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

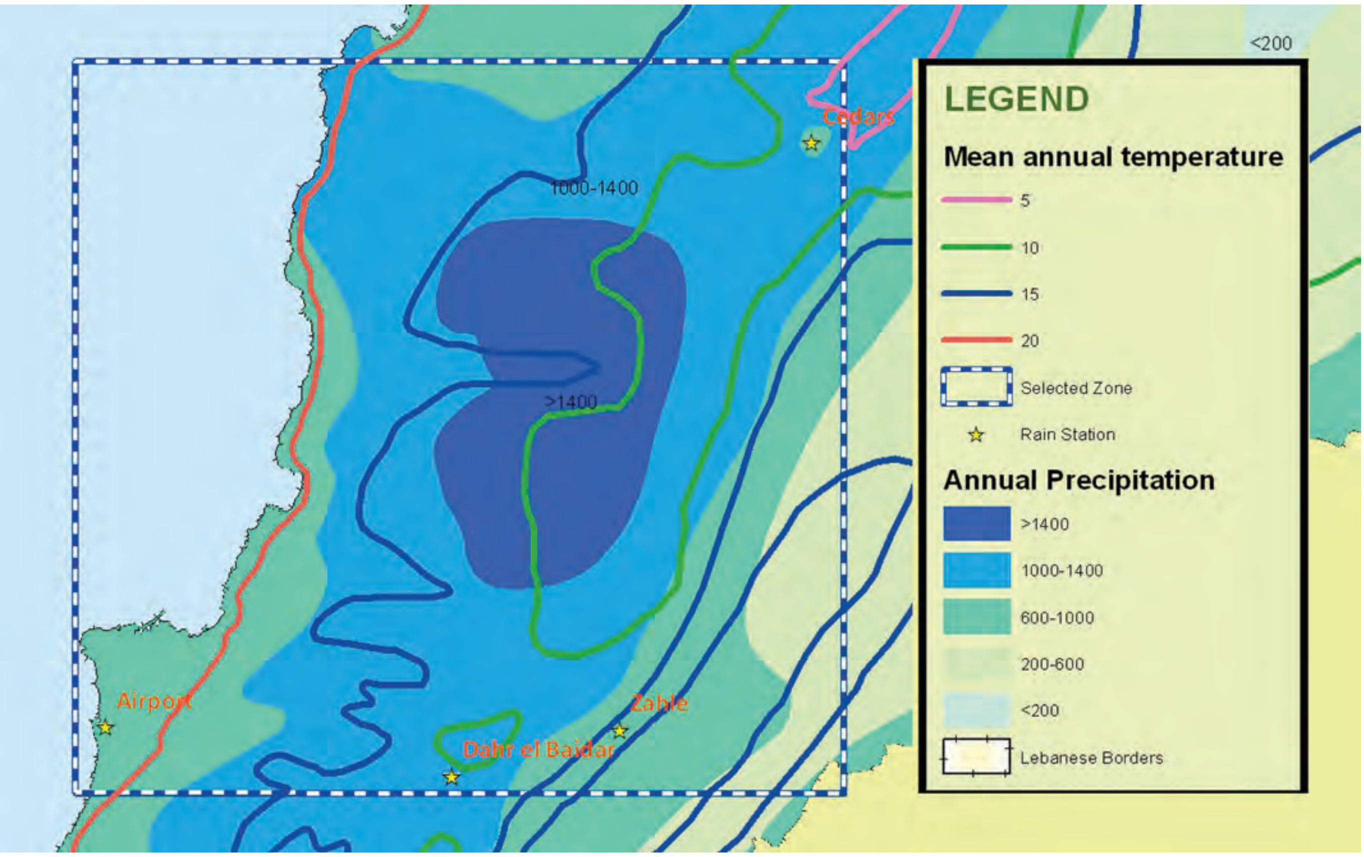

Figure 4-16 Temperature and precipitation isohyets in the study area

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)

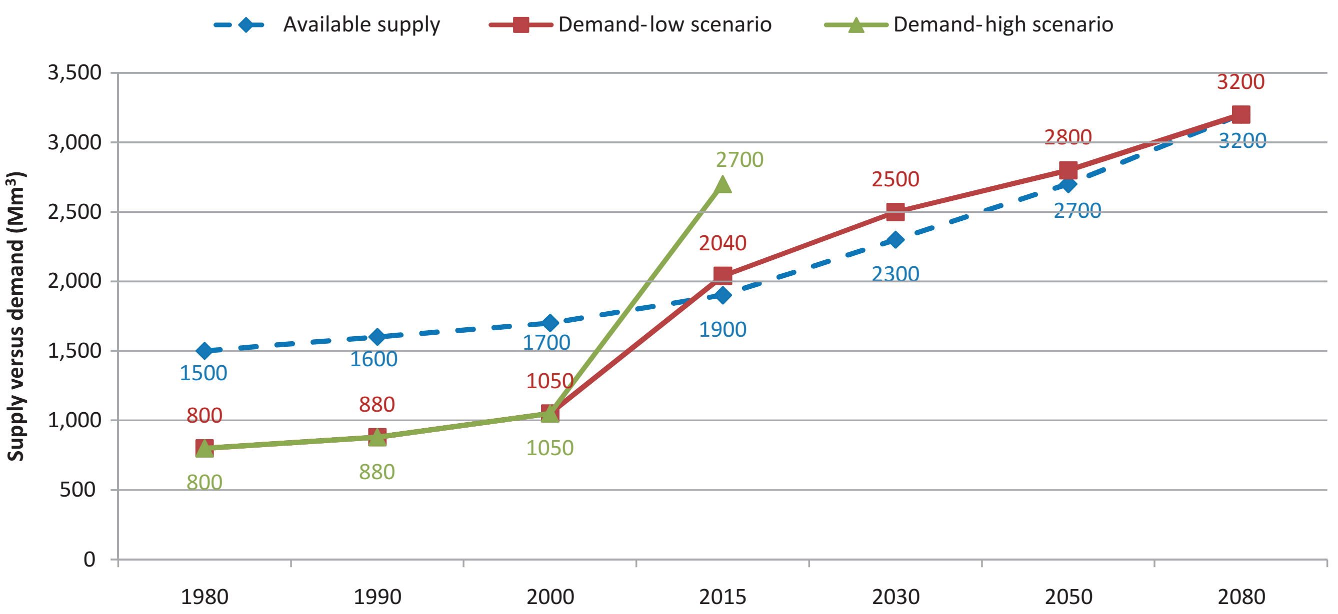

Figure 4-17 Baseline projections of supply and demand

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.

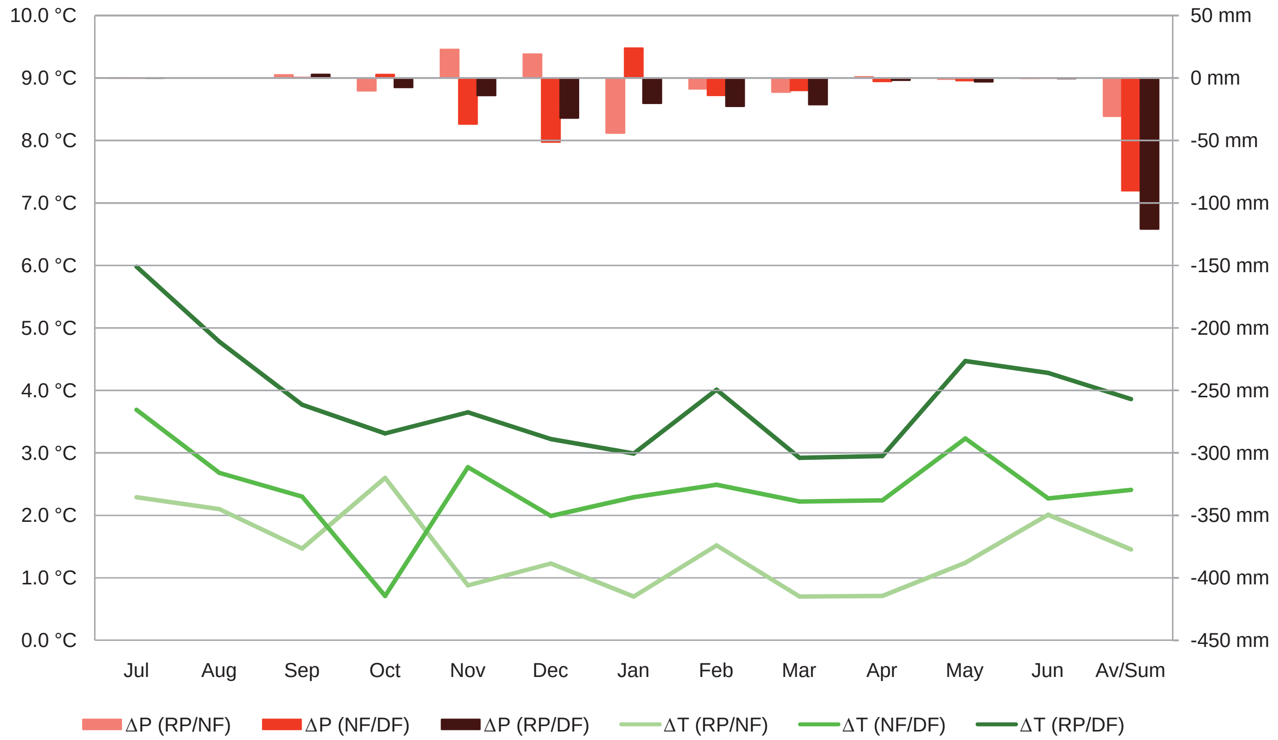

Figure 4-18 Projected changes in precipitation and average temperature – Beirut station

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

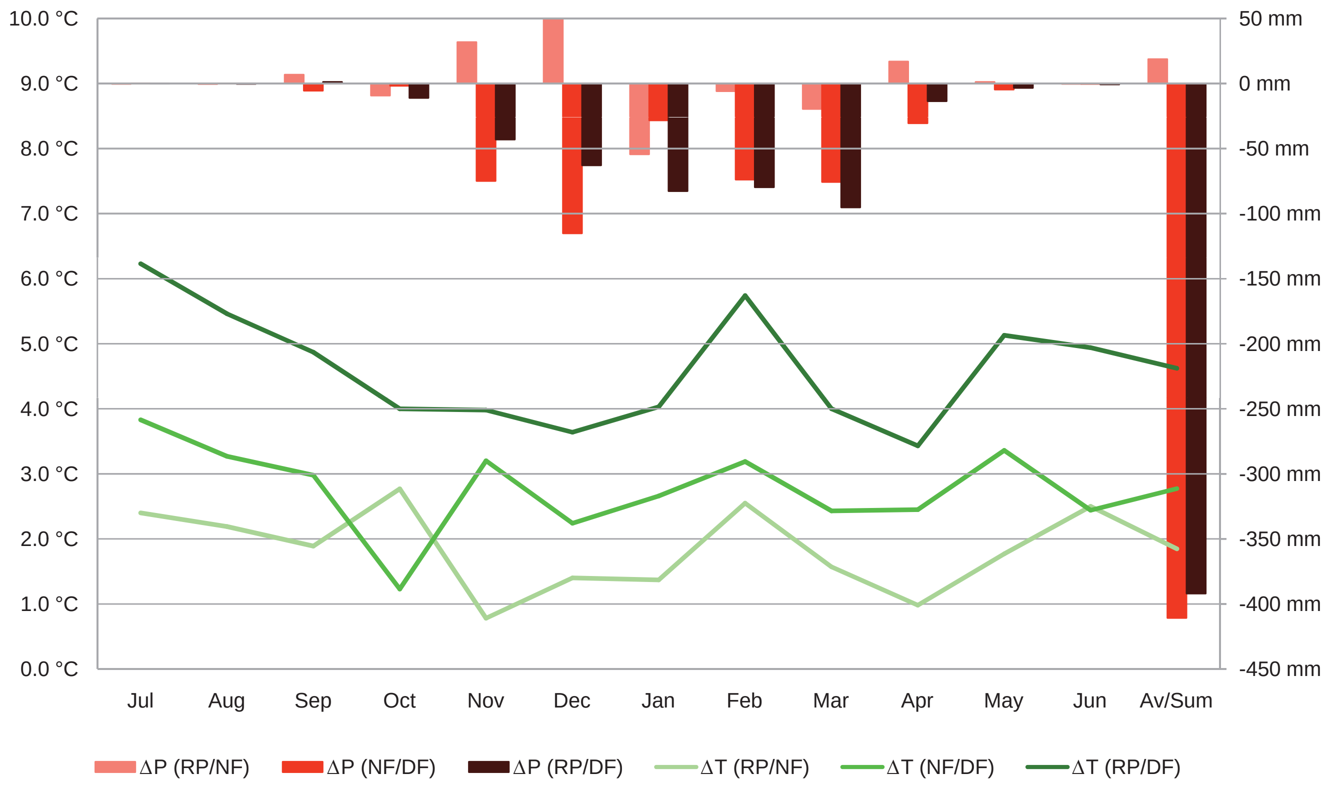

Figure 4-19 Projected changes in precipitation and average temperature – Daher-el-Baydar station

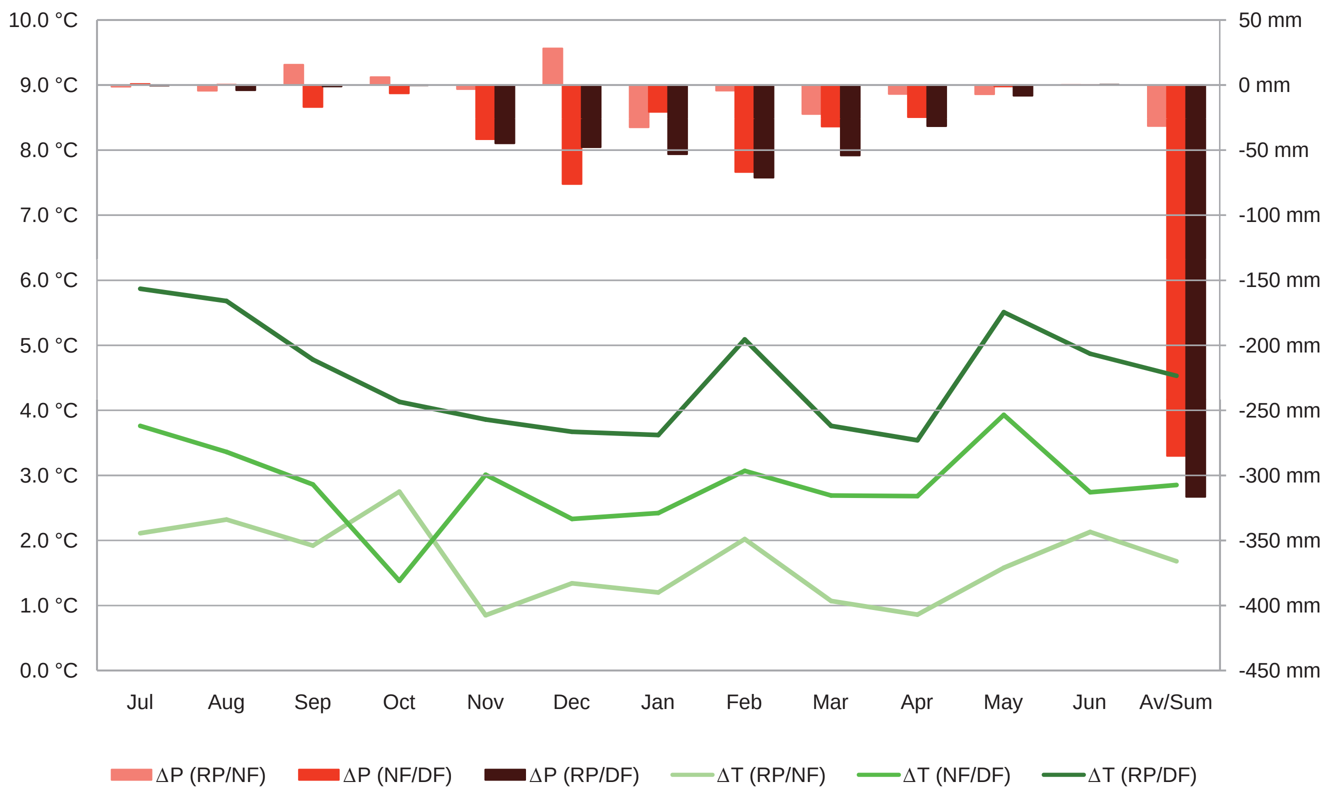

Figure 4-20 Projected changes in precipitation and average temperature – Cedars station

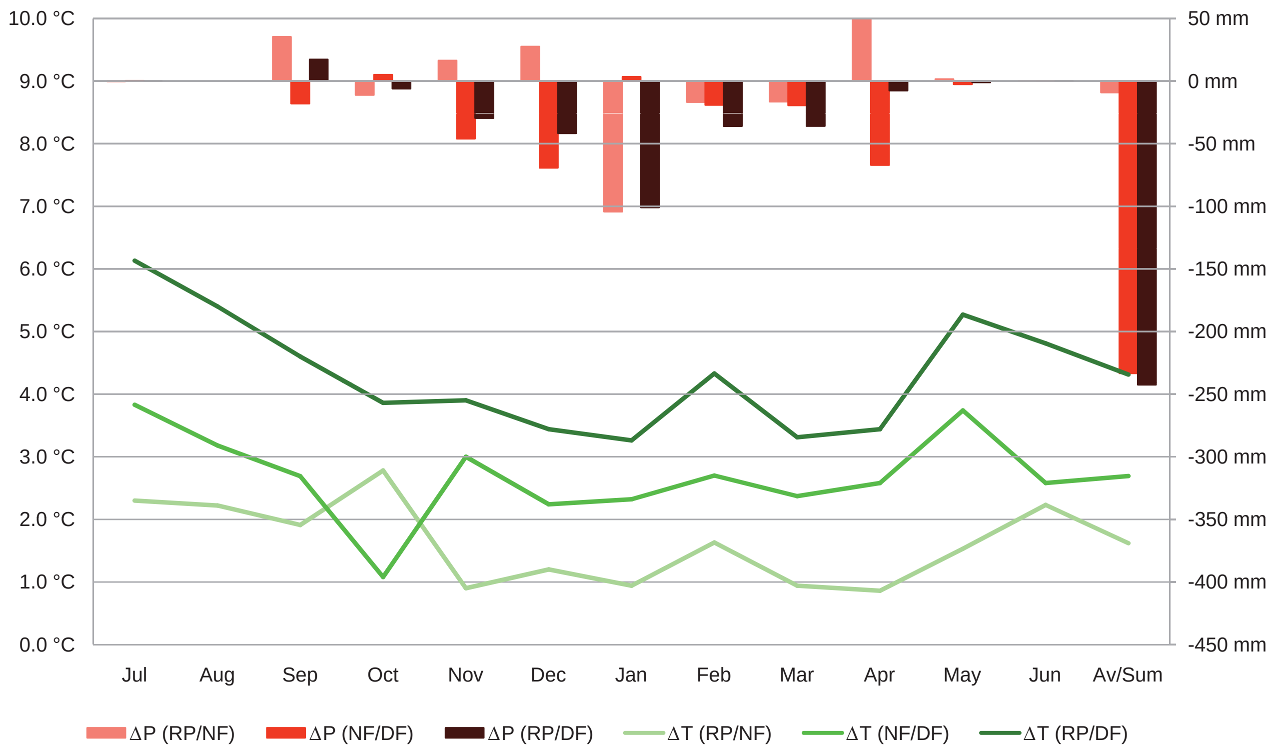

Figure 4-21 Projected changes in precipitation and average temperature – Zahleh station

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.

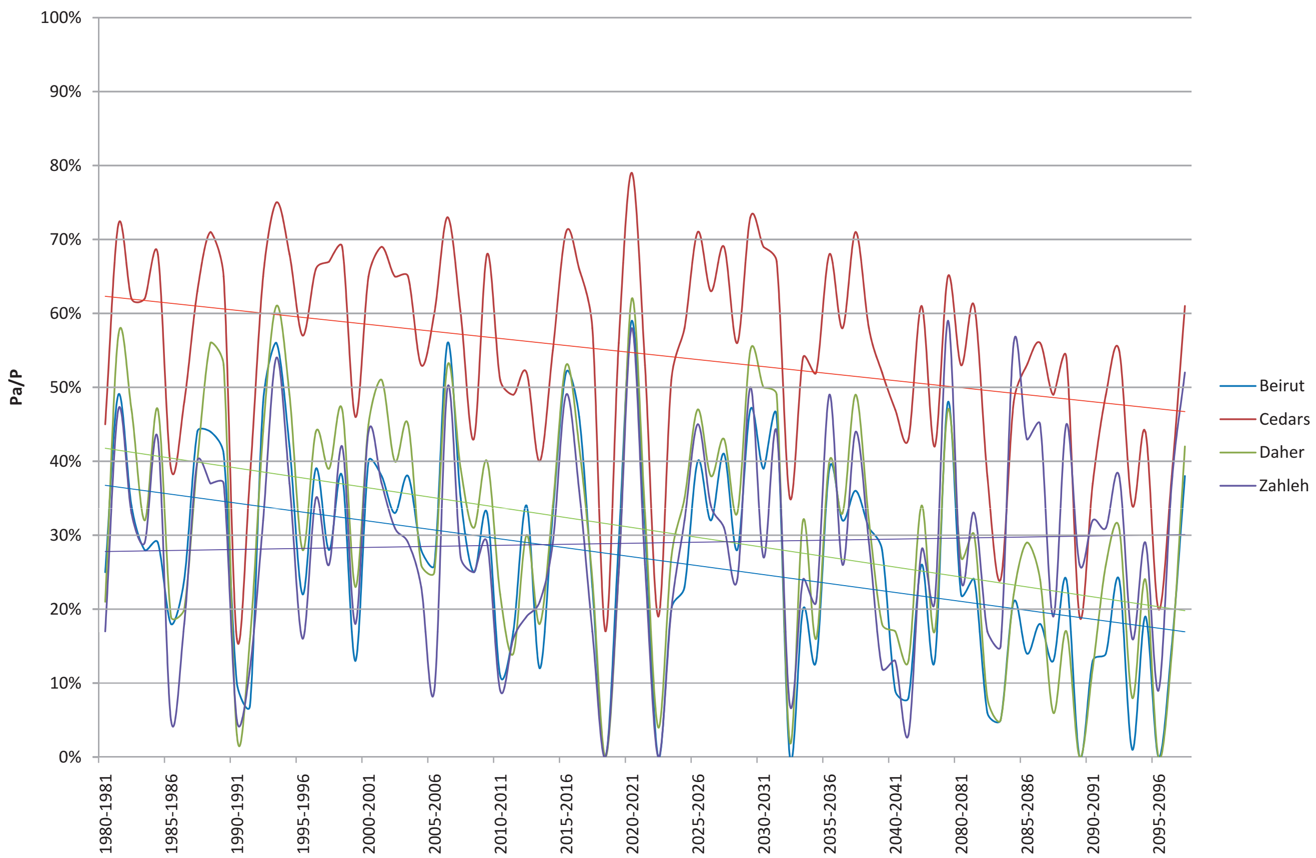

Figure 4-22 Trend pf the proportion of active precipitation out of total precipitation over time in the 4 grid boxes constituting the study area

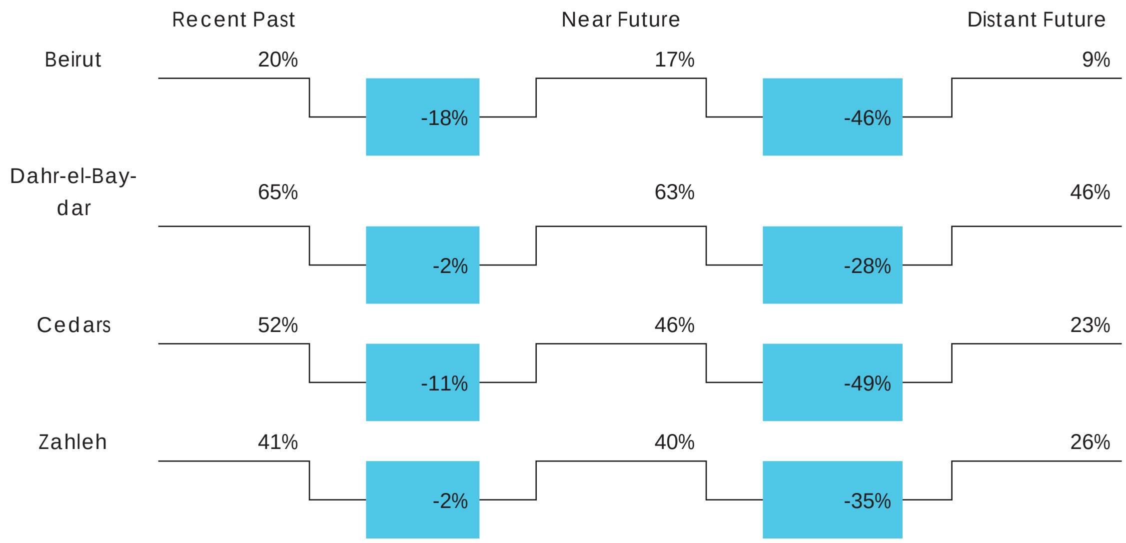

Figure 4-23 Decline in the proportion of active precipitation out of total precipitation in the different regions over time

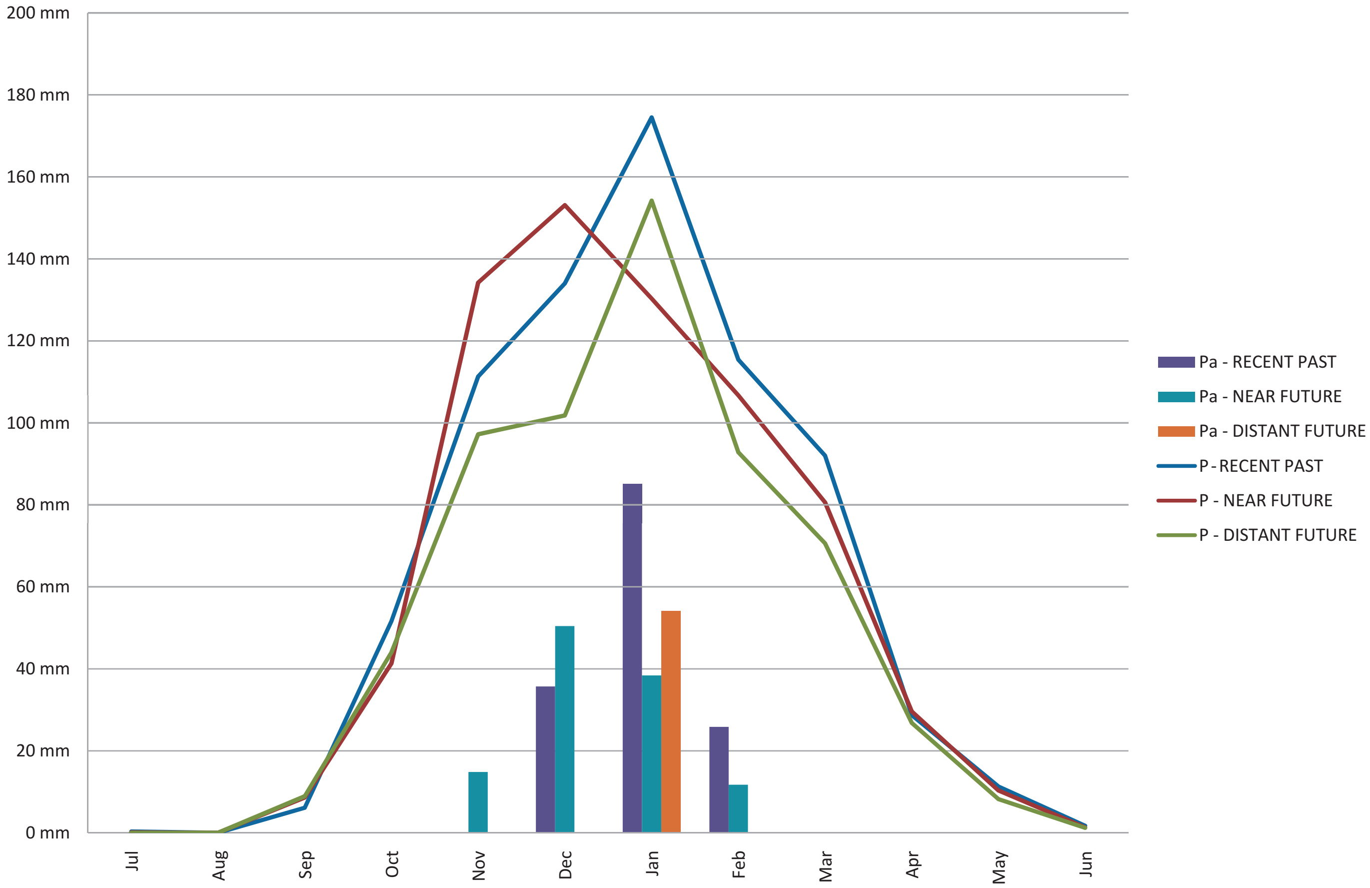

Figure 4-24 Monthly average of total and active precipitation in Beirut (past and projected)

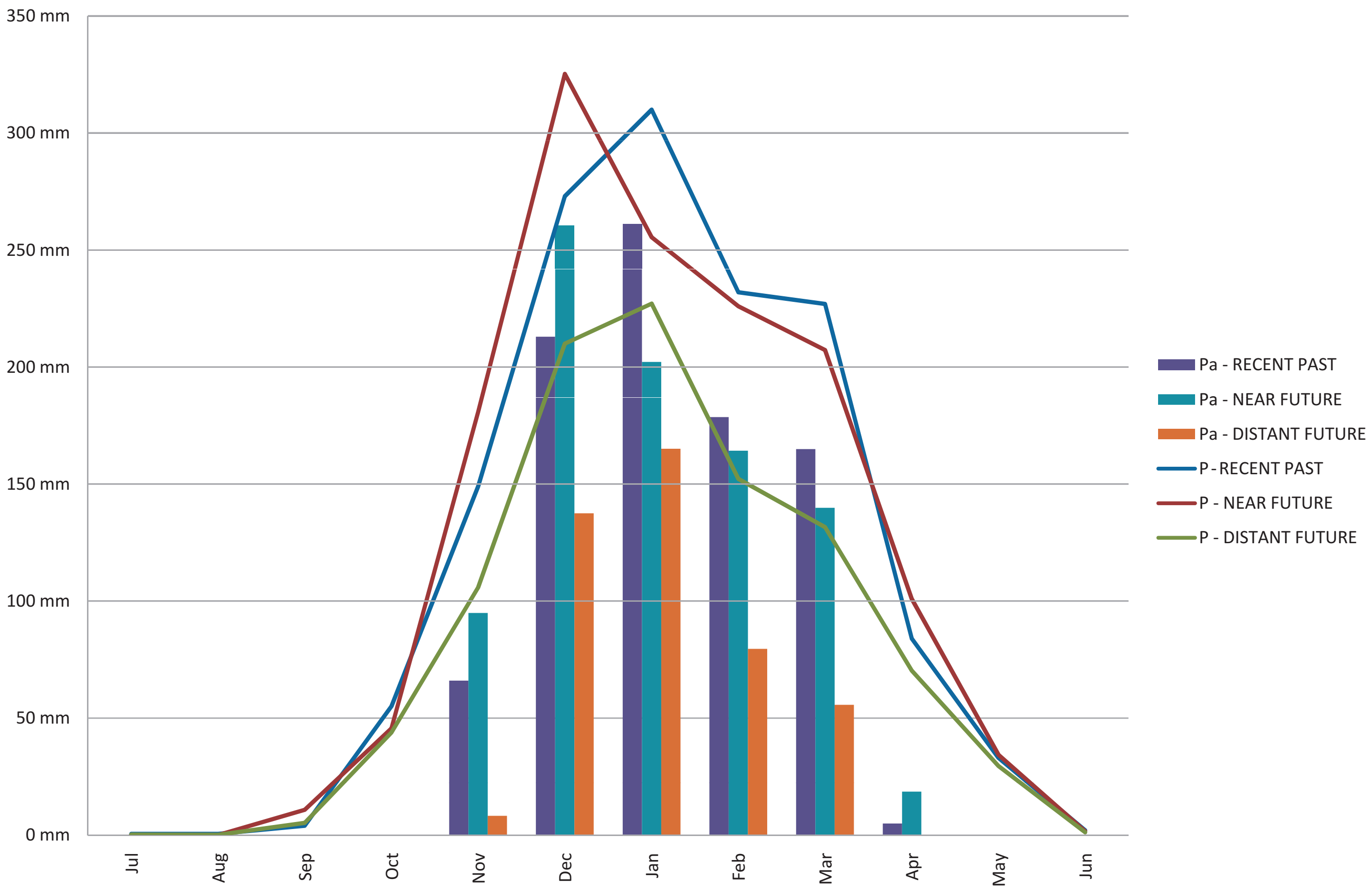

Figure 4-25 Monthly average of total and active precipitation in Daher-el-Baydar (past and projected)

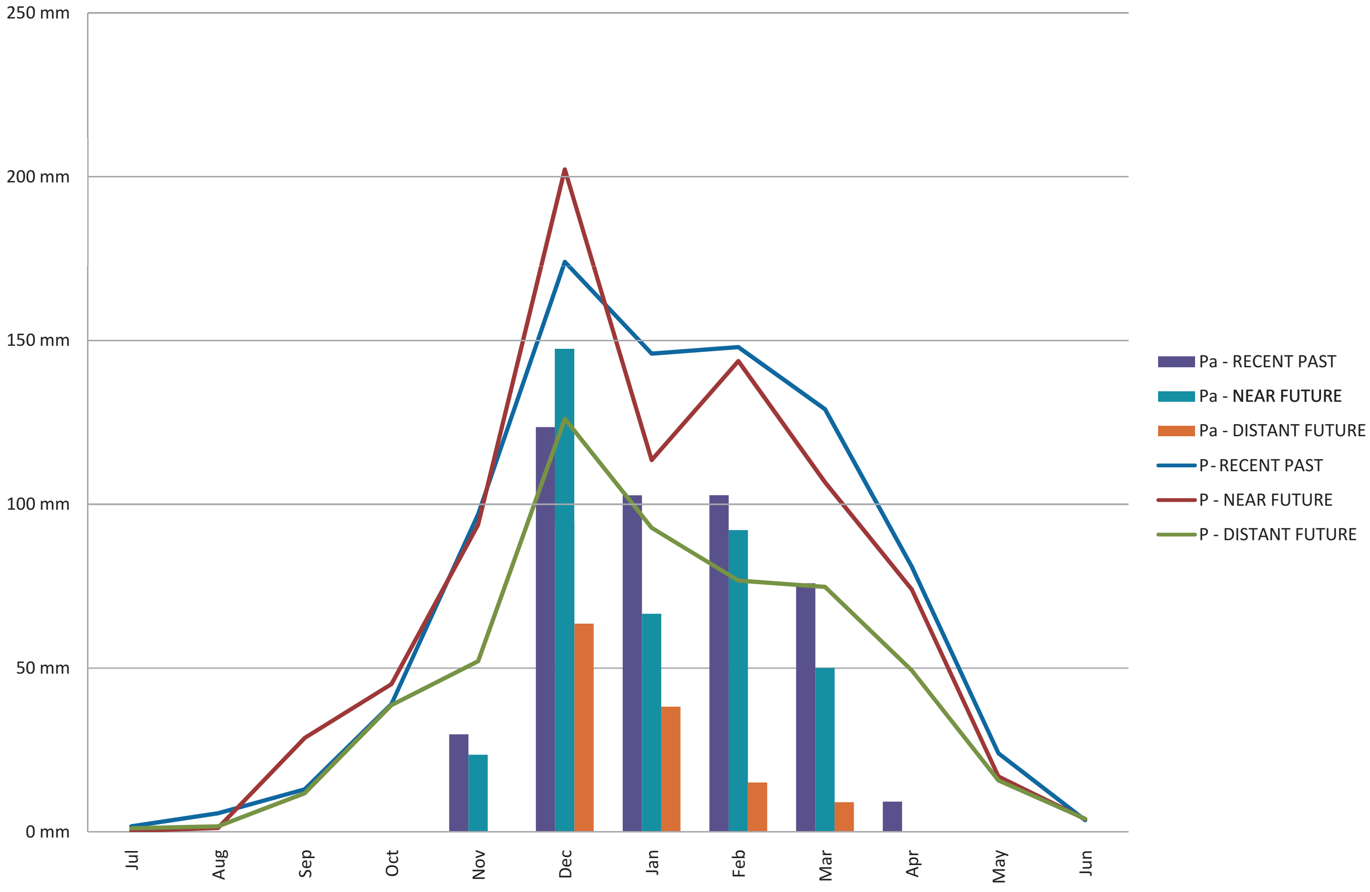

Figure 4-26 Monthly average of total and active precipitation in the Cedars (past and projected)

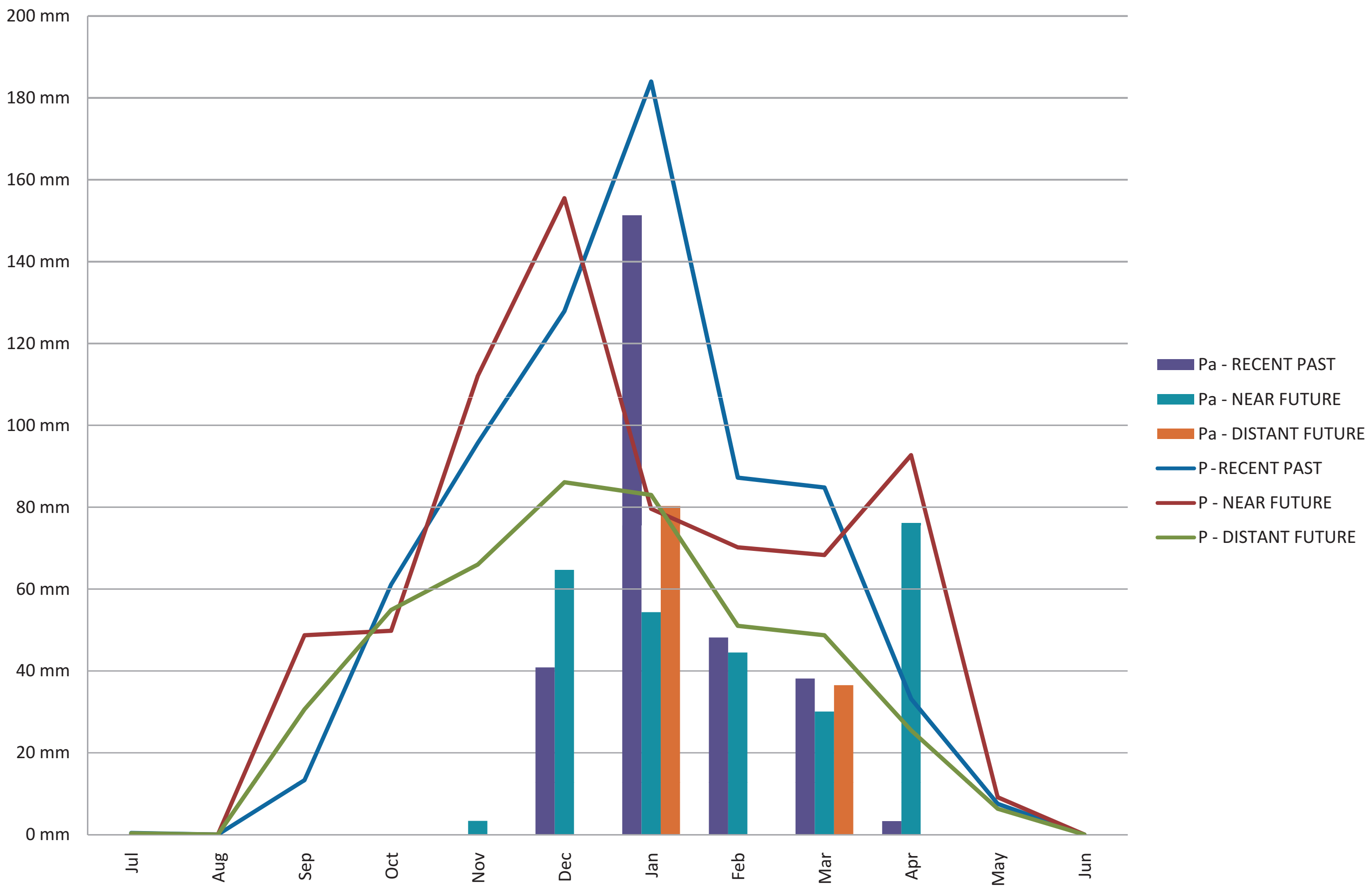

Figure 4-27 Monthly average of total and active precipitation in Zahleh (past and projected)

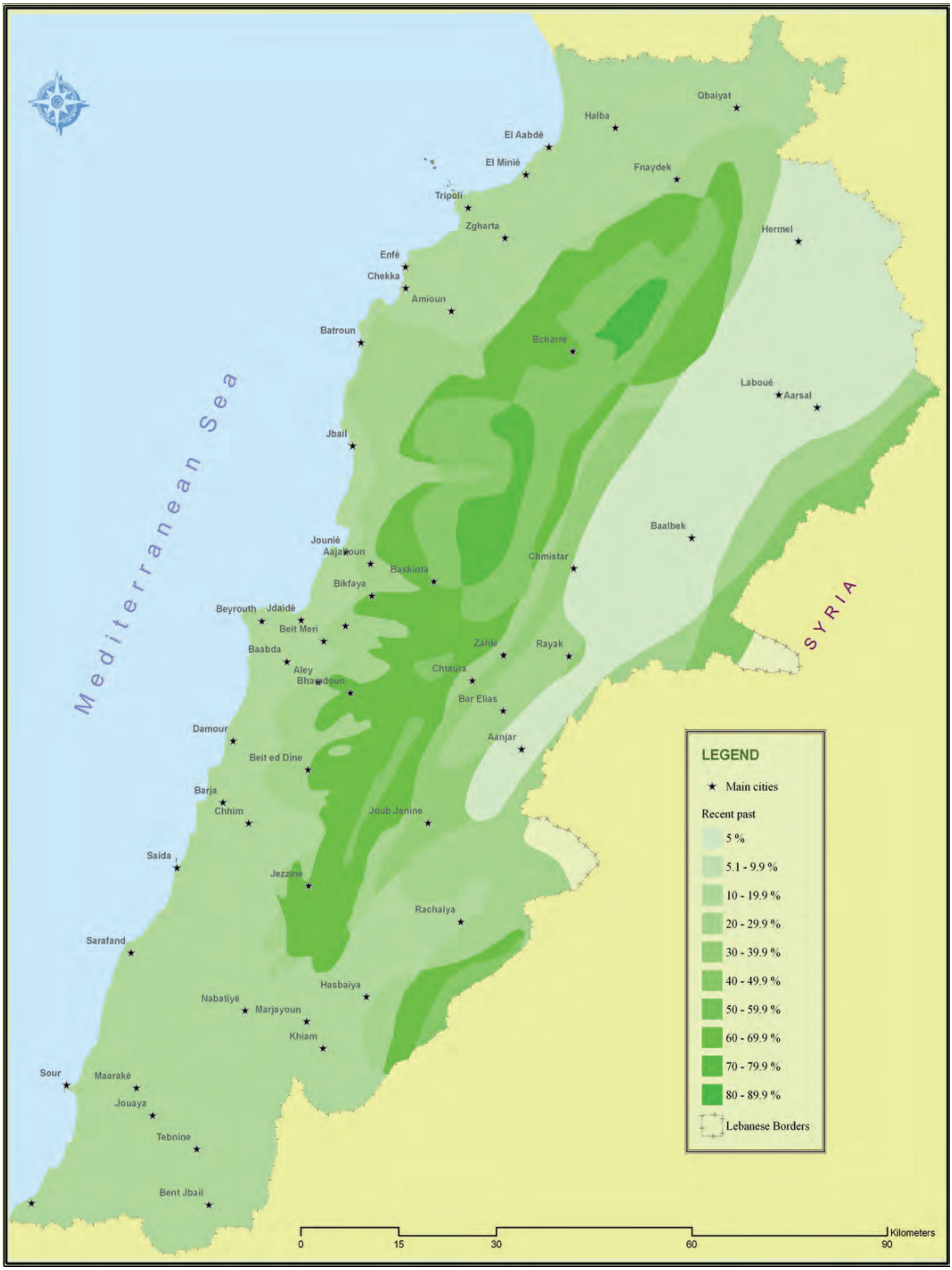

Figure 4-28 Proportion of active precipitation out of total precipitation for the recent past (1960-2000)

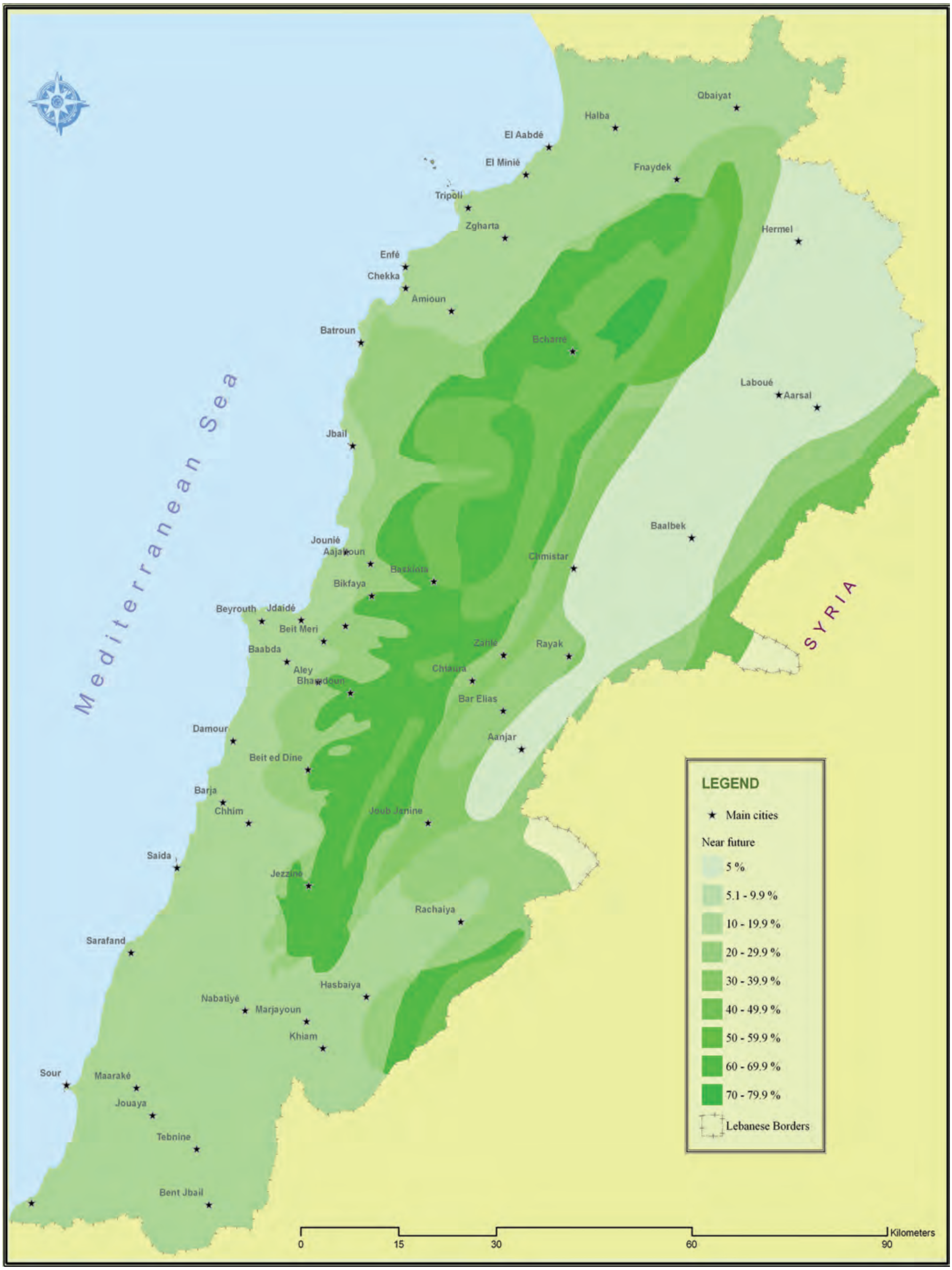

Figure 4-29 Proportion of active precipitation out of total precipitation for the near future (2025-2044)

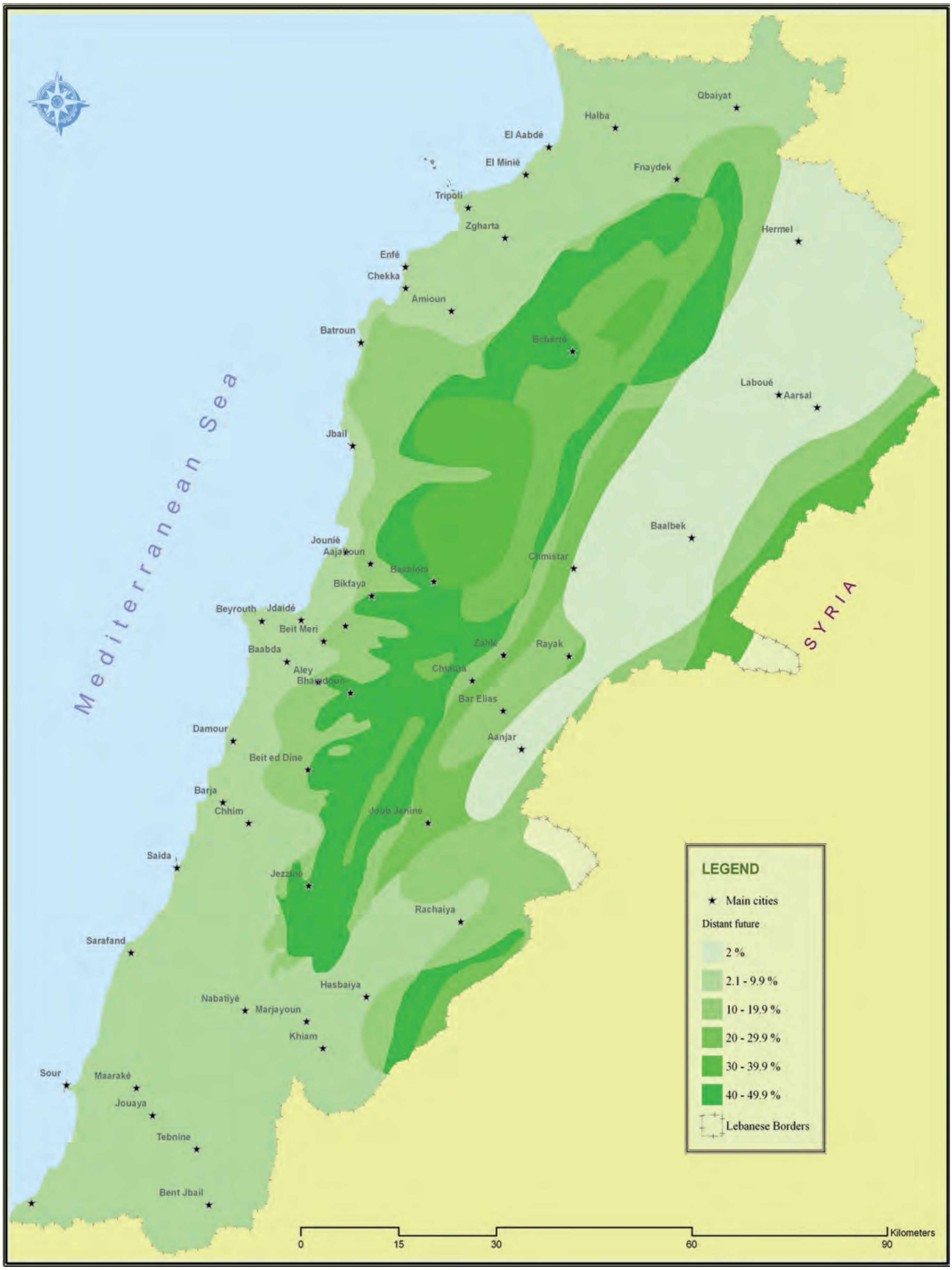

Figure 4-30 Proportion of active precipitation out of total precipitation for the distant future (2080-2098)

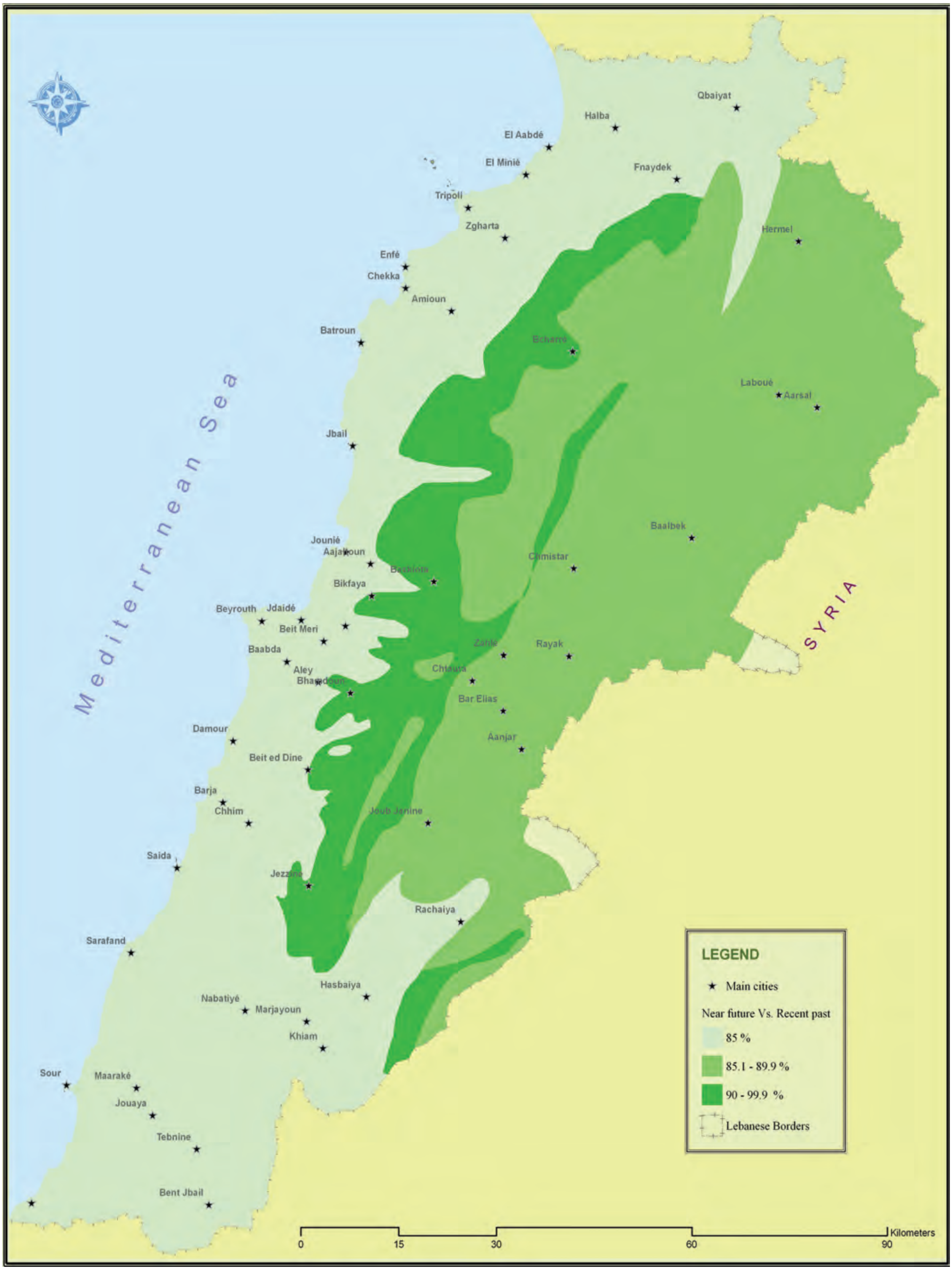

Figure 4-31 Decline in the proportion of active precipitation out of total precipitation from the recent past (1960-2000) to the near future (2025-2044)

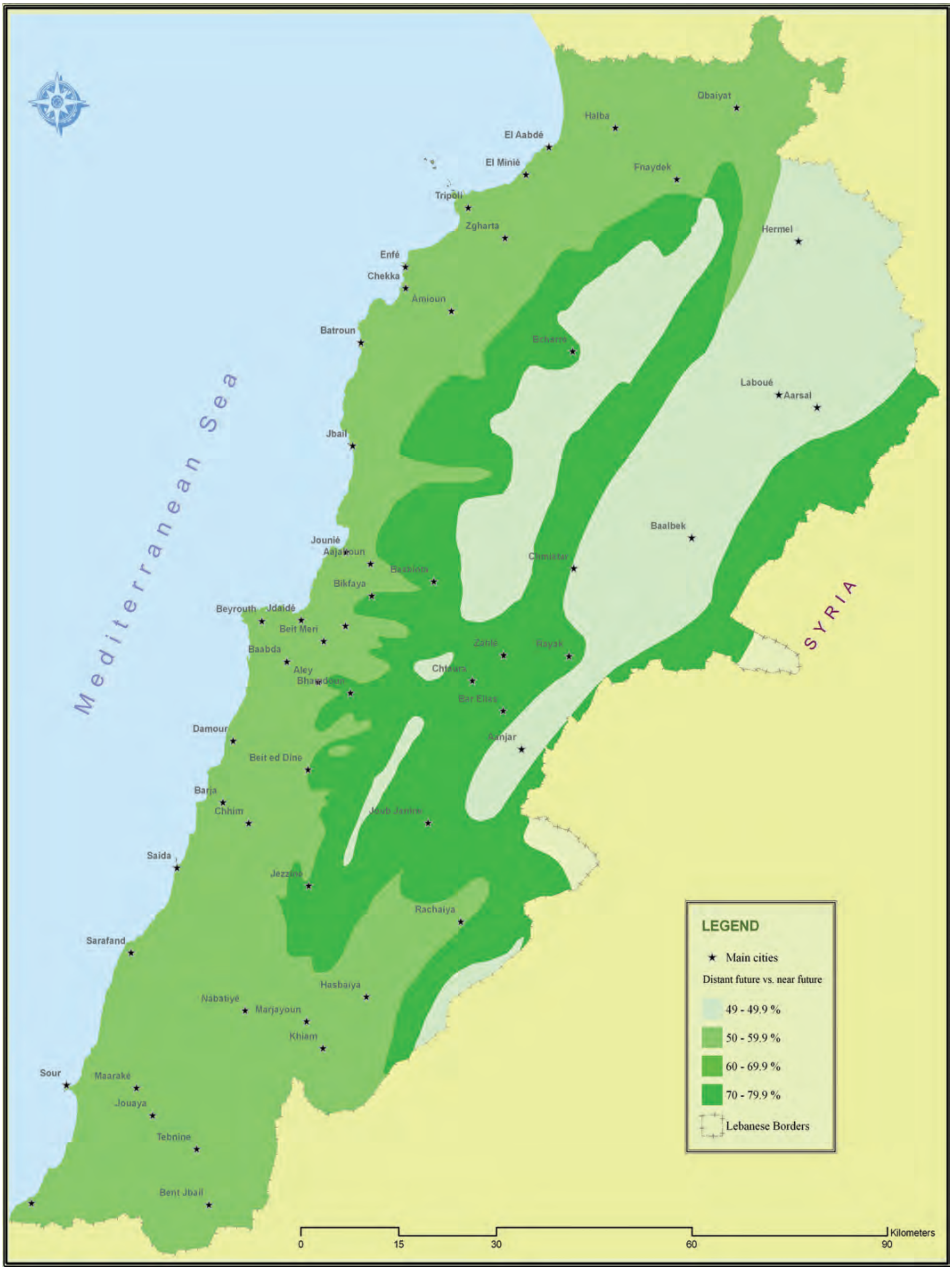

Figure 4-32 Decline in the proportion of active precipitation out of total precipitation from the near future (2025-2044) to the distant future (2080-2098)

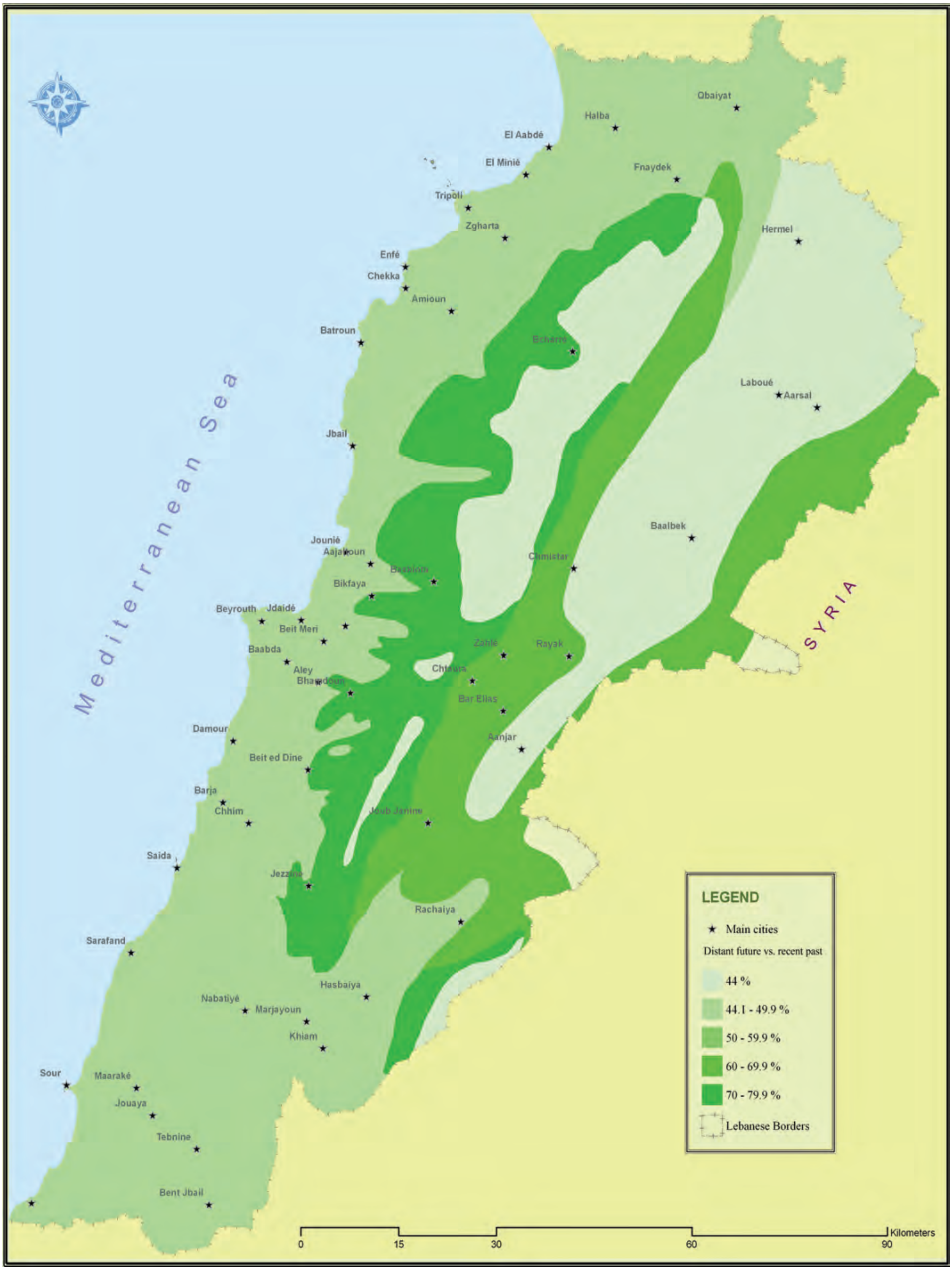

Figure 4-33 Decline in the proportion of active precipitation out of total precipitation from the recent past (1960-2000) to the distant future (2080-2098)

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

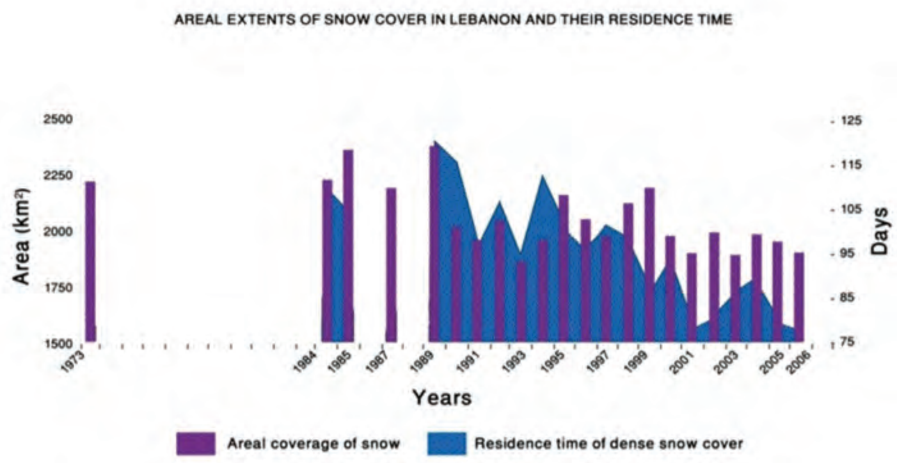

Figure 4-34 Areal extents of snow cover in Lebanon and their residence time Source: Shaban, 2009

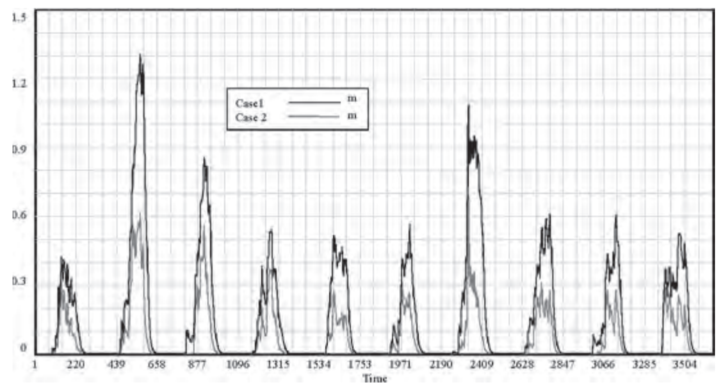

Figure 4-35 Mean snow width generated over 10 years (Case 1: reference simulation; Case 2: scenario of an increase by 2°C)

Source: Hreiche et al., 2007

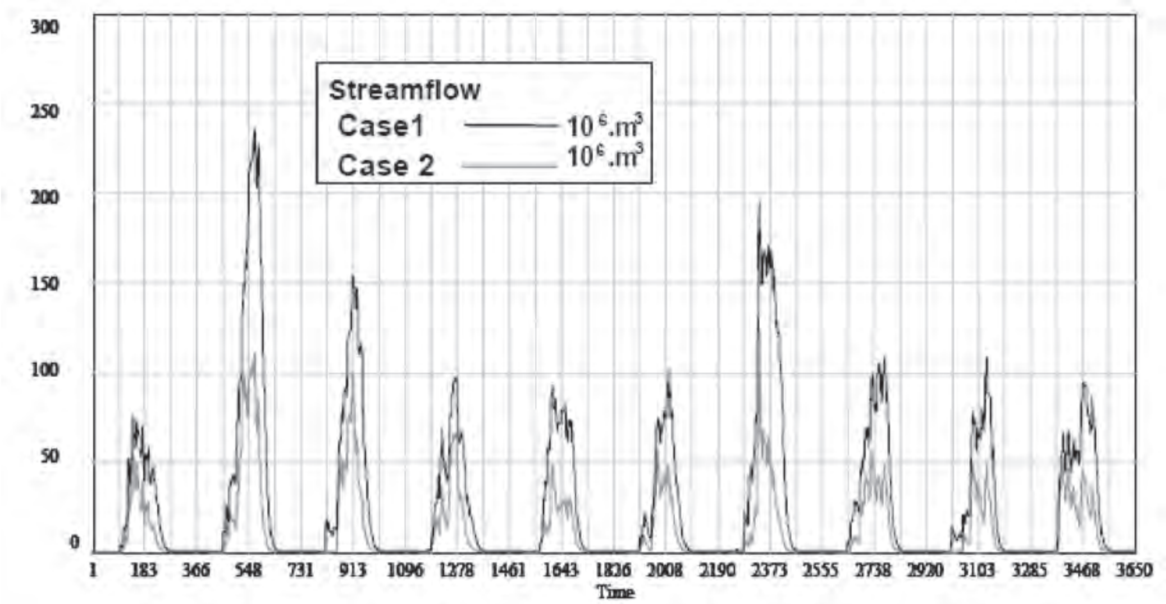

Figure 4-36 Evolution of the snowpack in Nahr Ibrahim catchment simulated over 10 years. (Case 1: reference simulation; Case 2: scenario of an increase by 2°C). Source: Hreiche et al., 2007

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

<table>
<tr><th>Impact</th><th>Proposed Adaptation Strategy</th><th>Activities</th></tr>
<tr><td rowspan="3">Decrease in water availability and increased incidences of unmet demand</td><td>Develop watershed management plans that take into consideration climate change</td><td>- 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</td></tr>
<tr><td>Implement pilot initiatives to demonstrate the feasibility of alternative sources of water supply and develop necessary standards and guidelines</td><td>- 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</td></tr>
<tr><td>Develop a water database to support decision-making</td><td>- 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)</td></tr>
</table>