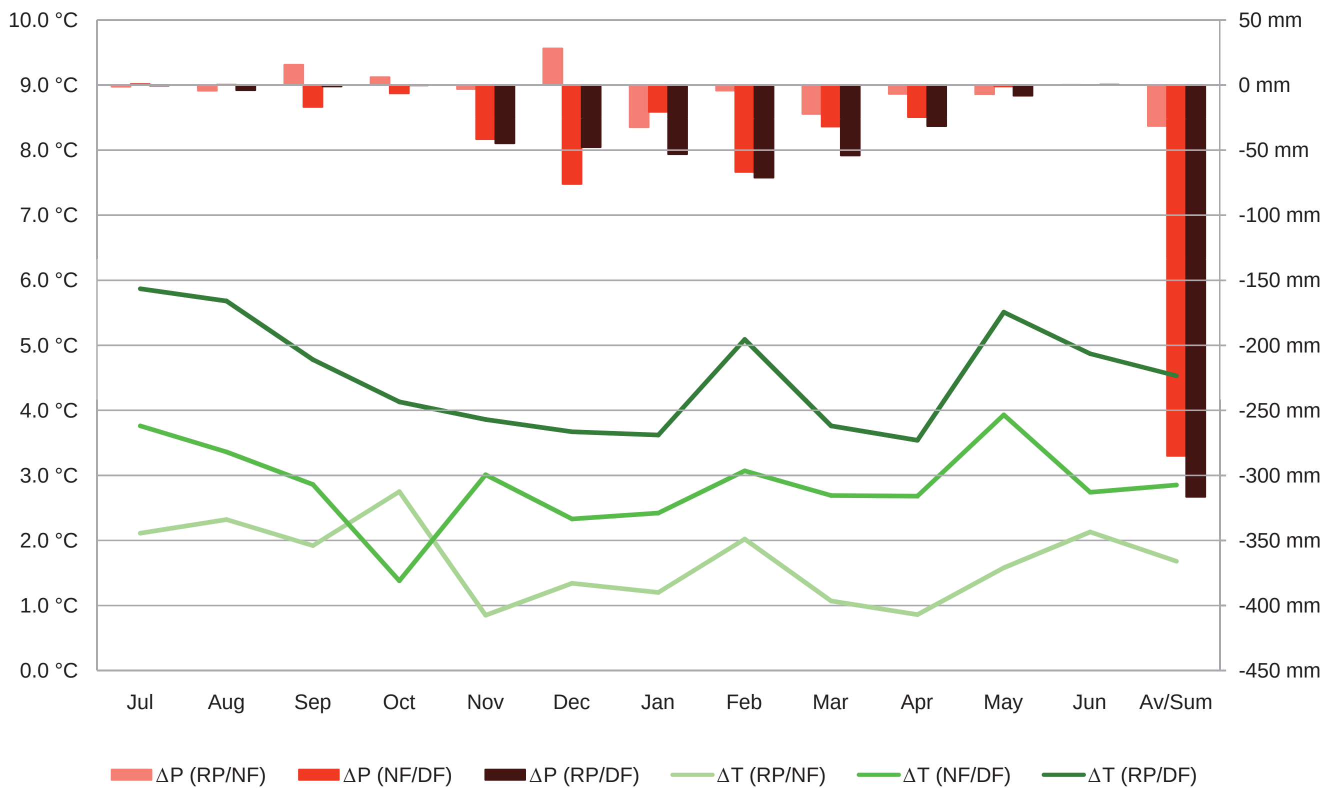


Figure 4-20 Projected changes in precipitation and average temperature – Cedars station

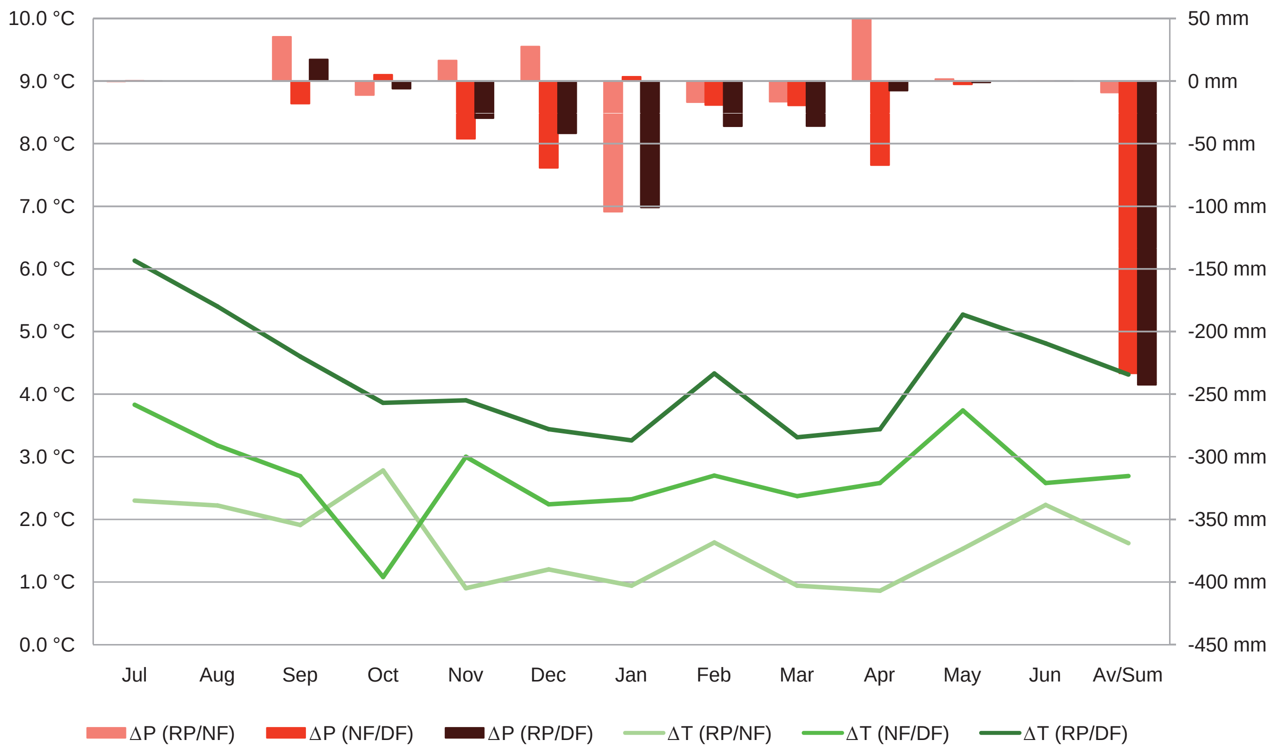


Figure 4-21 Projected changes in precipitation and average temperature – Zahleh station

Using the outcomes of the PRECIS model to determine the expected impact on active precipitation (Pa) as a proportion of total precipitation (P), a decline in Pa and in the proportion of Pa out of P is detected by the end of the century (Figure 4-22).

The decline in the ratio of active precipitation to total precipitation (Pa/P) is the highest in Beirut and the Cedars and the lowest in Daher-el-Baydar and Zahleh, and the percent Pa/P declines considerably more in the second half of the century, as appeared in Figure 4-23.

In addition to a forecasted decline in total and active precipitation, a shift in rainfall is expected in the near future in the 4 studied stations, consisting of higher precipitation in November and December, and a steep decline from January onward (the decline in P being insignificant overall). The overall decline in total precipitation is insignificant and the peak is noted mainly in December, with an additional peak in April for the Zahleh station (Figure 4-24 to Figure 4-27).

Figure 4-28 to Figure 4-30 illustrate the proportion of active precipitation out of total precipitation for the recent past, near future and distant future respectively; while Figure 4-31 to Figure 4-33 show the decline in these ratios: 1) from the recent past to the near future; 2) from the near future to the distant future, and 3) from the recent past to the distant future, respectively.

Renewable water resources available per capita would decrease with declining precipitation and higher ETP, leading to an increase in the average water deficit. An expected increase of 6 to 16% in ETP (Bakalowicz, 2009) will lead to a decline in the national water balance. Climate change is likely to reduce the total volume of water resources in Lebanon by 6 to 8% for an increase of 1°C in average yearly temperature, and by 12 to 16% for an increase of 2°C. Total resources, currently estimated at 2,800 to 4,700 Mm^3, are expected to decrease to 2,550 to 4,400 Mm^3 and 2,350 to 4,100 Mm^3 if temperatures rise by 1°C and 2°C respectively.

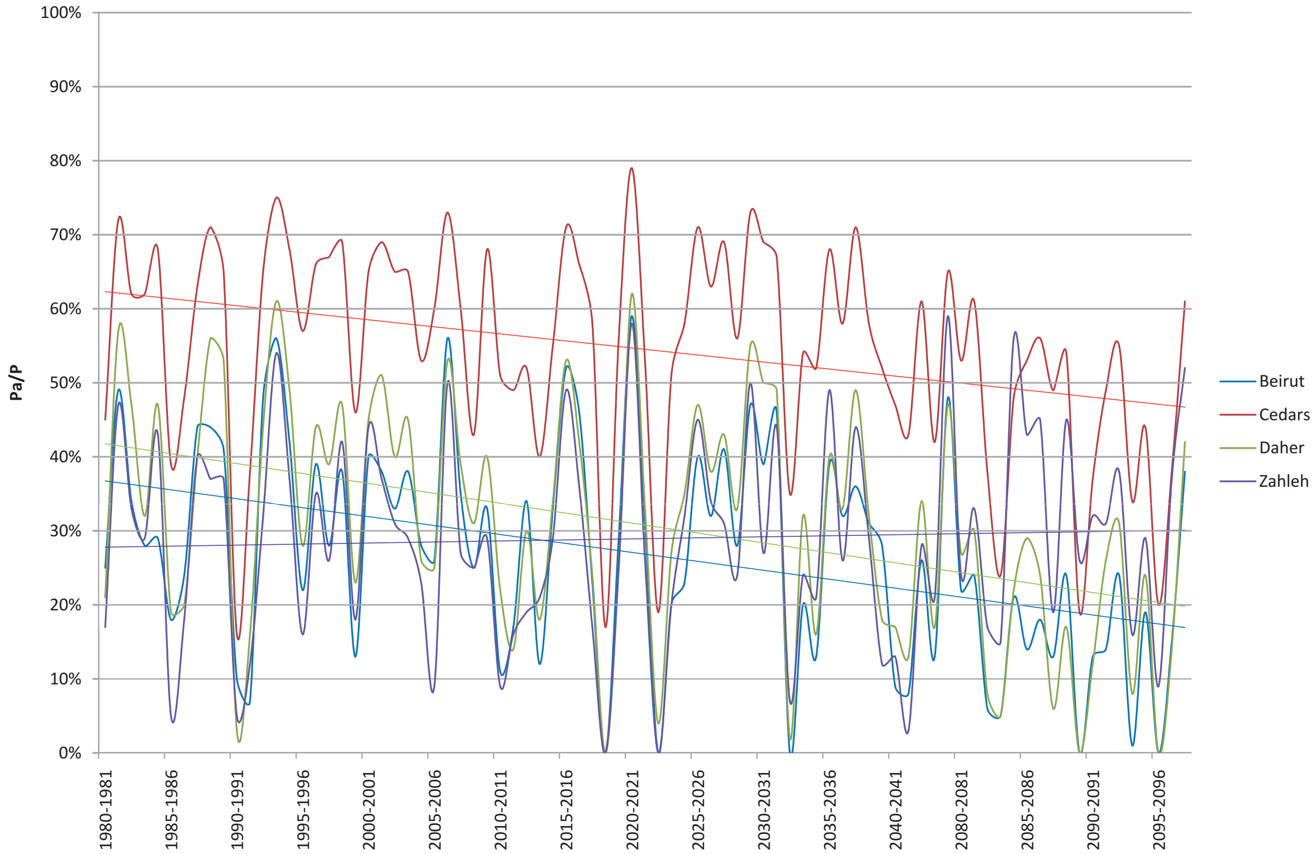


Figure 4-22 Trend pf the proportion of active precipitation out of total precipitation over time in the 4 grid boxes constituting the study area

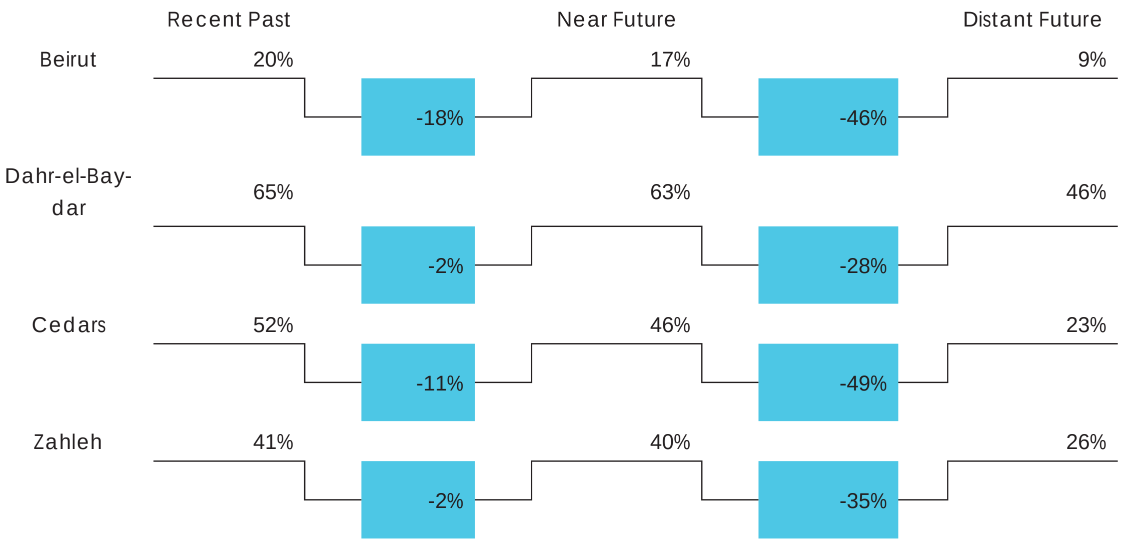


Figure 4-23 Decline in the proportion of active precipitation out of total precipitation in the different regions over time

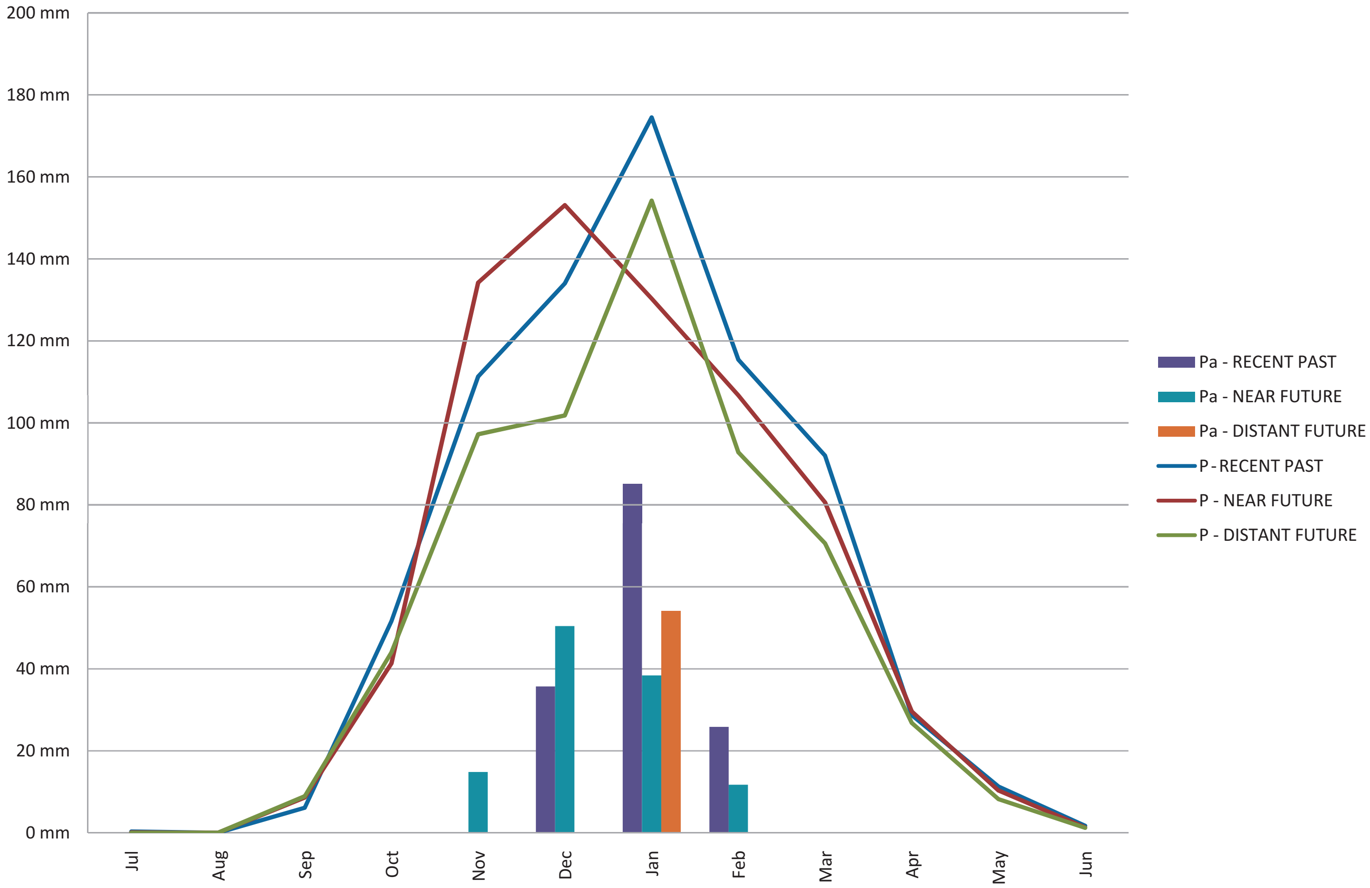


Figure 4-24 Monthly average of total and active precipitation in Beirut (past and projected)

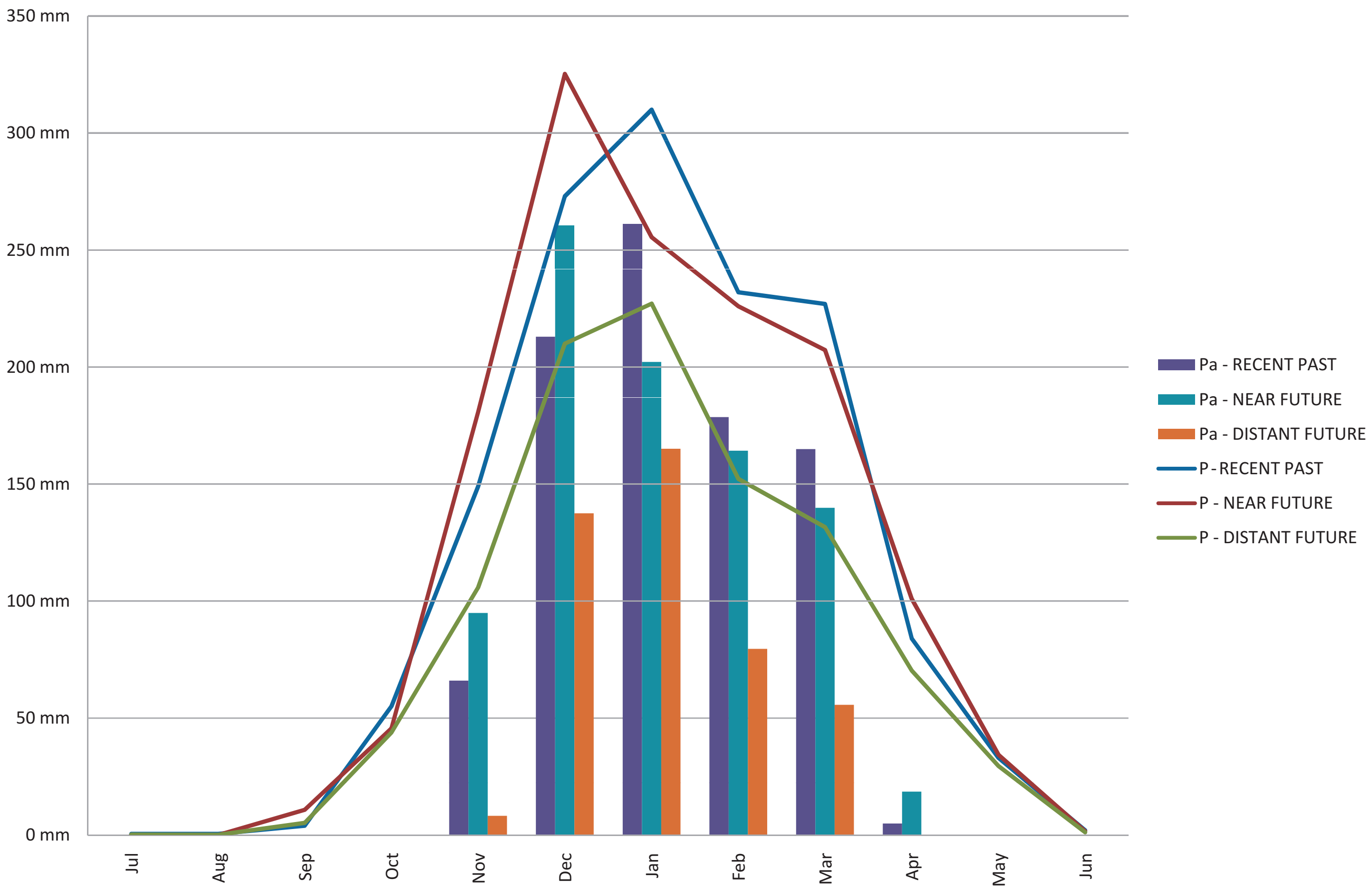


Figure 4-25 Monthly average of total and active precipitation in Daher-el-Baydar (past and projected)

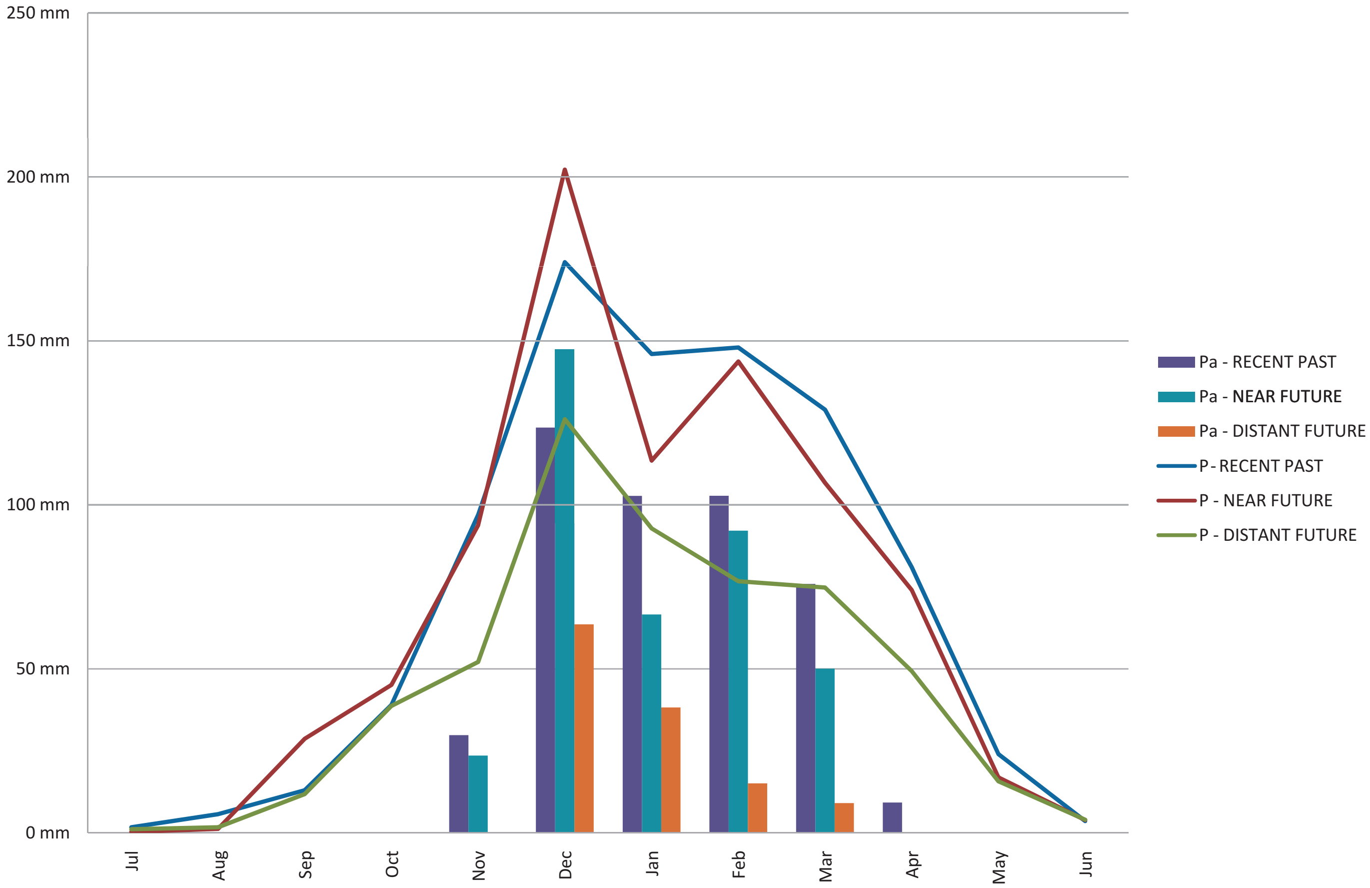


Figure 4-26 Monthly average of total and active precipitation in the Cedars (past and projected)

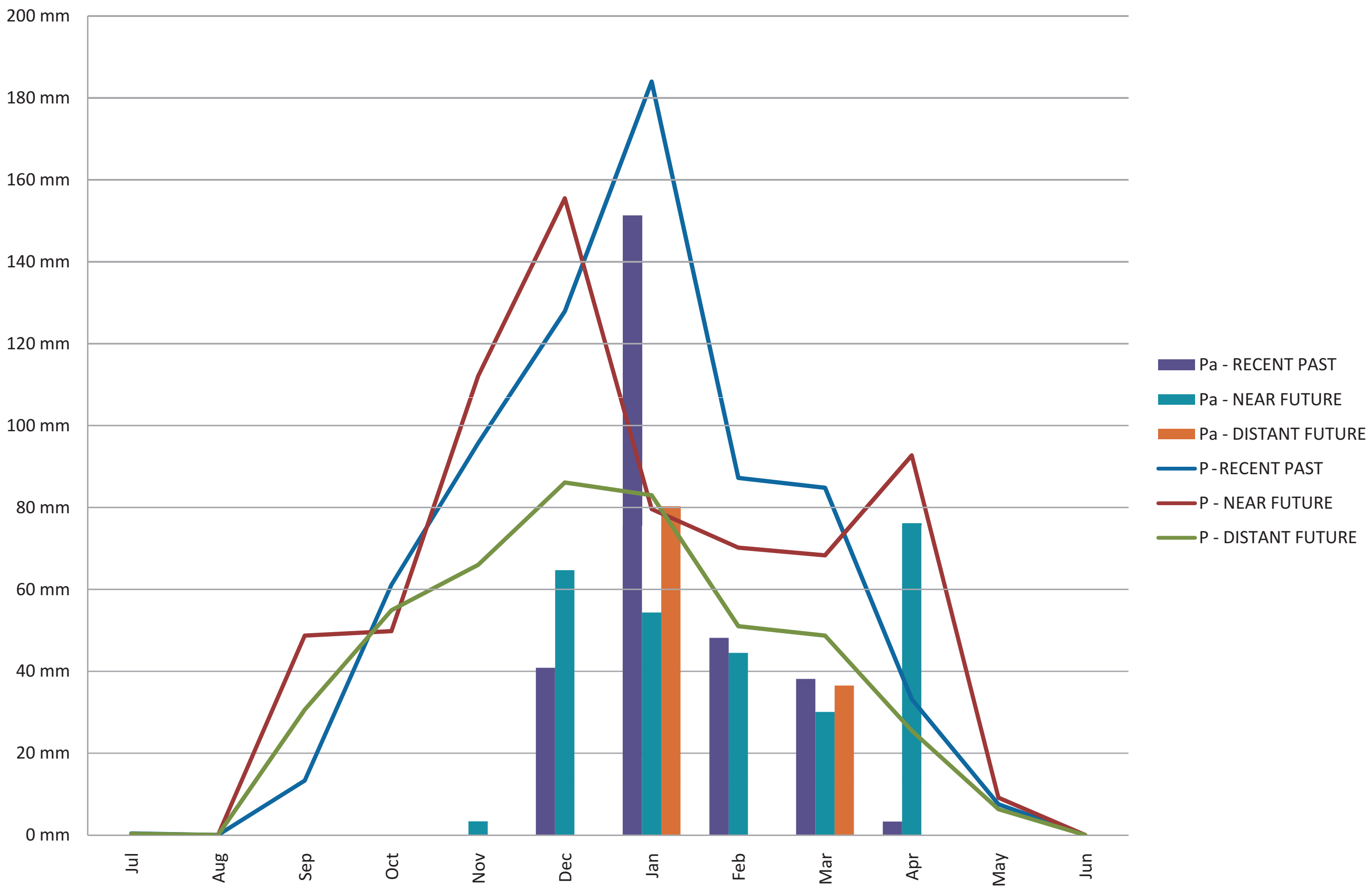


Figure 4-27 Monthly average of total and active precipitation in Zahleh (past and projected)

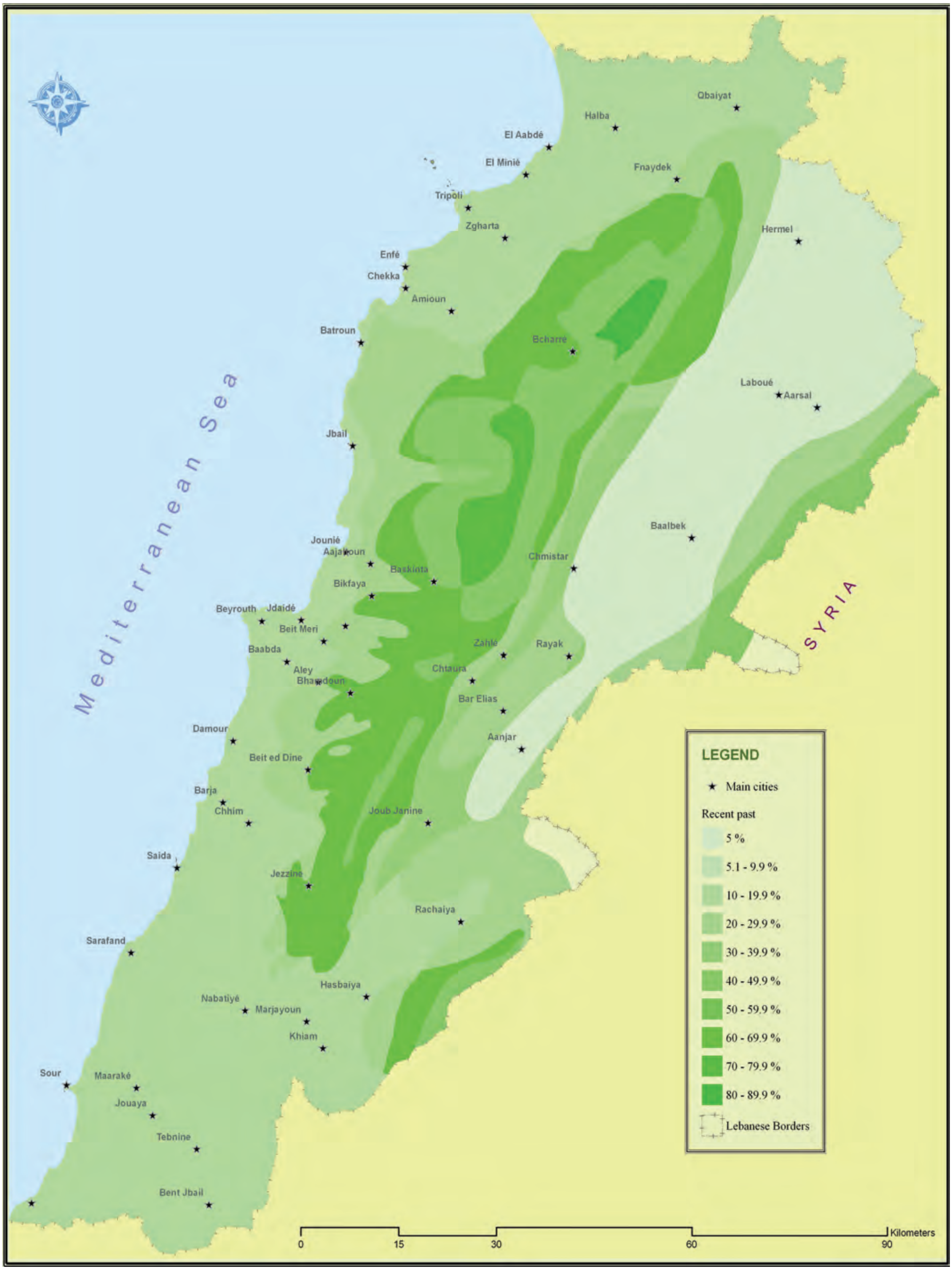


Figure 4-28 Proportion of active precipitation out of total precipitation for the recent past (1960-2000)

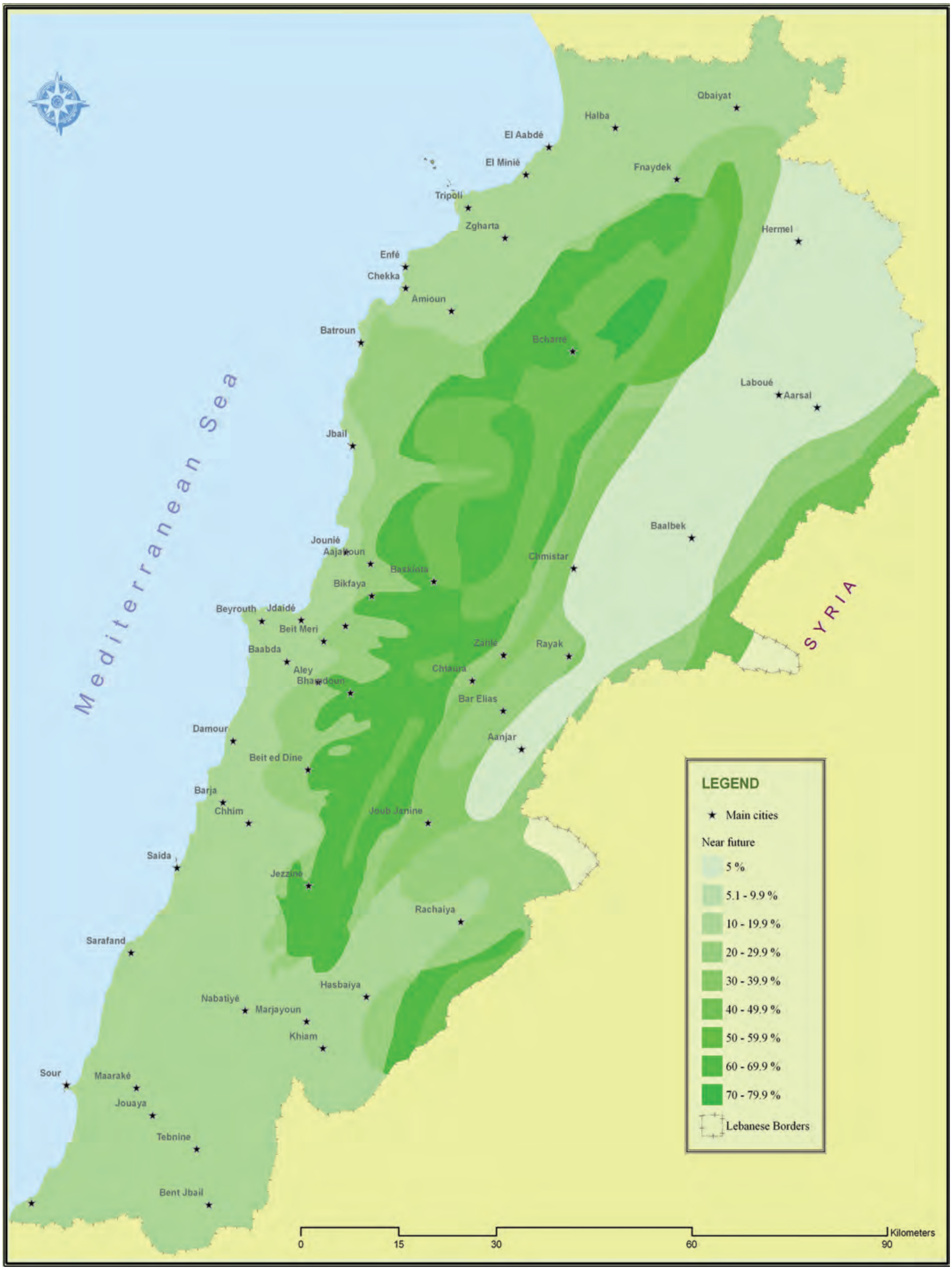


Figure 4-29 Proportion of active precipitation out of total precipitation for the near future (2025-2044)

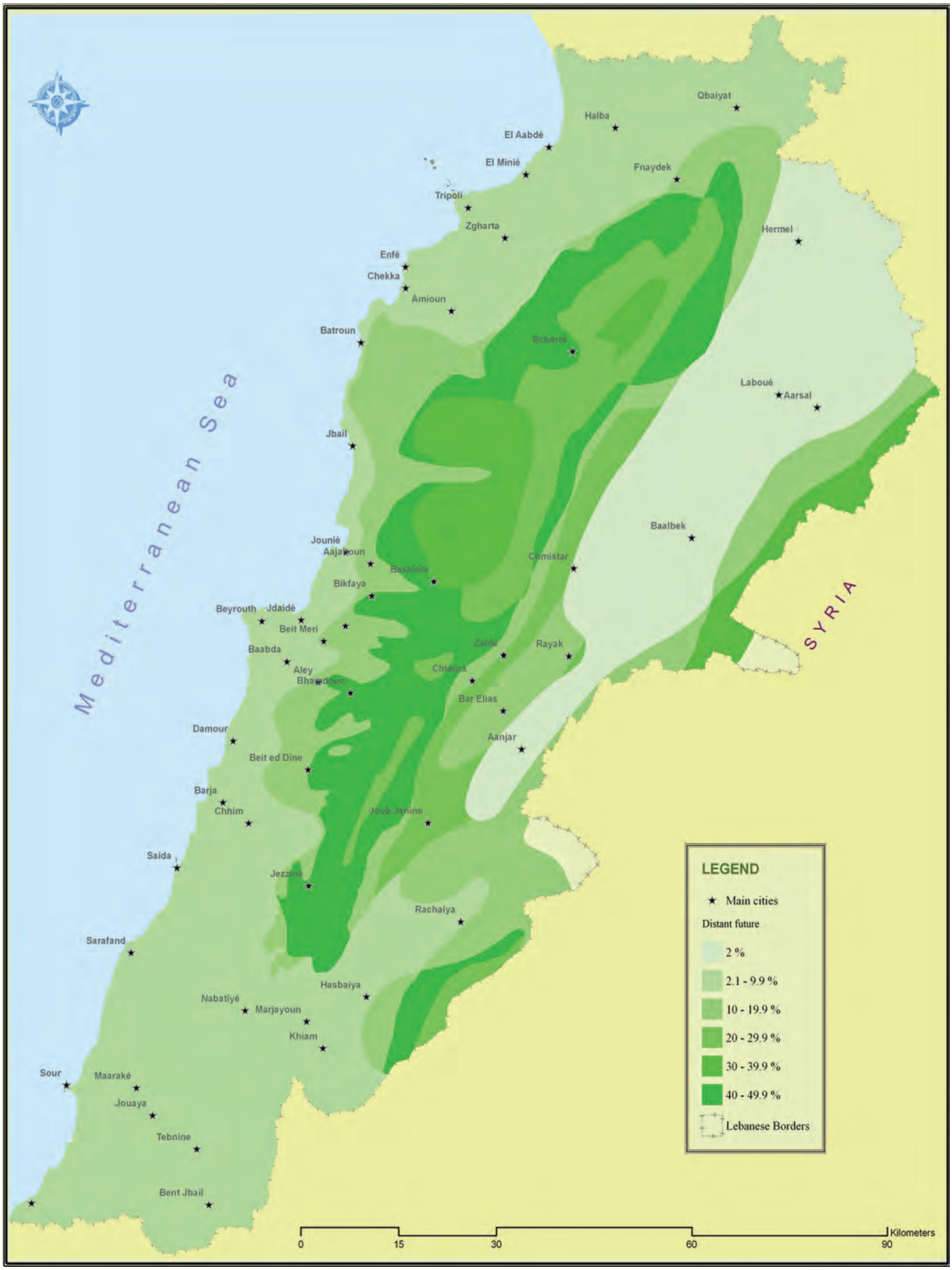


Figure 4-30 Proportion of active precipitation out of total precipitation for the distant future (2080-2098)

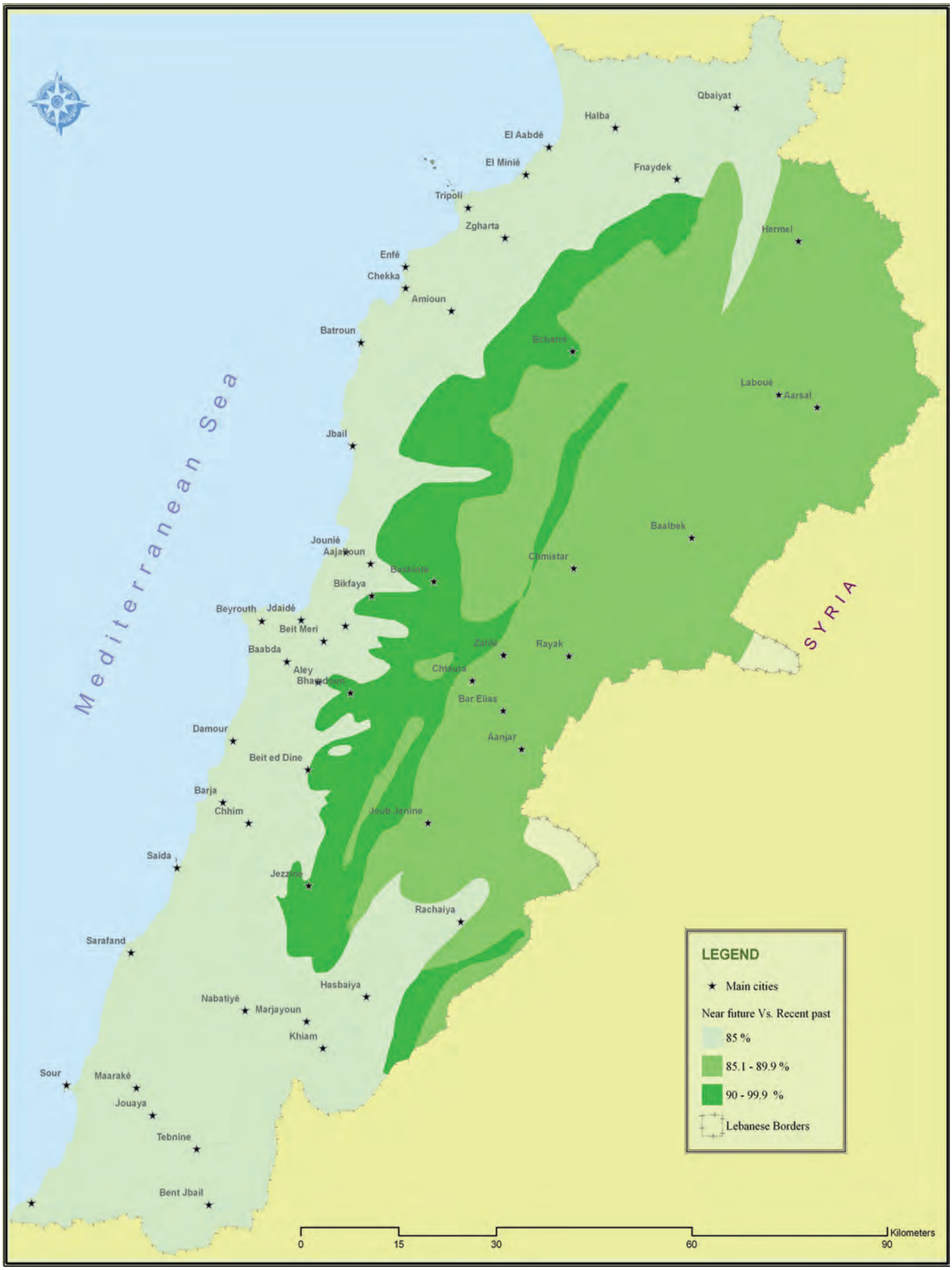


Figure 4-31 Decline in the proportion of active precipitation out of total precipitation from the recent past (1960-2000) to the near future (2025-2044)

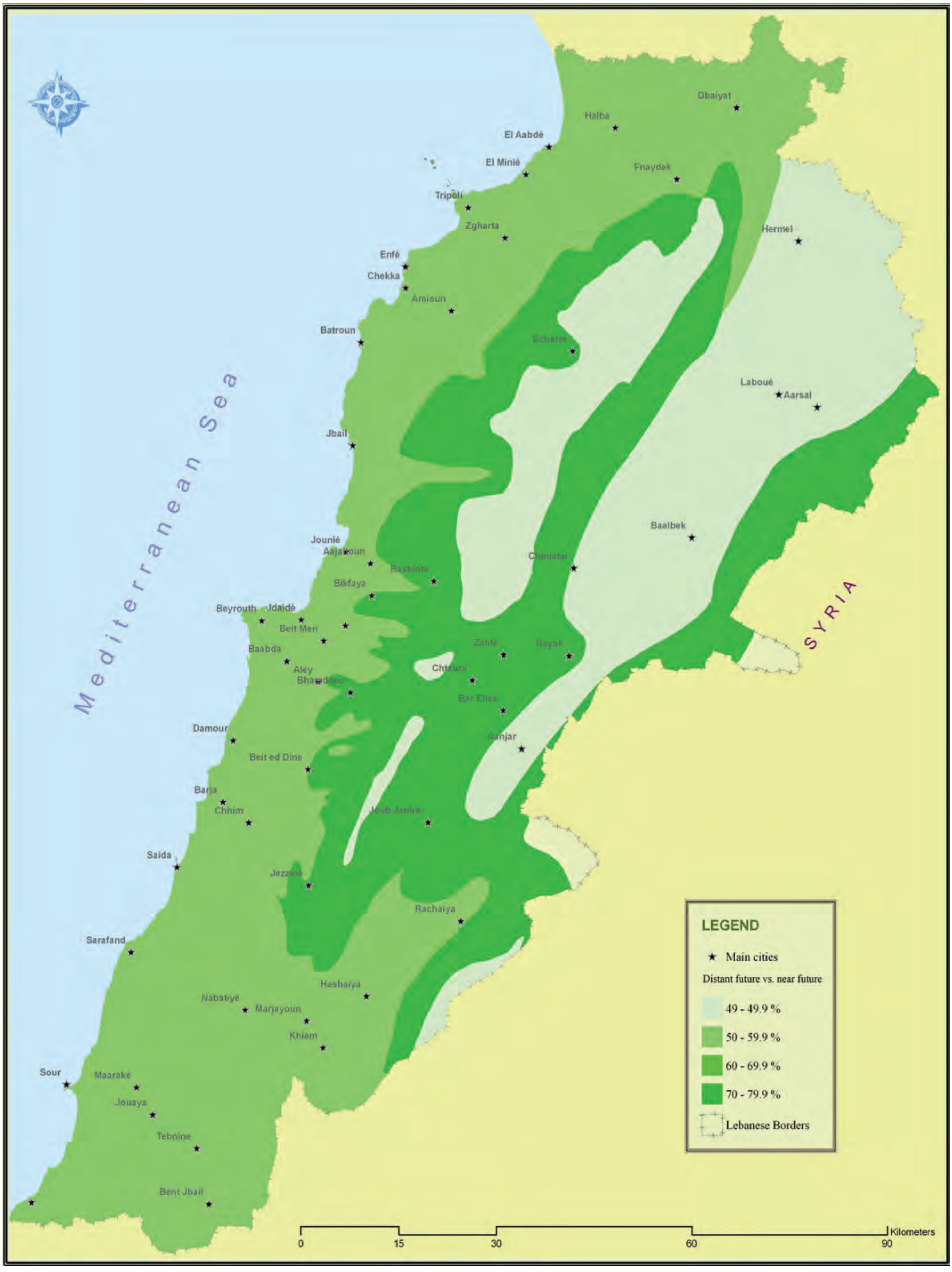


Figure 4-32 Decline in the proportion of active precipitation out of total precipitation from the near future (2025-2044) to the distant future (2080-2098)

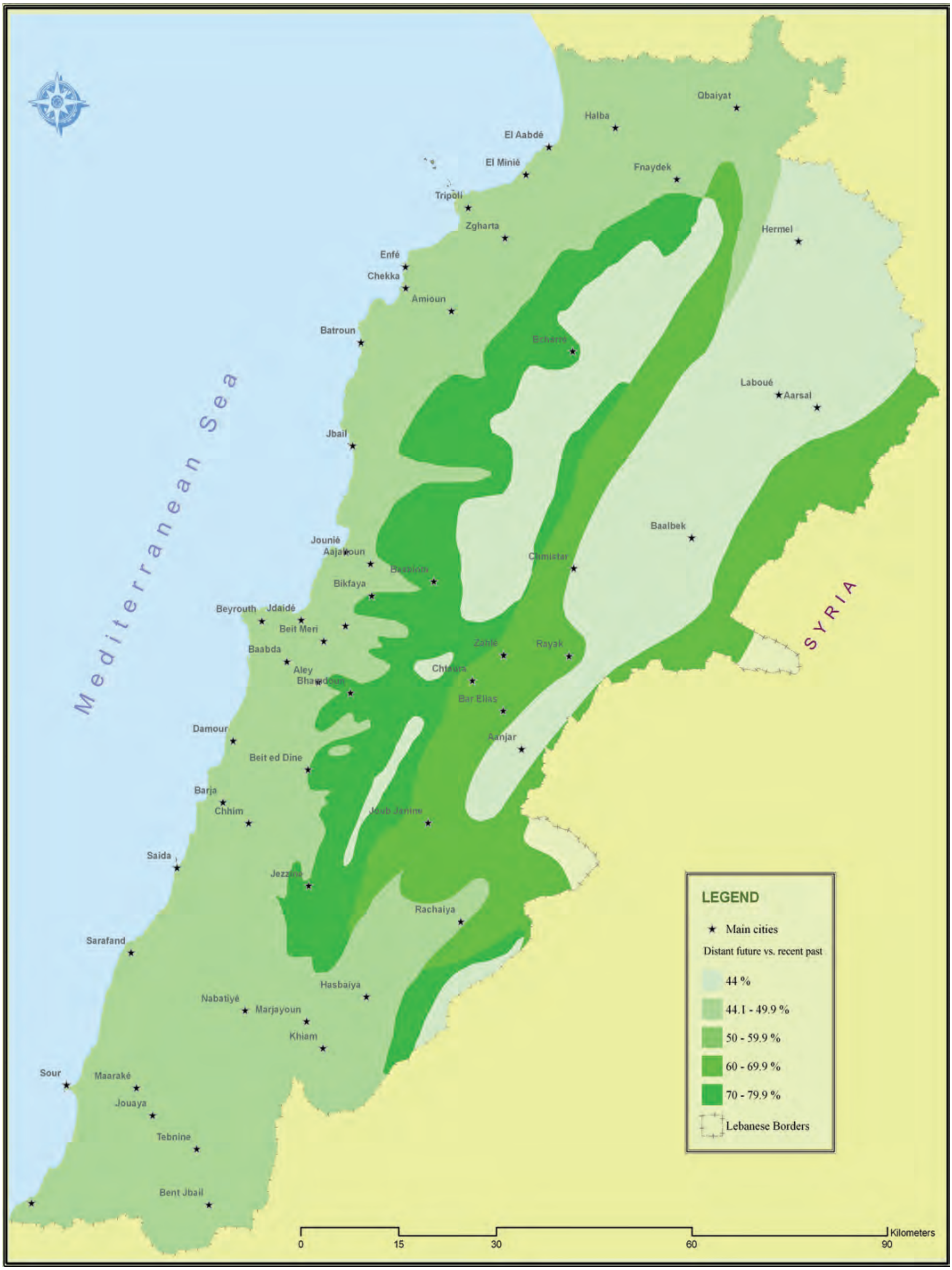


Figure 4-33 Decline in the proportion of active precipitation out of total precipitation from the recent past (1960-2000) to the distant future (2080-2098)

Potential impact on snow cover

In the absence of reliable in-situ measurements of snow cover, and with few measurements of snow depth in different regions that are limited in location and duration, the quantification of the impact of climate change on water equivalent from snow is difficult and is based on a few existing studies.

The analysis of satellite images for different dates have shown a noticeable decrease in the area of snow cover with a decrease in the residence time of dense snow cover, as a reflection of the increase in temperatures (Figure 4-34). Even though the number and succession of satellite images analyzed were not complete (in terms of time series) to depict a clear change in snow cover, the analysis showed a general changing trend. Before the 1990s, dense snow often covered more than 2,000 km^2 of the Lebanese mountains, averaging about 2,280 km^2. Lately, it declined to less than 2,000 km^2 with an average area of about 1,925 km^2. In addition, the average time that dense snow remains on mountains before melting processes have taken place was also decreased from 110 days to less than 90 days (Shaban, 2009).

Increase in temperature also has a considerable impact on snow width, density and volume. In fact, at the Cenomanian plateau of Nahr Ibrahim at an altitude of 2,000 m, a 2°C increase in temperature would cause a decrease of 50% in snow width in addition to a significant reduction in the maximum volume of snowpack (Figure 4-35 and Figure 4-36). In the upper basin of Nahr el Kalb, a 2°C warming (equivalent) would also reduce snowpack from 1,200 Mm^3 to 700 Mm^3, and a 4°C warming would further reduce it to 350 Mm^3. The altitude of snowpack that lasts would also shift upwards from 1,500 m to 1,700 m for a 2°C warming, and to 1,900 m for a 4°C warming (Najem, 2007). An increase of 0.8 to 1.0ºC in temperatures would also rise the limit of rain/snow limit by about 100 m, an increase of 1.6 to 2.0ºC would rise it by 200 m, and for 3ºC, by about 300 m (Hakim, 1985; El-Hajj, 2008; Bakalowicz, 2009). The rise in altitude of the rain/snow limit is expected to induce a reduction in the snow cover volume and hence in an equivalent amount of water.

This has consequently a main impact on the stream flow regimes of major rivers and springs. Drought periods would occur 15 - 20 days to over a month earlier for a 2 ºC and 4ºC warming respectively, and peak flows would shift from the end of April to the end of February. River flows would increase during winter months (December to February) while demand is low. In the absence of proper water storage structures, a considerable proportion of this water would be lost. From April to June, while the demand for irrigation water for agriculture is higher, the reduction in snowpack will not allow to sustain river flows, therefore posing a challenge on the sector. The dam planned for Boqaata might partially respond to the potential water storage problem, since it will have a capacity of 7 Mm^3 (CDR, 2005). However, it will probably not provide a solution to the coastal flooding issue as it is located at an altitude of 1,560 m (Mount Lebanon) (Hreiche et al., 2007; Najem, 2007).

The volume of water stored in the snow cover, the main source for the recharge of major mountain aquifers, is expected to decrease by about 50%. The snow cover would also melt faster, with the snowmelt period ending two to three weeks earlier than it currently does. The main consequence would consist in the lengthening of the aquifer depletion season, thus resulting in a decrease in spring and stream discharges towards the end of the dry season. Aquifer recharge conditions, however, remain less predictable, as one cannot easily forecast whether early precipitations would efficiently recharge the aquifers or simply contribute to fast runoff.

Another expected consequence is the reduction of the snowing period by 1 to 3 weeks towards the beginning and end of the season. Spring recession periods would consequently be extended - recession being the period during which an aquifer is naturally depleted after precipitations have ceased. When recession is prolonged, discharges keep diminishing exponentially, thus leading to the reduction of the volume of exploitable reserves, in the form of reduction of groundwater levels and spring discharges. Lower spring discharges and lower groundwater levels than those currently observed are thus expected towards the end of dry seasons. However, the decrease of the reserves of karst aquifers during the dry season is supposed to be compensated by their quick recharge during the first rainfall events, as fast infiltration is expected to spread (Hakim, 1985 ; El-Hajj, 2008; Bakalowicz, 2009).

These results highlight the increasingly difficult challenges that water resources management will be faced with in the future, particularly with respect to water supply, as a result of the expected increase in population and demand per capita, coupled with longer periods of water shortage. While autonomous adaptation through changing of sowing dates is possible in the agriculture

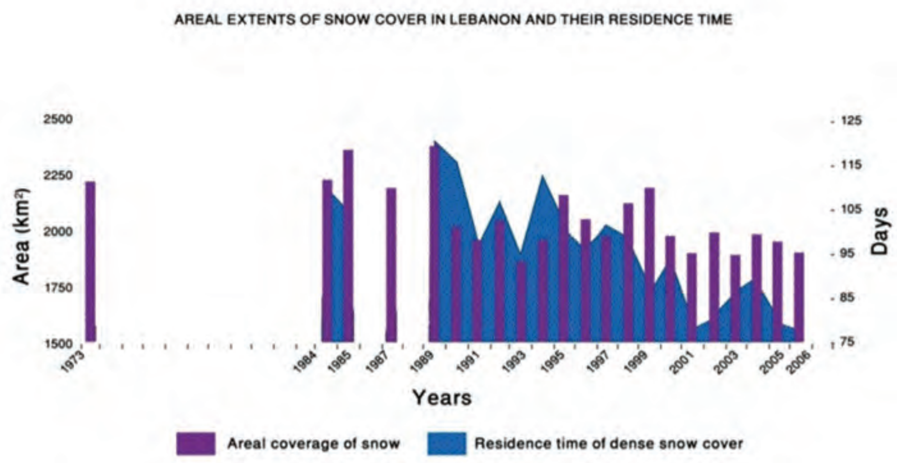


Figure 4-34 Areal extents of snow cover in Lebanon and their residence time Source: Shaban, 2009

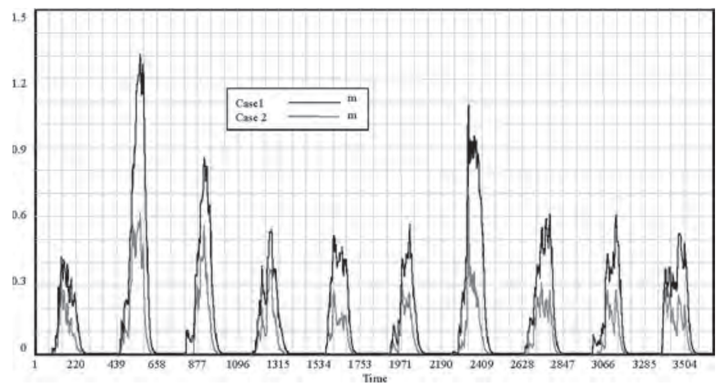


Figure 4-35 Mean snow width generated over 10 years (Case 1: reference simulation; Case 2: scenario of an increase by 2°C)

Source: Hreiche et al., 2007

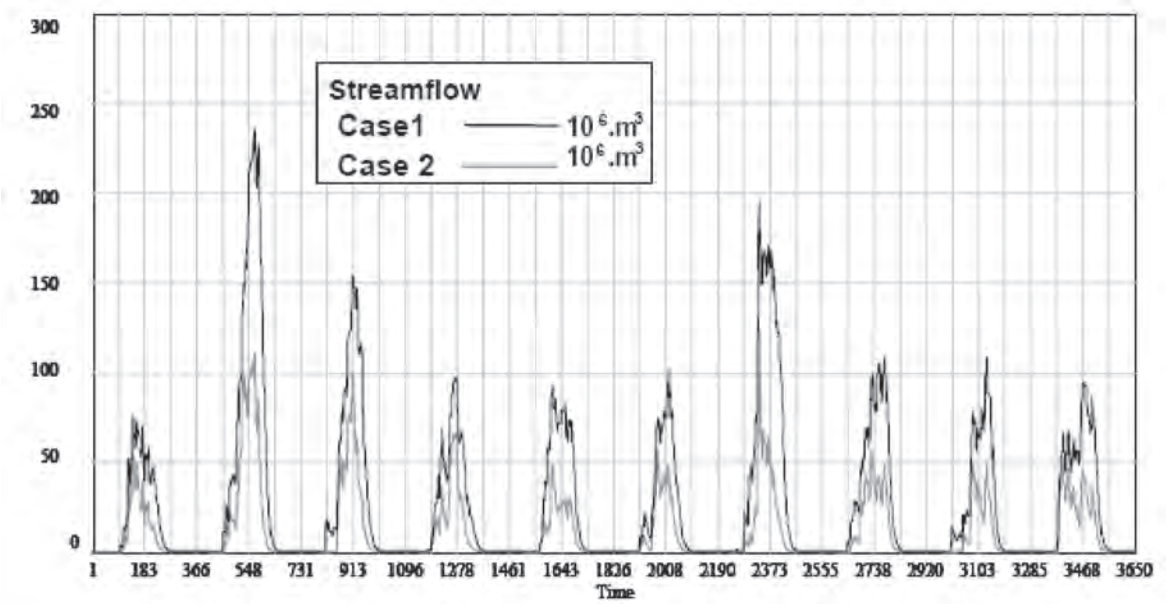


Figure 4-36 Evolution of the snowpack in Nahr Ibrahim catchment simulated over 10 years. (Case 1: reference simulation; Case 2: scenario of an increase by 2°C). Source: Hreiche et al., 2007

sector, the shortening of the season when aquifers and springs recharge will necessitate the construction of surface and underground storage reservoirs that can store enough water for the longer dry season (Hreiche et al., 2007; Najem, 2007).

The expected decline in water availability, coupled with the increase in water demand (especially under Scenario B), in the unmet water demand, and in groundwater salinity, will threaten water security in the country. However, the implementation of government plans in the water sector could be favored by the higher GDP growth and balanced development under scenario B, thus compensating for the shortages and improving water security.

4.5.4 Adaptation Measures

Table 4-9 presents the proposed adaptation action plan for the water sector.

Table 4-9 Water sector adaptation action plan

Impact	Proposed Adaptation Strategy	Activities
Increase in the salinity of coastal groundwater wells	Increase the resilience of groundwater to climate change in coastal areas	- Identify un-exploited and overexploited aquifers, potential sites for artificial recharge and define protective buffer zones with restrictions of land use - Assess feasibility of artificial groundwater recharge in major coastal areas - Strengthen the enforcement of wells permitting and monitoring in coastal areas - Develop awareness program to reduce water consumption in vulnerable areas - strengthen the capacity of water and wastewater establishments to monitor groundwater abstraction - Drafting a penal code for polluting water bodies based on the "polluter-pays" principle, which clearly delineates the responsibilities of the Ministries of Environment, Public Health, Energy and Water, and the Water Establishments in the management of water quality - Developing and implementing an emergency response plan to counter pollution events, and conducting capacity-building for the Civil Defense, Army, Internal Security Forces and others in pollution clean-up and recovery efforts
Increase in water demand due to increase in temperatures	Implement water demand side management strategies to reduce water demand in the domestic, industrial and agriculture sectors	- Design and implement a domestic water tariff structure which encourages water saving; this should be accompanied by proper water metering strategies; prioritize implementation in areas where water shortages are expected to be highest - Penalties must be imposed for over-abstraction by the pertinent authorities - Design and implement a water fees strategy for irrigation which encourages implementation of water efficient irrigation methods; prioritize highly vulnerable areas - Develop a targeted awareness campaign to major water users to promote reduction of water consumption - Establish a Lebanese Center for Water Conservation and Management

Impact	Proposed Adaptation Strategy	Activities
Decrease in water availability and increased incidences of unmet demand	Develop watershed management plans that take into consideration climate change	- Prioritize watersheds according to their vulnerability to climate change and initiate development of management plans on the most vulnerable ones - Assess water balance in each watershed taking into consideration projected precipitation decrease, temperature increase and other relevant climatic parameters - Prepare a management plan that considers future uses, water availability, and measures to reduce demand and provide alternative sources of water supply to ensure future demand is met - Develop dams and hill lakes to store rainwater for use during the dry period - Emphasize the importance of aquifer recharge in water sector plans and strategies. - Promoting water reuse at all levels: reuse of greywater, water harvesting, Best Management Practices for storm water runoff management, collecting and storing storm water for reuse in irrigation, and reuse of treated sewage
	Implement pilot initiatives to demonstrate the feasibility of alternative sources of water supply and develop necessary standards and guidelines	- Implement pilot rooftop water harvesting projects - Test feasibility of storm-water re-use in agriculture - Test -re-use of treated wastewater in agriculture and develop and endorse relevant standards - Test and develop guidelines for grey water re-use - Test and develop guidelines for aquifer recharge
	Develop a water database to support decision-making	- Assign one national institution to hold and implement the water monitoring data - Develop and implement a long-term river and spring monitoring program - Develop a comprehensive database of groundwater wells - Develop and implement a snow cover monitoring program in partnership with the private sector where possible (ski resorts operators)

4.6 Vulnerability and Adaptation of Coastal Zones

The Lebanese coastal zone extends about 230 km in length and is characterized by being very narrow, representing 8% of the total Lebanese surface area in a 500 m wide corridor along the coastline (CDR, 2005). The coastal zone has a very high population density estimated at around 594 inhabitants per km^2 in 2000 and is characterized by a concentration of Lebanon's main economic activity, In fact, the largest Lebanese cities (Beirut, Saida, Tripoli, Tyre) are located along the coast, and contribute to more than 74% of Lebanon's GDP through commercial and financial activities, large industrial zones, important agricultural lands as well as fishing and tourism (UNEP-MAP, 1999). Lebanon has four main commercial ports in Beirut, Tripoli, Saida, and Tyre, and a number of small ports are scattered along the coastline, primarily used for fishing and leisure purposes. The coast is characterized by the presence of beach resorts and marinas projects for leisure and recreational activities, archaeological monuments, natural landscape (Ras Chaqaa, Enfeh, Pigeon Rock), and natural reserves (Palm Islands, Tyre Coastal Nature Reserve). Figure 4-37 shows the types of urban development along the coastline.

4.6.1 Methodology

Scope of Assessment

This section examines the current and future vulnerability of urban, industrial, commercial, touristic and agricultural agglomerations along the Lebanese coast and the shoreline to sea level rise (SLR) and sea surface temperature (SST). It assesses the likely impacts of SLR and SST on coastal and marine biodiversity, on coastal populations and on the different types of coastal activities with priority given to low-lying areas, areas under anthropogenic pressures and areas that experience saltwater intrusion. Vulnerability and impacts assessment is examined throughout the whole year and during the periods of extreme storms such as January, April and September for high wind speed and January and February for extreme high waves.

Methods of Assessment

The vulnerability and impact assessment is conducted based on the baseline socio-economic scenarios (A and B) identified under the NPMLPT and on the climate change scenario identified by PRECIS.

Development of the sector under socio-economic scenarios

Under scenario A, tourism, food production industries and commerce activities will probably be the main economic activities, which will increase shipping activities over the four main commercial ports and will threaten the coastal zone's major assets and remaining agricultural lands in Akkar plain, Damour, and south Lebanon. Population density along the coastal zone is expected to remain stable or might face a slight decrease due to low population growth, increased emigration and the planned development of inland cities which is expected to stabilize the pressure on the coast. Salt water intrusion will remain a problem or could probably decrease as coastal population density slightly declines and as agricultural areas recede to be replaced by tourism infrastructure.

Under scenario B, population density and thus concentration of settlements will increase at a high rate along the coast as a result of the high population growth. The total income from fishing will probably increase as a result of the reorganization of the agriculture sector and the investment in the fishing sector. The contribution of coastal activities (industry, agriculture, tourism, etc.) to GDP is expected to significantly increase due to an increase in Lebanon's production that will boost its competitiveness. With the increase in water demand and overpumping, the risk of seawater intrusion will highly increase despite plans (under the NPMPLT) to reduce monoculture and intensive agriculture which could potentially reduce groundwater withdrawal for irrigation.

4.6.2 Vulnerability assessment

The coastline is sensitive to erosion due to natural factors such as strong storms, and different local, anthropogenic factors which act as pressures on coastal ecosystems. Sensitivity is higher in low-lying coastal areas such as in Tripoli, Chekka, Amchit, Jbeil, Jounieh, Damour, Jiyeh, Saida and Tyre which are more exposed to tides and have lower natural defense structures. Moreover, the improper management of agricultural activities, rural migration to coastal cities and urban sprawl is leading to the disappearance of the coastal agricultural lands which will lead to a reduction in water infiltration in the soil and therefore pose a greater risk of flooding of the lower coastal plains in the events of heavy rainfall (CDR, 2005; EC, 2006; UoB, 2006). The natural factors and anthropogenic pressures that prevail in some coastal

Figure 4-37 Land use along the Lebanese coastal zone

areas in Lebanon might result in an increased sensitivity of coastal areas and structures to climate change and its associated impacts.

The adaptive capacity of coastal communities is low, due to the concentration of activities and the mix of livelihood resources on the coast. The sensitivity and adaptive capacity are undermined by the urban sprawl and privatization of the coastline; marine pollution from solid waste disposal and wastewater discharge in the sea; beach quarrying and sand extraction; salt water intrusion; and coastal setbacks.

The absence of proper land use planning, high population density along the Lebanese coast, industrial and commercial activity, lack of legislation, and weak enforcement capacity increase the vulnerability of the Lebanese coast to climatic factors. The vulnerability of some coastal hotspots such as marginalized urban settlements and coastal slums, small and medium coastal enterprises, natural areas and coastal agricultural plains is higher with the exposure to sea level rise, storm surges, coastal inundation and flooding, and increased rainfall intensity. Indeed, small beach resorts and small fishing harbors are potentially vulnerable to coastal flooding and inundation from sea level rise combined with likely extreme storm events. Sandy beaches, which represent 20% of the shoreline, and corresponding habitats, are extremely vulnerable to shoreline erosion or the permanent loss of sand and gravel caused by high water level, wind-driven waves, and past sand and gravel dredging practices. Furthermore, the presence of the five large-scale dumps, namely Normandy, Bourj Hammoud, Tripoli, Tyre and Saida on the coast exacerbates coastal degradation and causes significant pollution of marine waters. As for agricultural plains, Akkar, Damour, Saida and Tyre are vulnerable to coastal flooding and inundation, especially under Scenario B with high population growth and high urbanization rate. The vulnerability of coastal zones to climate change in both scenarios could be low to moderate if steps to initiate investment in adaptation and internalize future risks from climatic variability are taken.

4.6.3 Impact assessment

The impacts of climate change on coastal zones are:

- Coastal flooding and inundation during high sea level conditions (e.g. storms), which degrades coastal ecosystem services, limits coastal use and damages infrastructures especially in heavily populated areas and agricultural plains (Georgas, 2003; Micallef, 2009);
- Sea water intrusion and salinization of coastal aquifers, especially that groundwater aquifers are over-utilized. The coastal area of Choueifat-Rmeileh region is one of many districts in Lebanon that are threatened by the penetration of seawater into the aquifers (El Moujabber and Bou Samra, 2002; El Moujabber et al., 2004);
- Coastal erosion due to an increase in the frequency and intensity of episodic weather events, sea level rise or an alteration of coastal circulation patterns. Studies have shown that between 1963 and 2003 erosion of the Lebanese coast was the highest in sandy and pebble sand (Abi Rizk, 2005);
- Losses in coastal and marine economic activities such as tourism, agriculture, fisheries, transportation and other essential services. Coastal communities relying on ecosystem services, such as fishing for livelihoods will bear the impacts of increases in sea water temperature as the marine fish stock might decrease and marine biodiversity might change or decline. However, other thermophilic species might become more abundant such as Sardina (MoE et al., 1999). The combination of higher water temperatures, overfishing and sewage discharge will cause a predominance of jellyfish and algal blooms in coastal waters (FAO, 2009c).

4.6.4 Adaptation measures

The purpose of coastal zone adaptation is to reduce the net cost of climate change impacts, whether those costs apply to an economic sector, an ecosystem, or a country. The vulnerability of the coastal zone is not only determined by the degree of climate change but also by the current social, economic and environmental conditions as well as existing management practices. Three generic options (Figure 4-38) should be adopted and the choice of the suitable option depends on the pattern of relative sea level change, geomorphologic setting, sediment availability and erosions as well as social, economic and political factors:

- **Planned retreat adaptation measures:** they consist of pulling back human activities from the coast through the creation of buffer zones on a minimum width of 100 m of the shore band and the creation of a network of coastal marine reserves through the rehabilitation and preservation of the 30 remarkable sites defined by the NPMLT (CDR, 2005). This measure will strengthen the ability of coastal habitats and species to adapt on their own.

- **Accommodation adaptation measures:** they consist of reactive measures to minimize human impacts through reducing or moving sources of urban, industrial and agriculture pollution and introducing effective early warning systems along the coast for coastal hazards.

- **Protection adaptation measures:** consist of proactive measures that consist of developing a defense strategy to control sea level rise through soft or hard engineering. Hard engineering techniques are coastal structures such as sea walls, dykes, and embankments against high water and sea storms. However, they do not stop beach erosion and can contribute negatively to coastal water quality. They are usually adopted on active economic environments that cannot be moved as well as on highly urbanized areas to protect expensive properties or infrastructures. Soft engineering techniques include beach nourishment by feeding a beach periodically with material brought from elsewhere to remedy erosion, and sand dune stabilization by planting vegetation such as beach grass that retains sand and creates natural habitats for animals and plants (Parry et al., 2009; Ozhan, 2002).

An overarching adaptation and management option to relieve pressures on the coastal zones can be the adoption of integrated coastal zone management that includes preservation of coastal ecosystems and preventing and reducing the effects of natural hazards. Additional adaptation measures are presented in Table 4-10.

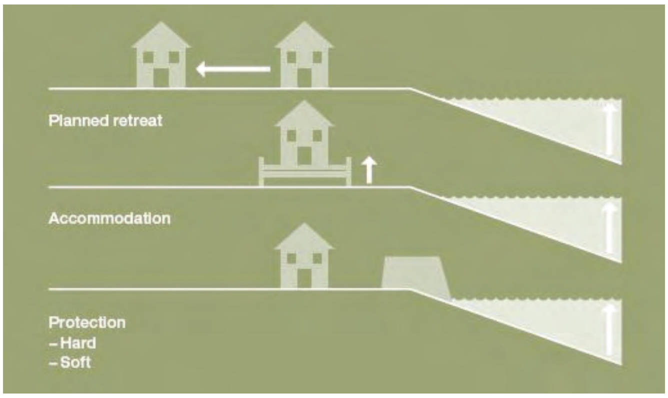


Figure 4-38 Illustration of the possible adaptation responses to sea-level rise. Source: Parry et al., 2009

4.7 Vulnerability and Adaptation of the Forestry Sector

Lebanon is a highly mountainous country with extreme variability in climatic conditions, soils and socio-economic status. Forests in Lebanon are very particular in their variation and characteristics as they represent a unique feature in the arid environment of the Eastern Mediterranean. Natural ecosystems in Lebanon and particularly forests are under various pressures most of which are landscape and habitat fragmentation, changes in land use, unorganized urban sprawl, forest fires and pest outbreaks. Many species have either disappeared or are endangered because of the different threats on their habitats (Asmar, 2005; AFDC, 2007). In view of this existing pressure on natural ecosystems, future expected climate change will mainly exacerbate their consequences.

4.7.1 Methodology

Scope of Assessment

The assessment focuses only on the forestry sector, particularly forest types that are most sensitive to climate change as identified by stakeholders during the scoping phase. The temporal scope of the assessment extends over the entire year, since forest vulnerability depends on both temperature increase (summer) and precipitation (winter). The year 2004 is taken as a baseline year, and projections are made until 2030, i.e., over a time frame of around 25 years.

Climatic 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 and illustrated in the phyto-association map published by Abi Saleh & Safi (1988), in which 10 vegetation levels can be clearly distinguished with respect to altitude (Figure 4-39). These vegetation levels derive from the "Quotient pluviothermique" of Emberger (Quezel,1976), which reflect the tolerance of species within a range of precipitation, mean maximum

Table 4-10 Adaptation Action Plan for the costal Zones Sector

Impact	Proposed Adaptation Strategy	Activities
Increase in the salinity of coastal groundwater wells	Increase the resilience of groundwater to climate change in coastal areas	- Assess feasibility of artificial groundwater recharge in major coastal areas - Strengthen the capacity of water and wastewater establishments to monitor groundwater abstraction - Develop awareness programs to reduce water consumption in vulnerable areas
Decrease in the income from coastal economic activities, mainly fishing, agriculture and small tourism enterprises (coastal resorts) due to flooding and inundation	Increase the protective capacity of vulnerable coastal areas	- Identify/confirm vulnerable economic activities along the coast - Design soft and hard measures to protect vulnerable areas
	Increase resilience of small holders to be able to adapt to climate change impacts	- Improve access to information by developing a database for national indicators and establishing monitoring systems for coastal zone indicators, such as sea water temperature, sea water level, monitoring of high tidal waves and frequency and intensity of storm surges - Develop of financing mechanisms to support small holders
	Establish an institutional mechanism to follow up on coastal zone impacts from climate change	- Initiate dialogue between MoWT, MoE, MoA, syndicate of fishermen, municipalities, etc. - Set up task force committee to coordinate adaptation efforts
Increase in the cost of beach erosion and degradation and loss of coastal habitats	Increase resilience of natural/historical coastal areas to climate change impacts	- Enforce coastal land use plan defined by CDR in the NPMPLT to ensure a sufficient buffer zone - Develop a management plan for key natural/historical sites taking into consideration climate change impacts - Set up an institutional mechanism to protect the remarkable sites

temperature of the hottest month and mean minimum temperature of the coldest month.

Methods of Assessment

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 (MoA and FAO, 2005b) 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 Q, and their ability to withstand future climate change; i.e., the forest types were designated as “most vulnerable” when the shift in bioclimatic level would overbear the tolerance of the forest type with reference to climagramme of Emberger for Lebanon (Abi Saleh et al., 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 cope with the projected change (Figure 4-40);
- Assessing for each forest type the margin of tolerance with respect to temperature and rainfall in reference to Table 4-11 adapted from Quezel (1976), Abi Saleh (1978) and M’Hirit(1999);
- Highlighting grids where the shift in bioclimatic level (Table 4-11) surpasses 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

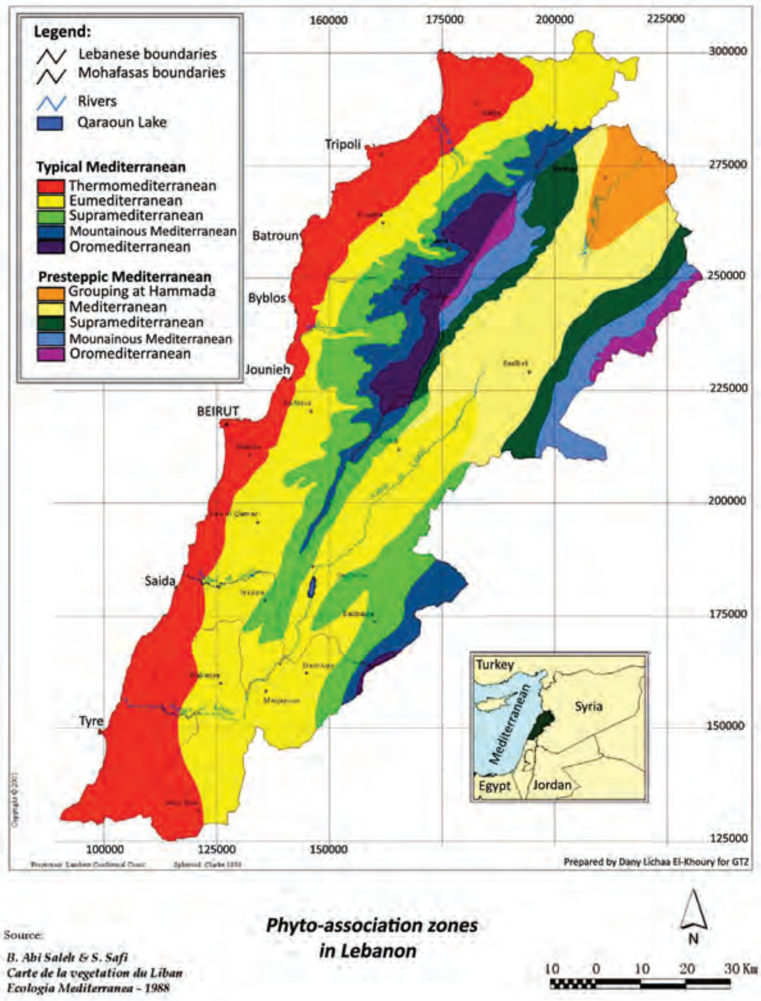


Figure 4-39 Phyto-association zones in Lebanon
Source: Abi Saleh and Safi, 1988

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 4-41);

- In order to represent a geophysical continuous distribution for the Q factor over Lebanon, a GIS spatial prediction method (Kriging) is used. Accordingly, the future potential presence of forest types with regard to the projected changes in climatic factors is mapped using ArcGIS facilities.

Assessing future response of forest to expected climate change holds an important number of uncertainties and assumptions because Mediterranean forests are already adapted to adverse climatic conditions and sustained human pressure, the response of natural ecosystems is multi-factorial and does not only respond to climatic parameter and forests need a very long term to react to climate variability (more than 50 - 100 years). The major assumptions in the assessment are the consideration that forests will shift to adapt with climatic variation and that the policies and strategies that are currently in place will be on the course of implementation by 2030.

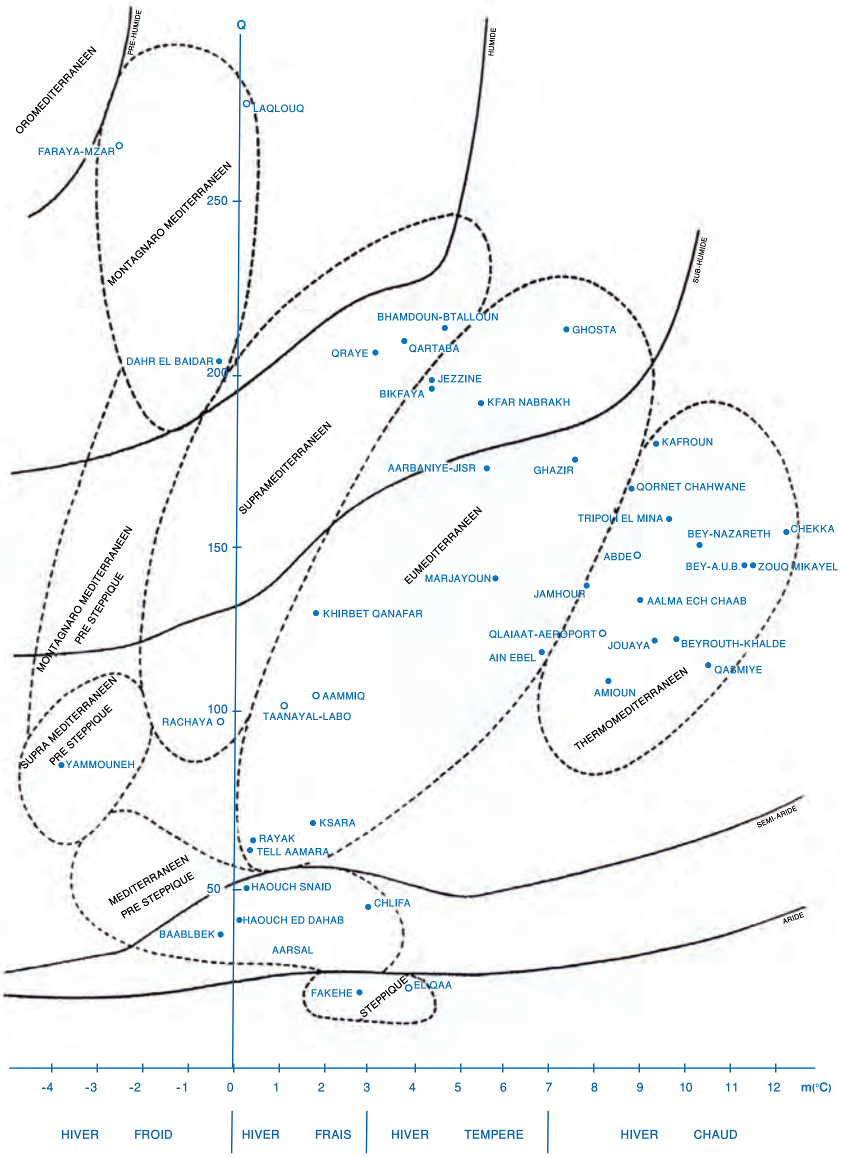


Figure 4-40 Distribution of bioclimatic levels in Lebanon with respect to Emberger Quotient
Source: Abi Saleh et al., 1996

Table 4-11 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 Moun-tainous 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)

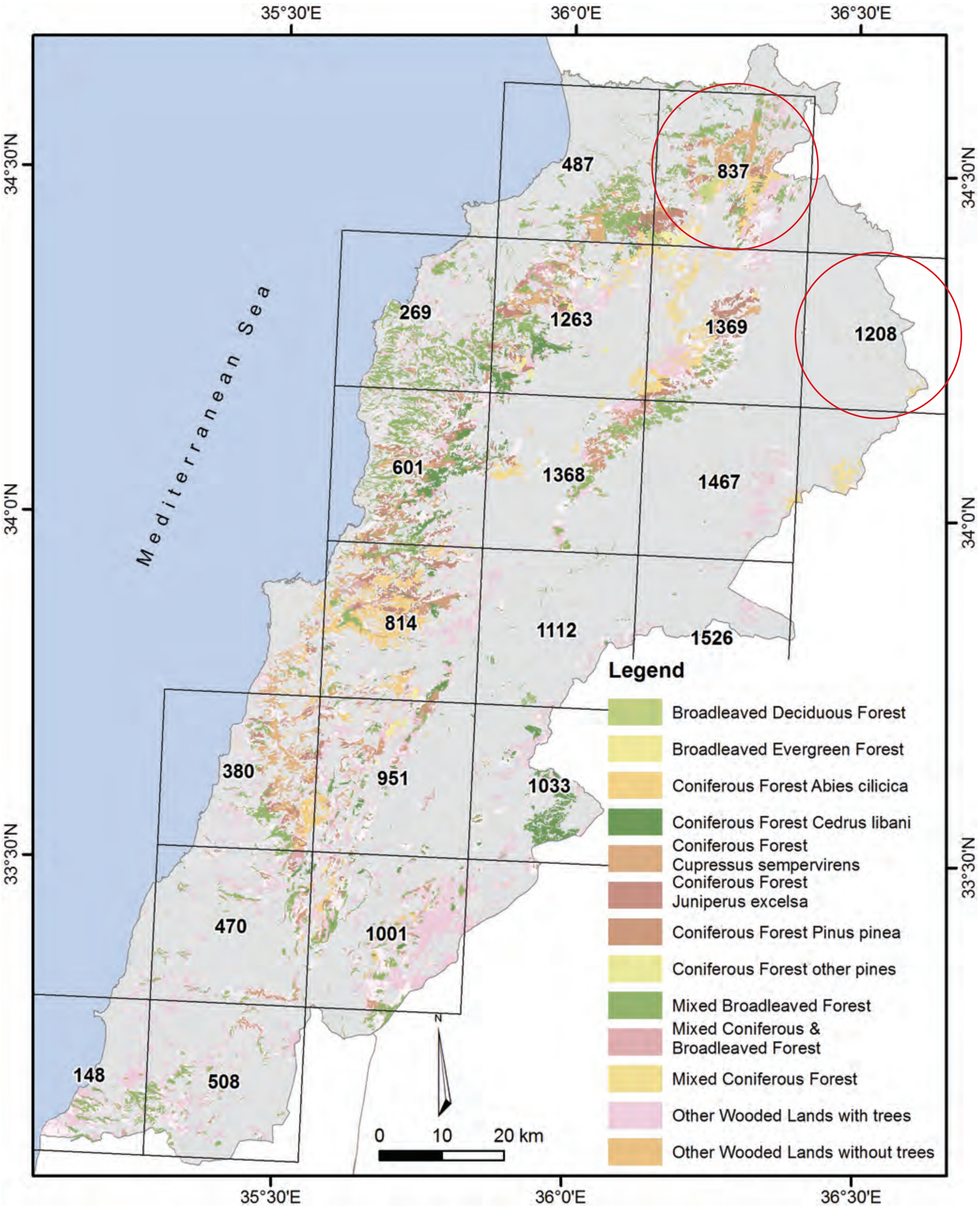


Figure 4-41 Areas (encircled) expected to be most impacted by climatic factors

Policies and strategies

Several public institutions are involved in forestry-related activities, namely the MoE and MoA, who are launching initiatives to save the natural patrimony and promote protection and proper management of natural resources. The MoE through its National Reforestation Plan has increased the surface area of forests by around 600 ha from 2001 to 2007 and is currently developing a strategy for safeguarding and restoring Lebanon's woodland resources, as a follow-up on the National Reforestation Plan. MoE has also prepared in 2009 the National Strategy for Forest Fire Management with AFDC and IUCN and in cooperation with other line ministries. In Parallel MoA has set its own priorities and strategies for forests and forestry until the year 2020 which include the application of a "natural management" approach and a global sustainable development plan through forest plantation and reduction of forests exploitation, the implementation of modern multidisciplinary management tools, and the creation of a forest research and the development of an independent forest authority.

Development of the sector under socio-economic scenarios

Under scenario A, forest development will replace abandoned agricultural lands. The 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, etc.) 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 ecotourism and nature-based activities, as well as in the value and associated services such as landscape and 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, etc).

Under scenario B, an increase in forest fragmentation is expected due to urban sprawl. Decrease in forest resources, soil degradation, desertification, loss of biodiversity, forest fires, pests and insects outbreaks and a severe decrease in land's productivity will result from an increase in the demand for fuel wood, and from unsustainable practices such as intensive agricultural production, absence of land use planning, urbanization of rural area etc. 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.

4.7.2 Vulnerability assessment

Various uncertainties exist on 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. Therefore, 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.

The adaptive capacity of a forest ecosystem to changing environmental conditions is determined by its size, biological and ecological diversity, as well as by the condition and character of the surrounding landscape. Species migration as a response to climate change is not "new" as analysis of pollen deposits in sediments and vegetation macrorests 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. However, species migration may not be fast enough to cover dispersal requirements under the predicted rate of climate change (Tinner and Lotter, 2001). The assessment of the adaptive capacity of different forest types in Lebanon, in terms of the impact of climate variability, socio economic importance, resilience to forest fires and pest attacks, ability to migrate upward, and the resources needed to adapt to climate change, reveal that the upper zone coniferous forests (*Cedrus libani; Abies cilicica*) and high mountain formations (*Juniperus excelsa*) have the lowest natural adaptive capacity to current and future trends (Table 4-12).

Various threats and in particular landscape fragmentation, have increased vulnerability of natural patches to various pressures and are seriously challenging their resilience and adaptive capacity. In view of existing pressure on natural ecosystems (whether forested or non-forested) future expected climate change will mainly exacerbate

Table 4-12 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	Low	Very High
Cedrus libani	High	Forest fragmentation and the location of forest stands on mountain crestline, which limits their ability the migrate upwards	Low-Moderate	High
Abies cilicica	High	Absence of pure fir stands, forest fragmentation and illegal logging	Low	High
Quercus cerris, Fraxinus ornus & Ostrya carpinifolia	High	Limited geographical extent and forest fragmentation	Low	High

their consequences. Some of the major threats on terrestrial biodiversity can be summarized as follows:

Forest Fires: Forest fires constitute a serious threat on the vegetation cover and influence the decline of Lebanese forests. Forest fire prone areas in Lebanon are usually near urban complexes and below an altitude of 1,200 m and encompass three main forest types: broadleaved forests (mainly *Quercus spp*.), *P. pinea* and *P. brutia* pine forests (Masri et al., 2006). The forest sector will have to face the impact of increased frequency and higher periodicity of fire events due to increased drought periods and the replacement of forest stands with fire prone shrub communities (Figure 4-42). High mountain forest stands (*Cedrus libani*, *Abies cilicica* and *Juniperus excelsa*) are considered little vulnerable to fire occurrence due to humid bioclimates. However, 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 their ability to face eventual fire events. As for Pinus halepensis, since most stands are on sloping lands and usually develop dense understory, their vulnerability to fire is considered moderate to high and inversely their potential resilience to fire events is considered varies from low to moderate.

Ecosystem fragmentation and land use changes: Urban expansion and road network development, human intervention by logging and overgrazing activities are the serious causes of ecosystem fragmentation in Lebanon where forests have been broken into isolated small pieces that are more susceptible to external disturbances. 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% of the total forest cover has been lost in 33 years, mainly affecting juniper stands (Jomaa et al., 2007). In addition, the important fragmentation of forests and natural habitats is also seriously challenging the migration of the cedars forest upward or northward, especially that most of existing stands are already present at the mountain peak line (Hajar et al., 2010).

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 which sometimes respond by increasing the level of leaf consumption and consequently damage trees. In addition, 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. 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

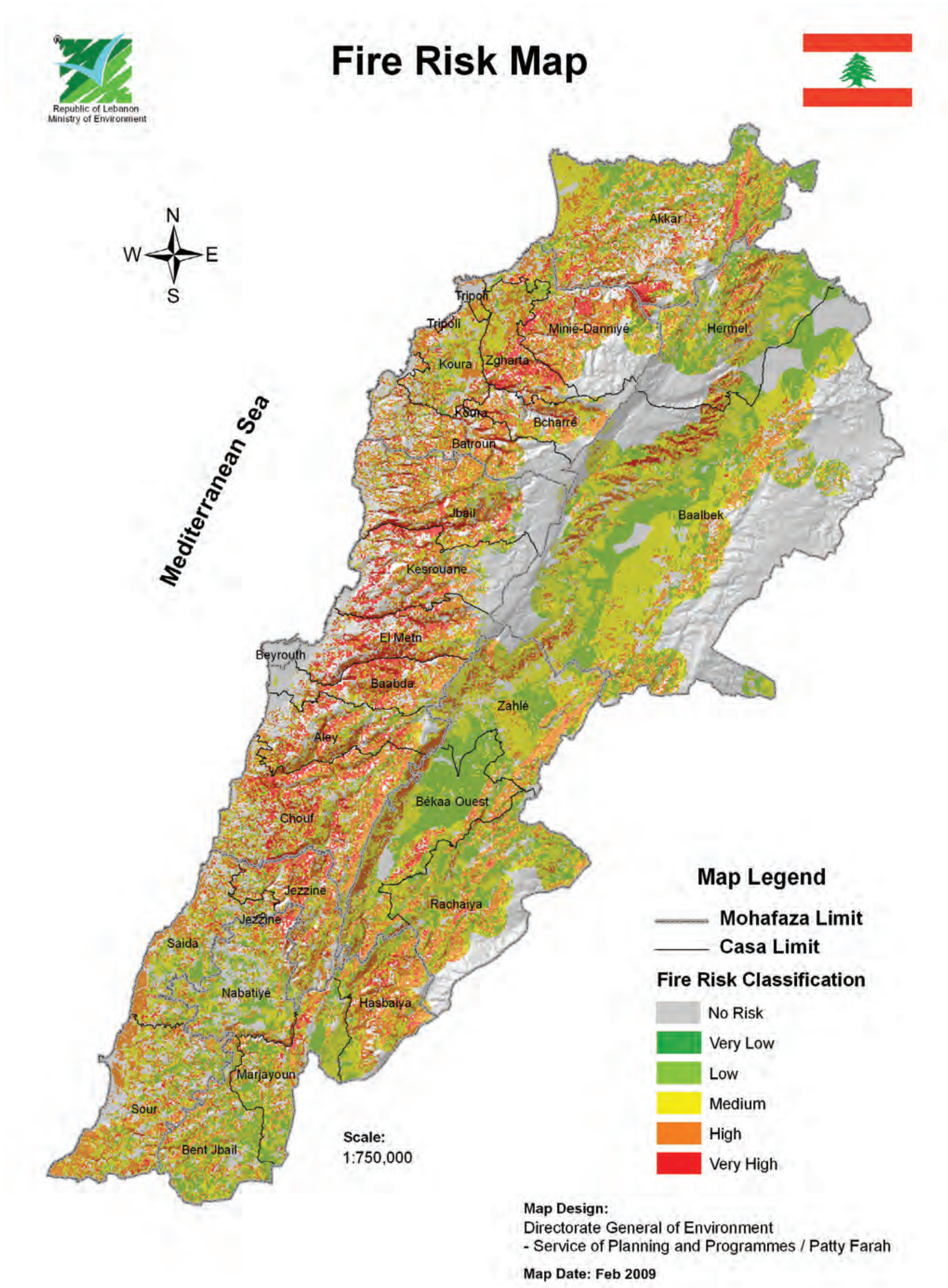


Figure 4-42 Forest fires risk map

decade (Nemer and Nasr, 2004). While pests on cedar forests have been studied, little is known about the pest attacks on junipers and firs.

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 majority of quarries in Lebanon are developed with no consideration for their environmental impact, thus causing the destruction of vegetation and important natural habitats and the permanent loss of biodiversity and natural resources, especially that 25% of existing quarries developed within forested land (Darwish et al., 2008; AFDC, 2007).

Grazing: The decline of grazing activities during the past decades has favoured 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.

4.7.3 Impact assessment

The expected changes in temperature and rainfall are expected to be accompanied by a significant change in bioclimatic levels in Lebanon, particularly their geographical extent in terms of percent of total cover. The Oromediterranean level is projected to disappear from Lebanon by 2080, while the Arid bioclimatic level is expected to increase from 5 to 15 % in area (MoE et al., 1999; UNEP-MAP, 2009). In addition to the 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;
- Increased 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;
- Increased recrudescence of pest outbreaks.

All forests in Lebanon deserve attention and investment; however, based on the above analysis, Figure 4-41 confirms that the most vulnerable forest stands which are expected to be the most impacted by climate change are located in north Lebanon (Akkar) and in Hermel areas, due to the shift from sub-humid to semi-arid bioclimatic level (Table 4-13). Adaptation efforts should therefore target those areas in priority.

As *Cedrus libani* is 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.

The identified 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.

4.7.4 Adaptation measures

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. However, since the forestry sector is considered as a sink and a vulnerable sector, many measures proposed for mitigation (to increase carbon sequestration) can be applied for adaptation. Additional measures could be recommended to assist the natural resilience of forests, anticipate future changes and promote landscape scale in the adaptation options.

Table 4-13 Changes in Q and in bioclimatic levels for the different forest types in Lebanon from 1960 - 1981 to 2080 - 2098

Grid box	Dominant forest type	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	*Quercus, 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

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

Table 4-14 below shows the major physical impacts corresponding to the vulnerable hotspots and the proposed adaptation action plan for the forestry sector. Each of the mentioned activities requires an in-depth assessment to determine its actual cost at the time of planning and implementation. In addition, legal and regulatory measures as well as financial and economic incentives are needed to implement the proposed activities.

The cost of vulnerability and adaptation in natural ecosystems is inherently problematic. The Lebanese government spends on nature conservation around USD 300,000 per year, mainly dedicated for the management of nature reserves, while the action plan for protected areas has foreseen a sum of USD 4,685,000 over 5 years (MoE, 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 4-14 Forestry adaptation action plan

Impact	Proposed Adaptation Strategy	Activities
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, etc. - 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 request a strategic environmental assessment 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
	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 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
	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

4.8 Vulnerability and Adaptation of the Public Health Sector

4.8.1 Methodology

Scope of Assessment

The assessment focuses on direct and indirect impacts on the human health sector, as defined below:

- The direct effects result from changing temperatures that trigger the outbreak of infectious diseases; from heat waves that can increase morbidity and mortality; and other extreme weather events and their consequences such as floods, storms, and massive fires, which can cause an increase in the number of casualties;

- The indirect effects of climate change on human health include droughts and floods affecting agriculture and leading to malnutrition; scarcity of clean water, which widely impairs hygienic conditions; and migration due to changing environments, which makes humans vulnerable to a whole host of diseases.

The assessment covers the whole country, focusing on vulnerable groups, as identified by stakeholders during the scoping phase, that include the elderly, women, children, workers in certain occupations, population groups with low socio-economic status and refugees. The year 2004 is taken as a baseline year and the whole timeframe for the analysis extends until the year 2030.

Methods of Assessment

As a result of limited data availability, a qualitative assessment is conducted to evaluate the impacts of climate change on human health in Lebanon. The future variation in the demographic, socio-economic and technological driving forces of the country is forecasted based on the two baseline socio-economic scenarios. The sensitivity and adaptive capacity of vulnerable groups is defined and the likely climate change impacts are identified through a literature review.

Development of the sector under socio-economic scenarios

Under scenario A, the likely developments in the provision of health services are limited to a low growth in the demand for health services and in hospital admissions in cases of emergency due to a low population growth in addition to a higher reliance on public provision of health services due to a low GDP growth. The current conditions of the health care system along with the standards of living will remain the same.

Under scenario B, the current conditions of the health care system will improve. While the high population growth implies higher demand for health care services and higher admissions in case of emergency, the high preparedness and increased use of prevention measures in the health care system will allow for better health services.

4.8.2 Vulnerability assessment

The sensitivity of the health sector is very high. Increases in average temperatures may lead to extreme heat waves and extended dry periods during summer which would affect vulnerable populations, especially those living inland where temperature increase are expected to be more severe. Other extreme weather events such as floods can also be destructive to human health and well-being by increasing event-related deaths, injuries, infectious diseases, and stress-related disorders (USEPA, 2010).

In addition, the overall adaptive capacity of the health sector is considered low due to 1) lack of economic resources since the budget allocated to MoPH never exceeded 4% of the total government budget, 2) poor infrastructure such as flood control structures, building insulation, sanitation facilities, waste water treatment and water systems and drainage and mass transit that can improve access and outreach in the case of weather-related disasters, 3) weak institutional arrangements, 4) unequal access to improved infrastructures and health care systems and 5) pre-existing disease burdens. However, advances in technology, such as new drugs or diagnostic equipment and the high level of “human capital” or knowledge in Lebanon are enhancing the adaptive capacity of the sector. Impacts will be more severely felt under Scenario A than under Scenario B which signals a higher adaptive capacity due to public investment in the health care services.

Taking into account sensitivity to climate change and adaptive capacity, the most vulnerable populations are:

Elderly population: Senior citizens (>65 years) are mostly sensitive to thermal stress during heat waves and heat stress due to their body’s weak ability to control their internal temperature. They have therefore a higher risk of heatstroke, cardiovascular and respiratory disease, and heat-related mortality. Their vulnerability is due to their low adaptive capacity amid the lack of public safety nets such as pensions and insurance systems for this group of the population. Additionally, the elderly population can face unequal access to healthcare, as they are often unable to travel long distances to the nearest health facility.

Women: They are mostly sensitive to thermal stress and extreme weather events due to physiological (e.g. menopausal women) and social factors (discrimination and poverty). Not having the same or direct access to the financial, technological and social resources that men have, in addition to limited participation in decision-making may have consequently made women less able to confront climate change (UNDP, 2009).

Children: Children are vulnerable to thermal stress and extreme weather events given their dependency and low natural resilience. Children are in a rapid stage of development and are less equipped to deal with deprivation and stress, due to rapid metabolism, immature organs and nervous systems, developing cognition, limited experience and various behavioral characteristics (Bartlett, 2008). Therefore, they are at increased risk of heat strokes, heat exhaustion and dehydration, injury, surrounding death, and infectious disease outbreaks. In addition, children's relatively lower level of understanding and especially their lack of social power within family and community (Bartlett, 2008), makes it more difficult for them to adapt to climate change implications.

Laborers in outdoor working environments: They are at higher risk of heat strokes due to the nature of their work that exposes them to extreme weather conditions.

Population groups with low socio-economic status: Given their low access to livelihoods assets, the poor infrastructure of their households and their unbalanced diet, the population groups with low socio-economic status are more sensitive to infectious diseases and mental illnesses, and have limited access to medical care. In addition, less adequate types of housing among this group might increase their risk of heat-related mortality. These populations are mainly concentrated in Tripoli, Akkar/Minieh-Dennieh, Jezzine/Saida, and Hermel/Baalbek.

Refugees: Refugees, constituted primarily of Palestinians and Iraqis, live in camps with poor building structures and lack of proper public infrastructure leading to water shortages, contaminated water supplies and poor sanitation. These conditions result in a higher risk for water-borne disease transmission. In addition, seasonal agricultural labor, mostly associated with Bedouins in the Bekaa valley, rely on tents for housing which increase their vulnerability to natural disasters.

4.8.3 Impact assessment

In the Eastern Mediterranean Region which includes Lebanon, the total deaths from malnutrition, diarrhea, malaria, floods, and cardiovascular diseases attributable to climate change for the year 2000 was estimated at 5,650/million population and the total estimated disease burden attributable to climate change for the year 2000 was estimated at in DALYs (Disability-Adjusted Life Years)166,620/million population (WHO, 2007a).

The expected direct and indirect impacts of climate change on health in Lebanon are:

Heat waves and heat-related impacts: Exposure to extreme and prolonged heat is associated with heat cramps, heat syncope, heat exhaustion and heat stroke (Nuwayhid et al., 2009), which affect those with existing heart problems, asthma, the elderly and the very young. Furthermore, intense short-term fluctuations in temperature can also seriously affect health, causing heat stress (hyperthermia) or extreme cold (hypothermia), and lead to increased death rates from heart and respiratory diseases (WHO, 2010b). In Lebanon, a strong association between temperature and mortality was found where a 1°C rise in temperature above the minimum mortality temperature threshold (T_{MM}) of 27.5°C yielded a 12.3% increase in mortality and a 1°C rise below T_{MM} yielded a 2.9% decrease in mortality (El-Zein et al., 2004). Overlaying these results with the PRECIS projections reveal that an increase in mortality above T_{MM} is expected to vary between 12.3% and 24.6 %, and a decrease in mortality below T_{MM} is expected to vary between 2.9% and 5.8% by 2030. The calculated percentages when applied to the crude death rate of 4.1 per thousand of 2004 (Ammar, 2009) and the population growth figures used in Scenarios A and B reveal that:

- For Scenario A, the average mortality above T_{MM} caused by climate change ranges between 2,483 and 4,967 additional deaths/year between 2010 and 2030;
- For Scenario B, the average mortality above T_{MM}

caused by climate change ranges between 2,627 and 5,254 additional deaths/year between 2010 and 2030.

Vulnerable population groups, especially the elderly and population groups in the more socio-economically deprived areas, in semi-arid areas and in areas with lower access to health services are more at risk as a result of their high sensitivity and lower adaptive capacity.

Floods: The effects from natural disasters can be either directly sensed through claiming the lives of many people and injuring a lot more, or indirectly through displacing people, destroying their crops, and temporarily disrupting their livelihoods especially in the less developed areas with weak socio-economic structures. Victims of natural disasters are at a high risk of malnutrition, diarrhea and water-borne diseases caused by crowding and lack of hygiene (WHO, 2007b), and women, children and the elderly, especially the uninsured, would be highly affected in such events.

Infectious diseases: They are considered to be indirect effects of climate change on health since it is difficult to discern their 'additionality' i.e., the increase in health problems that can be attributed to climate change (Nuwayhid et al., 2009). However, the evidence on the associations between climatic conditions and infectious diseases is well established at the global level (WHO et al., 2003). Infectious diseases that are climate sensitive and that may occur in Lebanon due to changes in climate are described in Table 4-15.

Table 4-15 Climate sensitive infectious diseases

Type		Relevance
Vector Borne diseases transmitted by arthropods, such as mosquitoes, ticks, sandflies, blackflies and rodents	Malaria	Changing patterns of rainfall, humidity and particularly seasonal variation of temperature influence the geographical distribution and intensity of transmission of Malaria (Confalonieri et al., 2007). Although the cases of malaria reported by MoPH had all originated in Africa, it is feared that the expected increase in temperature in Lebanon might widen the area of distribution of the vectors, favoring their growth and development over time. In that case, population groups with lower socio-economic status, no insurance coverage, and lower access to health care, as well as children and the elderly will be more vulnerable
	Dengue Fever	Its transmission increases with high rainfall, high temperature, and even, as some studies show, during droughts (Confalonieri, et al., 2007). Lebanon does not currently appear among the countries at risk of dengue transmission (WHO, 2003), however, with the expected increase in temperature and drought periods, dengue transmission might emerge in Lebanon
Rodent-borne diseases transmitted directly to humans by contact with rodent urine, feces, or other body fluids		Environmental factors that affect rodent population dynamics include unusually high rainfall, drought, introduction of exotic plant species and food sources (Confalonieri et al., 2007). Diseases associated with rodents and ticks include leptospirosis, tularaemia, viral hemorrhagic diseases plague, Lyme disease, tick borne encephalitis and Hantavirus pulmonary syndrome (WHO et al., 2003). These diseases might flourish in Lebanon in case of increased floods
Water-borne and food-borne diseases	Cholera Typhoid Hepatitis A Diarrhea	The outbreaks of these diseases occur where water supplies, sanitation, food safety and hygiene practices are inadequate. The potential contamination of drinking water supplies and disruption of sewer systems and/or wastewater treatment plants and flooding that could result from climate change could lead to an increased incidence of cholera, typhoid and Hepatitis A cases in Lebanon. Regions with lower access to sanitation will be more exposed to water-borne diseases, and those with lower access to health care and insurance coverage, in addition to children and the elderly, will be more affected (WHO, 2010c)

Respiratory diseases: They may be exacerbated by warming-induced increases in the frequency of smog (ground-level ozone) events and particulate air pollution (USEPA, 2010). Sunlight and high temperatures, combined with other pollutants such as nitrogen oxides and volatile organic compounds, can cause ground-level ozone to increase. In Lebanon, the proportion of the urban population with existing respiratory problems would be at a higher risk of damage to lung tissue as rising air temperatures cause a higher build-up of ground-level ozone concentrations. Climate change can also affect natural or biogenic sources of particulate matter (PM) such as wildfires and dust from dry soils (USEPA, 2010).

Malnutrition: Increasing temperatures on the planet and more variable rainfalls are expected to reduce crop yields in many tropical developing regions, where food security is already a problem (WHO, 2010b). Food security in Lebanon is also at risk, since Lebanon relies heavily on food imports. The expected reduction in crop yields to result from local climate variations would affect the most economically disadvantaged groups.

In general, impacts will be more severely felt under Scenario A than under Scenario B which signals a higher adaptive capacity due to public investment in the health care services. Even though Scenario A assumes a low growth in population size which implies a low growth in the demand for health services and a low growth in hospital admissions in cases of emergency, the low GDP growth entails an unequal access to health services leading to a lower adaptive capacity especially among the vulnerable groups. On the other hand, the improvement of the current conditions of the health care system along with the standards of living characterizing Scenario B in addition to the high preparedness and increased use of prevention measures in the health care system could allow for better health services leading to higher adaptive capacity of the population groups.

4.8.4 Adaptation Measures

The rebuilding and maintaining of public health infrastructure is often viewed as the "most important, cost-effective and urgently needed" adaptation strategy to climate change in the human health sector. Climate-related adaptation strategies should not be considered in isolation of broader public health concerns such as population growth and demographic change, poverty, public health infrastructure, nutrition, risky behaviors, and inadequate use of antibiotics, and environmental degradation. All of these factors will influence the vulnerability of populations and the health impacts they experience, as well as possible adaptation strategies.

Adaptive actions to reduce health impacts can be considered in terms of the conventional public health categories of primary or anticipatory adaptation where a hazard exposure is avoided, secondary or reactive adaptation where early intervention is implemented after a disease has begun, and tertiary prevention where the adverse effects of an already present disease or injury are minimized (WHO et al., 2003). By an initiative of WHO-Lebanon, MoPH and MoE, and in collaboration with AUB, the main adaptation measures for the health sector in Lebanon have been identified by the stakeholders to alleviate impacts of climate change and improve the adaptive capacity of public health services. A national framework of action was drafted, based on the general framework of action on climate change established by WHO and endorsed by the government of Lebanon. The objectives of the proposed national framework of action are as following:

Objective 1: To ensure public health concerns and health protection from climate change are at the centre of national, regional and international action on climate change

- Research national evidence and conduct sustained evidence-based advocacy to raise awareness;
- Assess the burden of disease by developing a list of indicators on which data needs to be collected and fed into registries for monitoring and surveillance and assess the magnitude of current health problems nationally;
- Form an inter-sectoral committee on which representatives from all ministries and concerned national authorities serve. The Committee shall oversee issues of climate change and health. This committee shall report to the Council of Ministers to suggest health protection measures that shall be integrated into the activities of all ministries.

Objective 2: To Implement adaptive strategies at local and national level to minimize impacts of climate change on population's health

- Undertake assessment of health vulnerability to identify the short, medium, and long term additional direct and indirect threats to health from climate change and map health resources available to cope with any additional burden of climate change on health;

- Strengthen health system monitoring by empowering the MoPH capacity of monitoring and early warning on a specific set of indicators such as meteorological conditions, environmental determinants related to energy, emissions, Pollution Standards Index, water security indicators, vector profile distribution and food security;
- Empower and ensure sustainability for existing environmental health functions and services. Priority threats are water security for health, water quality degradation, droughts, heat waves, food security and safety, vectors redistribution, air quality degradation, floods and other climate related natural disasters;
- Based on health resources mapping and identified gaps, strengthen health systems' preparedness to cope with the additional burden of climate-sensitive health problems. Priority groups of diseases are water-borne diseases, food-borne disease, malnutrition associated with food insecurity, health effects of heat waves and extreme cold conditions, respiratory and other diseases associated with air pollution, vector-borne diseases and health effects of climate related disasters. Develop specified and standard technical units for the diagnosis such as laboratories;
- Oversee the process of undertaking interdisciplinary applied research and demonstration projects on health vulnerability to climate change and on effectiveness of health protection measures. Ensure translation of scientifically based applied research findings into policies, practice, and working strategies.

Objective 3: To support "healthy" development strategies in other sectors that protects and promotes health and mitigates climate change

- Build the capacity of health sector professionals in the identification of health impacts from other sectors (e.g. transport, energy, food, water, housing and urban development) that have bearings on health. Capacity building shall be done to technical people, concerned authorities and policy makers;
- Engage health sector leaders and professionals in determining and supporting policy choices of other sectors that promote and protect health;
- Establish institutional and legislative mechanisms to facilitate and mandate the health sector engagement in determination of development policies and choices in other sectors.

Objective 4: To strengthen the institutional capacity of the public health systems for providing guidance and leadership on health protection from climate change.

- Establish a national focal point on climate change and health who would be appointed by the Ministry of Public Health to enable health sector leadership and collaboration with other sectors;
- Establish a health and climate change task force within the Ministry of Public health with membership of concerned stakeholders especially those involved in preventative and protection functions and those involved in preparedness and in response to the climate-sensitive health issues;
- Strengthen the existing units in order to address the climate change impacts. Define vulnerable groups and activate epidemiological surveillance. Incorporate new health outcomes in the Epidemiological Surveillance Unit that are expected to be of a great burden due to climate change. Increase and improve active reporting. At the preventive level, raise awareness on the health effects of climate change through organizing awareness events and training health care practitioners;
- Establish the institutional legislative mechanisms with the national UNFCCC focal point to mandate the health sector leadership on health protection from climate change within the national UNFCCC processes. MoPH as an essential stakeholder in climate change and health and a legal representative shall lead the committee and shall report to the government.

In addition to the national framework of action, enhancing the Early Warning Alert and Response System (EWARS) is crucial to improve the capacity of the current system to respond to climate change impacts. This can be achieved through the development of regional definitions for heat alerts/warnings, building the capacity to monitor dynamic changes in risk patterns at a high level of spatial and temporal resolution, development of preparedness/response strategies based on community needs and priorities and development of public communication strategies to ensure that warning information and recommended response strategies are conveyed to the populations at risk.

4.9 Vulnerability and Adaptation of the Tourism Sector

A close linkage exists between climate and tourism since climate defines the length and quality of tourism season and plays a major role in destination choice and tourist spending. Climate also affects a wide range of environmental resources that are critical attractions for tourism, such as snow conditions, biodiversity, water levels and quality. Moreover, climate has an important influence over environmental conditions that can deter tourists including disease spread, and extreme events such as heat waves, floods and extreme storms (UNWTO et al., 2008).

Tourism in Lebanon mainly consists of recreational tourism that includes beach holidays, winter sports, summer holidays in the mountains, cultural, religious, and adventure tourism, in addition to business tourism and health and education tourism (MoE, 2001). Related activities and infrastructure are concentrated in three areas: The high mountains where ski resorts and winter chalets are located; the hills overlooking Beirut and the coast where "country clubs" are found; and the coastline where beach resorts, public beaches and marinas are located, mainly on the northern coast (MoE, 2005). In recent years, alternative types of tourism and recreational activities have grown in Lebanon among which is ecotourism which has registered a significant increase in the number of ecotourism providers throughout the years since 1991 (MoE, 2001).

4.9.1 Methodology

Scope assessment

The assessment covers all the touristic areas of Lebanon with focus on the sites and activities that are likely to be vulnerable or "hotspots" such as coastal archaeological sites (e.g. world heritage sites of Tyre and the Fortress of Saida) and coastal touristic infrastructure, such as beach resorts, public beaches and marinas that may be damaged by sea-level rise, high mountains that may be affected by and shortening of the winter season and a reduction in snow cover and mountainous summer resort areas that may be affected by increase in temperatures. The assessment covers the whole year to tackle summer and winter climate changes. The baseline year is 2004, and projections are made until 2030 by forecasting the impacts of future variation in the demographic, socio-economic and technological driving forces as well as climate change on the tourism sector.

Development of the sector under socio-economic scenarios

In Lebanon, tourism growth and its sensitivity to climatic change are influenced by three main factors: 1) economic stability, whereby high prosperity levels in the country result in growth of the tourism sector; 2) security and political stability, whereby the absence of conflict and strife dispel uncertainties regarding investment in tourism; and 3) resources' availability, especially forests and the availability of water supplies that could become a major constraint.

Taking these factors into account, under scenario A, tourism will probably be among the main active economic sectors, having an important contribution to GDP. Both mass tourism and ecotourism will be growing with greater emphasis on ecotourism due to better understanding of the recreational value of natural assets, participation of civil society in its protection and law enforcement on forest management. This would create alternative livelihoods, especially for populations in remote areas, which would in turn influence internal migration and local sustainable economic development. However, the low resources availability under this scenario might limit ecotourism growth.

Under scenario B, a moderate growth in the tourism sector and mainly in mass tourism on one hand and a low growth of ecotourism on the other hand due to lack of awareness and degradation of available natural resources will entail a massive burden on environmental resources, leadingly to an unsustainable growth.

4.9.2 Vulnerability assessment

The relationship between tourism and climate is very complex and remains difficult to define. Tourism is sensitive to changes in temperature, rainfall, snowfall and extreme weather events that could lead to shifts in a variety of outdoor tourism and recreation opportunities in Lebanon, such as skiing in winter and beach activities in summer. The added effect of sea level rise may lead to coastal erosion, loss of beach area, and higher costs to protect and maintain seafront resorts and thus affect summer activities (UNWTO et al., 2008).

In terms of adaptive capacity, tourism sector has a relatively high adaptive capacity with ability to respond to changing demographic and economic conditions as well as to new demands and technologies. Tourists have the greatest adaptive capacity (depending on three key resources: money, knowledge and time) with relative freedom to avoid destinations impacted by climate change or shifting the timing of travel to avoid unfavorable weather conditions. Suppliers of tourism services and tour operators at specific destinations have less adaptive capacity while destination communities and tour operators with large investment in immobile capital assets (e.g., hotel, resort complex, marina or casino) have the least adaptive capacity (UNWTO et al., 2008). Figure 4-43 illustrates the relative adaptive capacity of major sub-sectors.

4.9.3 Impact Assessment

In general, warmer temperatures may cause heat stress and health risks for tourists and entail additional cooling costs, and expected lower precipitation and increased evaporation may lead to potential water scarcity, leading to competition for water between different sectors (e.g., agriculture and tourism), or between different forms of use in tourism establishments. Extreme weather events such as extreme storms may threaten tourism facilities which may require increased insurance costs due to loss of insurability and business interruption costs (UNWTO et al., 2008).

The main potential impacts of climate change and its implications on vulnerable tourism destinations in Lebanon are:

Implications on high-altitude Mountains: Warmer temperatures and precipitation reduction are expected to lead to a decrease in the intensity, residence time and thickness of the snow cover in the mountains of Lebanon as well as change in the altitude of regions covered by snow and thus shorten the skiing season, which is the key attraction for tourism during winter. Before the 1990s, dense snow often covered more than 2,000 km^2 of the Lebanese mountains and averaged about 2,280 km^2. Lately, it declined to less than 2,000 km^2 with an average area of about 1,925 km^2. In addition, the average time that dense snow remains on mountains before melting has also decreased from 110 days to less than 90 days (Shaban, 2009), and it is expected to further decrease to 45 days with a warming of 2ºC (Najem, 2007). Furthermore, the mountainous ecosystems have been depleted of their vegetation cover by several degradation factors, thus altering the potential for self regeneration and reconstitution of the vegetation cover in these areas.

Implications on mountainous summer resort areas: Higher temperatures may affect the mountainous summer resort areas as they offer a cooler climate compared to urban coastal cities. Given that this can be rather easily mitigated by increasing cooling intensity in areas with hotter temperatures or by the gradual and autonomous shift of mountainous summer resort to higher altitudes, the vulnerability of those areas are deemed to be relatively low. The adaptive capacity of residents and seasonal tourists in the mountainous summer resort areas is considered to be high, especially that many of the residences are second-homes.

Implications on coastline areas: Mediterranean Sea Surface Temperatures (SST) is expected to gradually increase due to climate change. The greatest benefit of a 2-3°C rise in SST would be the extension of the swimming season beyond May and October to the spring and autumn seasons. However, the coastline where

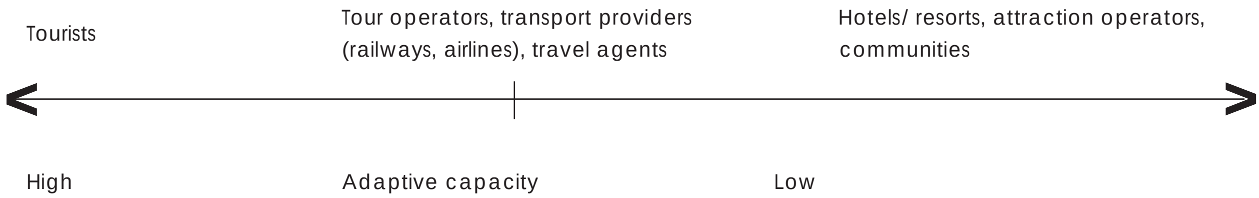


Figure 4-43 Relative adaptive capacity of major tourism sub-sectors

Source: Scott, D. and Jones, B. (2006)

archaeological sites, beach resorts, marinas and public beaches (e.g. Ramlet el Bayda, Tyre etc.) are located could be exposed to sea-level rise that may predictably attain a 12 to 25 cm rise by 2030 in the Mediterranean Sea. Such a rise may inflict damage on the touristic attractions due to their proximity to the shore if protective structures are not built. Sea-level rise may also affect the attractiveness of public beaches that are used by a significant proportion of the population, and cause coastal erosion and structural damage to the national archaeological heritage, inflicting higher costs to protect and maintain waterfronts.

Implications on natural areas of national interest: Higher temperatures and lower precipitation resulting in longer drought periods may impact protected areas and natural reserves by increasing the risk of forest fires and endangering some forest species. The expected increased frequency of fire events, the shift in forest lines and the risk of forest pest infestation are likely to provoke the loss of natural attractions, afflict potential damage to tourism infrastructure and natural assets and impinge on the livelihoods of the communities there (guesthouses, restaurants, souvenirs shops, etc.). In addition, some natural areas are at risk due to their coastal location, therefore might be affected by the expected sea level rise (e.g., the Palm Islands and Tyre Coastal Nature Reserve).

Indirect socio-economic impacts: The entire social fabric and infrastructure of certain communities in the region are based on tourists' flows attracted by the recreational opportunities of the vulnerable systems already identified. Changes in the availability of those recreational opportunities could have wide-reaching impacts on attracting tourists, and thus on the livelihoods of permanent residents that rely on the region's multi-faceted outdoor recreation industry. This in turn could lead to the migration of the affected groups that include hotels, restaurants, shops and other entities benefiting from the tourism sector. In terms of receipts from the tourism activities and the number of eco-tourists in the most vulnerable systems, they are likely to remain stable or slightly increase under scenario A due to the growth in the sector which, given stable political and security conditions, might overshadow any climate-induced negative impacts. Under scenario B, receipts are likely to range from a moderate decrease to stable returns, which, relative to scenario A, is a worse-off situation. This is mainly due to the expected, unsustainable growth trend in the ecotourism sector leading to a decrease in returns and the growth in mass tourism which might offset any losses due to climatic changes.

Climate change impacts and their implications on tourism are summarized in Table 4-16.

Table 4-16 Impacts of climate change and their implications for tourism

Impact	Implications for tourism
Warmer temperatures	Altered seasonality, heat stress for tourists, increase in cooling costs, changes in plant-wildlife-insect populations and distribution, infectious disease ranges
Decreasing snow cover due to lower precipitation	Lack of snow in winter sport destinations, increased snow-making costs, shorter winter sports seasons, aesthetics of landscape reduced
Reduced precipitation and increased evaporation	Water shortages, competition over water between tourism and other sectors, desertification, increased wildfires threatening infrastructure and affecting demand
Sea level rise	Coastal erosion, loss of beach area, higher costs to protect and maintain seafront resorts
Sea surface temperatures rise	Higher SST leading to an extension of the swimming season
Changes in terrestrial and marine biodiversity	Loss of natural attractions and species from destinations, losses in nature-based tourism
Increasing frequency and intensity of extreme storms	Risk for tourism facilities, increased insurance costs/loss of insurability, business interruption costs
More frequent and larger forest fires due to higher temperatures and less precipitations	Loss of natural attractions; increase of flooding risk; damage to tourism infrastructure

Source: UNWTO et al., 2008

4.9.4 Adaptation Measures

On the overall, despite the high vulnerability of some of the main tourism destinations in Lebanon to climate change, it is expected that in the tourism sector will adapt to the changes through increased investment in the tourism infrastructure. Specific aadaptation measures can be implemented according to the different locations of the touristic areas:

High mountain areas and winter tourism destinations at risk

- Establish a plan to organize and assist ski resorts to move ski slopes to higher altitudes or to colder north mountains or to invest in snow production. It is essential to involve the MoPWT in the excavation of roads leading to new ski slopes and the restoration of already existing ones;
- Improve insurance coverage in the face of extreme events, natural disasters and unprofitable seasons due to climatic changes;
- Promote industry partnerships (integration within resorts, cooperation between resorts) to reduce economic vulnerability;
- Enforce laws on controlling grazing in rangelands in the mountainous areas that are being afforested and reforested to preserve green spaces and encourage summer outdoor activities;
- Restore the vegetation cover by making available seeds of adapted species which will improve the vegetation cover, reduce erosion, increase water infiltration, and contribute to reducing the speed of snow melt.

Coastal areas at risk

- Implement 'soft' coastal protection measures to prevent erosion such as conservation of shore-stabilizing vegetation that act as natural buffers;
- Enforce enhanced design and planning guidelines for tourism establishments in order to increase their resilience to the impacts of climate change;
- Integrate climate change factors into regulatory frameworks for tourism development, such as environmental impact assessment and strategic environmental assessments;
- Adoption of water conservation measures at the resort level;
- Re-organize the urban sprawl in coastal areas;
- Preserve existing public beaches and marine ecosystems.

Natural areas at risk

- Support protected area management in order to enhance their resilience;
- Enhance and restore the forest cover in order to promote sustainable tourism;
- Implement all adaptation measures proposed for the forestry sector and coastal zones.

Other general adaptation measures include:

- Strengthen the role of MoPWT in traffic management and in establishment of new roads to facilitate access to tourism destinations;
- Create financial incentives to encourage investment in more sustainable touristic activities such as ecotourism to be sponsored by MoT;
- Establish "information offices", to be managed jointly by MoIM, MoT, MoPWT, municipalities and the private sector, in regions of touristic importance to promote the shift to adaptable and sustainable activities;
- Seek funds from international organizations to support projects for the development of the proposed adaptation measures;
- Sponsor direct awareness of tourists, through MoT, towards cultural and sustainable tourism in order to promote diversification of tourism activities;
- Improve provision of climatic information to the tourism sector through cooperation with the national meteorological services;
- Increase studies on changes in snow conditions.

4.10 Vulnerability and Adaptation of Human settlements and Infrastructure

4.10.1 Methodology

Scope of assessment

The assessment examines the vulnerability and likely impacts on human settlements and public infrastructure such as wastewater, solid waste and transportation caused by increase in rainfall intensity, increase in temperature and extended heat waves, sea level rise and increase in the frequency and intensity of storms. It focuses on 1) coastal areas that are vulnerable to sea inundation and harbor major infrastructure and investments, 2) mountainous areas that are vulnerable to landslides, rockslides and mudslides, and 3) urban agglomerations that are prone to flooding or are sensitive to extreme climatic events.

Development of the sector under socio-economic scenarios

Under scenario A, Lebanon will be counting on tourism and commercial services as the major income-generating economic sectors to secure its growth in the face of integrated international trade. Despite the moderate economic growth, investments will go into improving Lebanon's infrastructure in order to be capable to host international fairs, exhibitions and luxury tourism. Beirut Rafic Hairir Intenational Airport will be able to reach a satisfactory level of passengers per year, commercial ports will be competent with other ports in the region and new highways and roads will be established (CDR, 2005). By improving the means of transportation and as Lebanon's touristic assets are expanded over the country, population density in urban agglomerations will decrease to be slightly increased in rural areas. Improvements in the infrastructure sector will lead to a better access to sanitation and clean water.

Under scenario B, Lebanon will be counting on its industrial and agricultural sectors to face competition induced by imported products and increase its income from exports of goods. Improving the means of transport will allow the relocation of certain activities of the capital towards different regions. Nevertheless, the high population growth and the low migration rate will contribute in high population densities in all rural and urban areas, which makes human settlements more vulnerable to climate change in this scenario B. Nevertheless, the increase in GDP and the balanced economic development in this scenario could instigate the adoption of suitable adaptation measures to climate change.

4.10.2 Vulnerability assessment

The sensitivity of human settlements and infrastructure to climate change is related to the poor and old infrastructure that varies across regions, sectors, and communities. The sensitivity of public infrastructure is considered low to moderate, but increased investments could render it more resilient to changes in climatic and climate-related factors. Table 4-17 presents information on the likely risks of the different infrastructure/human settlements types to projected changes in climatic and climate-related factors.

Adaptive capacity of human settlements and infrastructure in Lebanon is more variable than its sensitivity. The community's adaptive capacity largely depends on how it is designed, the state of its infrastructure and its ability to adapt to new climatic conditions; it is affected by the social, economic and technological conditions. The lack of sufficient infrastructure to carry out the daily functions of the Lebanese community reduces its capacity to adapt to changing environmental conditions. Moreover, the absence of proper planning and implementation in the different infrastructure subsectors results in a low adaptive capacity, unless significant investments are made to improve the current infrastructure. The adaptive capacity of specific settlements and infrastructure are described below:

- **Human settlements:** The adaptive capacity is lower in poor communities that tend to reside in areas that are densely populated, haphazardly built and lack proper services such as slums;
- **Wastewater Infrastructure:** There is a total absence of a proper sewage control or treatment prior to disposal. Sewage networks lack proper maintenance and operational control. The current low adaptive capacity is expected to improve gradually with the increasing investments in wastewater infrastructure and treatment;
- **Solid Waste Infrastructure:** The disorganized management of MSW in Lebanon is characterized by rudimentary "collect and dump" approaches. Although at the moment, the adaptive capacity is considered low, it is expected to increase with time due to better awareness and larger investments streaming into improving the management of solid wastes;

Table 4-17 Climate change exposure and the sensitivity of human settlements and infrastructure

	Increase in hot summer days	Increase in rainfall intensity	Increase in extreme phenomena such as violent winds and storms	Sea level rise of 12-25 cm by 2030 and 22-45 cm by 2050
Human settlements				
Buildings and structures	Definite risk especially in urban areas where the increase in hot summer days may lead to intensification of existing phenomena such as the urban heat island	Negligible risk except for slums and poor settlements High risk in built-up, flood-prone areas	Negligible risk except for slums and poor settlements	Negligible risk except for slums built on beaches
Infrastructure				
Wastewater	Potential risk for additional odor problems	The risk is limited to the capacity of treatment works through greater volumes of storm water	Negligible Risk	Negligible risk
Solid waste	Negligible risk – more rapid degradation of organic material in landfills and open dumps, and more days of odors	Negligible risk	Negligible risk – More frequent blowing of garbage and more days of odors in the vicinity of open dumps	The risk is limited to coastal dumps such as Sidon and Tripoli solid waste dumps
Roads	Negligible risk: The risk is limited to a decrease in the viscosity of asphalt	Negligible risk: The risk is limited to an increase in the formation of potholes	Potential risk to mountainous roads with no adequate structure to prevent road blockages from trees and debris	Negligible risk
Airports	Negligible risk	Definite risk as B-RHIA is a coastal airport that is sensitive to storm surges that may disrupt operations and pose hazards to passengers		
Ports	Negligible risk	Potential risk of future flood risk with sea-level rise which may cause interruptions to goods movement at ports		

- **Transport Infrastructure:** Despite the investments in road transport infrastructure, the low adaptive capacity of the transport infrastructure is not expected to improve above its current low levels;

- **Areas prone to floods and landslides:** The areas prone to floods and landslides are highly vulnerable, especially the Nahr Abou Ali area which experiences exceptionally violent torrential floods (CDR, 2005), and the areas located around rivers (Abou moussa, El kaleb, Kadisha, El jaouz, Ibrahim) and along faults (Yammouneh, Wadi el Taym) that are affected by landslides. Figure 4-44 and Figure 4-45 show the areas that are naturally vulnerable to floods and landslides. However, the improvement in construction standards and adherence to building codes can mitigate the risk which buildings in those areas might face.

The vulnerability of the human settlements and public infrastructure is exacerbated by different risks and threats as well as by the communities' low adaptive capacity. People living in poverty are more exposed to the potential damages to infrastructure from extreme events. Urban agglomerations such as Beirut, Tripoli, Saida, Nabatieh, Baalbek, Zahle, are highly vulnerable due to the presence of a large percentage of extreme and overall poverty, the proliferation of slums, and the urban heat island effect of these agglomerations. Under both socio-economic scenarios, investment in public infrastructure is expected to increase. However, even though it is more likely that the increase in investment

Figure 4-44 Flood risk areas versus population distribution

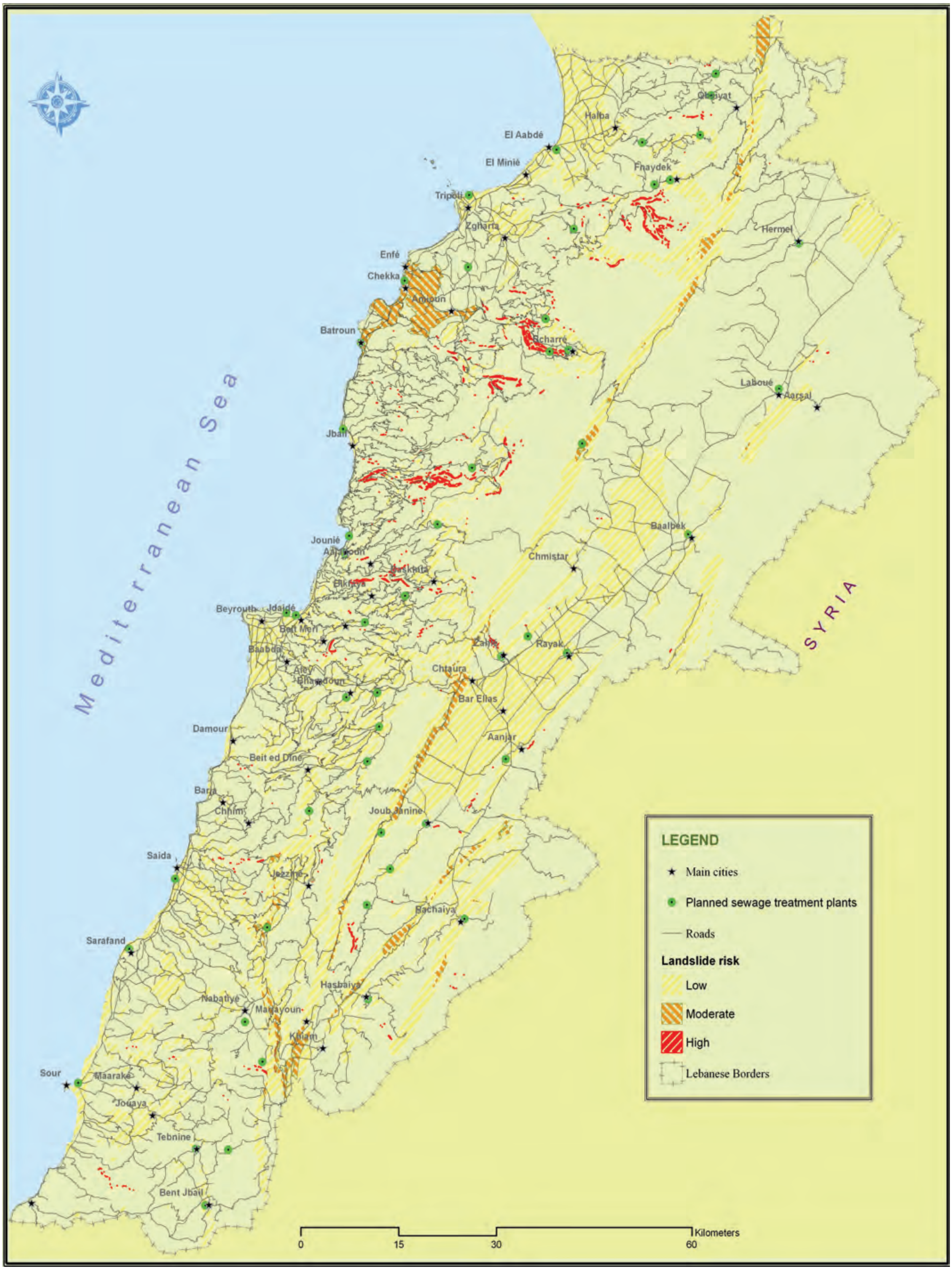


Figure 4-45 Landslide risk versus roads and sewage treatment plants

would be larger under Scenario B, urban communities will experience higher population densities and increasing pressures on the public infrastructure which might not be met with these increased investments. Hence, human settlements could be more vulnerable to climate change under scenario B.

4.10.3 Impact assessment

Physical infrastructure is directly affected by climate related changes while the economy of the areas of concern is affected in an indirect way. However, the uncertainty in the predictions of rainfall intensity and storms' frequency does not allow for an accurate determination of the climate change impacts. Nontheless, the most likely impacts are presented below:

Impacts on urban agglomeration

Financial losses in the infrastructure that supports the different economic sectors, resulting from climate change will reduce the quality of life, the level of income and induce a loss or a reduction in employment opportunities.

Impacts on buildings

A rise in sea level would place coastal settlements and buildings are a risk o inundation. The situation would be aggravated in case of a combination of storm surges with sea level rise. Furthermore, extreme weather events would jeopardize old buildings and facilities due to accelerated degradation of materials. Hence the maintenance costs and the potential of structural failure during extreme events are expected to increase (Assaf, 2009).

Impacts on public and service infrastructure

The projected changes in climate could lead to several damages in the transport infrastructure, water, and wastewater networks. Most of the expected damages are already being witnessed in different regions in Lebanon due to the poor and aging infrastructure which is highly vulnerable to snowy or sandy storms and to torrential rain.

An increase in the frequency and intensity of hot days could lead to a decrease in asphalt viscosity, resulting in a degradation of the quality of paved roads, e.g. potholes and cracks, and an increased risk of traffic and traffic accidents. Moreover, an excessive expansion in bridge joints and a deformation of the metal components of bridges are expected to occur as a result of the projected extreme hot waves.

High tides and storm surges in the winter season may cause the closure of coastal roads and bridges that could be threatened by inundation and the collapse of coastal waste dumps into the sea. These surges coupled with a high frequency and intensity of sandstorms or thunderstorms can also disrupt the operations at the Beirut Rafic Hariri International Airport.

Extreme cold events such as intense rainfall events and snowy storms could threaten mountainous roads due to an increased risk of mudslides and rockslides. Such events could increase peak volume and sediment loading into wastewater treatment plants leading to inadequate efficiency in treatment and overflows, if the capacity for treatment is exceeded (Assaf, 2009).

Impacts in socio-economic systems

Any financial losses in the infrastructure that supports agriculture, fishing and tourism and that might result from climate change will reduce the quality of life, the level of income and induce a loss or a reduction in employment opportunities. Moreover, areas where the population relies on artificial cooling during the summer season may see increased pressure on household budgets as average temperature is predicted to rise with time. Less-advantaged populations might not afford adaptation mechanisms such as artificial cooling/heating or climate-risk insurance. Although the poor might already have in place certain coping mechanisms, they might not be sufficient if climate change impacts transcend their ability to adapt (Wilbanks, 2007).

4.10.4 Adaptation measures

The adaptation measures for human settlements and infrastructure revolve around three main activities: 1) increasing the resilience of infrastructure to climate change impacts, 2) anticipation of floods and extreme events in vulnerable areas and 3) improving the efficiency and readiness of relief commissions during climate change induced catastrophes for a better intervention. More specifically, adaptation measures for human settlements and infrastructure include:

- Integrating climate change risks in SEAs and EIAs, especially in the planning phase and contingency plans;
- Taking into consideration the high-risk areas in urban planning and construction activities through restricting development and settlement in regions at risk of landslides or flood, adopting flood-sensitive

urban planning and adopting water-sensitive urban planning that may reduce surface runoff;

- Adopting flood sensitive urban planning through taking into consideration in the design of buildings, roads, solid waste and waste water treatment plants the potential impacts of climate change such as floods, landslides, rainstorms high tide, etc.;
- Adopting a better design of building envelopes to reduce cooling demand and render constructions capable of withstanding more extreme climatic conditions;
- Preparing an emergency management plan in case of extreme weather conditions and events, to be incorporated into routine operations in collaboration with emergency management agencies. This plan could include forecast techniques and information systems between weather bureau/meteorological offices and individuals through local government/offices (Jáuregui et al., 2001);
- Anticipating floods in vulnerable areas through hard engineering measures (dams, levees, diversions, etc.) and/or nonstructural methods (acquisition of properties, fiscal and financial incentives, regulations, warning systems/evacuation plans, etc.) (Jáuregui et al., 2001).
- Ameliorate the coordination between the High Relief Commission (HRC) and other governmental committees, regional offices or NGOs and establish regional offices of the HRC;
- Establish the "Unit Management Disaster" that should include NCSR, Order of Engineers, HRC as well as the relevant ministries;
- Periodically train or build capacity of technicians, employees, municipal members etc. on emergency intervention in case of floods/landslides or any other climate induced impact.