CLIMATE CHANGE VULNERABILITY AND ADAPTATION

WATER

Lebanon's Second National Communication

Ministry of Environment/UNDP

2011

1. VULNERABILITY AND ADAPTATION OF THE WATER SECTOR

1.1. VULNERABILITY ASSESSMENT

1.1.1. Background

Lebanon is in a relatively fortunate hydrologic position (MoE, 2001); it receives an average of 661 mm/ year as compared to 252 mm in Syria and 111 mm in Jordan (El Fadel, 2009). However, 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).

Precipitation:

Lebanon is typically characterized by a Mediterranean climate. Precipitation mainly occurs between the months of October and March. Lebanon has four dry months – June, July, August and September – during which water availability is limited due to the very low water storage capacity, the difficulty of capturing water close to the sea, and the shortcomings of the existing water delivery systems and networks.

Coastal areas experience precipitation ranging from 600 to 1,100 mm (Figure 1-1), reaching more than 1,400 mm on the peaks of Faraya and Becharreh, whereas a modest 300 to 400 mm is recorded inland (Figure1-3). Since Lebanon is at a higher elevation than its neighbors, it has practically no incoming surface water flow (FAO, 2008).

Figures referenced by Ziad Hajjar (1997) and recorded at 105 stations spread throughout the different governorates registered average yearly precipitation ranging from 700 mm in the Beqaa to 1,210 mm over Mount Lebanon (Table 1-1). Measurements were taken over several years ranging from 3 years in Terbol and Mayfouq stations to 51 years in the Tripoli station. The lowest level recorded for the country was 80 mm while the maximum observation reached 3,010 mm.

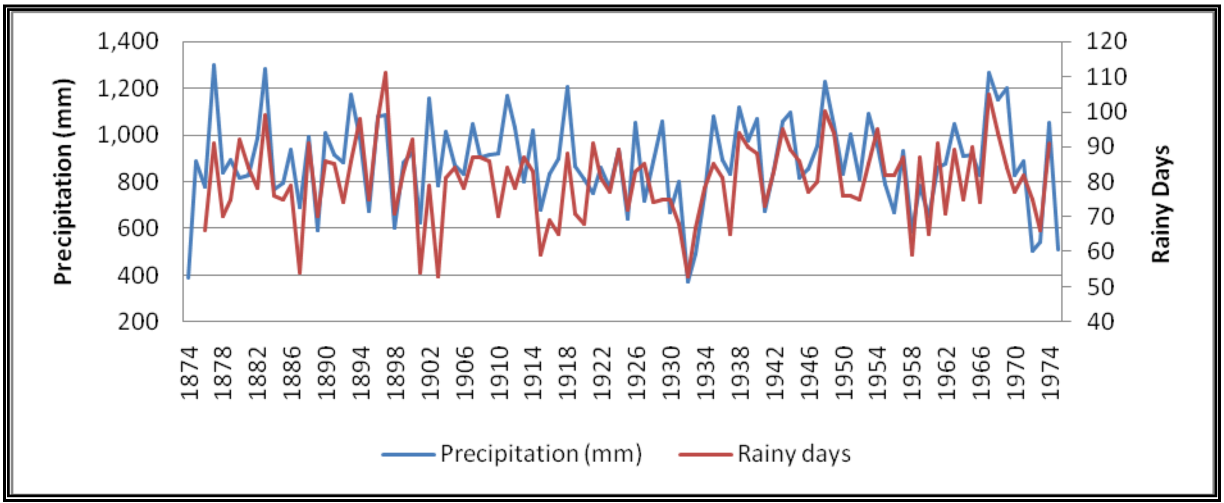


Figure 1-1 Total yearly precipitation levels observed at the American University of Beirut station between 1874 and 1975

Source: AUB Meteorological Station

Table 1-1 Precipitation levels recorded by region

	NUMBER OF STATIONS	STATION ALTITUDE		PRECIPITATION (MM/YEAR)		
		LOW	HIGH	YEARLY AVERAGE	MIN	MAX
Beirut	4	15	34	891.75	393	1600
North	25	2	1925	1055	425	1890
Mount-Lebanon	36	45	1840	1210.16	421	3010
South	26	5	1150	933.27	342	2139
Beqaa	36	650	1510	705.42	80	2374
Lebanon	105	5	1840	787	80	3010

Source: Hajjar, 1997

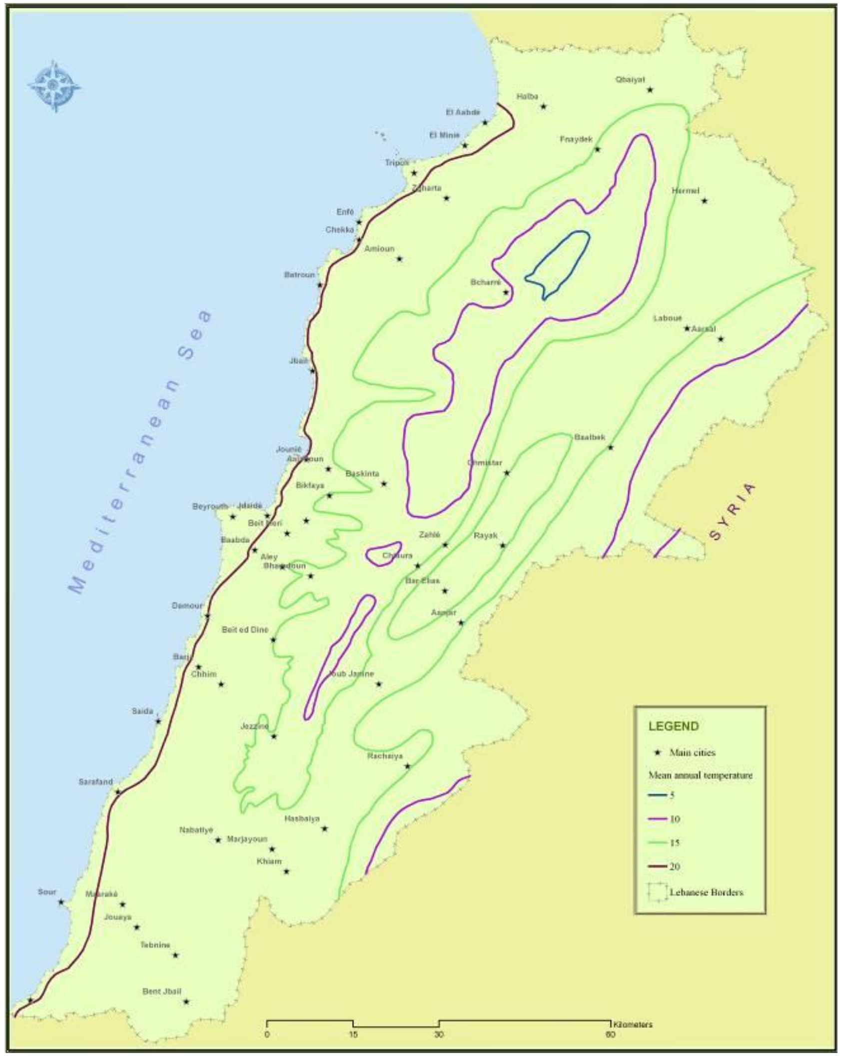


Figure1-2 Mean annual temperature over Lebanon

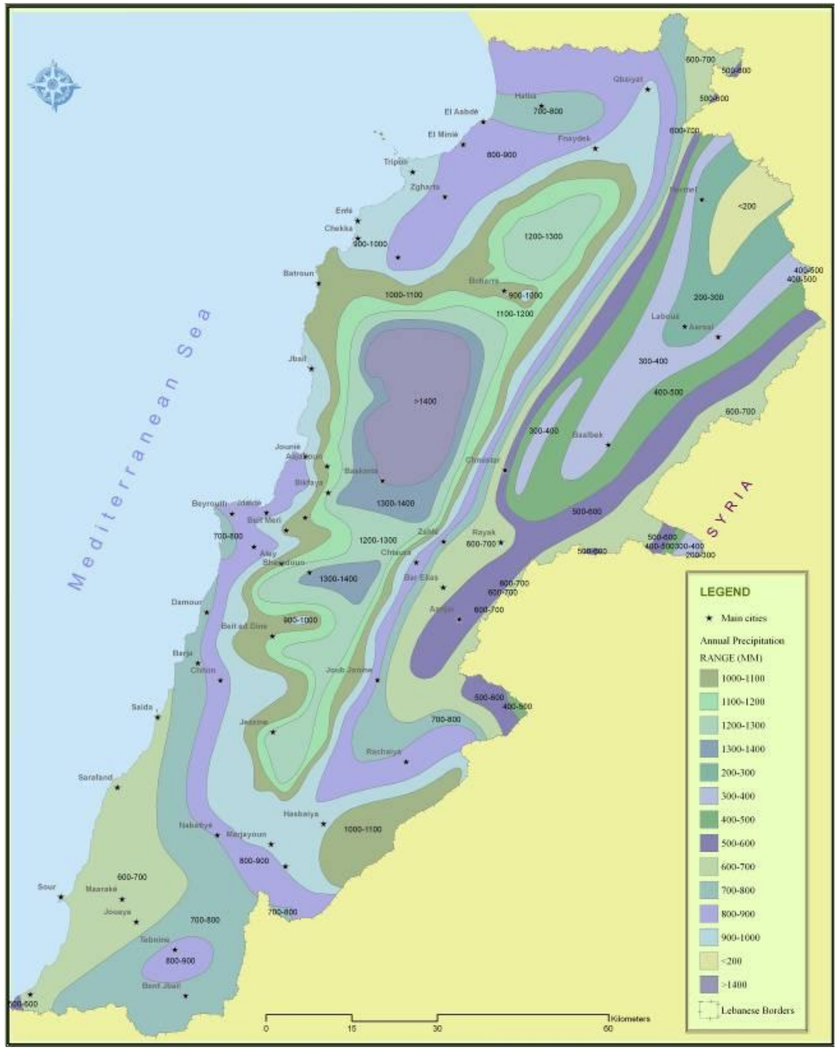


Figure1-3 Mean annual precipitation over Lebanon

Surface Water Resources:

Lebanon comprises 17 perennial streams and about 23 seasonal ones (Table 1-2), as well as more than 2,000 springs with a flow of around 1,000 Mm^3. The combined length of rivers is approximately 730 km (MoE, 2001).

The total surface water outflow is estimated at 735 Mm^3/year, of which 160 Mm^3 discharge into the sea. Surface water outflow to the Syrian Arab Republic is estimated at around 425 Mm^3 through the Asi-Orontes River and about 160 Mm^3 to the north of the occupied territories through the Hasbani/Wazani complex (FAO, 2008).

Table 1-2 shows flows in watercourses by Mohafaza during different periods of the year. River flow varies significantly between sources.

Table 1-2 Annual flow of the most important perennial rivers of Lebanon

REGION	RIVER	LENGTH (KM)		FLOW (MM^3/YEAR)			
		MOE, 2001	JABER, 1993	MOE, 2001	BAKALOWICZ, 2009	HAJJAR, 1997	JABER, 1993
North	El Kabir	58	58	190	131	190	190
	Ostuene	44	N.A.	65	67	65	65.1
	Araqa	27	N.A.	59	70	65	65
	El Bared	24	24	282	72	282	281.9
	Abou Ali	45	42	262	205	N.A.	262.4
	Kousba	N.A.	N.A.	N.A.	N.A.	112	N.A.
	Asamra	N.A.	N.A.	N.A.	N.A.	475	N.A.
	El Jawz	38	25	76	40	76	75.7
SUB-TOTAL*				**934**	**585**	**1265**	**940.1**
Mount Lebanon	Ibrahim	30	22	508	319	N.A.	507.9
	Janin	N.A.	N.A.	N.A.	N.A.	338	N.A.
	Khadira	N.A.	N.A.	N.A.	N.A.	508	N.A.
	El Kalb	38	28	254	117	254	252.6
	Beirut	42	20	101	65	101	101.4
	Damour	38	30	307	157	307	256.5
SUB-TOTAL*				**1,170**	**658**	**1508**	**1118.4**
South	El Awali	48	50	299	371	299	284.4
	Joun	N.A.	N.A.	N.A.	N.A.	545	N.A.
	Saitaniq	22	N.A.	14	111	N.A.	N.A.
	El Zahrani	25	N.A.	38	13	38	38.6
	Abou Assouad	15	N.A.	11	3	N.A.	N.A.
SUB-TOTAL*				**362**	**498**	**882**	**323**
Bekaa	Litani	170	N.A.	793	689	954	N.A.
	Upper Qaraon	N.A.	N.A.	N.A.	N.A.	393	404
	Lower Qaraon	N.A.	N.A.	N.A.	N.A.	161	N.A.
	Khardali - Sea	N.A.	170	N.A.	N.A.	130	129.9
	Yammouneh	N.A.	N.A.	N.A.	N.A.	59	58.7
	El Assi (Orontes)	46	45	480	656	518	414.5
	Hasbani	21	N.A.	151	85	151	138.3

REGION	RIVER	LENGTH (KM)		FLOW (MM³/YEAR)			
		MOE, 2001	JABER, 1993	MOE, 2001	BAKALOWICZ, 2009	HAJJAR, 1997	JABER, 1993
SUB-TOTAL*				**1,424**	**1,430**	**2366**	**1145.4**
Total*				**3,890**	**3,171**	**6,021**	**3,527**

*Sub-total and Total figures exclude certain river flows when relevant data is not available.

Source: MoE, 2001; Bakalowicz, 2009 (MED EUWI); Hajjar, 1997; and Jaber, 1997.

Table 1-3 Flows in watercourses in Lebanese Mohafazat

FLOWS IN WATER COURSES (AVERAGE VALUES) (IN MM^3)	NORTH LEBANON	MOUNT LEBANON	NORTH BEKAA	CENTRAL AND SOURHERN BEKAA	SOUTH LEBANON	TOTAL
Entire Year	670	990	480	830	430	3400
May to October (6months)	270	305	240	240	25	1080
July to October (4months)	115	95	155	115	10	490
September	22	18	38	27	2	107

Source: Comair, 2006

Although surface and groundwater are dealt with separately, it should be noted that almost all surface water resources in Lebanon are attributed to ground karstic aquifers (MED EUWI, 2009).

Major surface storage structures such as reservoirs are not abundant in Lebanon. The only major reservoir on a river is the Qaraoun Lake which is formed by the rockfill dam on the Litani river. The total reservoir capacity is 220 Mm^3. There are plans for other dams on the major rivers as per the government's 10-year plan for the water sector presented later in this section; these are to be executed by 2018 (MoE, 2005).

In 2007, the Shabrouh artificial reservoir and dam, was inaugurated with a storage capacity of 8 Mm^3. It is located the town of Faraya and provides water for domestic and irrigation purposes in Mount Lebanon (the district of Kesrwan and parts of the Metn region) (FAO, 2008).

Groundwater:

Groundwater recharge is estimated around 3,200 Mm^3, of which 2,500 Mm^3 constitute the base flow of rivers (FAO, 2008). Snow cover is the main source of groundwater recharge, in addition to rainwater percolation which is enhanced by fractures and fissures of a heavily dissected Limestone karstification along the coast of Lebanon (Saadeh, 2008a).

After having infiltrated deep into the ground and fed the aquifers, the water either 1) remains stored in aquicludes, some may be exploited through wells while others remain in deep layers untapped; 2) reappears as surface waters, at lower elevations, in the form of springs that feed into rivers; 3) forms submarine springs discharging near the coastline or the sea; or 4) is lost to deep layers and may reappear in the groundwater of neighboring countries (MoE, 2001).

Groundwater characterization requires determination of extent, hydrologic associations, storage capacity, quality and retention time in each aquifer. The most comprehensive studies conducted to assess the above date back to the 1970s.

Aquifers in Lebanon are mainly made of limestone and discharge significant quantities of water. The karstic nature of these aquifers is believed to play a major role in their performance.

The karstic aquifer sources are well known but for the time being none is subject to detailed monitoring in order to determine its specific characteristics. The available well data are scarce and of poor quality, which makes it difficult to properly assess aquifers.

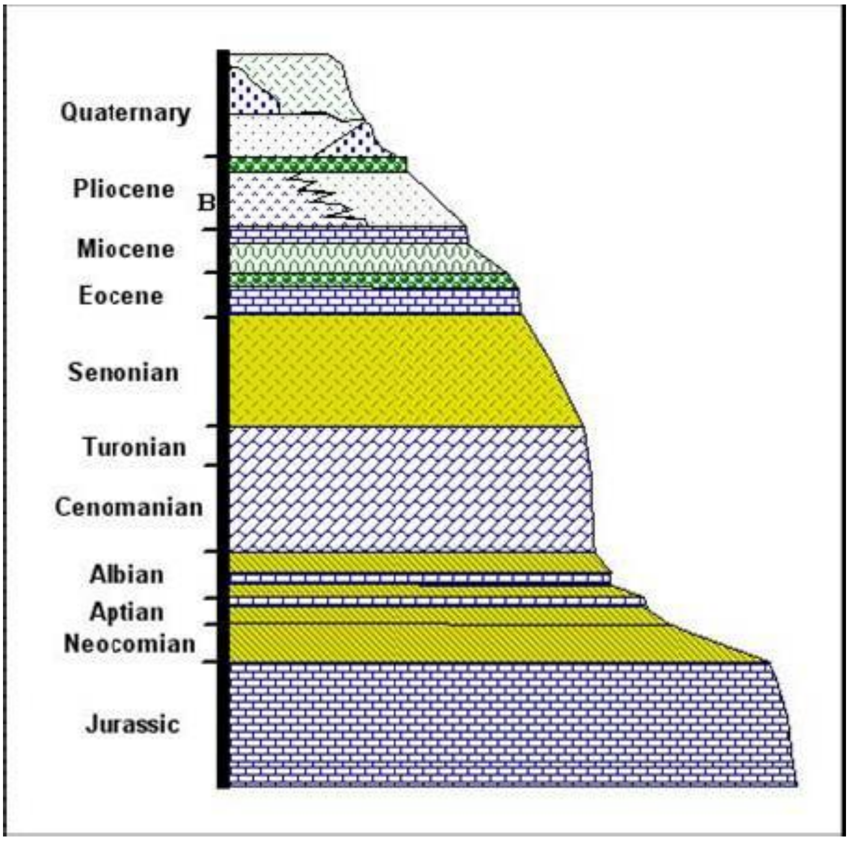


Figure 1-4 Schematic hydrogeological section showing aquifer formations separated by impermeable layers

Source: UNDP, 1970

The main aquifer formations (Figure 1-4) are composed of the Jurassic limestones and dolomites (1,000 m thick) and the Cretaceous (Cenomanian-Turonian) limestones (600 m thick). The Jurassic aquifer covers about two-third of the country, and the limestone aquifer of the Cenomanian-Turonian is considered as the major aquifer of Lebanon (Bakalowicz, 2009).

Other aquifer formations that are of limited extent and thickness do exist. These are the Upper Aptian limestones (50 to 100 m thick), the Albian limestones (5 m thick) and the Middle and Upper Eocene (50 to 100 m thick) known only in the southern part of the country.

Apart from the above-mentioned aquifers, there exist some alluvial aquifers in the Bekaa plain belonging to the Miocene and Quaternary ages, and others along the coastal plains belonging to Plio-Quaternary ages. These can be locally connected to some karstic aquifers that are susceptible to feed them.

Groundwater quality is already in an alarming situation, due to the infiltration of pollutants (wastewater, industrial wastes, solid waste leachate, etc.), seawater intrusion, and the increase of uncontrolled drilling of wells (more than 45,000 private wells (CAS, 1997 and CDR, 2005). This pollution has direct effects on public health and health-related expenditures. The costs of the health impacts of water pollution are estimated at USD7.3 million per year and the costs of excess bottled water consumption at about USD7.5 million, noting that these are conservative estimates that do not account for all associated direct and indirect costs (MoE, 2001).

Additionally, the inadequacy of public water supply to meet the country's growing water needs has led to a shift toward private solutions for water supply. In the absence of effective regulation and enforcement, reliance on private provision of water supply has accelerated the depletion of water resources, and has led to over-abstraction of groundwater. It is estimated that about 70 percent of wells are illegal due the lack of enforcement of licensing requirements (World Bank 2003).

Sea Water Intrusion

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.

A study conducted in 1972 in Beirut had indicated that chloride concentrations from 125 randomly sampled wells had risen from 340 mg/L in 1970/1, to 1200 mg/L in 1979, to over 4200 mg/L in 1985 (Khair, 1992). Although the presence of elevated concentrations of chloride is not by itself definitive proof of active seawater intrusion, it can be considered as such if repeatedly detected in an area where few other sources of saline contamination exist (Saadeh, 2008b).

Another study conducted between 1999 and 2002 on the region of Choueifat-Rmeyle (Bakalowicz, 2009) confirmed that the regions of Choueifat, Jiye and Rmeyle were subject to seawater intrusion, aggravating already existing salinity problems. Observed salinity rates oscillated between 0.7dS/m and 5.5dS/m, rendering the water and soil inadequate for the cultivation of many crops. Indeed, according to the FAO "Guidelines for Interpretation of Water Quality for Irrigation" (Ayers & Westcot, 1985), the degree of restriction on the use of water for irrigation should be "slight to moderate" for salinity rates between 0.7 and 3dS/m and "severe" for salinity rates over 3dS/m.

Further analysis revealed that the intrusion was directly and simultaneously linked to the water pumping period and intensity. The quantity of rainfall, on the other hand, appeared to have a less significant correlative influence on the results.

The Greater Beirut Area's subsurface water salinity levels were reported to be over 5,000 mg/L in some of the surveyed public and private wells being utilized for various domestic, industrial and limited agricultural purposes (Saadeh, 2008b). Such high levels of salinity theoretically indicate a mixing of no less than 10%, placing seawater intrusion way past the 2% irreversible contamination limit (Barlow, 2003) which would render subsurface water unsuitable for public supply.

Snow cover

Even though the estimation of the contribution of snow to available water resources and the water balance is important, relevant studies are scarce. Lebanon, with about 60–65% of mountainous terrain, receives a considerable amount of snow that covers about 25% of its area that is above 1,200 m (Shaban et al., 2004), thus shaping the mountain chains of Lebanon (Shaban, 2009). Average yearly precipitation is around 9 Mm^3, one third of which is in the form of snow, which covers the Mount Lebanon mountain range at altitudes between 1,700 m and 3,000 m for around 3 months every year. The snowpack is highest in March. In February and March, temperatures are sufficiently high to cause snowmelt at altitudes lower than 2,000 m. Snowmelt in springs feeds most rivers with some delay over rainfall, thereby sustaining their flow during spring and summer (Najem, 2007).

The snow that covered Mount Lebanon during the 2000-2001 winter contributed an equivalent of 1,250 Mm^3, with a 10% margin of error, compared to a total rainfall volume of 1,875 Mm^3.(CREEN, 2001). Using satellite imagery, the amount of water derived from snowmelt over Mount Lebanon for the years 2001–2002 was estimated to be around 1,100 Mm^3, equivalent to a precipitation rate of about 425 mm in the region, which suggests that about two thirds of the precipitation is derived from snowfall and not directly from rain, as snowmelt infiltrates the limestone and discharges at several karsts springs (Shaban et al., 2004; Hreiche et al., 2006; Shaban et al., 2009). Water from melting snow may contribute around 40% to 50% of the discharge of coastal rivers (Shaban et al., 2004 and Hreiche et al., 2006), indicating the essential role snow plays in replenishing the water resources in Lebanon.

Water Balance

Amid the absence of consistent information, it is generally accepted that approximately 50% of the average yearly precipitation (8,600 Mm^3) is lost through evapotranspiration, while additional losses include surface water flows to neighboring countries (estimated by the Litani River Authority to represent almost eight percent) and groundwater seepage (12 percent). This leaves around 2,600 Mm^3 of surface and groundwater that is potentially available, of which around 2,000 Mm^3 is deemed exploitable (MoE, 2001).Table 1-5, Table 1-6 and Table 1-7 show the annual water balance (total, surface water and groundwater) and water uses as reported in different sources.

Table 1-4 Summary of water balance

DESCRIPTION		MED EUWI, 2009	MOEW, 2004	WORLD BANK, 2003	UNDP, 1970	GEADAH, 2002	PLASSARD,1971
Precipitation (mm)		800 – 1,000	820	820	940	-	-
Evapotranspiration (mm)		500 -600	430	380	-	-	-
Precipitation (Mm³)		8,320 – 10,400	8,600	8,600	9,800	8,600	8,600
Evapotranspiration (Mm³)		4,300 – 6,240	4500	4,000	-	4,300	4,300
Total flow of the 40 major streams (Mm³)		3,673 – 4,800	3680	3,800	4,300	1,774	1,800
Surface flow to neighboring countries (Mm³)		300 – 670	945	700	~ 680	670	160 (Palestine) 510 (Syria)
Groundwater flow to neighboring countries (Mm³)		310		200	-	300	150 (Palestine)
Flow of submarine sources (Mm³)		385 – 1,000	385	700	711	880	880
Total resources (Mm³)	**Average year**	2,600 – 4,800	-	-	-	-	
	Dry year	1,400 – 2,200	-	-	-	-	
Exploitable resources (Mm³)	**Surface water**	1,500	-	-	-	-	1,800
	Groundwater	700 -1,165	-	-	-	-	800
	Total	1,400 – 2,200	-	-	-	2,000	-

Source: Bakalowicz/MED EUWI, 2009; MoEW, 2004; World Bank, 2003; UNDP, 1970 ; Geadah, 2002; and Plassard, 1971

Table 1-5 Surface water balance

SURFACE WATER BALANCE (UNIT: 1,000 M³)									
	AREA	IN				OUT			BALANCE
	(KM²)	TOTAL PRECIPITATION	FROM OTHER BASIN	SPRING	RECHARGE BY INFILTRATION	EVAPOTRANSPIRATION	RUNOFF	EXTRACTION	
Kebir	333.5	251,520	0	38	118,751	90,350	43,786	492	-1,821
Ostuene	169.6	127,962	0	10,331	45,749	45,718	45,830	1,836	-840
Akkar	133.1	100,429	0	8,728	44,278	32,487	33,322	289	-1,220
Bared	266.3	200,761	0	111,835	112,912	59,262	136,054	5,739	-1,371
Abou Ali	484.9	365,627	0	159,877	187,479	109,030	228,617	3,630	-3,252
Jouz	186.3	137,862	0	9,983	69,852	45,618	33,265	429	-1,319
Ibrahim	346.7	259,532	0	282,647	149,276	86,954	306,988	1,951	-2,988
Kelb	254.9	192,166	0	106,203	69,512	62,696	165,591	1,975	-1,405
Beirut	309.9	228,052	0	28,427	118,119	77,932	60,809	2,355	-2,738
Damour	186.2	139,555	0	84,472	66,285	44,690	108,875	5,730	-1,554
Awali	334.5	248,681	54,508	100,908	96,448	96,432	213,739	2,676	-5,197
Saintaniq	161.9	116,582	0	1,844	68,948	40,512	9,903	307	-1,244
Zahrani	104.1	75,831	0	7,346	48,119	26,032	9,539	403	-916
A Assouad	160.1	112,279	0	1,107	63,388	47,416	3,369	875	-1,662
Litani	2,231.30	1,661,272	0	85,809	931,747	641,286	107,612	76,995	-10,557
Assi	1,848.80	1,393,617	6,683	73,595	683,504	465,464	306,781	15,808	2,343
Hasbani	587.4	442,789	0	5,857	204,071	159,775	85,768	943	-1,910
SUB-TOTAL	**8,099.50**	**6,054,517**	**61,191**	**1,079,007**	**3,078,436**	**2,131,656**	**1,899,848**	**122,433**	**-37,652**
Percentage	80.40%	1.0	0.0	17.80%	50.80%	35.20%	31.40%	0.0	-
Coastal Basin	1,690.70	1,213,947	0	58,007	605,034	469,688	195,581	14,562	-12,911
Individuals	286.0	215,575	0	85,020	137,750	66,946	97,639	271	-2,011
SUB-.TOTAL	**1,976.70**	**1,429,522**	**0**	**143,027**	**742,784**	**536,633**	**293,220**	**14,834**	**-14,922**
Percentage	2.80%	1.0	0.0	0.1	0.5	37.50%	20.50%	0.0	0.0

SURFACE WATER BALANCE (UNIT: 1,000 M³)									
GRAND-TOTAL	**10,076**	**7,484,039**	**61,191**	**1,222,033**	**3,821,220**	**2,668,289**	**2,193,068**	**137,267**	**-52,574**
Percentage	1.0	1.0	0.80%	16.30%	51.10%	35.70%	29.30%	1.80%	-0.70%
					34.70%				

Source: JICA, 2003

Table 1-6 Groundwater balance

GROUNDWATER BALANCE (UNIT: 1,000 M^3)								
	AREA	IN		OUT				
	(KM^2)	RECHARGE	GROUNDWATER INFLOW	ARTIFICIAL PUMPING	SPRINGS	GROUNDWATER OUTFLOW	BALANCE	VOLUME
Kebir	333.5	118,751	0	30,147	38	114,687	-16,906	10,909,330
Ostuene	169.6	45,749	65,792	15,225	10,331	90,917	-20,216	3,942,469
Akkar	133.1	44,278	16,145	7,289	8,728	49,559	-16,167	2,971,683
Bared	266.3	112,912	45,218	27,867	111,835	30,183	-11,755	7,860,158
Abou Ali	484.9	187,479	98,569	18,413	159,877	123,450	-17,790	14,920,980
Jouz	186.3	69,852	6,708	4,825	9,983	74,616	-24,311	5,413,656
Ibrahim	346.7	149,276	197,813	9,660	282,647	63,088	-15,192	6,297,798
Kelb	254.9	69,512	119,864	10,544	106,203	87,096	-7,315	5,728,840
Beirut	309.9	118,119	18,409	9,025	28,427	119,991	-15,854	8,122,575
Damour	186.2	66,285	115,207	13,886	84,472	85,350	8,089	6,344,904
Awali	334.5	96,448	105,784	9,487	100,908	97,590	-5,752	6,211,775
Saintaniq	161.9	68,948	1,882	13,620	1,844	67,360	-11,995	4,650,250
Zahrani	104.1	48,119	11,019	3,680	7,346	54,588	-10,653	3,030,097
A Assouad	160.1	63,388	876	15,030	1,107	51,229	6,459	7,382,489
Litani	2,231.30	931,747	858	197,244	85,811	870,582	-221,032	78,590,310
Assi	1,848.80	683,504	58,698	119,292	73,595	715,287	-57,736	70,195,820
Hasbani	587.4	204,071	34,156	6,584	5,857	287,808	-62,022	23,107,250
SUB-TOTAL	**8,099.50**	**3,078,436**	**896,998**	**511,818**	**1,079,009**	**2,983,379**	**500,148**	**265,680,384**
Percentage	80.40%	1.0	29.10%	16.60%	35.10%	96.90%	-16.20%	
Coastal Basin	1,690.70	605,034	168,117	92,756	58,007	675,378	-59,176	41,326,900
Individuals	286.0	137,750	106,971	6,511	85,020	180,815	-27,625	12,442,920
SUB-TOTAL	**1,976.70**	**742,784**	**275,088**	**99,266**	**143,027**	**856,193**	**-86,802**	**53,769,820**
Percentage	2.80%	1.0	0.4	13.40%	19.30%	115.30%	-11.70%	
GRAND-TOTAL	**10,076**	**3,821,220**	**1,172,086**	**611,084**	**1,222,035**	**3,839,572**	**-586,950**	**319,450,204**

GROUNDWATER BALANCE (UNIT: 1,000 M³)							
Percentage	1.0	1.0	30.70%	0.2	0.3	100.50%	-15.40%

Source: JICA, 2003

The net potential surface and groundwater available includes water resources for which the cost of diversion/abstraction is prohibitive. The net exploitable surface and groundwater represent the total quantity of water that Lebanon can realistically recover during average rainfall years. It includes water that may be too polluted to use for domestic consumption (high treatment costs) (MoE, 2001).

The annual net exploitable surface water and groundwater resources, water that Lebanon can technically and economically recover during average rainfall years, are estimated at 2,000 Mm^3, consisting of 1,500 Mm^3 of surface water and 700 – 1,165 Mm^3 of groundwater (MED EUWI, 2009).

Water Consumption by Sector

The water sector is the hardest sector to assess due to the lack of data (ex: non-consistent measurement of river flows, lack of metering systems to measure withdrawals from each sector…) and the huge amount of losses as a result of leakages and widespread unlicensed wells where pumping is far from being monitored. This deficiency in data availability hinders possible predictions of water distribution among the three sectors: agricultural sector, domestic sector, industrial sector.

However, general estimates exist internationally and locally for water demand and water consumption by sector. Table 1-7 illustrates water consumption by sector in France, the United States of America (USA), and Lebanon. The share of domestic water consumption seems to be slightly lower in Lebanon than elsewhere. Losses, on the contrary, hold a larger share than that observed for the USA.

Table 1-7 Comparison of water consumption by sector in France, the USA, and Lebanon

<table>
<tr><th colspan="2" rowspan="3">SECTOR/ACTIVITY</th><th colspan="2">FRANCE
% OF DAILY NEEDS</th><th>USA
% OF DAILY NEEDS</th><th colspan="4">LEBANON
DAILY NEEDS AND % OF DAILY NEEDS</th></tr>
<tr><th colspan="2" rowspan="2">Hajjar, 1997</th><th rowspan="2">Hajjar, 1997</th><th colspan="3">Jaber, 1997</th><th>World Bank, unpublished</th></tr>
<tr><th colspan="2">L/day</th><th>%</th><th>%</th></tr>
<tr><td rowspan="4">Domestic</td><td>Cooking</td><td>12%</td><td rowspan="4">55%</td><td rowspan="4">51%</td><td>15 L</td><td rowspan="4">90 L</td><td rowspan="4">45%</td><td rowspan="4">26%</td></tr>
<tr><td>Washing</td><td>-</td><td>10 L</td></tr>
<tr><td>Shower</td><td>20%</td><td>40 L</td></tr>
<tr><td>Backyard Irrigation</td><td>23%</td><td>25 L</td></tr>
<tr><td rowspan="4">Services</td><td>Hotels, restaurants & pools</td><td>-</td><td rowspan="7">45%
-</td><td rowspan="4">(commercial) 18%</td><td>3 L</td><td rowspan="4">17 L</td><td rowspan="4">8.5%</td><td rowspan="4">-</td></tr>
<tr><td>Hospitals & health institutions</td><td>7%</td><td>7 L</td></tr>
<tr><td>Schools</td><td>-</td><td>7 L</td></tr>
<tr><td>Commercial</td><td>24%</td><td>-</td></tr>
<tr><td rowspan="3">Public</td><td>Public Institutions</td><td>5%</td><td rowspan="3">13%</td><td>17 L</td><td rowspan="3">24 L</td><td rowspan="3">12%</td><td rowspan="3">-</td></tr>
<tr><td>Military (Caserns)</td><td>-</td><td>7 L</td></tr>
<tr><td>Parks and Municipal</td><td>9%</td><td>-</td></tr>
<tr><td rowspan="2">Agriculture</td><td>Cattle</td><td colspan="2" rowspan="2">-</td><td rowspan="2">-</td><td>2 L</td><td rowspan="2">8 L</td><td rowspan="2">4%</td><td rowspan="2">65%</td></tr>
<tr><td>Horses</td><td>6 L</td></tr>
<tr><td>Industrial</td><td>Light Industries</td><td colspan="2">-</td><td>-</td><td>15 L</td><td>15 L</td><td>7.5%</td><td>9%</td></tr>
<tr><td colspan="2">Losses</td><td colspan="2">-</td><td>18%</td><td>46 L</td><td>46 L</td><td>23%</td><td>-</td></tr>
</table>

Source: Hajjar, 1997; Jaber, 1997; and World Bank, unpublished

Table 1-8 summarizes Lebanon's water demand by sector for the year 2002. Greater Beirut has the highest water demand and loss rate, followed by Mount Lebanon. Most of the demand is for domestic use. Public supply provides for most but not all of water supply, necessitating an additional private supply in all regions.

Table 1-8 Summary of domestic and industrial water use in 2002

REGION	WATER USE BY SECTOR (M³/DAY)				WATER SOURCE		DOMESTIC USE INCLUDING LOSSES (M³/DAY)	INDUSTRIAL USE INCLUDING LOSSES (M³/DAY)
	DOMESTIC	INDUSTRIAL	LOSSES	TOTAL	PUBLIC* SUPPLY	PRIVATE SUPPLY		
Mount Lebanon	122,692	26,334	81,824	230,850	181,832	49,018	195,829	35,021
Greater Beirut	241,203	49,450	178,883	469,536	397,518	72,018	401,271	68,265
North	93,088	22,854	74,250	190,192	164,998	25,194	159,010	31,182
South	72,134	9,736	38,046	119,916	99,222	20,694	108,326	11,590
Nabatiyeh	39,922	3,034	28,551	71,507	63,446	8,061	67,345	4,162
Bekaa	81,416	9,240	48,426	139,082	107,613	31,469	127,007	12,075
Total	**650,455**	**120,648**	**449,980**	**1,221,083**	**1,014,629**	**206,454**	**1,058,788**	**162,295**

* Public indicates Water Establishment.

Source: JICA, 2003

Table 1-9 shows water demand figures by sector and geographical area, and Table 1-10 presents estimates of total water consumption quoted by different sources. Water consumption data, with the possible exception of the 1966 data, are estimates. Thus, data vary considerably depending on the initial assumptions used (Amery, 2000).

Table 1-9 Water demand by sector and geographical area

	DOMESTIC USE (MM³)	INDUSTRIAL USE (MM³)	IRRIGATION (MM³)	TOTAL (MM³)
North Lebanon	53	13	150	216
Beirut & Mount Lebanon	127	30	78	235
North Bekaa	15	4	135	154
Central and South Bekaa	17	4	153	174
South Lebanon	38	9	159	206
Total	**250**	**60**	**675**	**985**

Source: Comair, 2006

Table 1-10 Estimated water consumption (Mm³/year) in Lebanon as referenced in different sources

	DOMESTIC USE (MM³)	INDUSTRIAL USE (MM³)	IRRIGATION (MM³)	TOTAL (MM³)
1966	94		400	494
1990 (An Nahar, 25 Feb 1996)	310	130	740	1180
1996	185-368	35-70	669-900	889-1338
2000 (Nasir Nasrallah, as quoted in An Nahar, 25 May 1996)	280	400	1600	2280

Source: Amery, 2000

Further studies have assessed agricultural water withdrawal assessment based on 11,200 m³/ha per year from surface water and 8,575 m³/ha per year from groundwater (FAO, 2008). The World Bank (unpublished) estimates that the agricultural sector is by far the largest water consuming sector of all, with around 65% of water available, followed by domestic (26%) and industrial (9%) uses, as shown in Figure1-5. The use of groundwater for irrigation has increased during recent years, because of the delay in the execution of dams and hill lakes as per the 10 year strategic plan. This situation has encouraged individual farmers to cope with water shortages by increasingly relying on private wells (Hreiche, 2009).

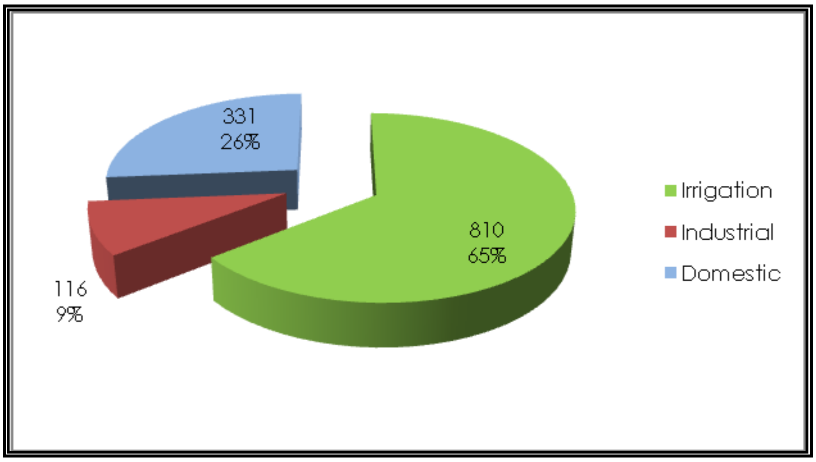


Figure1-5 Annual water demand by water use category (Mm³), 2003

Source: World Bank, unpublished.

Summary of stresses on the water sector

The water sector currently undergoes several environmental stresses resulting from different socio-economic activities and practices. These are summarized and described in Table 1-11 below.

Table 1-11 Environmental Stresses on Water Resources

ECONOMIC ACTIVITY	SOURCE OF IMPACT	EVIDENCE OF STRESS
Agriculture	Excessive use of surface and groundwater for irrigation	Seasonal water shortages
	Excessive application of agrochemicals	Possible contamination of groundwater from pesticides and nitrates
Industry	Discharge of liquid waste	Contamination of rivers and coastal waters
	Uncontrolled disposal of solid waste	Possible contamination of rivers and groundwater from leachate seepage
Transport	Disposal of waste oils	Waste oil dispersal in rivers, wells and coastal waters mainly through the sewage system
Energy	Hydropower	Intermittent drying of river beds during summer
Human settlements	Uncontrolled sewage disposal and no monitoring of septic tanks	Bacterial contamination of ground and surface water
	Excessive use of ground water resources for domestic supply	Seawater intrusion in coastal areas (as described above).

Source: MoE, 2001

1.1.2. Methodology

1.1.2.1. <u>Scope of Assessment</u>

Unit of Study

The water cycle, and thus the water balance and water resources in Lebanon are determined by two important factors: snow cover and evapotranspiration (Bakalowicz, 2009). 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.

Spatial Frame

Study areaThe study area upon which the analysis was initially conducted extends from Hadath in the South-West to the Cedars in the North East, spreading over an area of 50 km x 50 km (2,500 km²), as shown in Figure1-6. This area comprises coastal zone, mountains of more than 2,000 m of altitude, and a part of the Beqaa Valley, covering both a part of the western slope of Mount-Lebanon and a part of the interior zones.

It contains the totality of 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. 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 comprises 4 main rivers (out of a total of 17 rivers): Nahr al Jawz, Nahr Ibrahim, Nahr el Kalb and Nahr Beirut (Figure1-7). Their length and flow are shown in Table 1-12.

The results obtained for this study area were then extrapolated to the entire Lebanese territory, as described below.

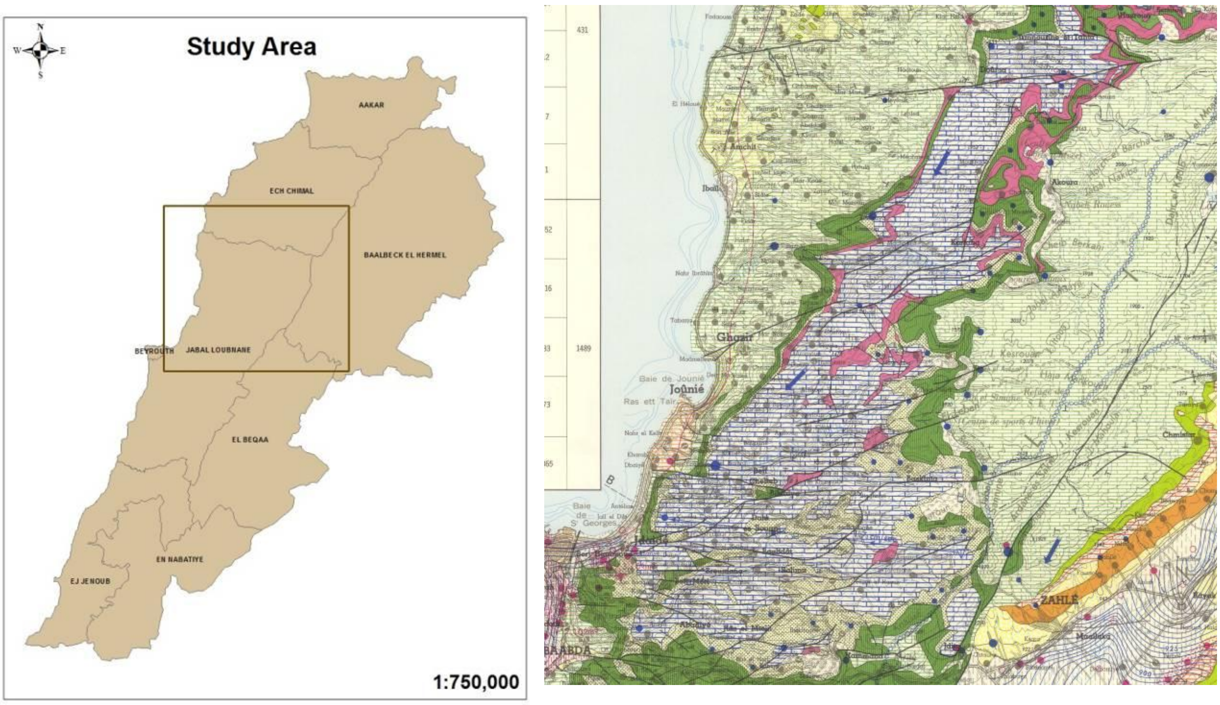


Figure1-6 Study area for the Water Sector

Source: UNDP, 1967

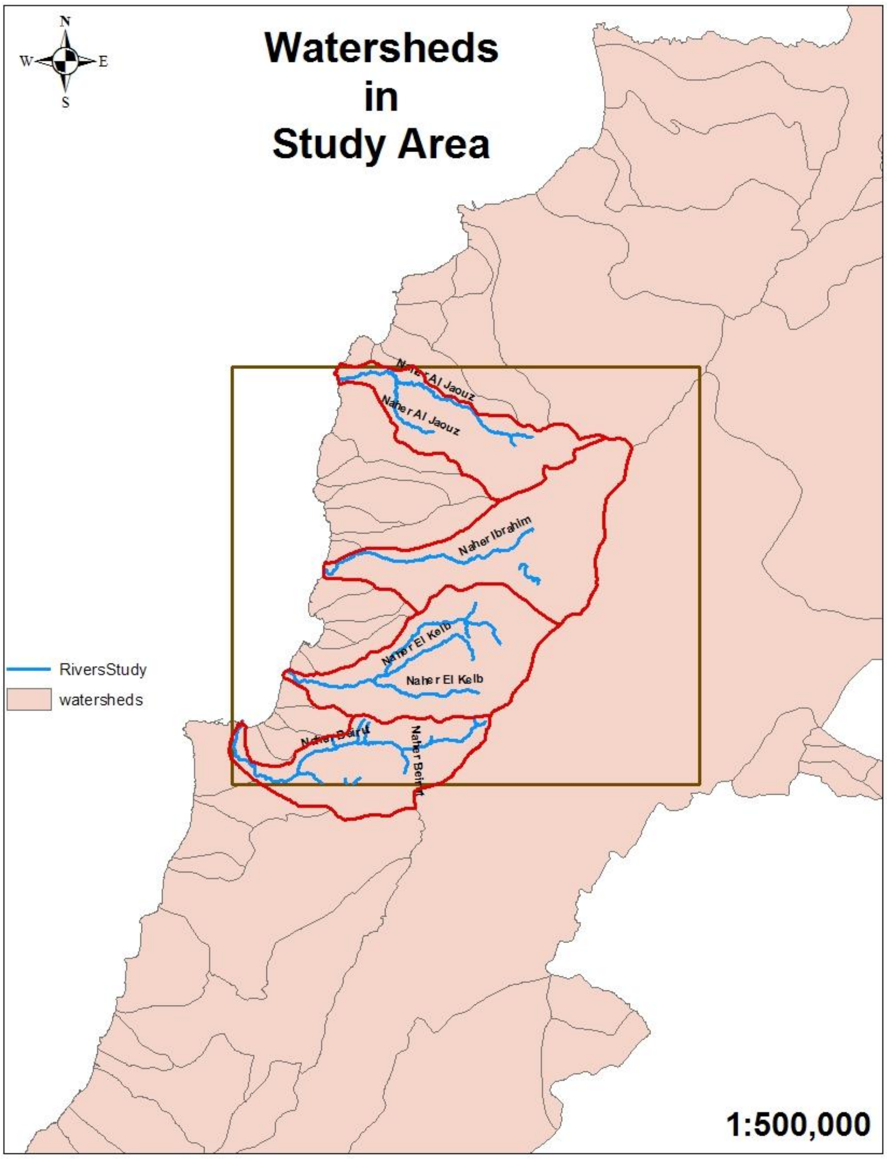


Figure1-7 Watersheds and rivers in the study area

Table 1-12 Characteristics of Rivers in the study area

RIVER NAME	LENGTH (KM)	FLOW IN MM³			
		Annual	Average	Max	Min
El Jaouz	38	76	2.4	6.18	0.4
Ibrahim	30	508	16.1	27.6	1.9
El Kalb	38	254	8.04	18.1	2.4
Beirut	42	101	2.59	10	0.1

Source: MoE, 2001

Around 15 springs are also located in the study area (Figure1-8); these are listed in Table 1-13 with their reported flow based on different sources. Overall, more than 2,000 springs are distributed throughout the Lebanese territory.

Table 1-13 Main springs in the study area

SPRING NAME	YEARLY AVERAGE DISCHARGE	
	UNDP, 1970 (M^3/S)	HAKIM, 1985 (L/S)
Aasal	2	750
Shaghour Hammana		350
Madiq		
Dayshounieh springs		800
Yammouneh	2.82	1100
Laban		750
Ain El Delbeh		1400
Afqa	4.62	2800
Chtaura	0.46	440
Bouerij		20
Sannine		100
Jeita	4.48	5500
Kashkoush		800
Berdawneh	1.41	800
Jaradeh		

Source: UNDP, 1970; Hakim, 1985.

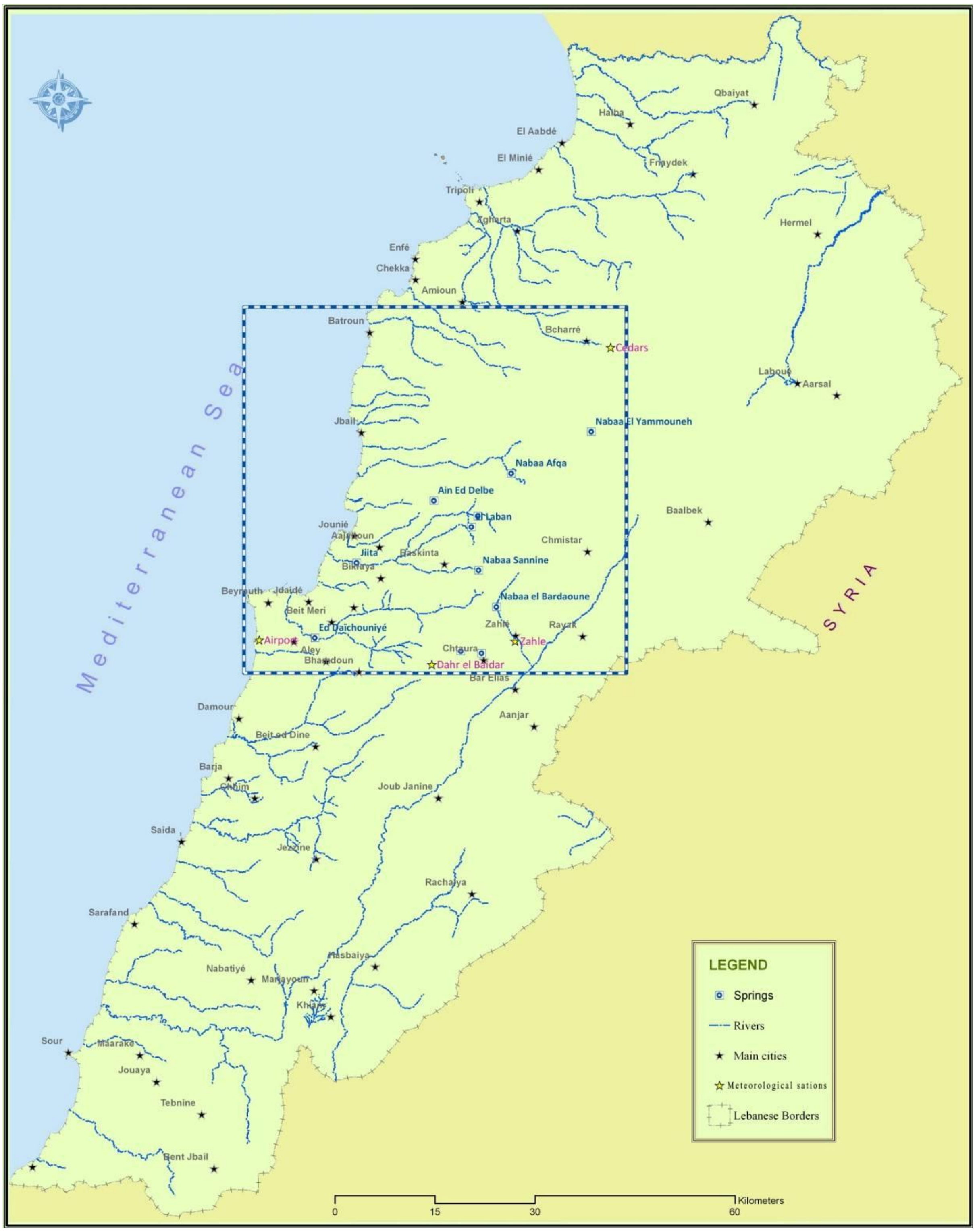


Figure1-8 Geographic Location of Springs

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 (Figure1-9):

- 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 Dahr el Baydar's meteorological station.
- <200 mm, and 20°C, represented by the Beirut Airport meteorological station.

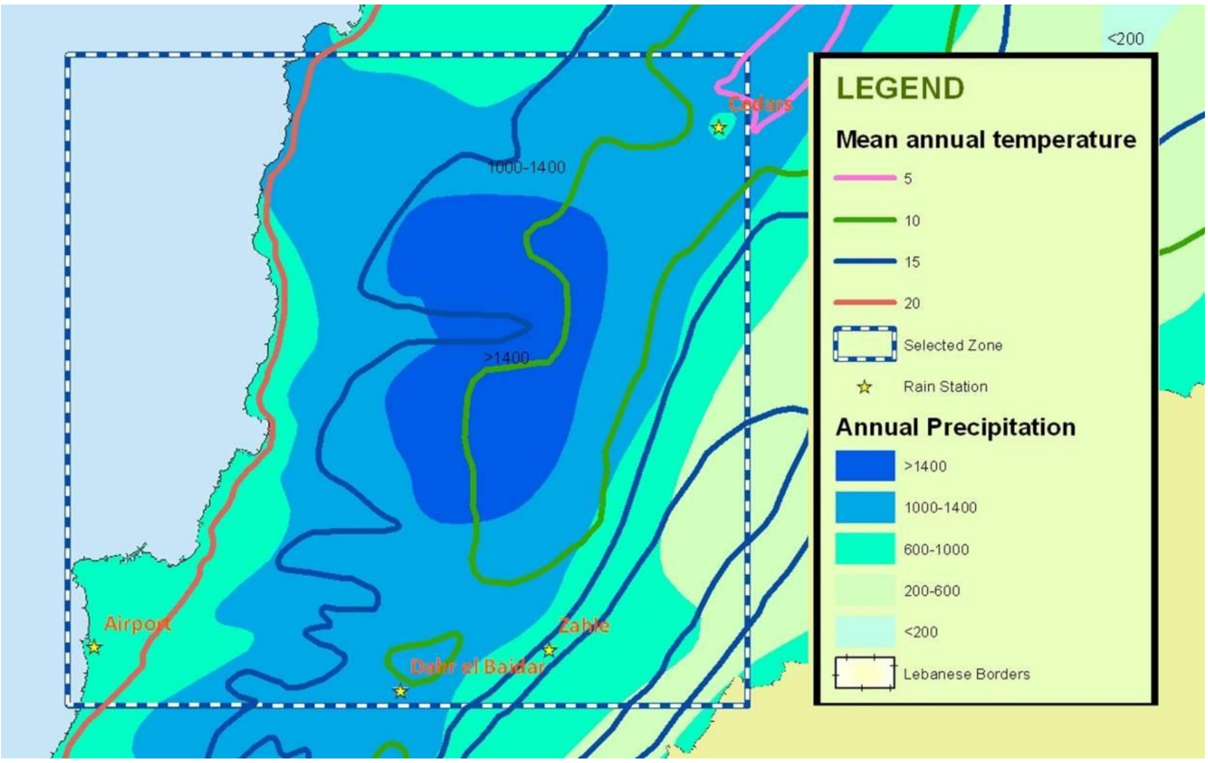


Figure1-9 Temperature and precipitation isohyets in the study area

Extrapolation to the entire Lebanese territory

Given that almost all subzones resulting from the above combinations of isohyets and isotherms throughout the Lebanese territory are represented in the study area, the results can be extrapolated to the entire territory. The only two minor subzones that are not represented in the study area are:

- The most arid subzone (<200 mm) located between the 15°C and 20°C isotherms, which covers a small area in Hermel; and
- The area located between the 600 and 1,000 mm isohyets, and between the 5 °C and 10 °C isotherms, covering the rest of Hermel.

Thus, it is possible to generalize the results from the study area to the entire territory.

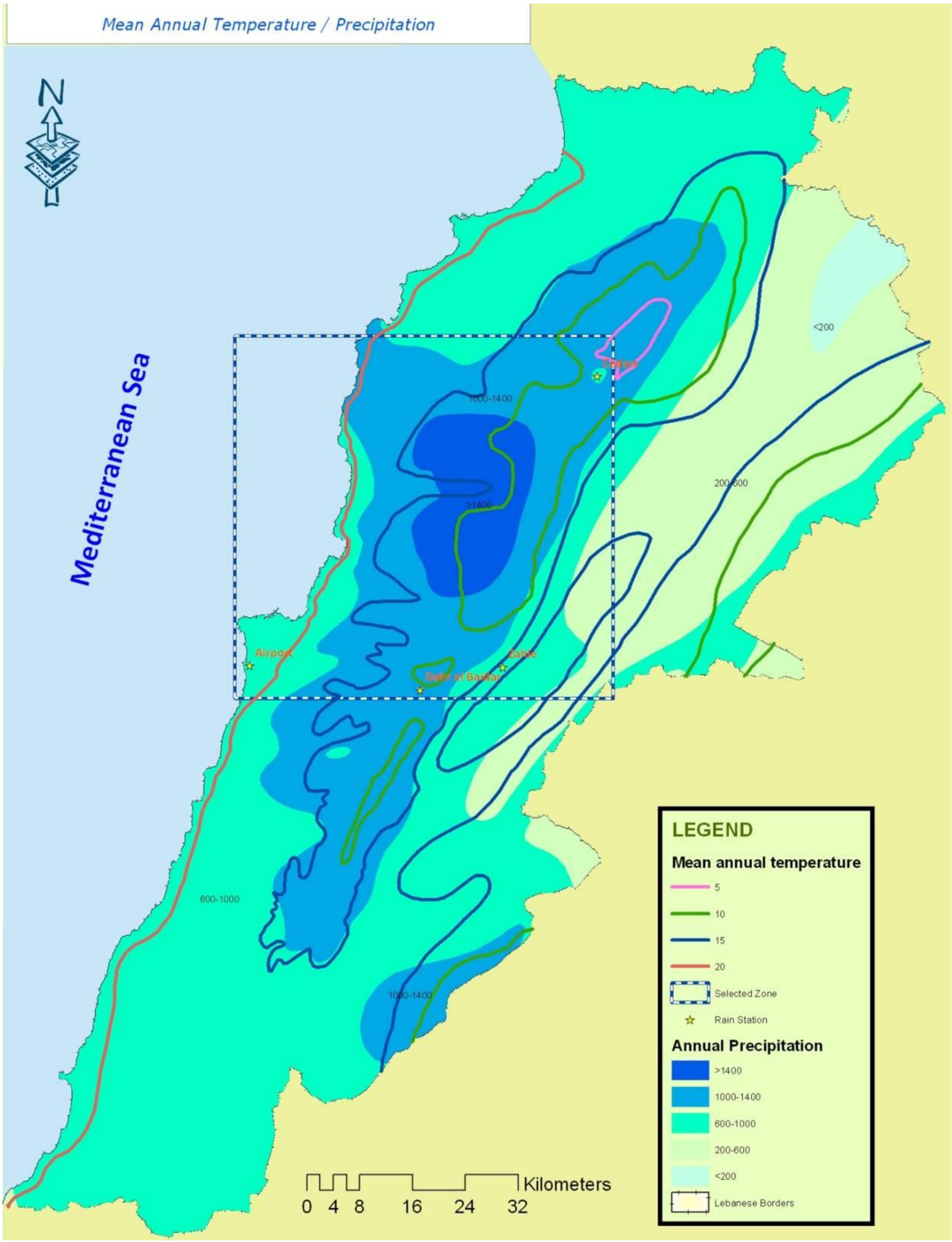


Figure 1-10 Temperature and precipitation isohyets throughout the Lebanese territory

Time Frame

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

1.1.2.2. *Climatic Factors*

The climatic factors of interest for the assessment are:

- Precipitation, which affects snow cover and water availability;
- Temperature, which affects snow cover and increases the rate of evapotranspiration; and
- Evapotranspiration, which decreases soil moisture and water availability (by decreasing active precipitation). As this parameter could not be accurately modeled by PRECIS as a result of insufficient data available, it was modeled as described below.

1.1.2.3. *Methods of Assessment*

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

The average rain-snow transition elevation becomes higher with a rise in temperature (as described in the impacts section below), and evapotranspiration drops with a reduction in precipitation and a rise in temperature. In fact, a reduction of 10% in precipitation (which corresponds to 1,000 to 900 mm), coupled with an increase of 0.5°C in temperature, would result in about 1% decrease in net evapotranspiration and a reduction of 20% in precipitation and an increase of 1°C in average temperature would result in about 4% decrease in net evapotranspiration (Bakalowicz, 2009). Therefore, it is active precipitation which is mainly affected by the decrease in precipitation and increase in temperature. Accordingly, a mathematical model was built to simulate the variability of active precipitation resulting from temperature and precipitation changes, 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. The model calculates potential evapotranspiration 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 evapotranspiration and active precipitation were calculated.

And since the relation evapotranspiration-humidity-temperature varies according to the area (western slope or interior zone) and the season as a result of different climatic conditions, several simulations were conducted for the precipitation and temperature series set for four clusters that represent the study area and for the four 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 were compared in order to deduce the effect of climate change on the variation in active precipitation.

The results of the 4 groups of series (four stations) were then extrapolated to the entire country.

As described above, and since the Lebanese territory can be divided into 4 pluviometric zones and 5 temperatures zones, 20 subzones were delineated by overlaying these two sets, four of which are represented by the four meteorological stations analyzed.

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 gives an idea of the varying extent of vulnerability of different subzones. As for subzones that do not have a match among the 8 series, a simple linear interpolation was used to draw an intermediate ratio between the ratios of adjacent subzones.

All these results were reported on maps divided into the 20 subzones as shown in the impacts section.

The results were then represented on a graph in order to detect the trend of active precipitation with time.

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

1.1.2.4. Data Sources and Gaps

The main data sources used in this assessment include:

- FAO's Information System on Water and Agriculture- Aquastat;
- CDR's National Physical Master Plan for the Lebanese Territories (NPMPLT);
- MED EUWI,
- The Ministry of Environment, The World Bank, and other sources from the scientific literature.

As for the main data gaps and limitations, they consist of limited and scattered data on river and spring flows that are difficult to access or compile; as well as wide ranges and inconsistencies in the data relating to the water balance; and the lack of seasonal and yearly data and measurements relating to snow cover.

1.1.2.5. Assumptions and Limitations

The major limitations and assumptions underlying this assessment are as follows:

- Meteorological data was only available for four zones, and the acquisition of such data for the remaining subzones was hampered by the high associated cost;
- Even though isohyets and isotherms follow a linear trend with altitude (Catafago and Jaber, 2001), it should be noted that this relationship does not necessarily apply to both parameters combined, especially where altitude changes abruptly. Thus, this limitation mainly applies to steep slopes (a small fraction of the entire territory), for which it was not possible to obtain more accurate estimates.;
- For simplification reasons, and in order to avoid having more than 20 subzones, pluviometric zones were combined into five distinct zones, and temperature zones into four distinct zones.

1.1.3. Scenarios

1.1.3.1. Socio-economic Scenarios

Lebanese water resources, though seemingly abundant, are not expected to meet the country's demand in the near future. Several pressures from a rapidly growing population, an expanding economy, increased urbanization and agricultural activities are leading to over-exploitation of groundwater and pollution of existing watercourses (Comair, 2006).

Policies, Plans and Prospects:

The MoEW published the 10-year Water Plan 2000–2009 for water and wastewater management in 1999, which defines the strategy to satisfy Lebanon's future water needs. The plan, promulgated as a law program, clearly acknowledges the need for a holistic approach, includes elements of an IWRM plan and calls for consideration of water resources within a complete policy and planning cycle. The total cost is USD 1.327 billion, of which almost two-thirds is allocated to increasing the water supply through the construction of dams and reservoirs. The strategy consists of six parts (FAO, 2008 and Hreiche, 2009):

- Increasing the water supply by building dams and lakes, which would increase the storage capacity to 800 Mm3 by 2010 (Table 1-14);
- Extending the drinking water projects, and developing, rehabilitating, and maintaining the adduction networks;
- Increasing the quantity of irrigation water;
- Building 20 wastewater treatment plants in 12 coastal regions until 2020 for the treatment of 80 percent of the produced volume of wastewater;
- Maintaining and cleaning the river courses; and
- Rehabilitating and extending electrical equipment in order to reach the villages not yet connected to the public utility network.

Table 1-14 Dam projects as per the 10 year water plan

DAM NAME	PURPOSE	CAPACITY (MM^3)	COST IN BILLION LEBANESE POUNDS (LBP)*		REGION
			STUDY	EXECUTION	
Bisri	Potable water and Irrigation	120		300	Greater Beirut
Noura el-Tahta / Nahr el-Kebir	Irrigation	60	1.5	40	North Lebanon
Qarqaf / Wadi Jamous	Irrigation	30	2.25	30	
Al-Bared / Source Al-Bared	Potable water	35	3	60	
Qamoua	Irrigation and tourism	1		12	
Aidamoun	Irrigation	0.3		4.5	
Rehabilitation of Kawachira hill lakes	Irrigation	0.35	0.1	1.2	
El Atlabi lake		1	-	-	
El Oyoun		-	-	-	
Brisa	Irrigation and Potable water	0.9		15	
Iaal	Irrigation and Potable water	10	2	30	
Becharre	Irrigation and Potable water	1	2.65		
Dar Beachtar	Irrigation and Potable water	55	1	100	
Kfifane	Potable water	1.5	1.25	18	
Tannourine	Irrigation and Potable water		1.25	18	
Balaa lake		1	-	-	
Aqoura / Majdal	Irrigation and Potable water	2	1.5	20	Mount Lebanon
Laqlouq lake		0.8	-	-	
Afqa	Irrigation and Potable water	2.5	1.5	20	

DAM NAME	PURPOSE	CAPACITY (MM^3)	COST IN BILLION LEBANESE POUNDS (LBP)*		REGION
			STUDY	EXECUTION	
Janneh	Irrigation and Potable water	30	5		
Chabrouh	Potable water	11	0.75	90	
Mayrouba	Irrigation and Potable water	18	3		
Beqaata	Potable water	6.5	3	50	
Habash/ Zaarour Lake	Potable water	0.55	0.75	15	
Qaisamani Lake	Potable water	0.55		14	
Azouniye Lake	Irrigation and Potable water	8	3	120	
Damour	Irrigation and Potable water	40	4		
Maasser el Shouf lake		2	-	-	
Yammouneh	Irrigation and Potable water	1.2		6	Bekaa
Younine	Irrigation	25	2	40	
Aassi	Irrigation and Potable water	25	2.5	40	
Massa	Irrigation	8	1.5	15	
Wadi Sbat lake		0.7 - 1	-	-	
Wadi Jriban lake		0.7 - 1			
Rachaya lake		<1	-	-	
Azibeh Lake		0.6	0.75	15	South Lebanon
Lebaa / Jensnaya Lake		0.8	1	15	
Kfar Souna Lake		1.1	0.75	8	
Kfarsir Lake		8	3	20	
Kfarhoun lake		1.2	-	-	
Khardaleh dam		120	5	200	

* 1,500 LBP = USD 1

Source: Comair, 2008 and Kamar, 2009

However, this plan was not achieved by 2010, and was renewed from 2008 to 2018 (Hreiche, 2009). Although many extensions, developments and rehabilitation works have been executed and others are still on-going and planned, only three dams (Shabrouh in Kesrwan- Mount Lebanon; Barissa in Donnieh-North Lebanon; and Yammouneh spring in Baalbeck) have been built so far. Projects that are under preparation include (CDR, 2009):

- The Qaysmani dam in the district of Baabda, with a capacity of about 0.55 Mm3, which aims at supplying the districts of Baabda and Aley with potable water (around 6,000m3 per day);
- The construction of a lake in Jbailiyeh-Manzoul in the Metn district, which aims at supplying the district with potable water.

The key reforms identified since 2005 by the Lebanese Government in view of restructuring the water sector include (Hreiche, 2009):

- Updating the 10 year strategic plan, endorsed by the Lebanese Government and the Lebanese Parliament, and preparing an integrated water sector strategy with a clear vision under the concept of the Law 221, its amendment and the bylaws published in October 2005;

- Preparing a National Water Master Plan and approving the Water Code;
- Adopting a tariff structure that would be based on costs and volumetric consumption, with respect to social equity principles regarding the disadvantaged population;
- Preparing a short and medium term investment plan for the water sector taking into account the priorities and available funds.

Key elements for reviewing the 10 year Strategic Plan for Water have been identified; these include (Hreiche, 2009):

- Brief analysis of current needs and trends (up to 2020) of the water supply sector in Lebanon, with an emphasis on demand management for domestic, irrigation and industrial uses as well as on nonconventional water resources (eg. wastewater reuse, desalination) and techniques (e.g., recharging of aquifers). The analysis was built on national targets, including targets for food security and the consequent increase in irrigated land.
- Analysis of the technical projects included in the Plan, justification with current needs and elaboration of policy recommendations.
- Consolidation of the Plan with the provisions of the Law 221, including the evolution of Water Establishments with regard to Public Private Partnerships.
- Development of an awareness component in the Plan focusing on enhancing water demand management and non-conventional water resources.
- Development of a capacity building component to assist in the implementation of the Plan.
- Development of policy recommendations for adaptation to climate change impacts.

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 National Physical Master Plan for the Lebanese Territory (NPMPLT) looks at the 2030 horizon, and gives the priority for domestic supply, given the critical situation of this part of the demand. The increase in water demand for domestic consumption is related to demographic growth (30% in 30 years) as well as to the growth in daily personal usage of water (that could be estimated to be 10% in 30 years). The satisfaction of domestic water demands in Lebanon in 2030 under a middle scenario (between scenarios A and B defined below) will require around 420 Mm^3 (220 l/d/c x 365 d x 5.2 million people), i.e., 41% more than in 2000, namely an annual volume of 525 Mm^3 to pump and distribute (Table 1-15), with a system loss rate of 20% (against more than 50% in 2005). 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 roughly 280 Mm^3, only half of which reaches consumers (because of 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: even if current losses in networks of 50% will be reduced to 20% in 2030, Water Authorities will have to distribute 525 Mm^3 (11% of the annual water balance in Lebanon after evaporation) in order to satisfy the total domestic need. This presumes a simultaneous increase of 86% of the current distributed quantities by the authorities, in addition to losses reduction; hence the need to mobilize new resources. 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).

It is worth noting that if domestic demand projections from the other sources (Table 1-18) are used, the volume of water that needs to be secured and distributed by authorities will be even higher.

Table 1-15 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 Mm^3	418 Mm^3	+41%

Source: CDR, 2005

Irrigation projects should be developed to the maximum allowed by corresponding public budget. The irrigation sector mobilized in 2005 around 650 Mm^3 which is between 25% and 33% of the maximum exploitable resources. The use of available water resources for agriculture, after satisfying the domestic and industrial demands, would mean the activation of around 1,600 Mm^3 for this sector 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 this context, the MoEW has 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 that would serve as spillways, rather than storage work. The capacities of the proposed dams vary between 4 and 128 Mm^3, while those of lakes vary between 0.35 and 2 Mm^3. The planned lakes are distributed evenly all over the country, especially on the eastern slopes of Mount Lebanon. From the 23 lakes, the locations of 17 are known, and 5 lakes are to be located in the Cazas (districts) of Marjaayoun, Bint Jbayl, Hasbaya, Nabatiyeh and Tyre (Table 1-16). 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 assure irrigation water for the effectively irrigable lands of Lebanon (this is around half of the currently cultivated lands). 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 perceived more as a development scheme, rather than a finalized and scheduled program (CDR, 2005).

Figure 1-10 and Figure 1-11 show the proposed dams and lakes by investment priority (CDR, 2005), based on four criteria:

- The capacity of the establishments to satisfy the domestic water demands. This criterion is twice as important compared to other criteria;
- The improvement that the work would bring to the irrigated lands;
- The possibility that the project could bring improvements to other objectives, especially tourism and protection against floods, and that it does not harm the environment; and
- Finally, the degree of progress of feasibility studies and implementation.

Table 1-16 Investment priorities of NPMPLT for the proposed dams and lakes

<table>
<tr><th>DAMS</th><th>PRIORITY</th><th>LAKES</th><th>PRIORITY</th></tr>
<tr><td>Noura et-Tahta</td><td rowspan="7">High</td><td>Yammouneh</td><td>High</td></tr>
<tr><td>Bared</td><td>Qammouaa</td><td rowspan="7">Medium</td></tr>
<tr><td>Iaal</td><td>Qartlab / Otlab</td></tr>
<tr><td>Younine</td><td>Kouashra</td></tr>
<tr><td>Shabrouh</td><td>Sbat</td></tr>
<tr><td>Massa</td><td>Massa</td></tr>
<tr><td>Al-Hasbani / Ibl Saqi</td><td>Jriban</td></tr>
<tr><td>Aassi</td><td>Medium</td><td>Azzibe</td></tr>
</table>

DAMS	PRIORITY	LAKES	PRIORITY
Janne		Maasser el Shouf	
Boqaata		Brissa	
Azzounieh		Balaa	
Damour		Laqlouq	
Bisri		El Habash	
Khardali		Qaissamani	Low
Qarqaf		Rashaya	
Dar Beashtar	Low	Lebaa	
Qalaat el-Mseilha		Kfarhouneh	
Kfarsir		Other unidentified	

Source: CDR, 2005

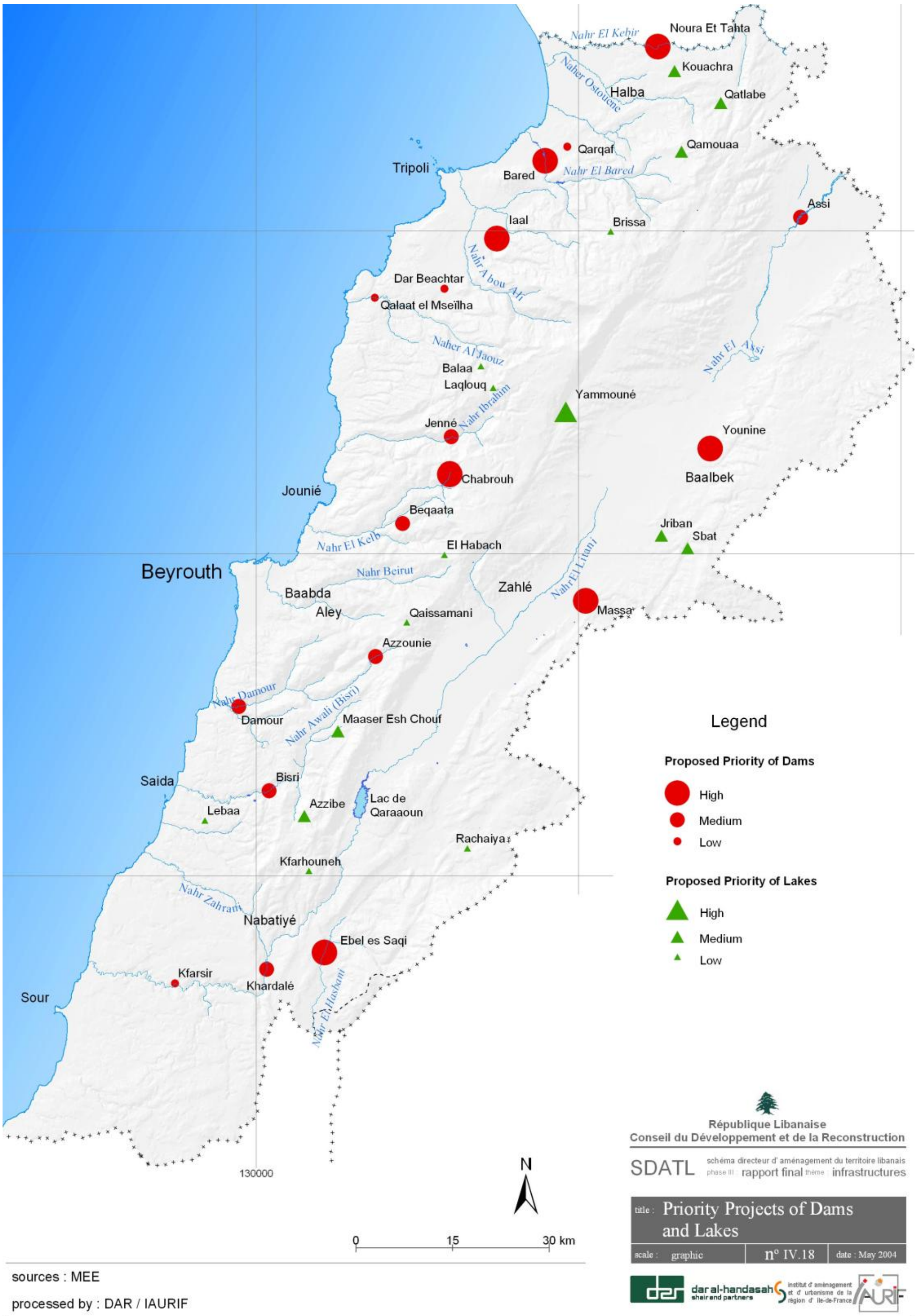


Figure 1-11 Priority Projects of Dams and Lakes

Source: CDR, 2005

Socio-Economic scenario

Table 1-17 illustrates the projected decline in annual renewable water resources in Lebanon regardless of climate change impacts. The level below which a country is considered water poor varies between different agencies and experts, but is consistently around 1,000 m^3/capita/year (Bou-Zeid and El-Fadel, 2002). Lebanon falls below this level in the long-term, and far below the world average of 4,780 m^3 per capita (Berkoff, 1994).

Table 1-17 Projections for annual renewable water resources in Lebanon

	YEARLY RENEWABLE WATER RESOURCES (M^3/CAPITA)	TOTAL YEARLY RENEWABLE WATER RESOURCES (BILLION M^3)
1997	766–1,287	2.00 – 3.94
2015	336–979	
2025	262–809	

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

The CDR (2005) projects a total water demand of 2,265 Mm^3 by 2030, distributed as follows: 23% for domestic use, 6% for industrial use, and 71% for irrigation use. Total demand projection in 2030 by Bou-Zeid and El-Fadel (2002) and the World Bank (unpublished) are significantly higher: 3,280 Mm^3 and 2,818 Mm^3 respectively. The projected share of demand that will be allocated to agriculture according to CDR is considerably higher than the other sources; while the opposite applies to the share of industrial use (Table 1-18).

The World Bank (unpublished) expects the composition of water demand to change significantly over the next 20 years: domestic and industrial water demand are anticipated to grow at about 5 percent per annum, much faster than irrigation water use, estimated to grow at about 1 percent per annum; thus reversing the trend of increase in demand for irrigation water. The World Bank's Policy Note on Irrigation Sector Sustainability (2003) puts irrigation water demand by 2030 at 1,127 Mm^3, with the Bekaa as the largest consumer but reaching a stable demand after 2020 (Figure 1-12).

Domestic water demand, which represented 25 percent of total demand in 2003, is expected to exceed irrigation demand by 2030, reaching 45 percent of total water use (this estimate is considerably higher than those of the other sources). In parallel, industrial water use is estimated to triple in volume by 2030 (Table 1-18). Domestic water demand is largely driven by increase in income and population, forecasted to grow at 2.5 percent per annum; the surge in industrial demand is attributed to the growth in the tourism industry (World Bank, unpublished). The MoE (2001) projections are in line with this trend (Figure1-13).

Table 1-18 presents water demand projections by Mohafaza and sector. The country's demand for the domestic and industrial sectors is lower than estimates from other sources (Table 1-19) for 2020, and close to CDR's projection for 2030. Demand projection for the irrigation sector is close to the World Bank's estimate for 2020 and 2030. Total demand is lower than the other sources' estimates.

As for projections that were made in Lebanon's First National Communication, they are illustrated in Figure1-14. A water deficit of 140 Mm^3 was forecasted 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, 1999).

Table 1-18 Annual water demand, 2003-2030 by water use category

YEAR	DOMESTIC WATER DEMAND, MM³/YEAR (%)			
	Hajjar, 1992	**Bou-Zeid & El-Fadel, 2002**	**World Bank, unpublished**	**CDR, 2005**
2010	-	425 (23)	467 (31)	-
2020	850 (32)	641 (25)	767 (37)	-
2030	-	876 (27)	1,258 (45)	525 (23)
	Industrial water demand, Mm³/year (%)			
	Hajjar, 1992	**Bou-Zeid & El-Fadel, 2002**	**World Bank, unpublished**	**CDR, 2005**
2010	-	445 (24)	163 (11)	-
2020	240 (9)	598 (23)	268 (13)	-
2030	-	804 (24)	440 (16)	140 (6)
	Irrigation water demand, Mm³/year (%)			
	Hajjar, 1992	**Bou-Zeid & El-Fadel, 2002**	**World Bank, unpublished**	**CDR, 2005**
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 (%)			
	Hajjar, 1992	**Bou-Zeid & El-Fadel, 2002**	**World Bank, unpublished**	**CDR, 2005**
2010	-	1,897	1,530	-
2020	2,690	2,589	2,055	-
2030	-	3,280	2,818	2,265

Source: Hajjar, 1992; Bou-Zeid and El-Fadel, 2002; World Bank, unpublished; and CDR, 2005

Table 1-19 Projected water demand by Mohafaza by 2030 (Mm³)

REGION	SECTOR	2002	2005	2010	2015	2020	2025	2030
Beirut	Domestic	55.85	57.69	63.90	70.05	75.17	77.50	78.78
	Industrial	5.92	6.11	6.40	7.11	7.94	8.94	9.97
	Irrigation	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	**61.78**	**63.80**	**70.31**	**77.17**	**83.11**	**86.44**	**88.74**
Mount Lebanon	Domestic	162.43	169.35	192.20	217.84	242.30	257.00	269.29
	Industrial	30.45	31.38	32.88	36.64	41.02	46.17	51.49
	Irrigation	78.40	78.40	78.40	78.40	78.40	78.40	78.40
	Total	**271.28**	**279.13**	**303.48**	**332.89**	**361.72**	**381.57**	**399.18**
North Lebanon	Domestic	74.50	77.42	87.72	99.32	110.24	114.98	118.56
	Industrial	12.79	13.27	13.99	15.75	17.78	20.04	22.37
	Irrigation	158.31	158.31	158.31	158.33	174.83	174.69	174.54
	Total	**245.60**	**249.01**	**260.03**	**273.40**	**302.84**	**309.71**	**315.47**
South Lebanon	Domestic	41.60	42.96	48.46	54.87	61.29	64.29	67.06
	Industrial	4.23	4.43	4.74	5.41	6.21	7.11	8.08
	Irrigation	117.75	145.42	145.19	167.89	192.26	191.62	220.46

REGION	SECTOR	2002	2005	2010	2015	2020	2025	2030
	Total	**163.59**	**192.81**	**198.39**	**228.16**	**259.76**	**263.02**	**295.61**
Bekaa	Domestic	48.50	50.62	57.68	64.80	71.42	74.29	76.36
	Industrial	4.41	4.61	4.90	5.52	6.22	7.02	7.85
	Irrigation	411.66	412.24	478.08	477.71	481.82	481.55	481.00
	Total	**464.56**	**467.46**	**540.67**	**548.02**	**559.46**	**562.87**	**565.21**
Nabatiyeh	Domestic	26.01	26.32	28.69	31.59	34.17	34.96	35.39
	Industrial	1.52	1.57	1.64	1.83	2.05	2.31	2.57
	Irrigation	15.85	101.46	100.75	117.86	117.56	116.70	172.58
	Total	**43.37**	**129.35**	**131.08**	**151.29**	**153.78**	**153.97**	**210.54**
Grand Total	Domestic	408.88	424.36	478.66	538.48	594.58	623.04	645.44
	Industrial	59.34	61.36	64.56	72.26	81.22	91.58	102.33
	Irrigation	781.97	895.83	960.74	1,000.19	1,044.86	1,042.96	1,126.99
	Total	**1,250.18**	**1,381.55**	**1,503.95**	**1,610.93**	**1,720.67**	**1,757.58**	**1,874.75**

Source: JICA, 2003

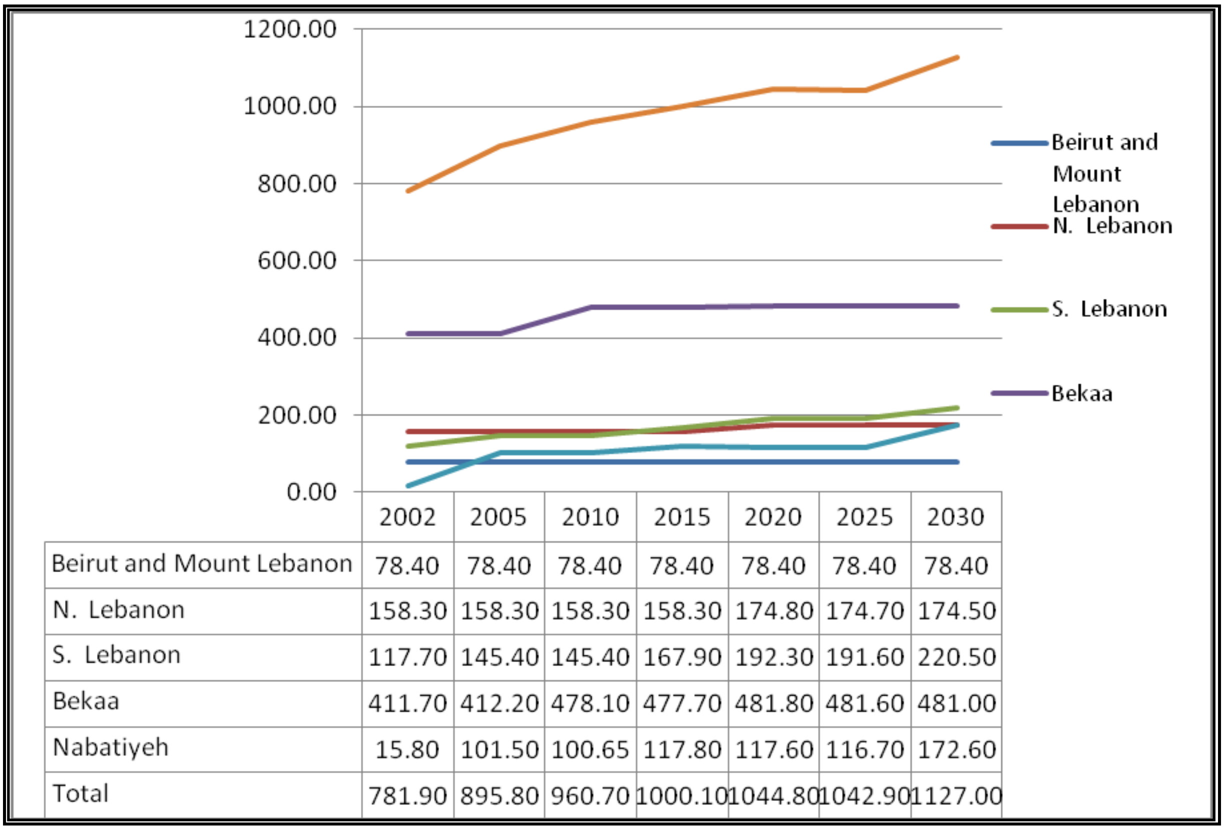
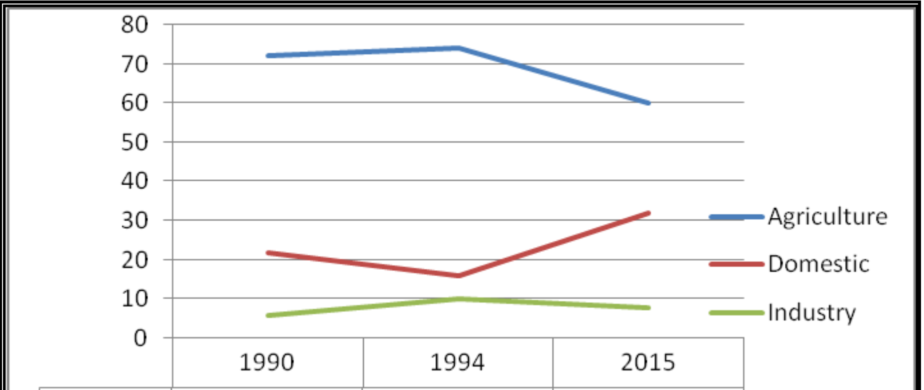


Figure 1-12 Projections of demand for irrigation water by Mohafaza (Mm³)

Source: World Bank, 2003



	1990	1994	2015
Agriculture	72	74	60
Domestic	22	16	32
Industry	6	10	8

Figure1-13 Percentage of Water deployed by sector between 1990 and 2015

Source: MoE, 2001

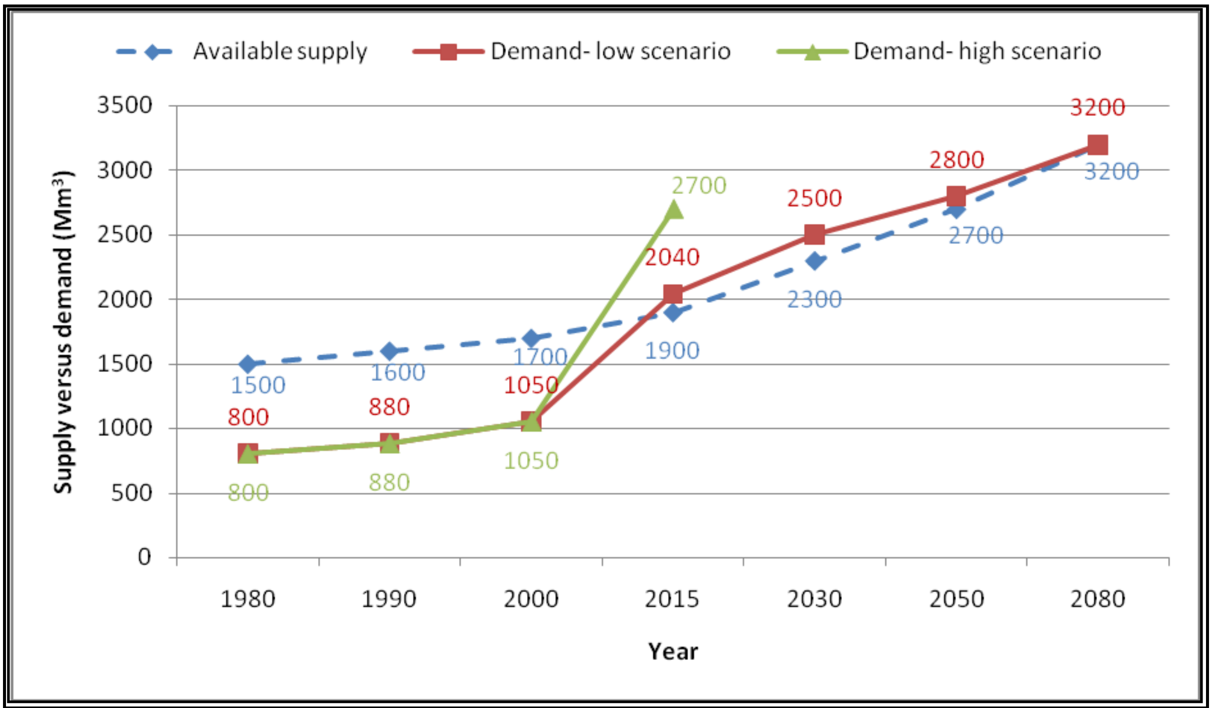


Figure1-14 Baseline projections of supply and demand – First National Communication

Based on the NPMPLT's projections for population size, economic growth, and development patterns by 2030 (CDR, 2005), the following two scenarios were defined for the water sector:

Scenario A	
Growing integration of international trade, Lebanese production 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 The migration balance[3] between 2001 and 2030 will be around (-27,000) persons yearly Same standard of living.	Under this scenario, water demand for the domestic sector 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. Water demand for the agricultural and industrial sectors will not increase significantly either, as these sectors are not expected to grow significantly (Agricultural production is expected to slightly decrease). However, 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.
Scenario B	
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%[4] between 2010 and 2030 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	Under this scenario, water demand in all sectors (domestic, agriculture, industry, and tourism) will increase with the high population growth rate, the high economic growth covering all sectors, and the expected improvement in standards of living. 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 to

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 constant-fertility scenario** as projected in the World Population Prospects: The 2008 Revision (UN, 2009).

3 The migration balance is defined as 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, 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 constant-fertility scenario as projected in the World Population Prospects: The 2008 Revision (UN, 2009).

population: growth of 284 km² of urbanized areas The migration balance between 2001 and 2030 will be around (-6,000) persons per year Better standards of living: ~ 2.4 times higher.	relieve 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.

1.1.3.2. Climatic Scenarios

Table 1-20 summarizes the projections of the climatic factors of relevance to the Water sector for the Mediterranean region and for Lebanon as they figure in the IPCC Fourth Assessment Report and the EEWRC Climate simulations respectively. However, it should be noted that evapotranspiration could not be projected with accuracy by the PRECIS model as a result of limited historical data availability, and thus it was predicted using the active precipitation v/s precipitation mathematical model developed for this sector.

Table 1-20 Projected change in climatic factors of significance to the water sector

CLIMATE FACTOR	PROJECTIONS FOR THE MEDITERRANEAN REGION[1]	PROJECTIONS FOR LEBANON[2]
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.	Increases in Tmax 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.
Precipitation	The annual area-mean change from the period 1980 -1999 to 2080- 2099 varies from –4% to –27% in the Mediterranean region.	Rainfall reduction is projected to be between -10 and -20% by 2040, and between -25% and -50% by 2090.
Evapotranspiration (results obtained from the model developed)		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 Dahr el Baydar: 5% increase by 2044, and 6% increase from 2044 to 2098.

Sources:

1 Christensen et al., 2007

1.1.4. Vulnerability Assessment

1.1.4.1. Sensitivity to Climatic factors

Water resources are sensitive to increases in temperature and decreases in precipitation. Temperature increase leads to higher evapotranspiration rates on one hand, and shifting of snowfall to higher altitudes. Decreased precipitation means reduced rainfall and snowfall, and thus a decline in water resources.

1.1.4.2. Adaptive Capacity

Adaptive capacity to any reduction in water resources available is low due to several factors such as:

- Limited capacity for storage of rainwater
- Excessive reliance on groundwater resources leading to seawater intrusion and depletion of these resources
- Considerable losses in the distribution network
- The fact that the agriculture sector consumes around 65% of water, and relies on inefficient methods- surface irrigation
- The lack of measures that promote water conservation (including metering systems, tiered pricing, awareness efforts, etc.).

However, if the 10-year water plan and CDR plans are implemented, the storage capacity of rainwater and the volume of water resources available will increase, leading to a higher adaptive capacity.

1.1.4.3. Vulnerability Assessment Results

Vulnerable hotspots in the water sector were defined based on their sensitivity to climate change and their adaptive capacity under each scenario (Table 1-21). Vulnerability of water resources is expected to be higher under scenario B as a result of high population growth, low emigration rate and higher urbanization rates. Nevertheless, the higher GDP growth and more balanced economic development can incur a higher adaptive capacity through faster implementation of water projects.

The following systems were identified to be vulnerable to climate change:

Water Demand

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

Water availability

Water availability will decrease with lower precipitation and higher evapotranspiration rates, until the water plan is executed to increase storage 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.

Water quality

Water quality will deteriorate as a result of increasing demand on water resources leading to higher seawater intrusion into groundwater aquifers, given the high rate of excessive and uncontrolled groundwater abstraction from limited storage capacity of rainfall. This effect can only be reversed if the water plan is implemented and groundwater aquifers are recharged to reduce their salinity.

Table 1-21 Vulnerability of Systems

SYSTEM	SENSITIVITY	ADAPTIVE CAPACITY		VULNERABILITY
Water demand	Moderate due to increasing per capita consumption, decreasing precipitation and increasing temperatures	Scenario A	Moderate	Moderate
		Scenario B	Low	High
Water availability	High due to the forecasted decrease in precipitation and	Scenario A	Moderate	High

	increase in temperatures	Scenario B	Low	Very high
Water supply	High due to the challenge of meeting the increasing demand as water availability decreases	Scenario A	Moderate	High
		Scenario B	Low	Very high
Water quality	High due to increasing pressure on water resources, and increasing seawater intrusion into groundwater aquifers	Scenario A	Moderate	High
		Scenario B	Low	Very high

1.1.5. *Impact Assessment*

1.1.5.1. *Selected Impact Indicators*

The following indicators were selected for illustrating the impacts of climate change on water resources (Table 1-22):

Table 1-22 Selected indicators for impact assessment in the water sector

INDICATOR	RELEVANCE
Per capita water consumption	Water consumption increases in warmer weather
Demand by sector (domestic, industrial, agriculture)	Demand increases when temperatures increase, especially in the domestic and agricultural sectors
Renewable water resources per capita	Renewable resources available per capita decrease as precipitation decreases
Average % water deficit	Average deficit increases as demand increases and water availability decreases due to reduced precipitation and higher evapotranspiration
Unmet demand (m3/ capita)	Unmet demand increases as water availability increases while demand increases
Salinity of groundwater	Salinity of groundwater increases as withdrawal is sustained/ increased while recharge decreases due to decreased precipitation and higher evapotranspiration

1.1.5.2. *Impacts due to non-climatic factors*

Under a business-as-usual scenario, demand for water is forecasted to increase in the coming decades as a result of increased demand from both population growth and economic growth. The latter will lead to a higher per capita consumption, decrease in water resources per capita and an increase in the average water deficit especially under scenario B where standards of living are forecasted to be higher. Population growth being also higher under scenario B, the increase in demand will be considerably higher compared to scenario A. This effect will only be alleviated by the implementation of plans and strategies in the water sector. Higher economic growth, standards of living and the more balanced development under scenario B will allow a better and faster implementation of water plans, therefore reducing the gap between increasing demand and supply.

As for groundwater quality, it is expected to deteriorate as long as it constitutes an important source of water, especially under scenario B, with high urbanization and population growth. The sea water intrusion impact of sea level rise can be exacerbated by increased groundwater withdrawal due to upconing[6] and urbanization.

Salt water intrusion poses a serious threat to the quality of freshwater, particularly that in some locations seawater has actually intruded several kilometers inland into coastal aquifers. The coastal area of

6 Upconing is a phenomenon where literally a cone of salt water forms beneath the point of buffer layer of fresh water, hence increasing the risk of salt water intrusion.

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).

With the gradual implementation of the water plan, groundwater abstraction is expected to decline, thus alleviating seawater intrusion.

1.1.5.3. Impacts from Climatic Factors

Under a climate change scenario, the various impact indicators would change as follows:

- Water demand and consumption per sector would increase with increasing temperatures;
- Renewable water resources available per capita would decrease with declining precipitation;
- The average water deficit and unmet demand (in the form of rationing) would consequently increase;
- 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, according to Section on Coastal Zone vulnerability and adaptation).

Available data and analytical means clearly demonstrate that precipitations over the Mediterranean Basin, most specifically its Eastern part where Lebanon lies, have not experienced any particular increasing or decreasing trends over the past century. Long-term rainfall series, however, do reveal wide multiannual variations, where lengthy humid periods follow lengthy dryer periods. These variations are often mistakenly perceived as "climatic changes" (Bakalowicz, 2009).

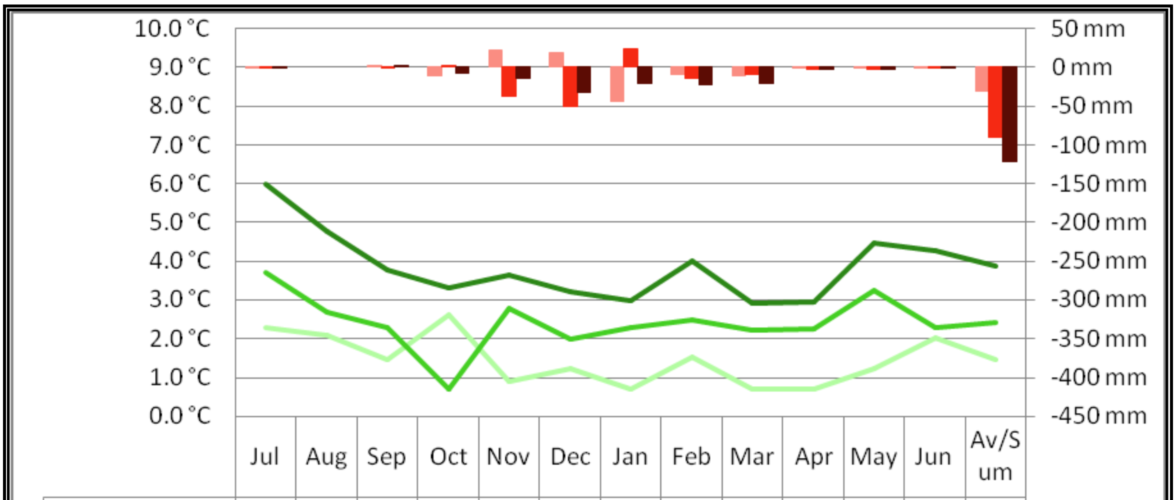
Indeed, according to Najem et al. (2006), a study analyzing rainfall in 35 Mediterranean stations over 10-year periods revealed there was no detectable trend in precipitation or a major shift in the rainy season in the region over the last century.

Similarly, stochastic models for precipitation events in the Mediterranean region were developed using daily precipitation datasets from 17 countries around the Mediterranean Sea (Zeinoun, 2004). Wherever a trend was detected using the Mann-Kendall test in the Mediterranean region, it corresponded to a break in the dataset which implies that there is no proof of any trends in precipitation in the region.

It is believed that no model is able to forecast changes in the seasonal distribution of precipitation either (Bakalowicz, 2009).

Impact on projected precipitations

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, the following charts were obtained (Figure 1-15 to Figure 1-18).



	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Av/Sum
ΔP (RP/NF)	-0.1	0.00	2.45	-10.	22.8	19.1	-44.	-8.7	-11.	0.93	-0.9	-0.3	-30.
ΔP (NF/DF)	-0.0	0.00	0.38	2.73	-36.	-51.	23.8	-13.	-9.9	-2.7	-2.1	-0.0	-90.
ΔP (RP/DF)	-0.2	0.00	2.83	-7.5	-14.	-32.	-20.	-22.	-21.	-1.8	-3.0	-0.4	-120
ΔT (RP/NF)	2.29	2.10	1.47	2.60	0.88	1.23	0.70	1.52	0.70	0.71	1.24	2.01	1.45
ΔT (NF/DF)	3.69	2.68	2.30	0.71	2.77	1.99	2.29	2.49	2.22	2.24	3.23	2.27	2.41
ΔT (RP/DF)	5.98	4.78	3.77	3.31	3.65	3.22	2.99	4.01	2.92	2.95	4.47	4.28	3.86

Figure 1-15 Projected changes in precipitation and average temperature – Beirut station

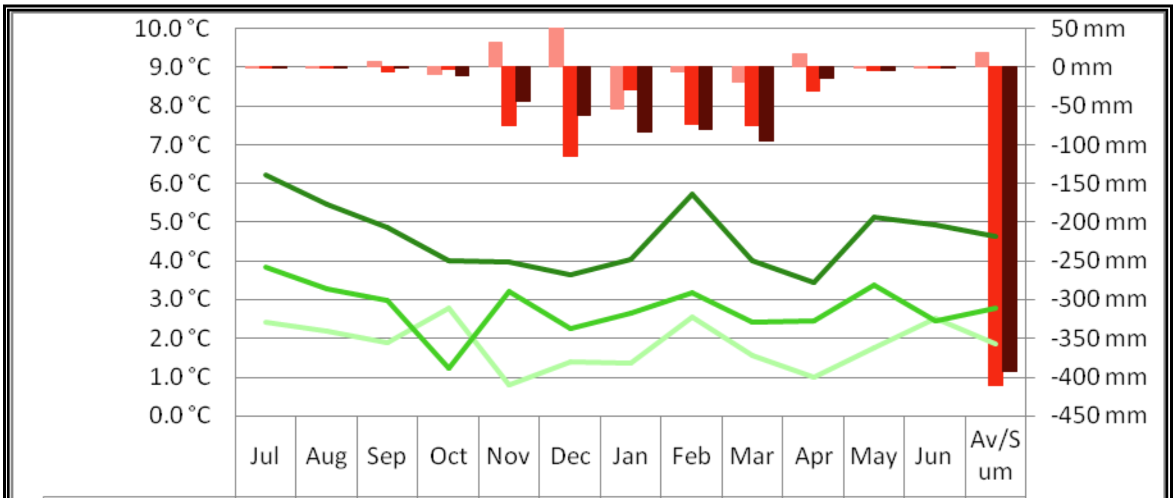
RP: Recent Past

NF: Near Future

DF: Distant Future

ΔP: Variation in Total Precipitation

ΔT: Variation in Temperature



	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Av/Sum
ΔP (RP/NF)	-0.3	-0.4	6.83	-9.3	31.8	52.3	-54.	-5.9	-19.	16.9	1.32	-0.3	18.7
ΔP (NF/DF)	0.19	0.06	-5.5	-1.7	-74.	-115	-28.	-73.	-75.	-30.	-4.7	-0.3	-410
ΔP (RP/DF)	-0.2	-0.3	1.30	-11.	-43.	-62.	-82.	-79.	-95.	-13.	-3.4	-0.7	-392
ΔT (RP/NF)	2.40	2.19	1.89	2.77	0.78	1.40	1.37	2.55	1.57	0.98	1.77	2.50	1.85
ΔT (NF/DF)	3.83	3.27	2.98	1.23	3.20	2.24	2.66	3.19	2.43	2.45	3.36	2.44	2.77
ΔT (RP/DF)	6.23	5.46	4.87	4.00	3.98	3.64	4.03	5.74	4.00	3.43	5.13	4.94	4.62

Figure 1-16 Projected changes in precipitation and average temperature – Dahr el Baydar station

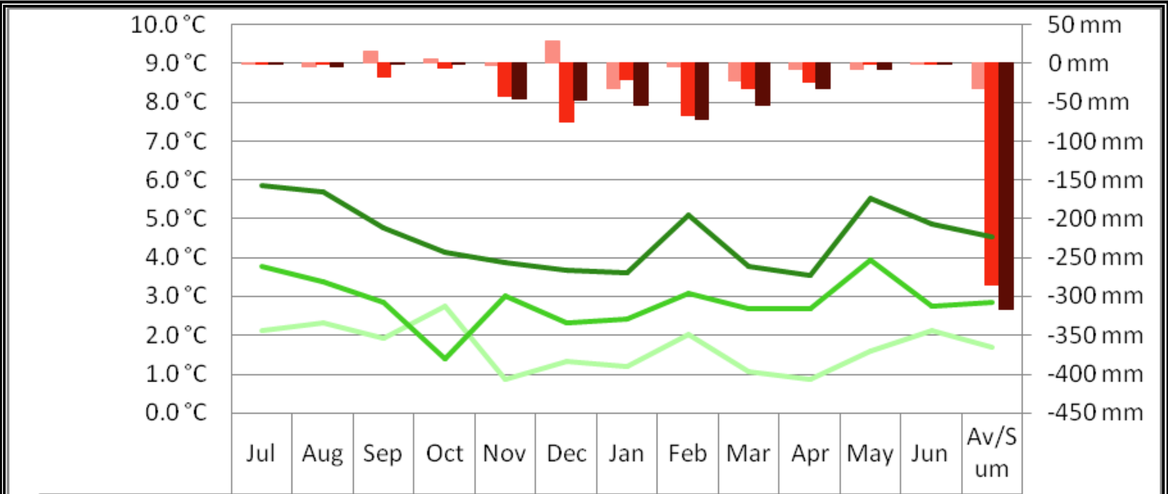
RP: Recent Past

NF: Near Future

DF: Distant Future

ΔP: Variation in Total Precipitation

ΔT: Variation in Temperature



	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Av/Sum
ΔP (RP/NF)	-1.3	-4.4	15.7	6.14	-3.1	28.2	-32.	-4.3	-22.	-6.9	-7.0	0.31	-31.
ΔP (NF/DF)	0.85	0.45	-16.	-6.4	-41.	-76.	-20.	-66.	-31.	-24.	-1.1	0.12	-285
ΔP (RP/DF)	-0.5	-3.9	-1.1	-0.2	-44.	-47.	-53.	-71.	-54.	-31.	-8.2	0.43	-316
ΔT (RP/NF)	2.11	2.32	1.92	2.75	0.85	1.34	1.20	2.02	1.07	0.86	1.58	2.13	1.68
ΔT (NF/DF)	3.76	3.36	2.86	1.38	3.01	2.33	2.42	3.07	2.69	2.68	3.93	2.74	2.85
ΔT (RP/DF)	5.87	5.68	4.78	4.13	3.86	3.67	3.62	5.09	3.76	3.54	5.51	4.87	4.53

Figure 1-17 Projected changes in precipitation and average temperature – Cedars station

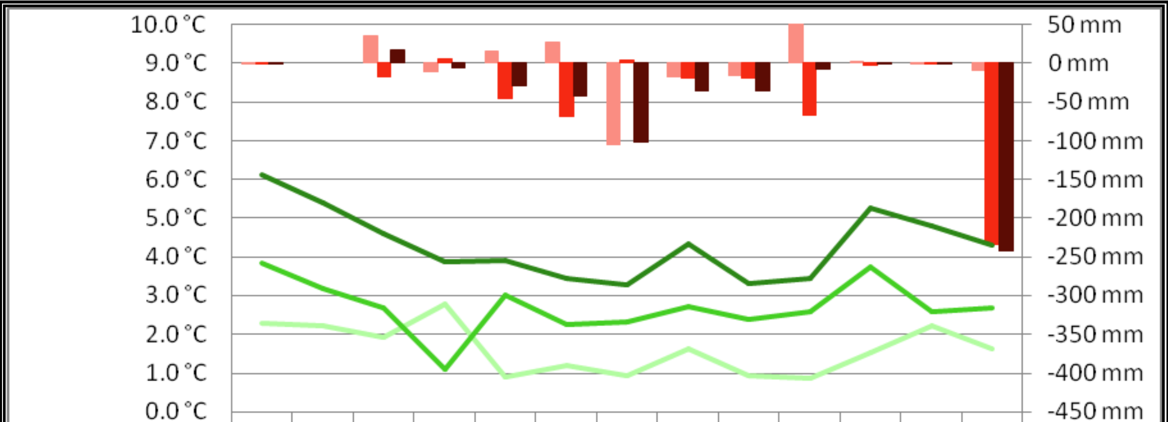
RP: Recent Past

NF: Near Future

DF: Distant Future

ΔP: Variation in Total Precipitation

ΔT: Variation in Temperature



	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Av/Sum
ΔP (RP/NF)	-0.4	0.00	35.3	-11.	16.4	27.5	-104	-16.	-16.	59.4	1.59	-0.0	-9.2
ΔP (NF/DF)	0.28	0.00	-18.	5.10	-46.	-69.	3.42	-19.	-19.	-67.	-2.7	-0.0	-233
ΔP (RP/DF)	-0.1	0.00	17.2	-6.2	-29.	-41.	-101	-36.	-36.	-7.6	-1.1	-0.0	-242
ΔT (RP/NF)	2.30	2.22	1.91	2.78	0.90	1.20	0.94	1.63	0.94	0.86	1.53	2.23	1.62
ΔT (NF/DF)	3.83	3.18	2.69	1.08	3.00	2.24	2.32	2.70	2.37	2.58	3.74	2.58	2.69
ΔT (RP/DF)	6.13	5.40	4.60	3.86	3.90	3.44	3.26	4.33	3.31	3.44	5.27	4.81	4.31

Figure 1-18 Projected changes in precipitation and average temperature – Zahleh station

RP: Recent Past

NF: Near Future

DF: Distant Future

ΔP: Variation in Total Precipitation

ΔT: Variation in Temperature

These graphs show a differential seasonal change in the trends. 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 Dahr 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.

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

Results of the model used for impact assessment

This section presents the results of the modeling conducted (as per Section1.1.2.3) in terms of the expected impact of increasing temperature and declining precipitation on active precipitation as a proportion of total precipitation. An assessment of the consequences on selected indicators under the two scenarios already defined follows.

Figure1-19 shows the four grid boxes representing the preliminary study area for the water sector, for which climate simulation data were analyzed.

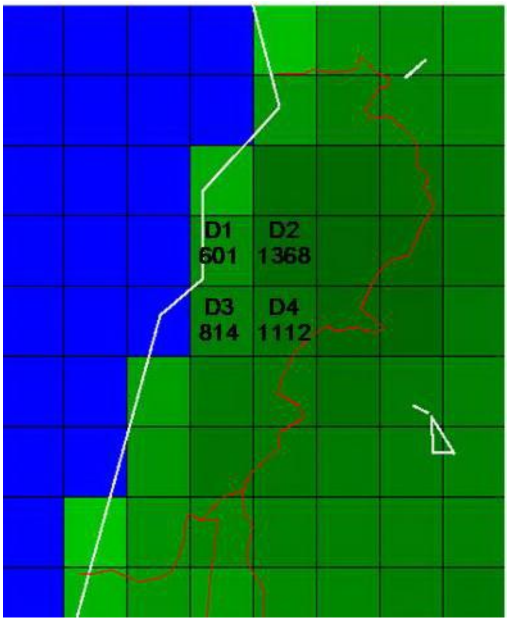


Figure1-19 Grid boxes D1 to D4 representing the study area for the water sector and their altitude in meters

ANNUAL ANALYSIS

The annual results of the model built for the water sector assessment in terms of active precipitation (Pa) out of total precipitation (P) can be found in Appendix B.

The annual analysis yields the following graphs and trend equations for the four clusters of the study area (Figure1-20 to Figure1-23):

Figure1-20 to Figure1-23 show a decline in Pa and in the proportion of Pa out of P until the end of the century in all four grid boxes of the study area except D4, where Pa/P increase. The trend in all four grid boxes appears in Figure 1-24.

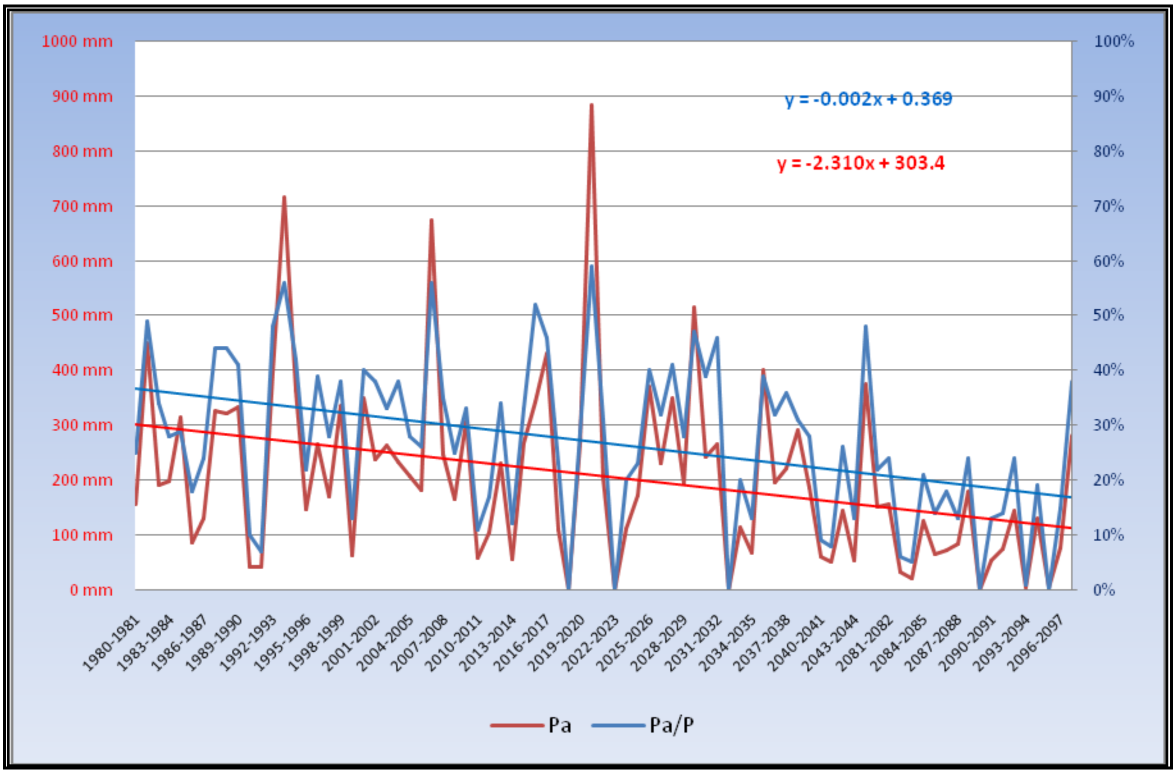


Figure1-20 Active precipitation out of total precipitation in grid box D1of the study area

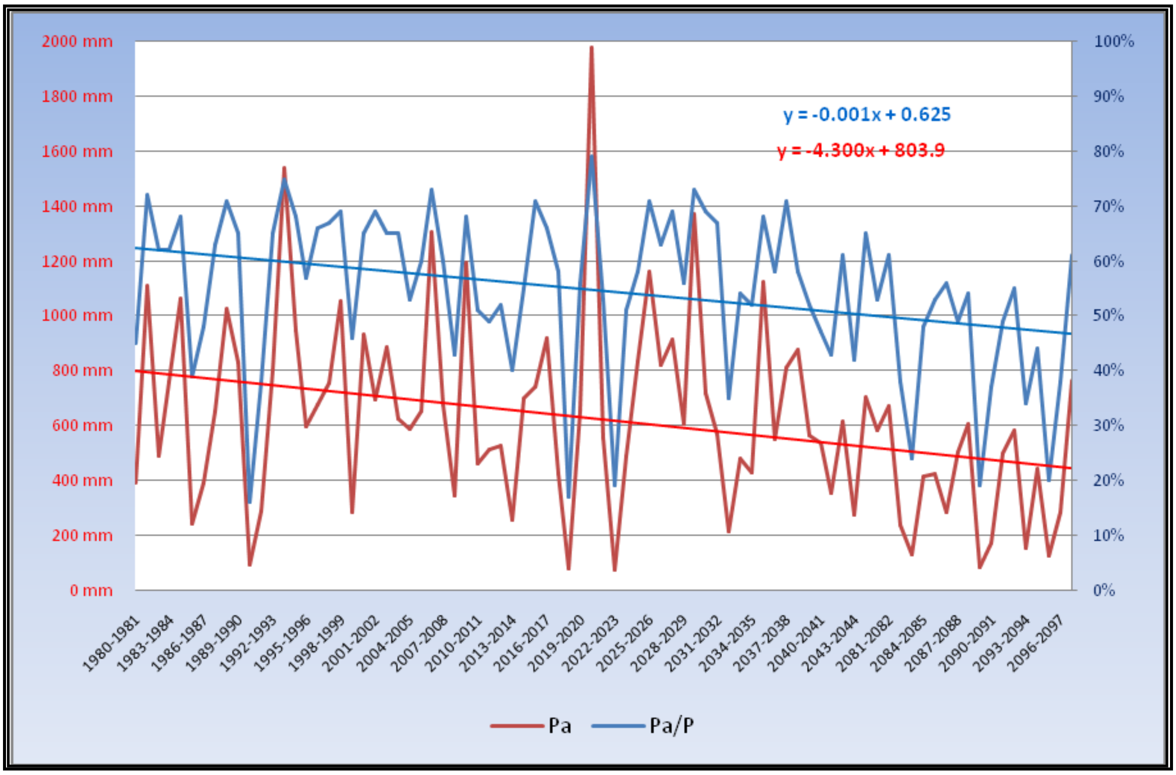


Figure1-21 Active precipitation out of total precipitation in grid box D2 of the study area

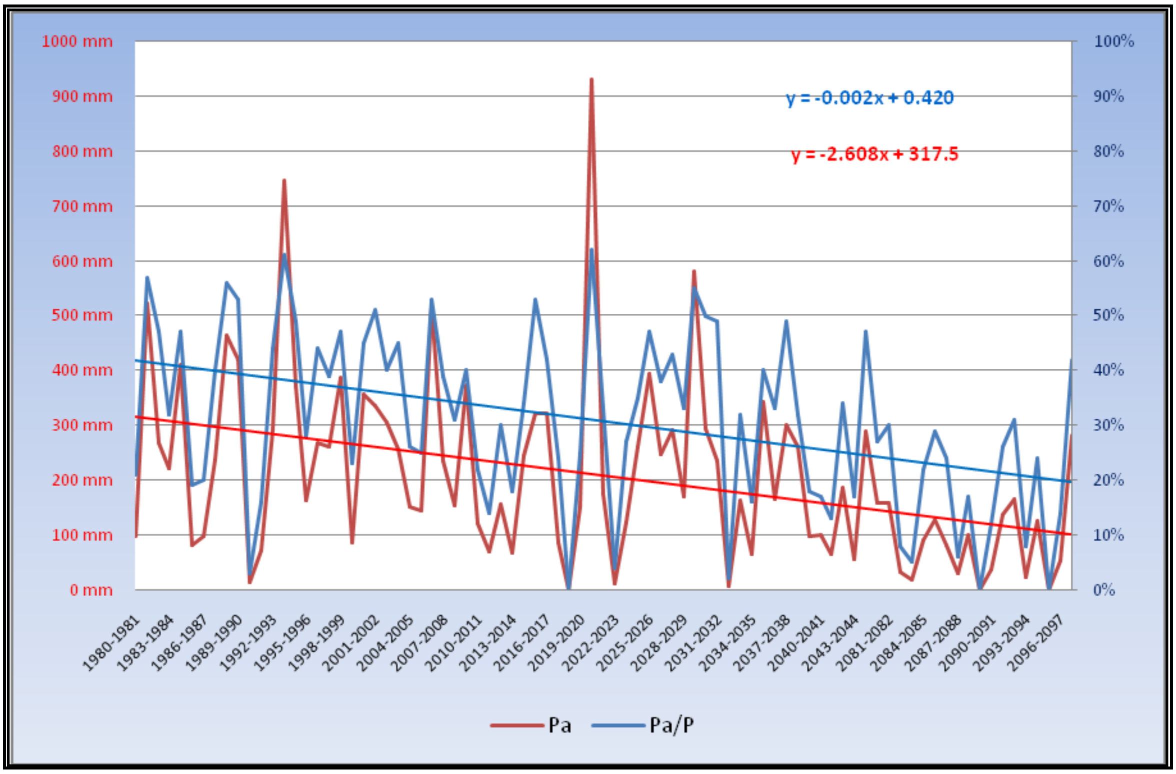


Figure 1-22 **Active precipitation out of total precipitation in grid box D3 of the study area**

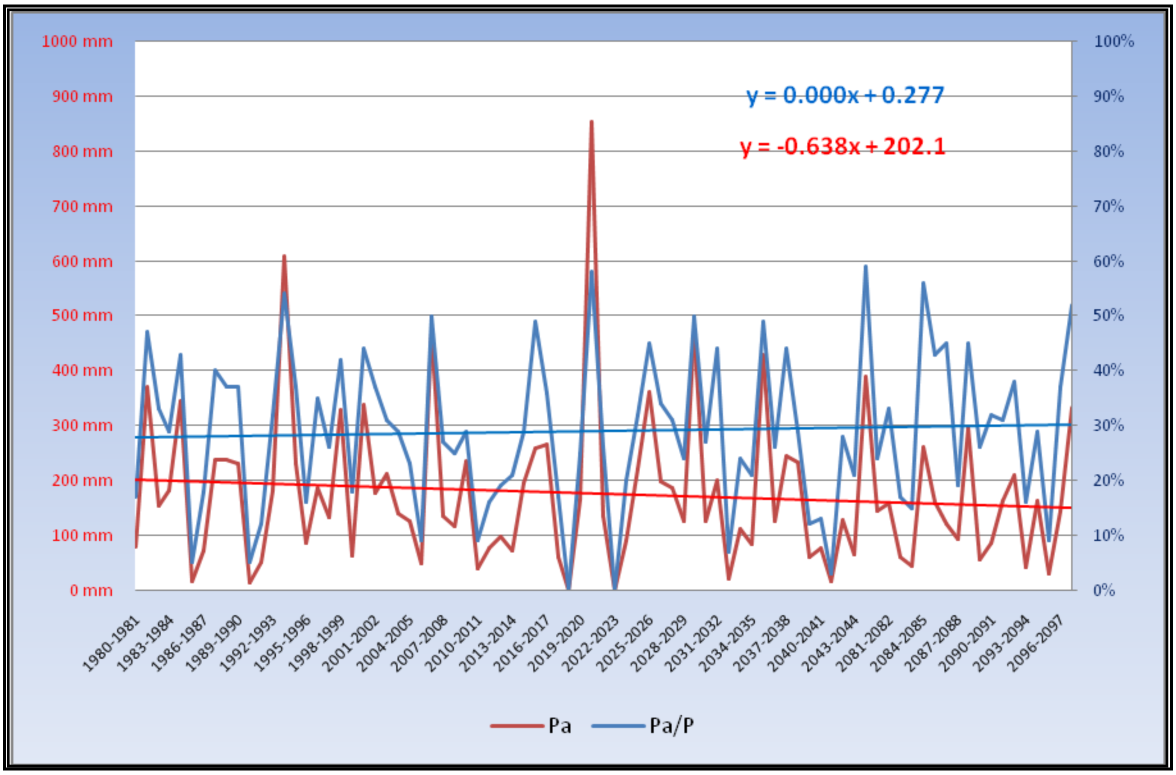


Figure1-23 **Active precipitation out of total precipitation in grid box D4 of the study area**

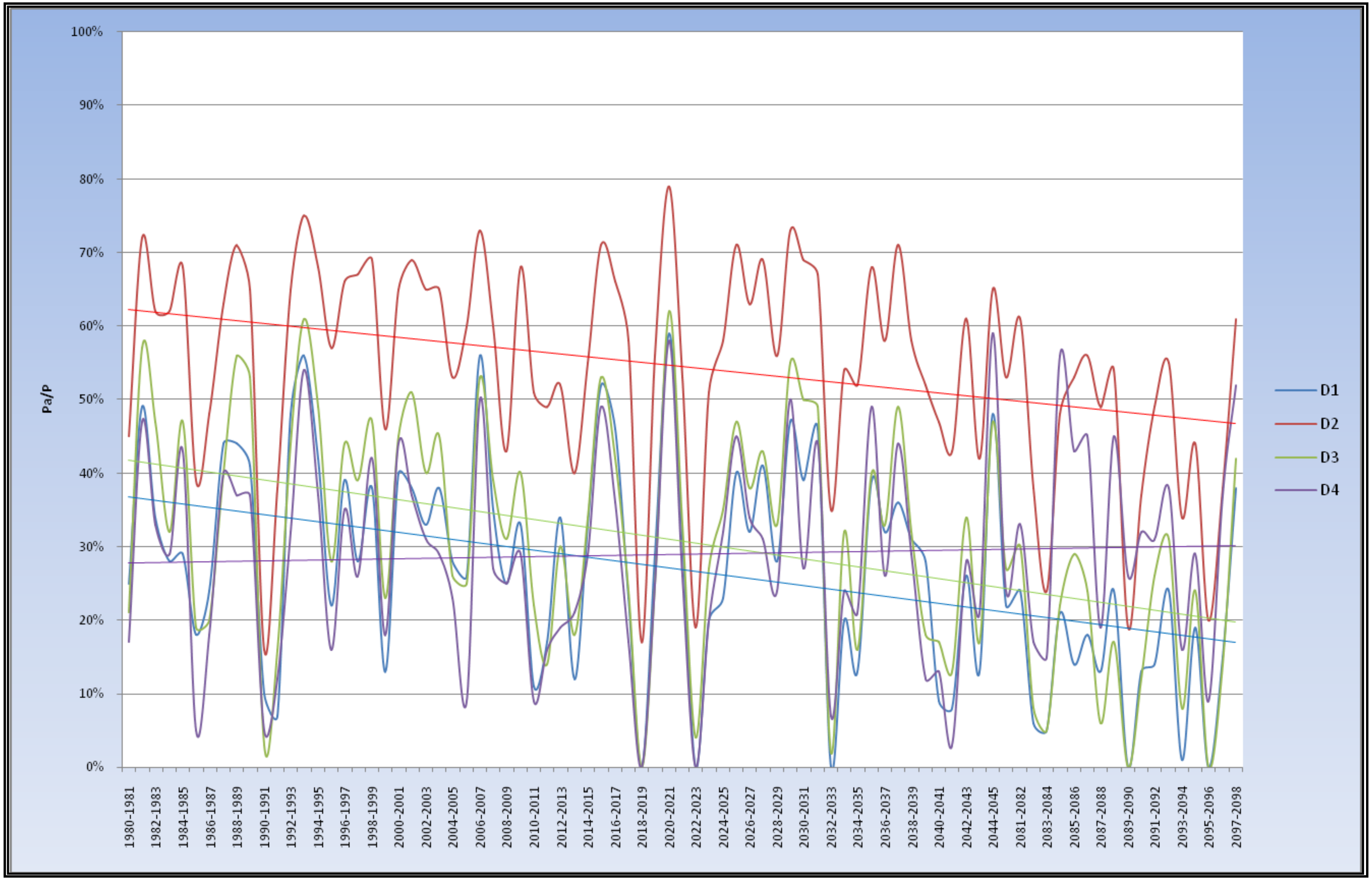


Figure 1-24 **Trend of the proportion of active precipitation out of total precipitation over time in the 4 grid boxes constituting the study area**

MEAN ANALYSIS

The mean results in terms of active precipitation out of total precipitation obtained can be found in Appendix B. The same analysis as above was conducted for four major climatological stations representing the whole Lebanese territory, yielding the following graphs and functions.

1. Beirut

The following graph (Figure 1-25) illustrates the analysis of mean results for Beirut over the three time-periods (1961-2000; 2025-2044; and 2080-2099):

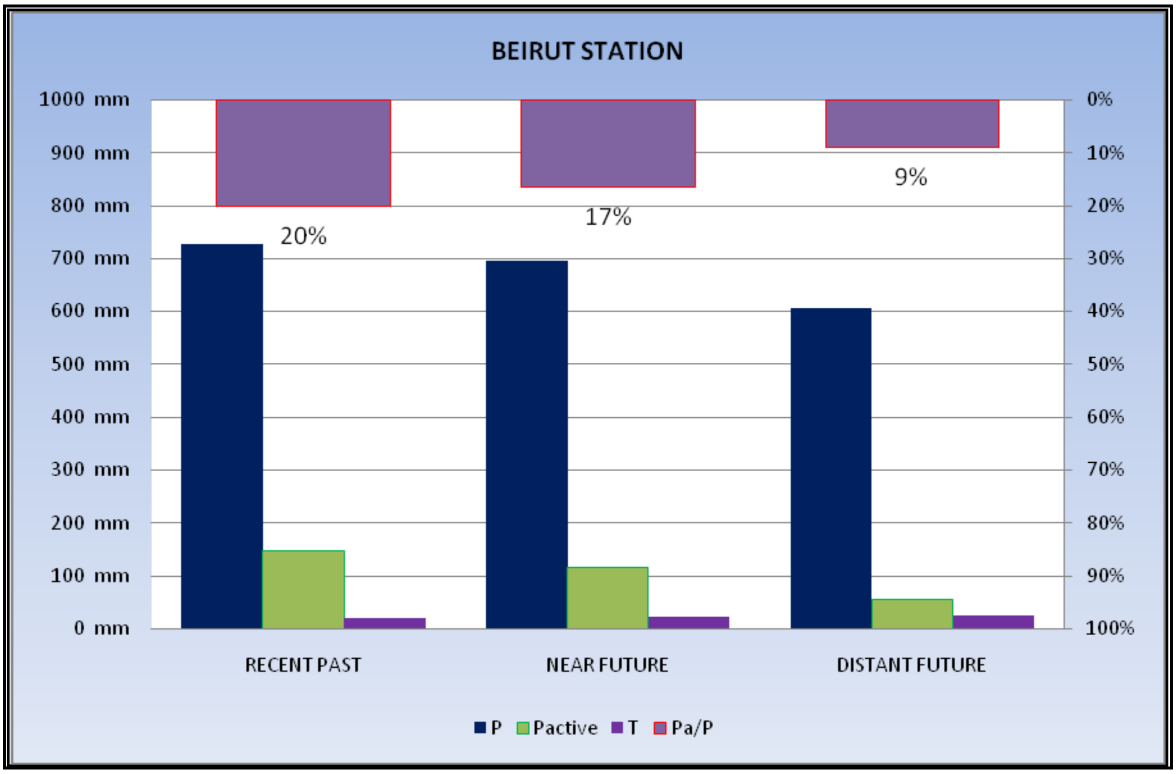


Figure 1-25 **Trend of temperature and active precipitation out of total precipitation over time for Beirut**

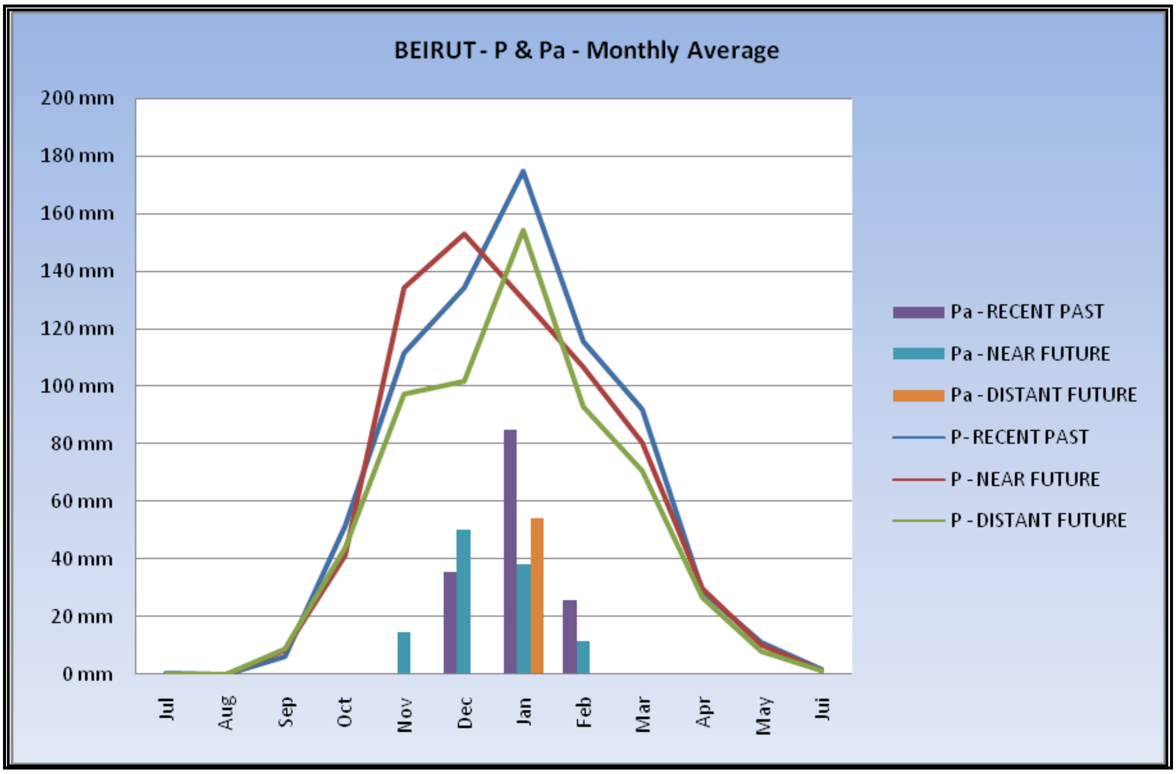


Figure 1-26 Monthly average of total and active precipitation in Beirut (past and projected)

Evapotranspiration is highest in Beirut, leading to the lowest Pa/P. Figure 1-25 shows a decline in Pa/P between the three consecutive periods of time. In addition to a forecasted decline in total and active precipitation mostly in the distant future, a shift in rainfall is expected in the near future, consisting of higher precipitation in November and December, and a steep decline from January onward (the decline in P being insignificant overall). The peak is noted in December. As for the distant future, the shape of the curve is similar to the recent past curve, but the amount of rainfall is lower (Figure 1-26).

2. Dahr el Baydar:

The following graph (Figure 1-27) illustrates the analysis of mean results for Dahr el Baydar over the three time-periods:

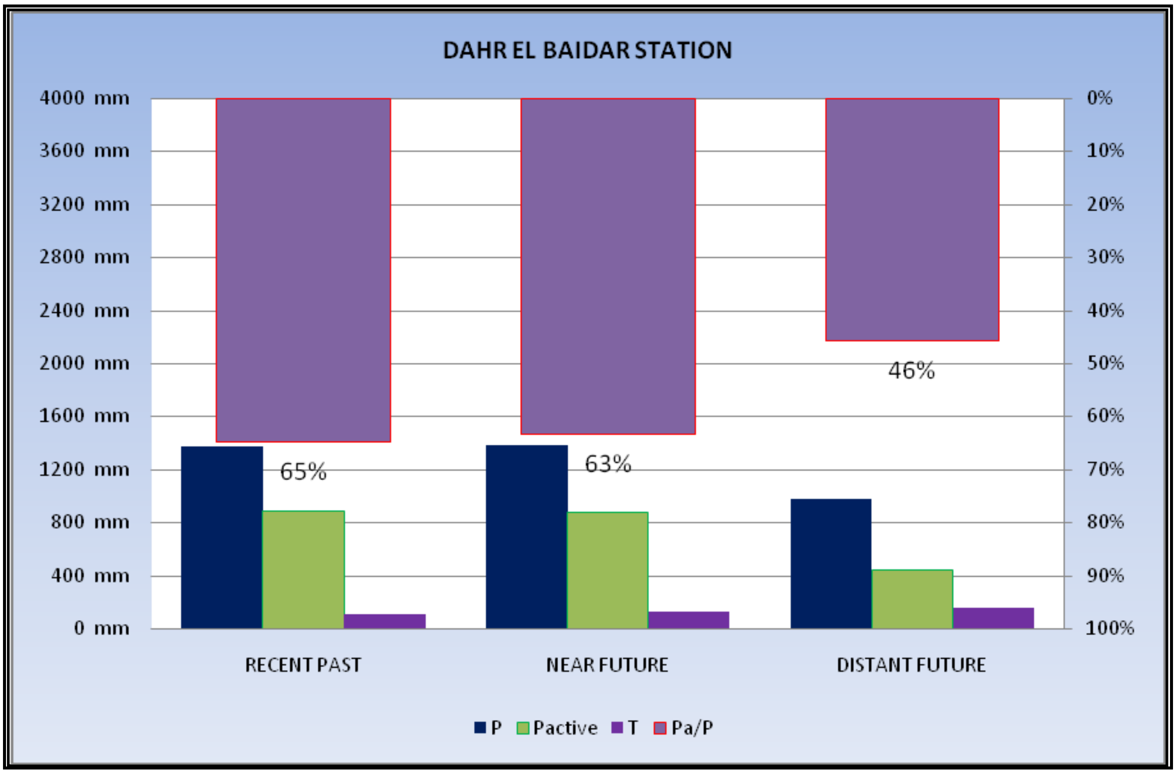


Figure 1-27 **Trend of temperature and active precipitation out of total precipitation over time for Dahr el Baydar**

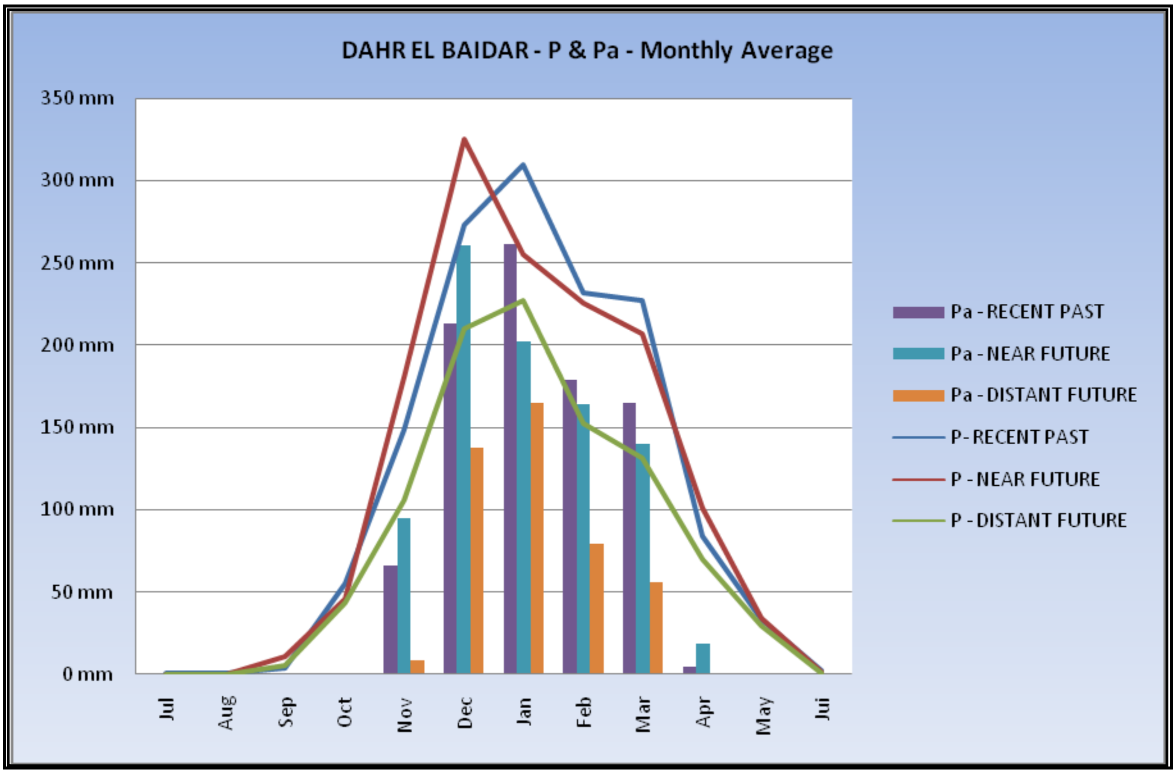


Figure 1-28 **Monthly average of total and active precipitation in Dahr el Baydar (past and projected)**

Pa/P is higher in Dahr el Baydar than in the other regions. Figure 1-27 shows a slight decline in Pa/P from the recent past to the near future, and a significant decline from the near future to the distant future. In addition, a shift in rainfall similar to Beirut is forecasted (Figure 1-28).

3. Cedars:

The following graph (Figure 1-29) illustrates the analysis of mean results for the Cedars over the three time periods:

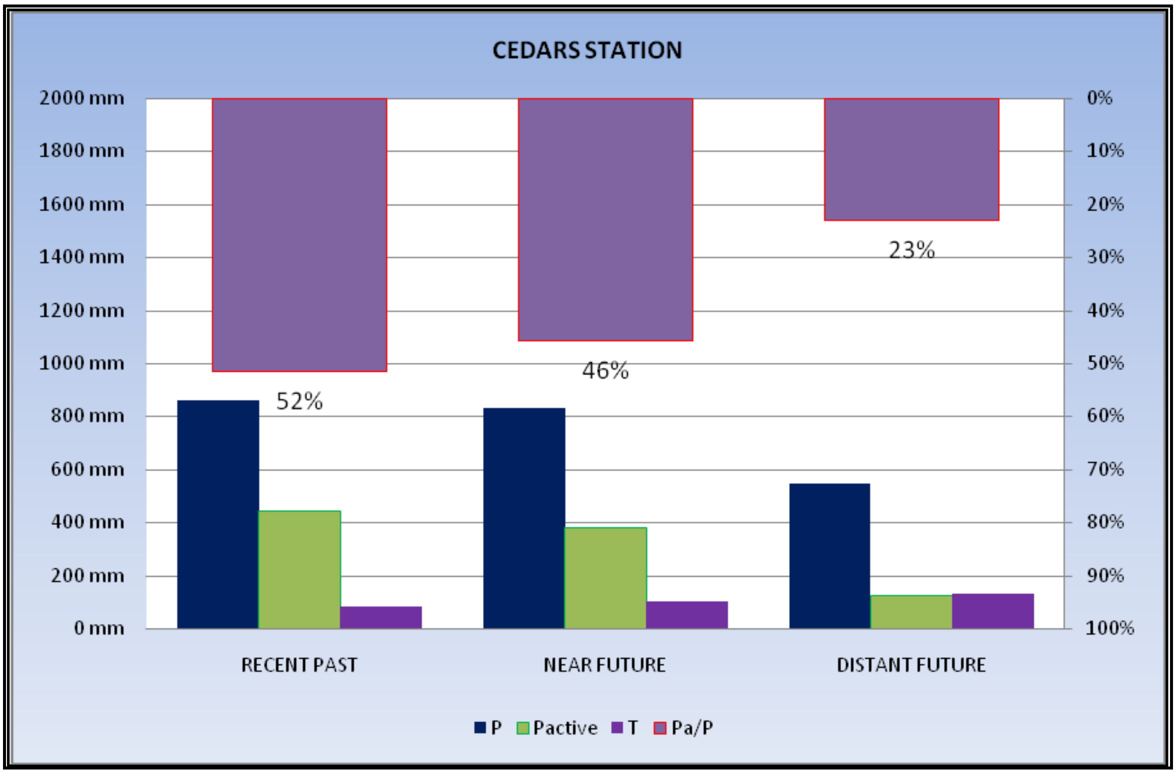


Figure 1-29 Trend of temperature and active precipitation out of total precipitation over time for the Cedars

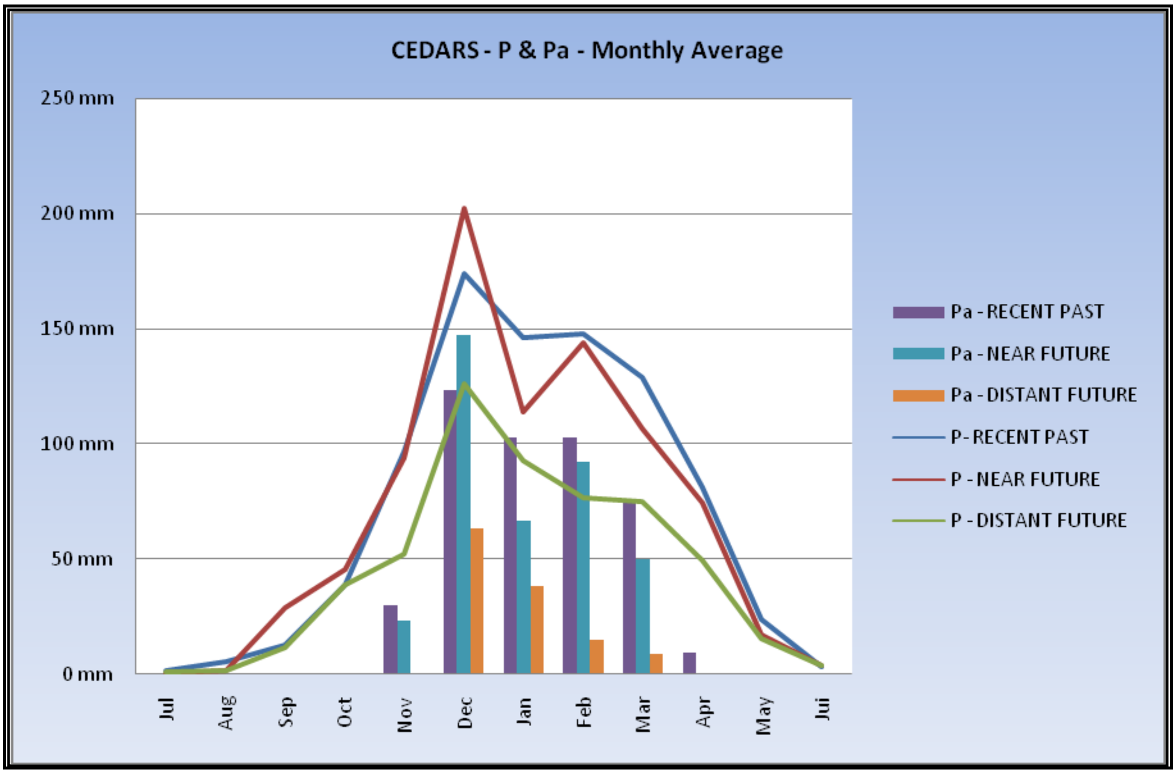


Figure 1-30 Monthly average of total and active precipitation in the Cedars (past and projected)

Pa/P is higher in the Cedars than in Beirut and Zahleh, but lower than in Dahr el Baydar. Figure 1-29 shows a slight decline in Pa/P from the recent past to the near future, and a significant decline from the near future to the distant future. In addition, a change in rainfall pattern is noted in the near future, consisting of higher rainfall in December, a steep decline in January and another peak in February that is not seen for the recent past. The overall decline in P is insignificant, and the highest peak is still noted in December. As for the distant future, the shape of the curve is similar to the recent past curve, but the amount of rainfall is significantly lower (Figure 1-30).

4. Zahleh:

The following graph (Figure 1-31) illustrates the analysis of mean results for Zahleh over the three time periods:

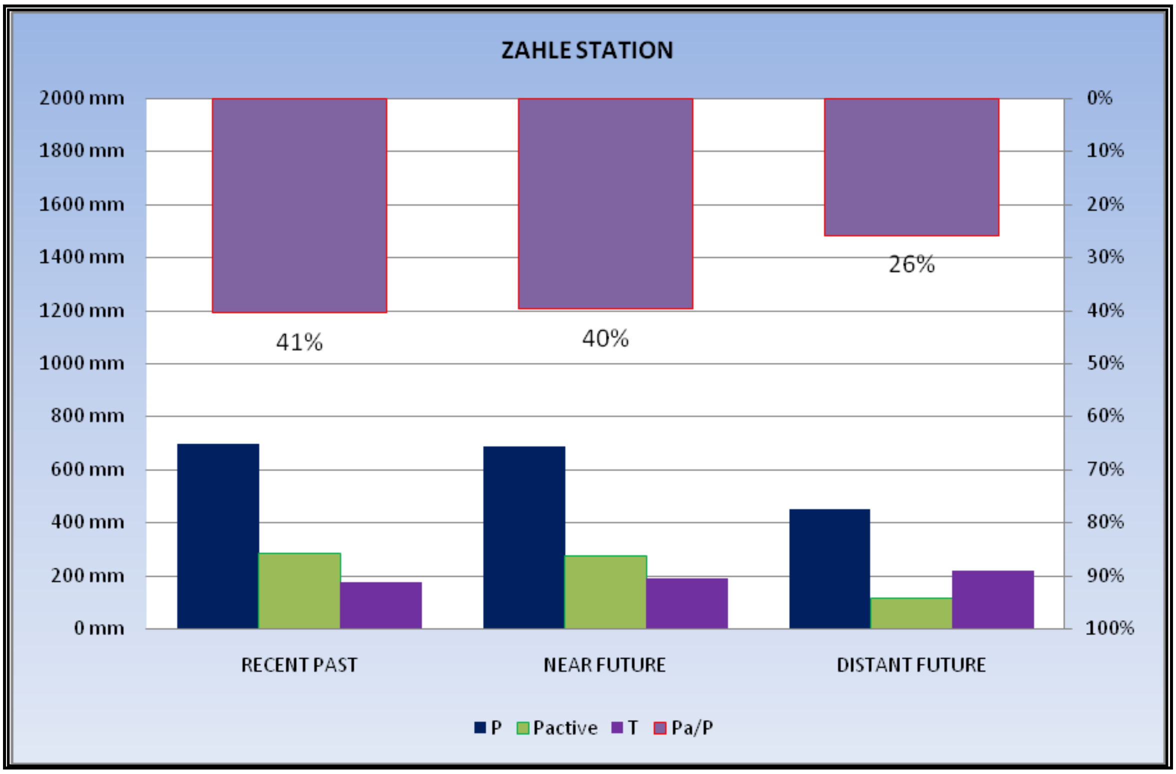


Figure 1-31 **Trend of temperature and active precipitation out of total precipitation over time for Zahleh**

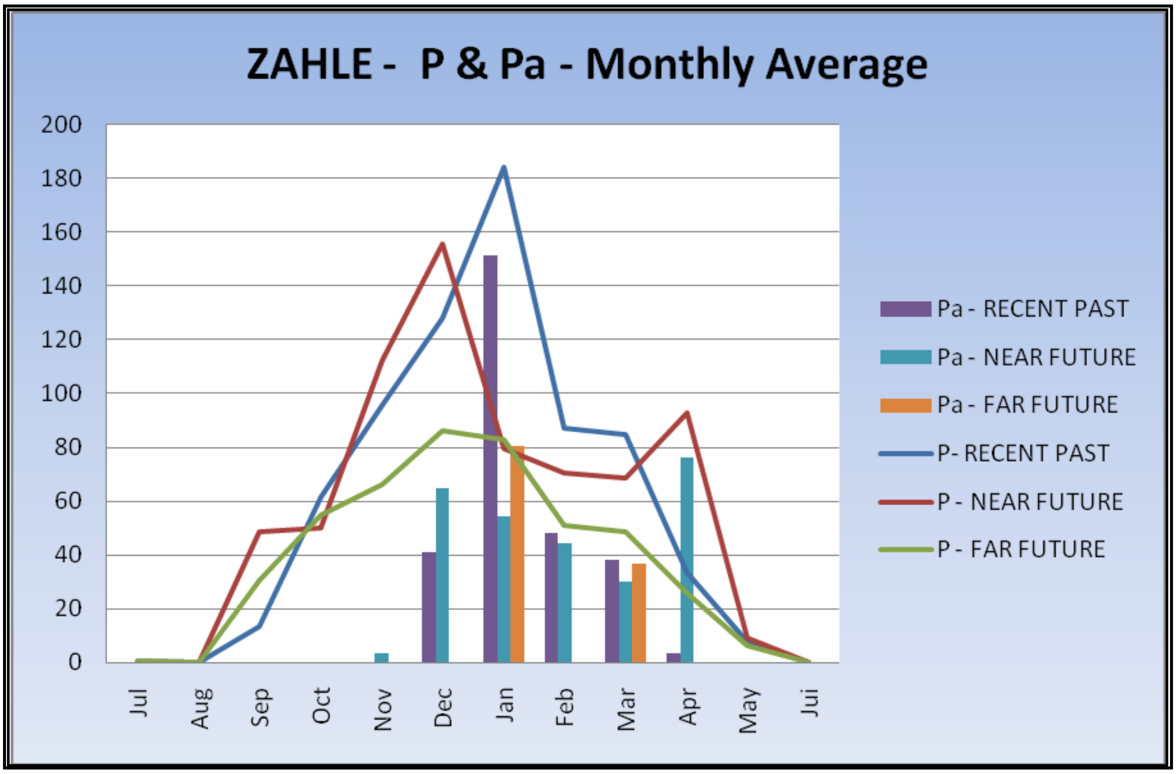


Figure 1-32 **Monthly average of total and active precipitation in Zahleh (past and projected)**

Figure 1-31 shows a significant decline in Pa/P from the near future to the distant future. In addition, a shift in rainfall is noted in the near future, with two peaks in December and April. As for the distant future, it exhibits a significant reduction in total and active precipitation (Figure 1-32).

Total decline in the proportion of Active Precipitation out of Total Precipitation

The decline in the percentage of active precipitation out of total precipitation in different sub-zones from the recent past average values to the average of the near future hydrological cycles, and from the near future cycles to the average of the distant future cycles, can reveal the extent to which a sub-zone will be affected by climate change.

The results shown in Table 1-23 are illustrated in the maps (Figure 1-33 to Figure 1-38). It is clear that the percent Pa/P declines considerably more in the second half of the century; the reduction being lowest in Dahr el Baydar and Zahleh (by the middle of the century), and highest in Beirut and the Cedars (by the end of the century).

Table 1-23 Decline in the proportion of active precipitation out of total precipitation in the different regions over time

	RECENT PAST		NEAR FUTURE		DISTANT FUTURE
BEIRUT	20%	-18%	17%	-46%	9%
DAHR EL BAYDAR	65%	-2%	63%	-28%	46%
CEDARS	52%	-11%	46%	-49%	23%
ZAHLEH	41%	-2%	40%	-35%	26%

Total decline in the proportion of Active Precipitation out of Total Precipitation in different sub-zones:

In order to generalize the results obtained in both the study area and the four major stations to the entire country, Lebanon was divided into 13 subzones according to isohyets and isotherms, as previously described. The results were reported into 6 maps showing the vulnerability of these sub-zones. Figure 1-33 to Figure 1-35 illustrate the proportion of active precipitation out of total precipitation for the recent past, near future and distant future respectively; while Figure 1-36 to Figure 1-38 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.

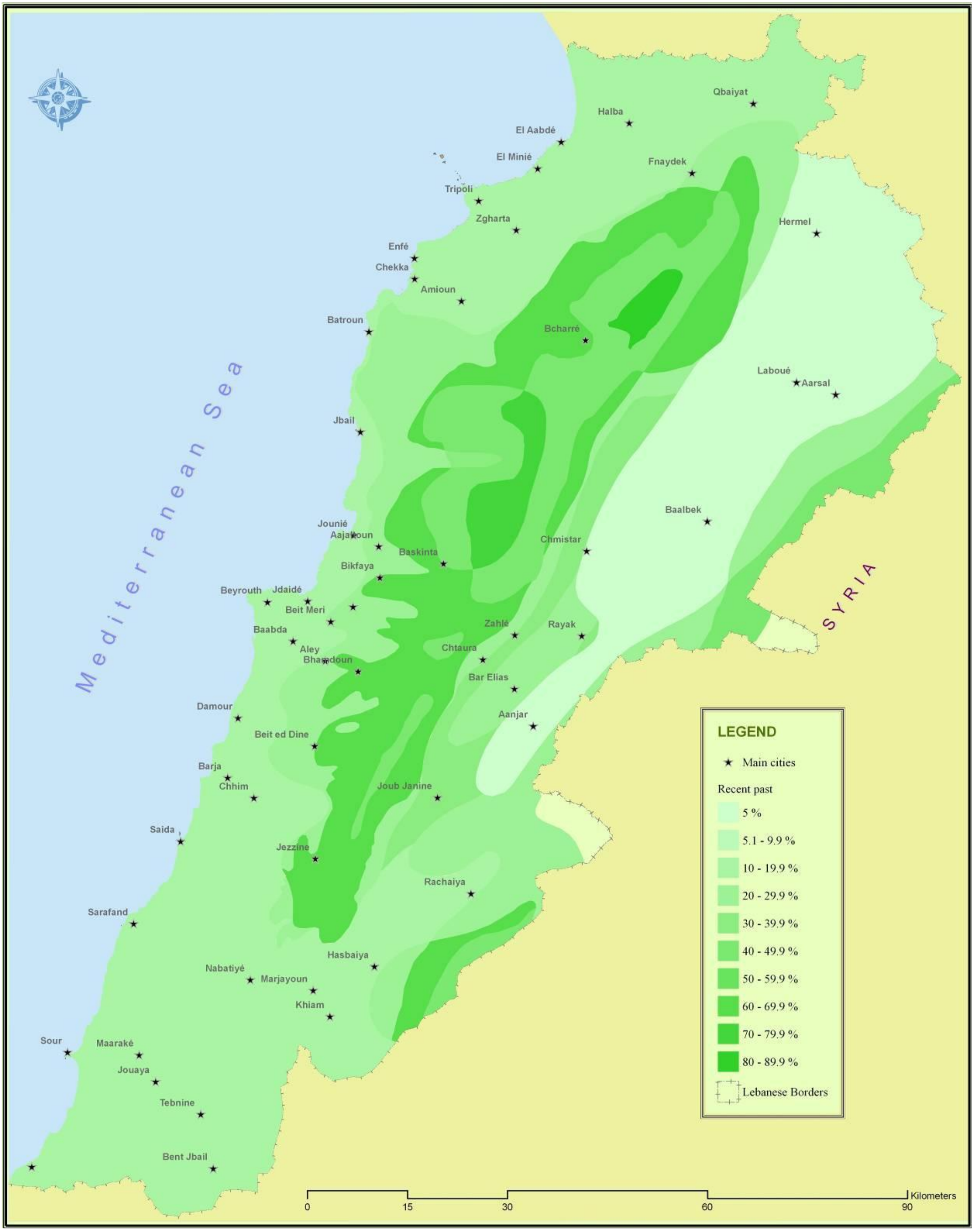


Figure 1-33 **Proportion of active precipitation out of total precipitation for the recent past (1960-2000)**

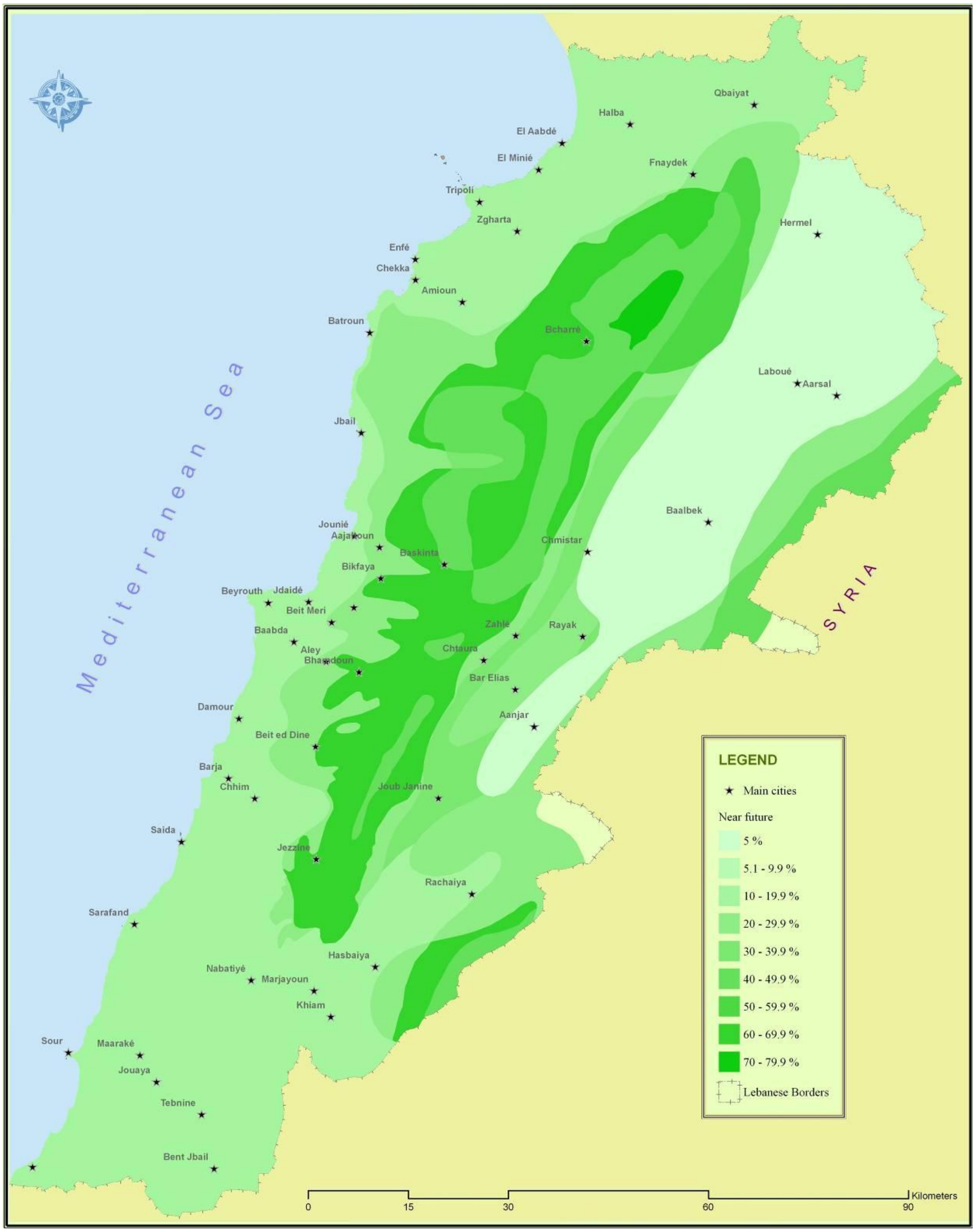


Figure 1-34 Proportion of active precipitation out of total precipitation for the near future (2025-2044)

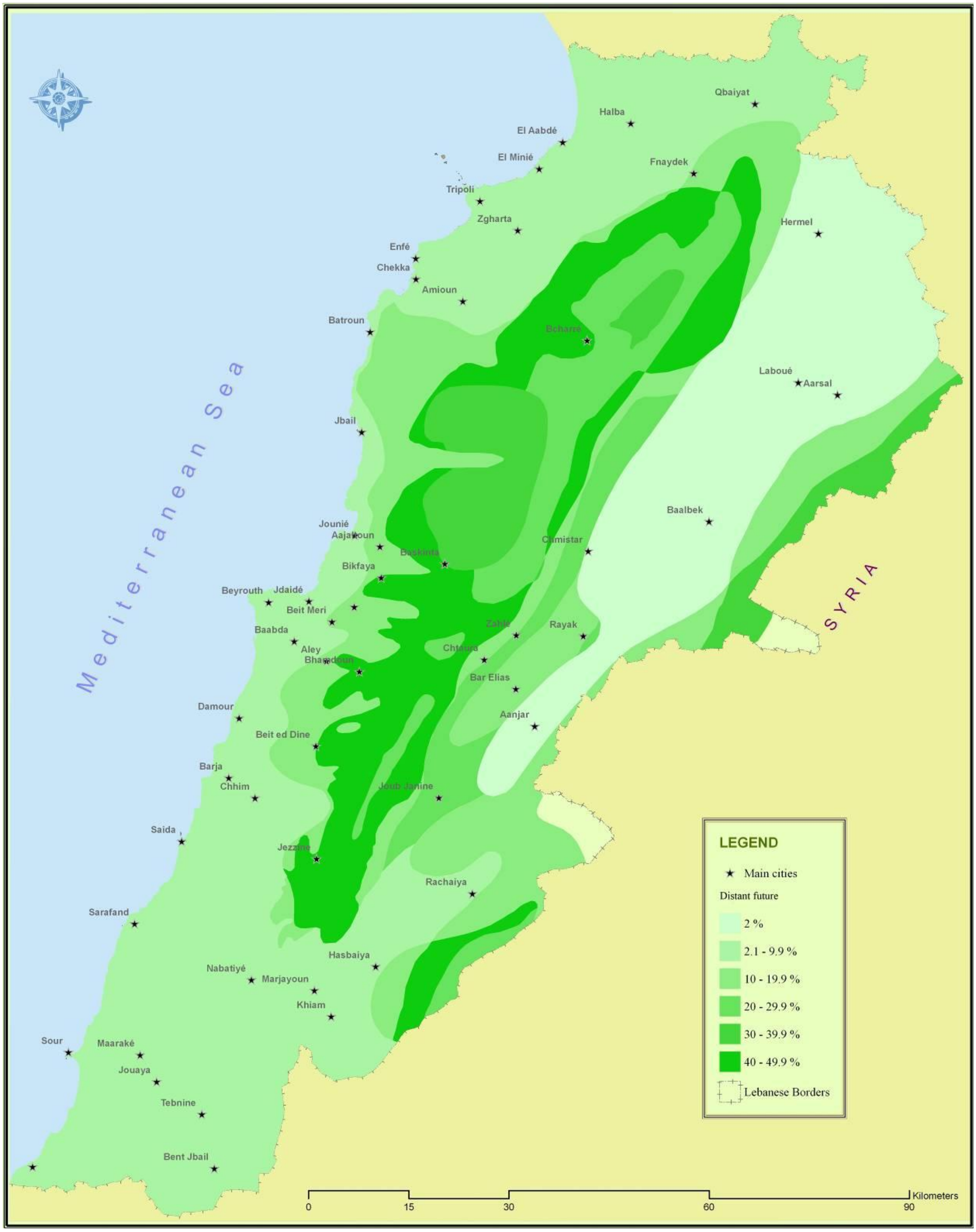


Figure 1-35 **Proportion of active precipitation out of total precipitation for the distant future (2080-2098)**

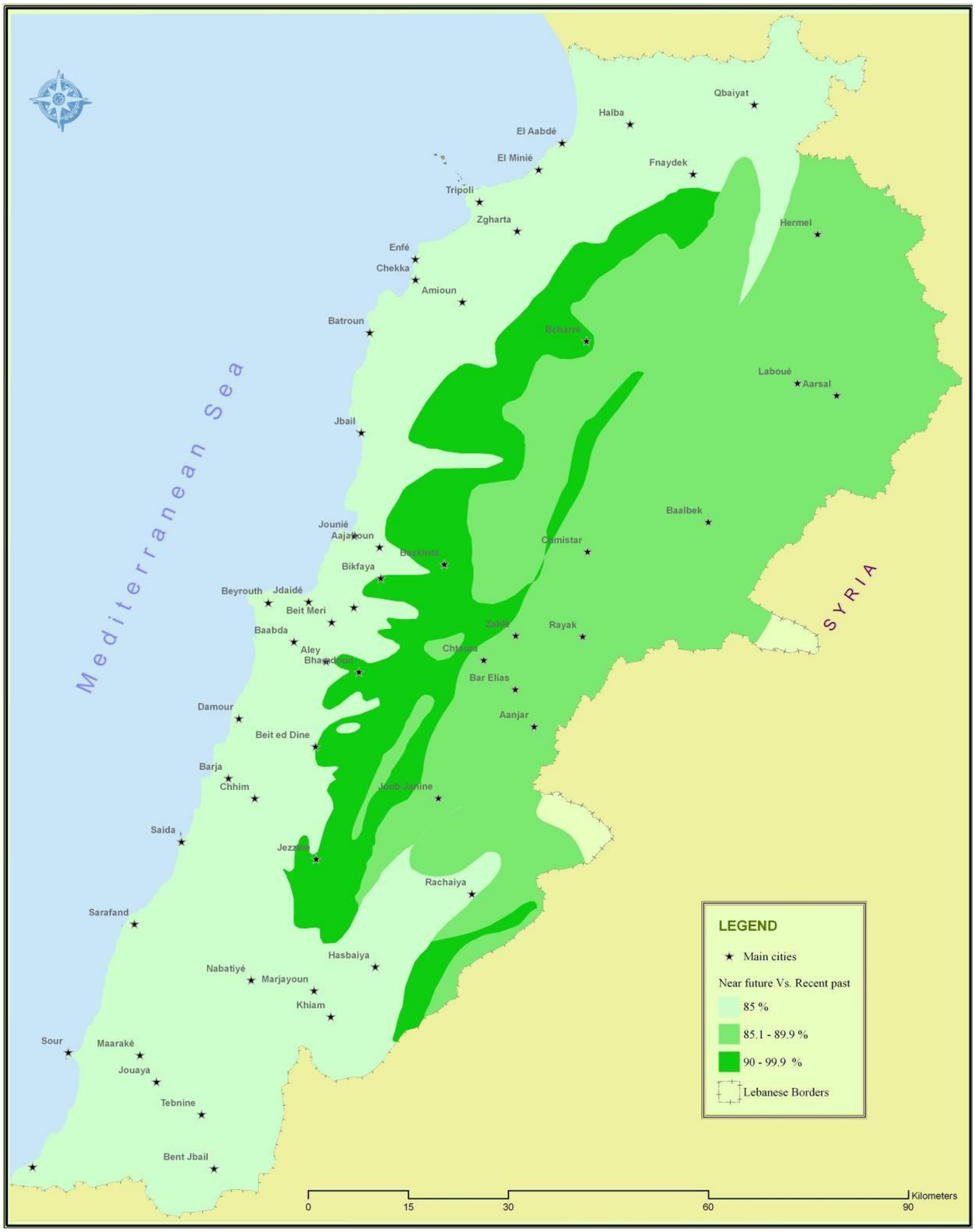


Figure 1-36 **Decline in the proportion of active precipitation out of total precipitation from the recent past (1960-2000) to the near future (2025-2044)**

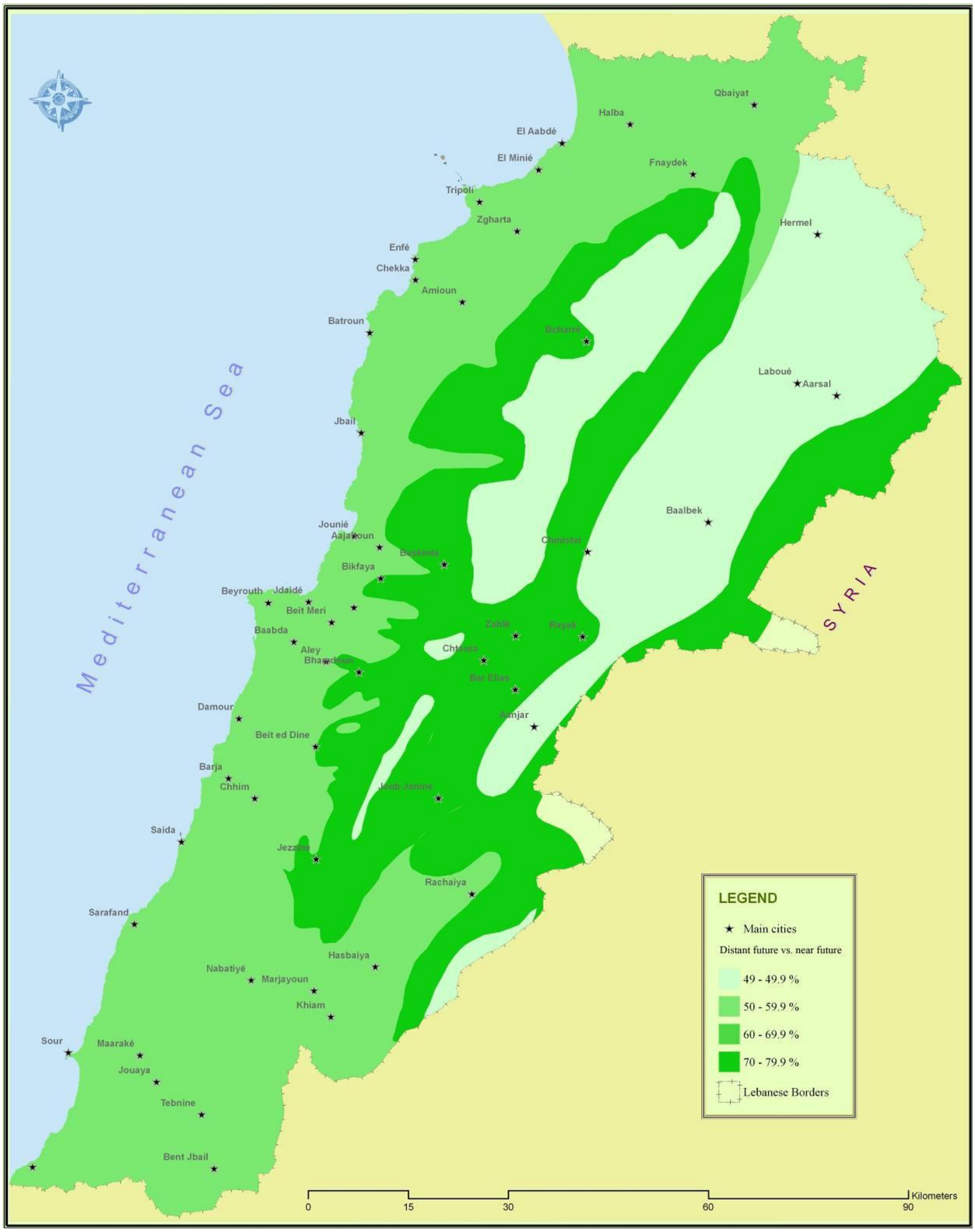


Figure 1-37 Decline in the proportion of active precipitation out of total precipitation from the near future (2025-2044) to the distant future (2080-2098)

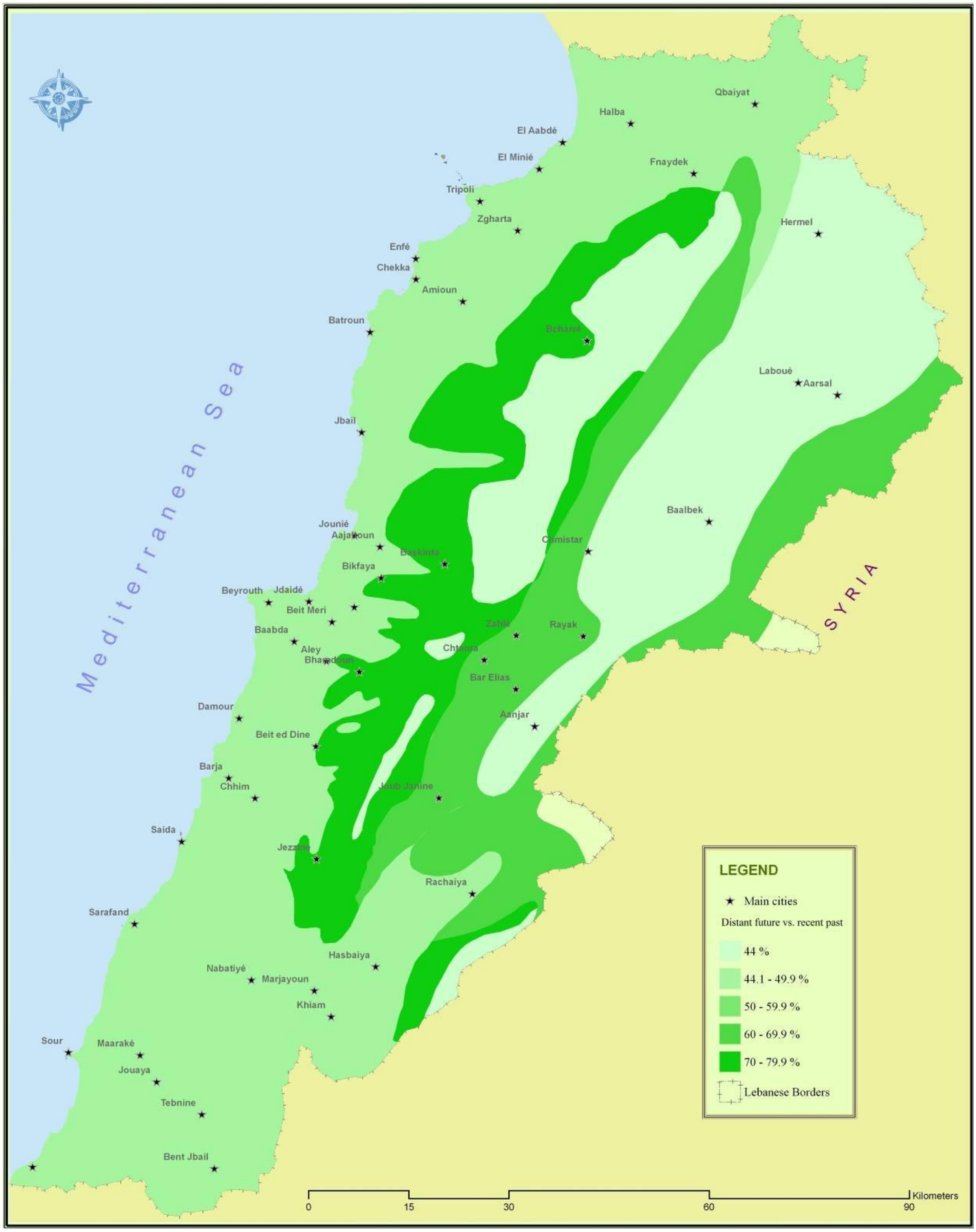


Figure 1-38 **Decline in the proportion of active precipitation out of total precipitation from the recent past (1960-2000) to the distant future (2080-2098)**

The work of Bakalowicz (2009) revealed that evapotranspiration is likely to increase by 6 to 16% depending on the scenario considered. As a consequence, the national water balance is likely to decline. Total water resources currently estimated at 2,800 to 4,700 Mm^3 are thus expected to drop to 2,550 - 4,400 Mm^3, which corresponds to a decrease of about 250 million m^3 per year in exploitable resources, if temperatures rise by 1°C. If temperatures rise by 2°C, water resources are expected to drop to 2,350- 4,100 Mm^3, which corresponds to a decrease of about 450 million m^3 per year.

The range considered here for current water resources takes into account both the uncertainty in knowledge, and the gap between exploitable resources in dry years and average interannual resources (Bakalowicz, 2009).

POTENTIAL IMPACT ON SNOW COVER:

In the absence of reliable in-situ measures on 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 was 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 (Figure1-39) (Shaban et al., 2009).

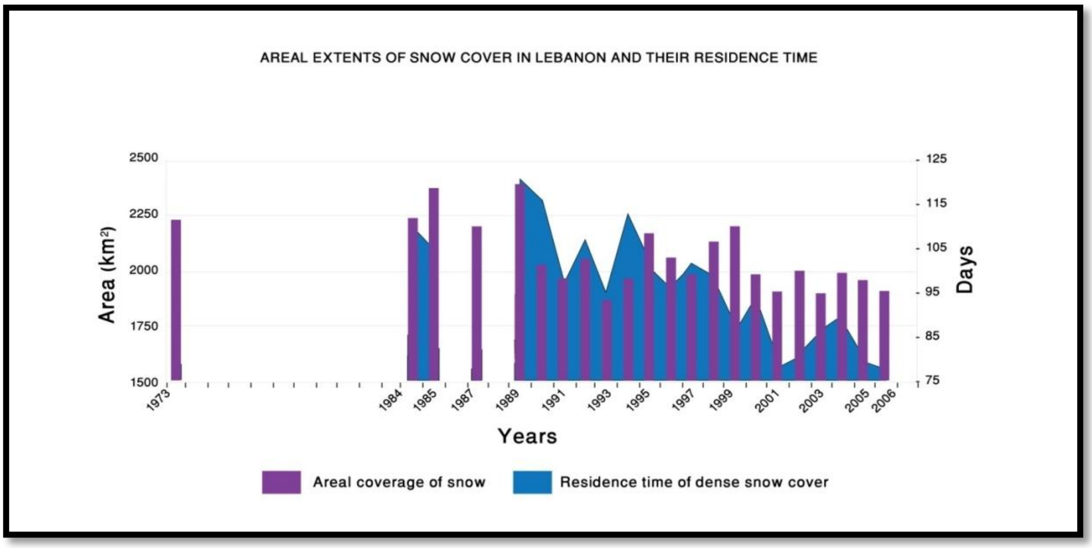


Figure1-39 Areal extents of snow cover in Lebanon and their residence time

Source: Shaban, 2009

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.

According to Hreiche et al. (2006 and 2007), temperature has a double effect on water equivalence of snow: it ensures the transformation of precipitation into snow if the temperature is rather low, and of snow into rain if it is rather high. Snowmelt is commanded by a threshold of temperature: when temperature at 2 meters off the ground is lower than 3°C, precipitation consists of snow. When this temperature is higher than 0°C, snow starts to melt. Between 0°C and 3°C, the two mechanisms are simultaneous and the stock evolves differently according to the intensity of precipitation and snowmelt.

This concept was used to assess the potential impact of a 2°C increase in temperature (in accordance with the PRECIS projections for mountainous regions inland) on the flow characteristics of the Nahr Ibrahim watershed that is strongly affected by snow cover for four months of the year

(Hreiche et al., 2007). A conceptual rainfall-runoff model -MEDOR- coupled to a stochastic model of rainfall and temperature, was used to estimate the change in runoff by simulation of 6 scenarios testing the response to the rainfall structure, the duration of rainy events, their frequency, and the duration of the rainy season. The model, which was successfully tested on several Mediterranean basins, used 50 years of temperature and rainfall data to simulate 50 years of streamflow output for two scenarios: 1) the reference scenario and 2) a 2°C increase in temperature.

The analysis results over 50 years show that snow width at the Cenomanian plateau of Nahr Ibrahim at an altitude of 2,000 m decreases tremendously (approximately 50%) with a 2°C warming, and mean width can reach as little as or less than 20 cm (Figure1-40). The maximum volume of snowpack is also greatly reduced (Figure1-41).

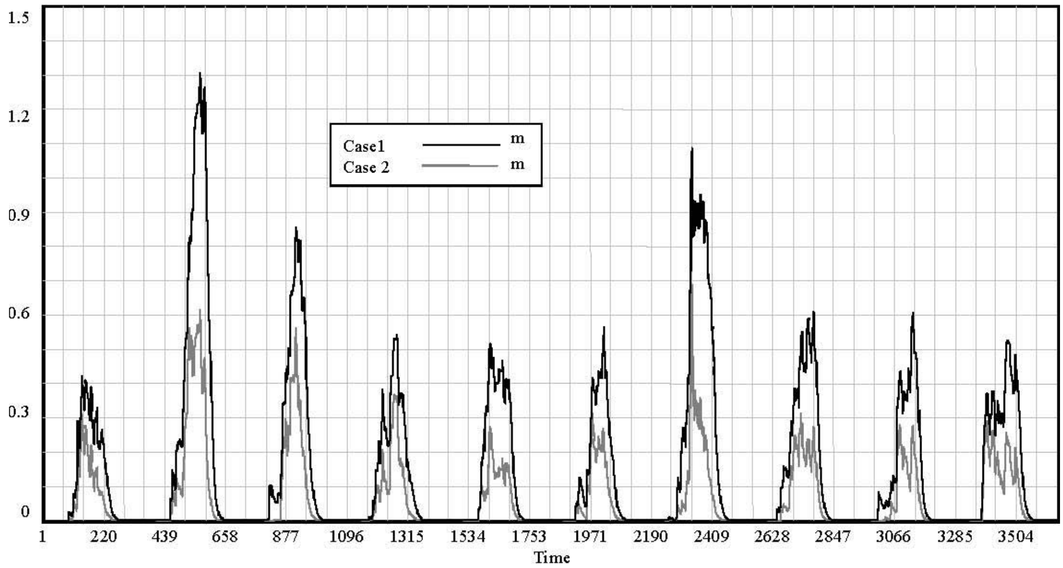


Figure1-40 Mean snow width generated over 10 years (Case 1: reference simulation; Case 2: scenario of an increase by 2°C).

Source: Hreiche et al., 2007

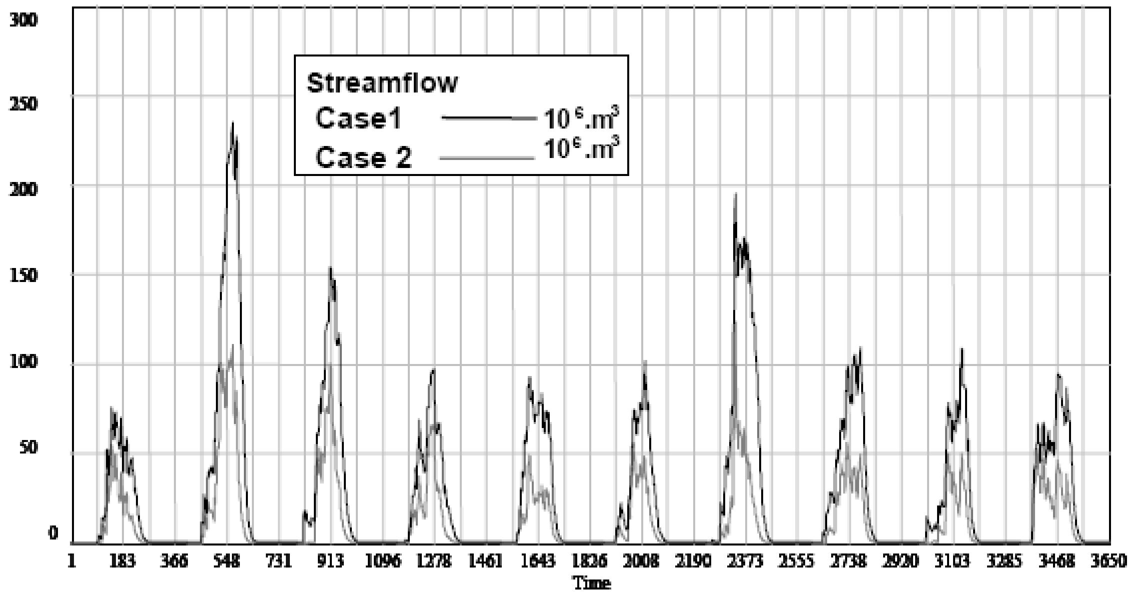


Figure1-41 Evolution of the snowpack in Nahr Ibrahim catchment simulated over 10 years (Case 1: reference simulation; Case 2: scenario of an increase by 2°C).

Source: Hreiche et al., 2007

With a 2°C increase in temperature, the modifications of the stream flow regimes are also significant. Drought periods would occur 15 days to one month earlier; thus, the drought period would be prolonged by this duration. Peak flow would shift from the end of April to the end of February; and snowmelt floods in April - May would often be replaced by rainfall floods. This would disturb the hydrological regimes of rivers such as Nahr Ibrahim and yield important water management problems.

Another study carried out by CREEN (Najem, 2007) on the upper basin of Nahr el Kalb, with data collection on snow between 1999 and 2004, estimates that a 2°C warming (equivalent) would 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 rise from 1,500 m to 1,700 m for a 2°C warming; and to 1,900 m for a 4°C warming. Negative consequences would follow on the tourism sector (as discussed in the Tourism chapter), as well as on springs and rivers, posing challenges on water resources management, as mentioned above. 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. Drought periods would occur 20 days earlier for a 2°C warming, and over a month earlier for a 4°C warming. In the latter case, winter floods along the coastal zone might increase by 30% or more. 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).

Other studies report a vertical temperature gradient - which corresponds to the variation in temperature with altitude - of -0.6 to -0.7°C/100 m as yearly average (Hakim, 1982, 1985 ; El-Hajj, 2008; Bakalowicz, 2009). This gradient is much higher during rainfall events, reaching -0.87 to -0.97°C/100 m. These are the values to be considered rather than annual average values, as the transition between rain and snow actually occurs during rainfall. Hence, for an increase of 0.8 to 1.0°C in temperatures, the average rain/snow limit can be expected to rise by about 100 m. For an increase of 1.6 to 2.0°C, the limit would rise by 200 m, and for 3°C, by about 300 m.

The volume of water stored in the snow cover, main source for the recharge of major mountain aquifers, is expected to decrease by about 50%. Faster runoff and infiltration would thus be incurred towards the beginning of the rainy season. 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.

The rise in altitude of the rain/snow limit is also expected to induce a reduction in the snow cover volume and hence in an equivalent amount of water. Subsurface runoff from snowmelt and slow infiltration would thus decrease, while fast runoff and infiltration intensify. This would lead to an increase in peak flows, especially towards the beginning of rainy seasons.

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. At a first stage, the flooded area (or groundwater reservoir) undergoes depletion while infiltration recharges it, as infiltration can last several weeks after precipitations or snowmelt have ceased. At a second stage, the flooded area is depleted without being recharged – that is recession. When recession is prolonged, discharges keep diminishing, exponentially. The lengthening of the recession period thus leads to the reduction of the volume of exploitable reserves, hence the reduction of groundwater levels and of 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.

These studies 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 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 and Najem, 2007).

1.1.5.4. Summary of Impact Assessment

The expected rise in average annual temperature will have both quantitative and qualitative consequences on water resources, mainly consisting of a reduction in global water reserves and of a change of the seasonal distribution of discharged volumes (Bakalowicz, 2009).

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..

Therefore, Integrated Water Resources Management plans in Lebanon, as well as projects and developments aiming at the regulation of seasonal variations, should consider a volume of exploitable resources in the range of 2,300 Mm^3 as a target for 2050.

Based on the above analysis, the following steps were used in illustrating the implications of future climatic changes on water resources under the two socio-economic scenarios defined above:

- Physical and economic indicators that would measure changes in the vulnerable coastal systems were chosen.
- Changes in the indicators under each of the two socio-economic scenarios were examined.
- Changes in the indicators under the climatic scenario were examined.
- The overall change in the indicators was assessed under each of the two socio-economic scenarios and under the likely climatic change scenario, i.e. combining the results from steps 2 and 3.

Table 1-24 illustrates these impacts by analyzing the severity of changes inflicted under each scenario on the different systems identified as vulnerable hotspots in section 1.1.4.3. Per capita consumption, as well as domestic, industrial and agricultural water demand, were identified as key indicators of water demand; renewable water resources and average water deficit as indicators of water availability; the unmet demand as an indicator of water supply; and the salinity of groundwater as an indicator of water quality. Accordingly, the overall changes induced by non-climatic and climatic factors were analyzed for each of the indicators.

The analysis clearly shows that the impacts are expected to be more severe under scenario B, as most indicators are projected to undergo harsher changes under that scenario than under scenario A. 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.

Table 1-24 Impact of Climate Change on Specific Indicators

VULNERABLE HOTSPOTS	INDICATORS	CHANGES IN INDICATORS UNDER NON-CLIMATIC (BUSINESS-AS-USUAL) SCENARIOS		CHANGE IN CLIMATIC FACTORS	CHANGES IN INDICATORS UNDER A CLIMATE CHANGE SCENARIO	OVERALL CHANGE IN INDICATORS	
Water demand	Per capita consumption Demand- domestic sector Demand- industrial sector Demand- agriculture sector	Scenario A	Slight increase Slight increase Moderate increase No increase	Increase in temperature	Moderate increase Moderate increase Moderate increase High increase	Scenario A	Moderate increase Moderate increase Moderate increase High increase
		Scenario B	High increase High increase High increase Moderate increase			Scenario B	High increase High increase High increase High increase
Water availability	Renewable water resources (m^3/ capita/ year) Average % water deficit	Scenario A	Slight decrease Slight increase	Increase in temperature Decrease in precipitation Increase in evapotranspiration	Moderate decrease Moderate increase	Scenario A	Moderate decrease Moderate increase
		Scenario B	Moderate decrease Moderate increase			Scenario B	Moderate decrease Moderate increase
Water supply	Unmet demand (hours/ day)	Scenario A	Slight decrease		Moderate increase	Scenario A	Slight increase
		Scenario B	Moderate increase			Scenario B	Moderate increase
Water quality	Salinity of groundwater	Scenario A	Slight increase		Moderate increase	Scenario A	Moderate increase
		Scenario B	High increase			Scenario B	High increase

1.2. ADAPTATION MEASURES

Adaptation measures for the water sector include the following:

1. Implementing the planned wastewater treatment plants throughout the country in order to preserve surface and groundwater quality.

2. Establishing a database of groundwater resources, aiming at:

- Identifying un-exploited and overexploited aquifers;
- Identifying major karstic zones and defining optimal drilling sites;
- Defining major aquifers' vulnerability to pollution, and accordingly defining protective buffer zones with restricted to be integrated into future land use plans;
- Identifying potential sites for artificial recharge operations (as described below);
- Identifying potential sites for the extraction of brackish groundwater with a view to establishing brackish groundwater desalination plants.

1. Developing and promoting sound management of water resources, dams and hill lakes so as to reduce seasonal variations and defining a priority use for each dam (potable water/ hydroelectricity/ irrigation/ tourism), so as to optimize the use of scarce resources. Dams and hill lakes' role is to store rainwater for use during the dry period, which preserves groundwater resources that become strategic reserves. It is essential here to take into consideration the potential increase in evaporation losses from reservoirs and artificial lakes at planning stages to account for the expected increase in evapotranspiration over the next decades. In this context, relying on aquifer storage rather than surface storage of water would decrease losses through evapotranspiration.

2. Revising water pricing for domestic use, through increasing block rate, or tiered pricing, which reduces water use by increasing per-unit charges for water as the amount used increases. For instance, the first volume of water (block) used is charged a base rate, the second block is charged the base rate plus a surcharge, and the third block is charged the base rate plus a higher surcharge using metering systems. It is also important to impose strict fees on coastal well abstractions in order to control seawater intrusion. Progressive charges impose a self-control mechanism on the user and ensure that wasteful consumption is minimized. Penalties must also be imposed for over-abstraction by the pertinent authorities, namely the Ministry of Energy and Water.

3. Enhancing infrastructure to support water conservation, through the allocation of funds for the rehabilitation of the existing water infrastructure and supply network (reservoirs, canals, network, meters, etc.). One important aspect is the control of leaks from canals and conduits, which can be facilitated through the use of modern network management and tracking systems**.** The use of new technology must be linked with development of the human resources specifically at the Water and Wastewater Authorities and the MoEW.

4. Reconsidering water fees for irrigation purposes through:

- The promotion of efficient irrigation by raising water exploitation fees while providing financial incentives and subsidies for the use of water-efficient irrigation schemes (such as drip irrigation) and equipments;
- Restriction of well drilling permits;
- Conducting regular inspections of wells, meters, etc.

5. Developing an agricultural policy that redefines crop types per region based on water needs and availability

6. Promoting water reuse at all levels:

- Promoting the reuse of greywater[7], by designing plumbing systems to separate it from blackwater. Greywater can be recycled for use in irrigation, toilets, and exterior washing, resulting in water conservation. This measure can be initiated for new buildings as a start, through a reduction of permit fees for buildings incorporating greywater reuse in their design.
- Promoting water harvesting, which is the gathering or collection and storage of rainwater. Rainwater harvesting can be done both in large-scale landscapes, such as parks, schools, commercial sites, parking lots and apartment complexes, and in small residential landscapes. Roof catchment systems can be used for that purpose.
- Adopting Best Management Practices for storm water runoff management, which has the following advantages: protection of wetlands and aquatic ecosystems, improved quality of receiving water bodies, conservation of water resources, protection of public health, and flood control.
- Collecting and storing storm water for reuse in irrigation.
- Promoting the reuse of treated sewage (recycled or reclaimed water) for irrigation purposes once wastewater treatment plants are constructed and operational. Guidelines would need to be developed and adopted to ensure that quality and safety requirements are met. Appendix A provides a list of international and regional guidelines and standards (WHO, US EPA, Australia, Jordan, Kuwait, and Saudi Arabia) setting quality parameters for the different water reuse categories

7. Recharging coastal aquifers using water sources complying with international standards for aquifer recharge. This measure has been proven to protect groundwater from seawater intrusion by displacing the saltier groundwater, thus allowing the conservation of groundwater resources (Karam, 2002). An attempt to recharge a costal groundwater aquifer (Hadeth-Cenomanian aquifer) has been undertaken since 1961 in the context of the «Projet d'étude des eaux souterraines au Liban» (Joint project between the UNDP, FAO and the Lebanese government). The recharge has consisted of injecting water from Beirut river through the Deychouniyeh irrigation canal into two wells drilled in the Hadath area. This has lead to a perceptible increase in the water level in the targeted aquifer (Massaad, 1971). Groundwater recharge can also be used to preserve water levels in wetlands that are maintained by groundwater.

   The recharged coastal aquifers would not be exploited, and their role would be to prevent saltwater from intruding into those aquifers located away from the shore, which can then be exploited to provide fresh water for the different sectors. Surface water that is used to generate hydropower in major rivers can be used to recharge coastal aquifers after conducting simple sedimentation in ponds.

8. Building and recharging artificial groundwater reservoirs: the main purpose of aquifer recharge is to store excess water in times of surplus to meet need in times of demand for later use (for

7 (wastewater from bathtub, shower drain, sinks, washing machines, and dishwashers), which accounts for around 60% of the outflow produced in homes, and contains little or no pathogens and 90% less nitrogen than black water (toilet water). Because of this, it does not require the same treatment process.

irrigation and other uses), while improving water quality by recharging the aquifer with high quality water.

9. The water withdrawn from the aquifer can be used for irrigation purposes. These and other possible uses of the water (e.g., increase of drinking water supplies) will depend on public acceptance of such schemes (CSIRO, 2009). Aquifer recharge can be done through injection or infiltration. Injection is carried out using a bore (injection well) or series of bores, generally for deeper or confined aquifers. Infiltration is preferred from an environmental and economic point of view. Infiltration methods include recharge basins/ small dams, surface spreading, irrigation pits, and trenches (EPA, 2005).
10. 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.
11. 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.
12. Establishing a Lebanese Centre for Water Conservation and Management, responsible for:

- Identifying needs and conducting technical capacity building on sustainable water management with public institutions, notably the MoEW;
- Coordinating efforts for establishing a groundwater database;
- Conducting a national awareness raising campaign on sustainable water use and management.

Table 1-25 presents the proposed adaptation action plan for the water sector. It should be noted that the indicative budget is a rough estimate based on professional judgment, and sometimes reflects the cost of studies that need to be carried out prior to the implementation of the proposed activities. Each of the mentioned activities requires an in-depth assessment to determine its actual cost at the time of planning and implementation.

Table 1-25 Water Sector Adaptation Action Plan

IMPACT	PROPOSED ADAPTATION STRATEGY	ACTIVITIES	RESPONSIBILITY	PRIORITY (ST/ MT/ LT)	INDICATIVE BUDGET (USD)	SOURCES OF FINANCING/ IMPLEMENTATION PARTNERS
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 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 - Develop a comprehensive database of groundwater wells	MoEW Water and Wastewater establishments Municipalities	ST	1 to 5 million	MoEW budget International donors
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 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	MoEW MoF LRA MoA Water and Wastewater Establishments MoE Local authorities	ST	1 to 2 million for technical assistance and development of implementation budgets	MoEW budget USAID Other bi-lateral cooperation agencies Adaptation fund

IMPACT	PROPOSED ADAPTATION STRATEGY	ACTIVITIES	RESPONSIBILITY	PRIORITY (ST/ MT/ LT)	INDICATIVE BUDGET (USD)	SOURCES OF FINANCING/ IMPLEMENTATION PARTNERS
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 Emphasize the importance of aquifer recharge in water sector plans and strategies.	MoEW Water and Wastewater Establishments LRA	ST	200,000 to 800,000 per watershed; 500,000 for awareness campaign	MoEW budget Bi-lateral cooperation EU FP7 (regional cooperation)
	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	MoE Water and Wastewater Establishments MoA DGUP CNRS Academic institutions (Balamand- Institute of Environment, AUB, USJ)	ST	5 to 10 million	Bi-lateral cooperation

IMPACT	PROPOSED ADAPTATION STRATEGY	ACTIVITIES	RESPONSIBILITY	PRIORITY (ST/ MT/ LT)	INDICATIVE BUDGET (USD)	SOURCES OF FINANCING/ IMPLEMENTATION PARTNERS
	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 and implement a snow cover monitoring program in partnership with the private sector where possible (ski resorts operators).	MoEW Water and Wastewater Establishments LRA CNRS Academic institutions Private sector	ST	250,000 for program development	ESCWA Bi-lateral cooperation agencies including: USAID AFD Italian Cooperation

1.3. RECOMMENDATIONS FOR FURTHER WORK

The following recommendations for further work to improve and facilitate the analysis of vulnerability of the water sector to climate change and its expected impacts can be made:

- River and spring flows should be monitored continuously, and relevant data should be centralized and made accessible for future studies;
- Research and measurements of snow cover should be initiated by public authorities in order to provide a database and allow long-term monitoring of potential changes; the private sector (owners of ski resorts) can be important partners in such monitoring campaigns.
- Climatic data (particularly precipitation and temperature) should be collected by one agency that should analyze it and develop trends to compare with historical data and detect any changes.

APPENDIX A:

The WHO "*Guidelines for the safe use of wastewater, excreta and greywater*" were designed to protect the health of farmers (and their families), local communities and product consumers. They are meant to be adapted to take into consideration national sociocultural, economic and environmental factors. Table 1 presents recommended microbiological guidelines for reuse in agriculture.

The guidelines have been revised in 2006. The revised "Guidelines for the safe use of wastewater, excreta and greywater" describe minimum requirements of good practice and provide information that is then used to derive health-based targets. However, neither the minimum good practices nor the health-based targets are mandatory limits.

Table 1 Recommended Microbiological Quality Guidelines for Wastewater Use in Agriculture[a] (WHO, 1989)

CATEGORY	REUSE CONDITION	EXPOSED GROUP	INTESTINAL NEMATODES[B] (/L*[C])	FAECAL COLIFORMS (/1000ML**[C])	WASTEWATER TREATMENT EXPECTED TO ACHIEVE REQUIRED QUALITY
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parks[d]	Workers, consumers, public	≤1	≤1000	A series of stabilization ponds designed to achieve the microbiological quality indicated, or equivalent treatment.
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees[e]	Workers	≤1	None set	Retention in stabilization ponds for 8-10 days or equivalent helminth removal.
C	Localised irrigation of crops if category B if exposure of workers and the public does not occur	None	Not applicable	Not applicable	Pre-treatment as required by the irrigation technology, but not less than primary sedimentation.

a In specific cases, local epidemiological, sociocultural and environmental factors should be taken into account, and the guidelines modified accordingly.

b Ascaris and Trichuris species and hookworms.

c During the irrigation period.

d A more stringent guideline (≤200 faecal coliforms/100ml) is appropriate for public lawns with which the public may come into direct contact.

e In the case of fruit trees, irrigation should cease 2 weeks before the fruit is picked and none should be picked off the ground.

* Arithmetic mean

** Geometric mean

Many countries have adopted much stricter guidelines than those recommended by the WHO (CMHC, 2005). The United States appears to have the greatest number of standards, with each state developing its own guidelines, regulations and monitoring programs (CMHC, 2005). The most widely known standard is California's *Title 22*, upon which many standards in North America and abroad are based.

The U.S. Environmental Protection Agency (USEPA) has issued manual titled *Guidelines for water reuse* and revised it in 2004 to assist regulating agencies in developing reuse programs and regulations. It included an inventory of all state regulations, including California's (presented in Table 2 below).

Based on the inventory, current regulations and guidelines were divided into the following reuse categories:

- Unrestricted urban reuse – irrigation of areas in which public access is not restricted, such as parks, playgrounds, school yards, and residences; toilet flushing, air conditioning, fire protection, construction, ornamental fountains, and aesthetic impoundments.
- Restricted urban reuse – irrigation of areas in which public access can be controlled, such as golf courses, cemeteries, and highway medians.
- Agricultural reuse on food crops – irrigation of food crops which are intended for direct human consumption, often further classified as to whether the food crop is to be processed or consumed raw.
- Agricultural reuse on non-food crops – irrigation of fodder, fiber, and seed crops, pasture land, commercial nurseries, and sod farms.
- Unrestricted recreational reuse – an impoundment of water in which no limitations are imposed on body-contact water recreation activities.
- Restricted recreational reuse – an impoundment of reclaimed water in which recreation is limited to fishing, boating, and other non-contact recreational activities.
- Environmental reuse – reclaimed water used to create manmade wetlands, enhance natural wetlands, and sustain or augment stream flows.
- Industrial reuse – reclaimed water used in industrial facilities primarily for cooling system make-up water, boiler-feed water, process water, and general washdown.
- Groundwater recharge – using infiltration basins, percolation ponds, or injection wells to recharge aquifers.
- Indirect potable reuse – the intentional discharge of highly treated reclaimed water into surface waters or groundwater that are or will be used as a source of potable water.

Table 2 Standards for the State of California (source: US EPA, 2004)

	Unrestricted Urban Reuse; Agricultural Reuse (food crops) and Unrestricted Recreational Reuse	Restricted Urban Reuse and Agricultural Reuse (non-food crops)	Restricted Recreational Reuse	Industrial Reuse	Ground-water Recharge
Treatment	Oxidized, coagulated, filtered, and disinfected	Secondary - 23, oxidized, and disinfected	Secondary - 23, oxidized, and disinfected	Oxidized and disinfected	Case-by-case basis
BOD5	NS	NS	NS	NS	
TSS	NS	NS	NS	NS	
Turbidity	2 NTU (Avg)	NS	NS	NS	
	5 NTU (Max)				
Coliform	2.2/100 ml (Avg)	23/100 ml (Avg)	2.2/100 ml (Avg)	23/100 ml (Avg)	
	23/100 ml (Max in 30 days)	240/100 ml (Max in 30 days)	23/100 ml (Max in 30 days)	240/100 ml (Max in 30 days)	

NS: Not Specified by State Regulation

Different states and territories in Australia also have different sets of requirements regarding the reuse of treated waste water. Table 3 below presents the guidelines relative to the Australian Capital Territory.

Table 3 Australian Capital Territory Wastewater Reuse Guidelines for Irrigation (source: CMHC, 2005)

REUSE APPLICATION	REUSE QUALITY REQUIREMENTS			
	MEDIAN FC (CFU/100 ML)	30 MIN CHLORINE RESIDUAL (MG/L)	PH (90% CENT)	TURBIDITY (NTU)
Municipal irrigation—dust suppression, ornamental water bodies—uncontrolled public access (except for subsurface irrigation—see below)	≤ 10	≥ 1	6.5-8.0	≤ 2
Municipal irrigation—dust suppression —controlled public access				
Subsurface irrigation for all purposes				
Horticulture	≤ 1,000	≥ 1	6.5-8.0	present
Residential—Garden watering, toilet flushing, car washing,. path/wall washing	≤ 10	≥ 1	6.5-8.0	≤ 2
Monitoring <3ML/year	weekly initially for 3 months, then monthly	weekly	weekly	as required

REUSE APPLICATION	REUSE QUALITY REQUIREMENTS			
	MEDIAN FC (CFU/100 ML)	30 MIN CHLORINE RESIDUAL (MG/L)	PH (90% CENT)	TURBIDITY (NTU)
Monitoring >3ML/year	weekly	daily	weekly	continuous
Food crops in direct contact with water, for example, sprays	≤ 10	≥ 1	6.5-8.0	≤ 2
Monitoring <3ML/year	weekly	daily	weekly	as required
Monitoring >3ML/year	weekly	daily	weekly	continuous

Other countries, including countries from the Middle East, have also adopted guidelines often based on WHO recommendations or on standards enacted in California. Tables 4, 5 and 6 summarize those standards used in Jordan, Kuwait and Saudi Arabia.

Table 4 Jordanian Standards (JS: 893/2002) for effluent reuse for agricultural irrigation

PARAMETER	UNIT	CATEGORY		
		COOKED VEGETABLES, PARKING AREAS, PLAYGROUNDS AND SIDE OF ROADS INSIDE CITIES	PLENTEOUS TREES AND GREEN AREAS, SIDE OF ROADS OUTSIDE CITIES	FIELD CROPS, INDUSTRIAL CROPS AND FORESTRY
BOD5	mg/L	30	200	300
COD	mg/L	100	500	500
TSS	mg/L	50	150	150
DO	mg/L	> 2.0	–	–
pH	unit	6.0–9.0	6.0–9.0	6.0–9.0
Turbidity	NTU	10	–	–
NO3	mg/L	30	45	45
T-N	mg/L	45	70	70
E. coli	MPN/100 mL	100	1000	–
Intestinal helminth eggs	egg/L	≤ 1.0	≤ 1.0	≤ 1.0

Table 5 Treated Wastewater Criteria for Reuse in Kuwait

PARAMETER	MAXIMUM ALLOWABLE

pH	6.5–8.5
BOD5 (5 days, 20 °C)	20
COD (dichromate)	100
FOG	5
TSS	15
TDS	1500
Most probable number of total coliforms	400
Most probable number of faecal coliforms (MPN/100 mL)	20
Egg parasites (no/litre)	< 1.0
Worm parasites	Absent
Most probable number of total coliforms	400
Most probable number of faecal coliforms (MPN/100 mL)	20
Egg parasites (no/litre)	<1
Worm parasites	Absent

Source: Annex No. (15), Decree No. (210), 2001.

All units are in mg/L except where noted otherwise.

Table 6 Reclaimed Water Standards for Restricted Irrigation In Saudi Arabia

PARAMETER	MAXIMUM CONCENTRATION
BOD5	40.0
TSS	40.0
TDS	2000
TTCC (MPN/100 mL)	1000
Living intestinal nematodes (no/litre)	1.0

Source: Treated Wastewater and Reuse Bylaw No. 42, 2000.

All units are in mg/L unless indicated otherwise.

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APPENDIX B

Beirut

a. Recent past (1981-2000):

CYCLE	PRECIPITATION (P)	ACTIVE PRECIPITATION (PA)	% OF PA OUT OF P
1981-1982	748.5	238.2	32%
1982-1983	809.2	267.0	33%
1983-1984	635.0	133.3	21%
1984-1985	492.6	103.6	21%
1985-1986	603.3	123.6	20%
1986-1987	881.3	328.2	37%
1987-1988	1,064.8	459.8	43%
1988-1989	615.6	102.4	17%
1989-1990	433.1	6.6	2%
1990-1991	682.7	169.0	25%
1991-1992	1,130.5	580.1	51%
1992-1993	794.2	275.5	35%
1993-1994	556.0	157.8	28%
1994-1995	784.2	239.4	31%
1995-1996	807.7	330.8	41%
1996-1997	691.5	92.3	13%
1997-1998	790.7	207.9	26%
1998-1999	439.0	93.1	21%
1999-2000	677.6	263.2	39%
Average	717.8	219.6	31%

b. Near Future (2025-2044):

CYCLE	PRECIPITATION (P)	ACTIVE PRECIPITATION (PA)	% OF PA OUT OF P
2025-2026	719.5	182.0	25%
2026-2027	791.5	253.3	32%
2027-2028	587.7	65.5	11%

CYCLE	PRECIPITATION (P)	ACTIVE PRECIPITATION (PA)	% OF PA OUT OF P
2028-2029	460.0	46.6	10%
2029-2030	566.7	81.6	14%
2030-2031	880.9	338.3	38%
2031-2032	1,042.4	440.5	42%
2032-2033	607.6	122.1	20%
2033-2034	427.0	14.3	3%
2034-2035	617.5	92.9	15%
2035-2036	1,119.1	579.1	52%
2036-2037	786.0	265.9	34%
2037-2038	499.8	86.8	17%
2038-2039	814.3	311.2	38%
2039-2040	782.4	291.6	37%
2040-2041	635.9	41.5	7%
2041-2042	761.8	174.8	23%
2042-2043	421.6	74.1	18%
2043-2044	604.4	172.4	29%
Average	690.9	191.3	28%

c. Distant Future (2080-2100):

CYCLE	PRECIPITATION (P)	ACTIVE PRECIPITATION (PA)	% OF PA OUT OF P
2080-2081	753.3	229.1	30%
2081-2082	718.4	96.1	13%
2082-2083	530.4	45.2	9%
2083-2084	521.6	43.0	8%
2084-2085	453.4	13.8	3%
2085-2086	688.5	75.4	11%
2086-2087	818.7	155.0	19%
2087-2088	712.2	66.3	9%
2088-2089	366.3	0	0%

CYCLE	PRECIPITATION (P)	ACTIVE PRECIPITATION (PA)	% OF PA OUT OF P
2089-2090	295.0	0	0%
2090-2091	934.2	201.0	22%
2091-2092	750.3	233.0	31%
2092-2093	471.4	37.2	8%
2093-2094	786.1	153.7	20%
2094-2095	463.8	52.5	11%
2095-2096	671.8	120.8	18%
2096-2097	611.2	5.4	1%
2097-2098	542.6	77.0	14%
2098-2099	359.6	-	0%
2099-2100	672.2	197.9	29%
Average	606.1	90.1	15%

Zahleh:

d. Recent past (1994-2000)*:

CYCLE	PRECIPITATION (P)	ACTIVE PRECIPITATION (PA)	% OF PA OUT OF P
1994-1995	784.2	392	50%
1995-1996	807.7	480	59%
1996-1997	691.5	223	32%
1997-1998	790.7	393	50%
1998-1999	439	185	42%
1999-2000	677.6	334	49%
Average	698.5	334.5	48%

*Due to the limited availability of meteorological data

e. Near Future (2032-2038):

CYCLE	PRECIPITATION (P)	ACTIVE PRECIPITATION (PA)	% OF PA OUT OF P
2032-2033	842.67	453	54%
2033-2034	800.48	464	58%
2034-2035	725.83	170	23%
2035-2036	755.72	295	39%

2036-2037	470.37	231	49%
2037-2038	625.02	175	28%
Average	703.3	298	42%

f. Distant Future (2087-2092):

CYCLE	PRECIPITATION (P)	ACTIVE PRECIPITATION (PA)	% OF PA OUT OF P
2087-2088	518.75	186	36%
2088-2089	487.77	231	47%
2089-2090	501.19	127	25%
2090-2091	509.53	149	29%
2091-2092	266.45	76	29%
Average	458	162	35%

AVERAGE MONTHLY RESULTS:

Beirut:

g. Recent Past (1981-2000):

MONTH	PRECIPITATION (P)	ACTIVE PRECIPITATION (PA)	% OF PA OUT OF P
October	51.60	0	0%
November	111.30	0	0%
December	134.00	36	27%
January	174.50	85	49%
February	115.40	26	22%
March	92.00	0	0%
April	28.70	0	0%
May	11.30	0	0%
June	1.70	0	0%
July	0.30	0	0%
August	-	0	0%
September	6.10	0	0%

h. Near Future (2025-2044):

MONTH	PRECIPITATION (P)	ACTIVE PRECIPITATION (PA)	% OF PA OUT OF P
October	41.30	0	0%
November	134.20	15	11%
December	153.10	50	33%
January	130.30	38	29%
February	106.70	12	11%
March	80.60	0	0%
April	29.60	0	0%
May	10.30	0	0%
June	1.30	0	0%
July	0.10	0	0%
August	-	0	0%
September	8.60	0	0%

i. Distant Future (2080-2098):

MONTH	PRECIPITATION (P)	ACTIVE PRECIPITATION (PA)	% OF PA OUT OF P
October	44.00	0	0%
November	97.20	0	0%
December	101.80	0	0%
January	154.20	54	35%
February	92.80	0	0%
March	70.60	0	0%
April	26.80	0	0%
May	8.20	0	0%
June	1.20	0	0%
July	-	0	0%
August	-	0	0%
September	8.90	0	0%

Dahr el Baydar:

j. Recent Past (1971-2000):

MONTH	PRECIPITATION (P)	ACTIVE PRECIPITATION (PA)	% OF PA OUT OF P
October	55.00	0.00	0%
November	149.00	65.99	44%
December	273.00	212.96	78%
January	310.00	261.06	84%
February	232.00	178.65	77%
March	227.00	164.96	73%
April	84.00	4.93	6%
May	33.00	0.00	0%
June	2.00	0.00	0%
July	0.50	0.00	0%
August	0.50	0.00	0%
September	4.00	0.00	0%

k. Near Future (2025-2044):

MONTH	PRECIPITATION (P)	ACTIVE PRECIPITATION (PA)	% OF PA OUT OF P
October	45.60	0.00	0%
November	180.80	94.94	53%
December	325.30	260.53	80%
January	255.50	202.21	79%
February	226.00	164.25	73%
March	207.30	139.88	67%
April	100.90	18.58	18%
May	34.30	0.00	0%
June	1.60	0.00	0%
July	0.10	0.00	0%
August	0.00	0.00	0%

September	10.80	0.00	0%

l. Distant Future (2080-2098):

MONTH	PRECIPITATION (P)	ACTIVE PRECIPITATION (PA)	% OF PA OUT OF P
October	43.80	0.00	0%
November	105.80	8.22	8%
December	210.00	137.52	65%
January	227.10	165.09	73%
February	152.20	79.56	52%
March	131.60	55.69	42%
April	70.30	0.00	0%
May	29.50	0.00	0%
June	1.20	0.00	0%
July	0.20	0.00	0%
August	0.10	0.00	0%
September	5.20	0.00	0%

Cedars:

m. Recent Past (1960-1981):

MONTH	PRECIPITATION (P)	ACTIVE PRECIPITATION (PA)	% OF PA OUT OF P
October	39.00	0.00	0%
November	97.00	29.79	31%
December	174.00	123.57	71%
January	146.00	102.74	70%
February	148.00	102.77	69%
March	129.00	75.87	59%
April	81.00	9.25	11%
May	24.00	0.00	0%
June	3.60	0.00	0%
July	1.70	0.00	0%

August	5.70	0.00	0%
September	13.00	0.00	0%

n. Near Future (2025-2044):

MONTH	PRECIPITATION (P)	ACTIVE PRECIPITATION (PA)	% OF PA OUT OF P
October	45.10	0.00	0%
November	93.80	23.57	25%
December	202.20	147.43	73%
January	113.50	66.58	59%
February	143.70	92.14	64%
March	106.70	50.06	47%
April	74.00	0.00	0%
May	16.90	0.00	0%
June	3.90	0.00	0%
July	0.30	0.00	0%
August	1.20	0.00	0%
September	28.70	0.00	0%

o. Distant Future (2080-2098):

MONTH	PRECIPITATION (P)	ACTIVE PRECIPITATION (PA)	% OF PA OUT OF P
October	38.70	0.00	0%
November	52.10	0.00	0%
December	126.10	63.57	50%
January	92.80	38.22	41%
February	76.70	15.09	20%
March	74.80	9.07	12%
April	49.30	0.00	0%
May	15.70	0.00	0%
June	4.00	0.00	0%
July	1.10	0.00	0%

August	1.70	0.00	0%
September	11.80	0.00	0%

Zahleh:

p. Recent Past (1960-1981):

MONTH	PRECIPITATION (P)	ACTIVE PRECIPITATION (PA)	% OF PA OUT OF P
October	61.10	0.00	0%
November	95.70	0.00	0%
December	127.90	40.84	32%
January	184.00	151.27	82%
February	87.20	48.17	55%
March	84.80	38.13	45%
April	33.20	3.30	10%
May	7.50	0.00	0%
June	0.00	0.00	0%
July	0.40	0.00	0%
August	0.00	0.00	0%
September	13.30	0.00	0%

q. Near Future (2025-2044):

MONTH	P	PA	%
October	49.80	0.00	0%
November	112.10	3.34	3%
December	155.50	64.69	42%
January	79.60	54.36	68%
February	70.20	44.49	63%
March	68.30	30.08	44%
April	92.70	76.05	82%
May	9.10	0.00	0%
June	0.00	0.00	0%

July	0.00	0.00	0%
August	0.00	0.00	0%
September	48.70	0.00	0%

r. Distant Future (2080-2098):

MONTH	P	PA	%
October	54.90	0.00	0%
November	66.00	0.00	0%
December	86.10	0.00	0%
January	83.00	80.32	97%
February	51.00	0.00	0%
March	48.70	36.52	75%
April	25.50	0.00	0%
May	6.30	0.00	0%
June	0.00	0.00	0%
July	0.30	0.00	0%
August	0.00	0.00	0%
September	30.60	0.00	0%

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