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MINISTRY OF ENVIRONMENT

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LEBANON'S SECOND NATIONAL COMMUNICATION TO THE UNFCCC

MINISTRY OF ENVIROMENT
2011

Republic of Lebanon

Ministry of Environment

Lebanon's Second National Communication to the United Nations Framework Convention on Climate Change

Beirut

February, 2011

Lebanon's Second National Communication to the United Nations Framework Convention on Climate Change

Executed by

Ministry of Environment

Funded by

Global Environment Facility

Implemented by

United Nations Development Programme, Lebanon

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Foreword

It is my pleasure to present Lebanon's Second National Communication (SNC) to the United Nations Framework Convention on Climate Change (UNFCCC), which is formulated in accordance with the guidelines adopted by the Parties to the Framework Convention on Climate Change. It presents basic facts about Lebanese society and reviews the various economic sectors according to the classification commonly used in the context of climate. Emissions of different greenhouse gases (GHGs) are presented for each sector for the year 2000 and as an aggregate figure for each year from 1994 to 2004. The SNC describes Lebanon's vulnerability and what needs to be done to adapt to climate change. The material on which the national communication is based has been obtained through extensive work undertaken by government agencies, academic institutions, the private sector and non-governmental organizations, led by the Ministry of Environment. Most of the work on the SNC was carried out during the period extending from the summer of 2007 to the fall of 2010.

Since Lebanon's ratification of the UNFCCC, successive governments have implemented various policies and measures to fulfill Lebanon's commitments under the Convention. In comparison to the First National Communication, this Communication includes new chapters, actions, policies and measures. It is hoped that this new approach identifies Lebanon's real needs under the Convention, and brings forward a set of mitigation and adaptation plans at a relatively early stage that would allow Lebanon to prepare for the unavoidable consequences of climate change early on.

Climate change is a serious global challenge that will require sustained action by all high GHG emitting nations over many generations. Lebanon's SNC comes to ascertain once again that Lebanon's GHG emissions are insignificant at the global level. Nevertheless, a set of prioritized measures are recommended to bring GHG emissions reduction, cut energy demand and increase energy supply, contribute to sustainable development and enable Lebanon to mobilize resources under the Convention in order to mitigate climate change. We believe that combating climate change is a shared responsibility that rests on all our shoulders. It is more important to find a common solution than to debate the relative responsibility of each of us. For that reason, we have voluntarily committed in Copenhagen in 2009 to increase our renewable energy mix to 12% by 2020.

The impact of global climate change on Lebanon is tremendous. Temperatures are projected to increase between 1°C and 5°C from now till the end of the century, and rainfall is projected to decrease by 25 to 50% over the same period. Such drastic changes in climate will only aggravate the already existing environmental, social and economical challenges Lebanon is facing today.

Considerable experience has been gained, national momentum on climate change has developed and many lessons were learnt. This exercise has become a necessary tool for mainstreaming climate change related issues into national sectoral development policies and plans.

Mohammad Rahal, February 2011
Minister of Environment

Acknowledgments

The development of Lebanon's Second National Communication to the UNFCCC has been a joint undertaking of the Ministry of Environment and the UNDP Lebanon in the frame of the support to capacity building in the field of climate change provided by the Global Environment Facility under the "Enabling Activities for the Preparation of Lebanon's Second National Communication to the UNFCCC" project.

The SNC project team would like to express its appreciation to the main authors of the SNC chapters for their valuable work, patience and perseverance:

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Université Saint-Joseph – Dr. Jocelyne Gerard, team Leader and LUCF sector; Dr. Wehbe Farah, energy sector; Nada Saliba, industry sector; Dr. Rita Zaarour, agriculture sector and Dr. Maher Abboud, waste sector.

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Atlantis Consulting (Cyprus): Dr. Charalambos Panayiotu, hydrometeorology expert.

We thank the PRECIS team of the UK Met. Office Hadley Centre for provision of (and help with) the PRECIS software.

The SNC project team would like to acknowledge the invaluable contributions and inputs into various parts of the Second National Communication that were made either directly or indirectly by various institutions and government agencies, which lead to the formulation of appropriate national action plans, policies and strategies. The time and effort invested in providing information and reviewing the draft documents by several individuals working within the mandate of line ministries, research institutions, NGOs, and the private sector are highly appreciated.

Our most sincere gratitude goes to Dr. Talal Darwish (NCSR), Dr. Wajdi Najem (USJ-CREEN), Dr. Hamed Assaf (AUB), Dr. Issam Bashour (AUB), Dr. Samir Safi (LU), Elie Helou (CDR) and Dr. Tammam Nakkash (Team International) for providing expert opinion and advice; Michelle Bachir and Fadi Doumani for providing guidance, and Dr. Charles Heap (SEI) for training and support on the use of LEAP software.

Special thanks also go to Grace Rachid, Georges Akl, Patty Farah, and Bassam Sabbagh (MoE); Lama Mghames (MoE/UNDP - National Ozone Unit); Dr. Milad Fakhri, Dr. Amin Shaban and Dr. Ghaleb Faour (NCSR); Farjallah Srour (MoIM); Hassan Chaaban (MoPWT); Mahmoud Haidar, Dima Haidar, Ghassan Zayour and Mona Fakih (MoEW); Dr. Assad Khoury (MoPH); Bechara Attieh and Nicolas Saba (EDL); Hussein Nasrallah and Amal Salibi (MoA); Faten Adada (MoA/GTZ-CODEL); Gloria Abou Zeid (MoA/Green Plan); Ali Shaar, Dr. Riad Al Khodari, and Marc Wehaibi (LMS); Pierre Khoury (MoEW/UNDP); Lea Hakim (MoF/UNDP); Dr. Jaoudat Abou Jaoudeh (CDR); Rabih Saab and Marwan Jawhar (MoI); Ghassan Nasrallah (Lebanese Customs); Dr. Dominique Salameh (AEC); Rola Khater (Maliban); Rania Abi Khalil (Soliver); Karim Ghorra (Uniceramic); Reem Assouad (Almaza); Marie-Louise Azezian (Ksara); Alain Mansour (APIC); Khalil Daya and Georges Abdallah (Cimenterie Nationale); Dr. Fouad Jaafar (Ciments de Sibline); Mansour Abdel Samad and Rody Abou Naccoul (Holcim); Solange Saadeh and Michel Bassil (FAO); Dr. Walid EL Deghaili and Dr. Tarek Sadek (ESCWA); Nohal El-Homsi (WHO); Dr. Nadim Farjallah and Dr. Iman Nuwayhid (AUB).

The SNC team would also like to thank Mr. Yamil Bonduki from UNDP-NCSP, for the coordination of the peer review of the GHG Inventory chapter, and Dr. Carlos Lopez of the Institute of Meteorology in Cuba for providing valuable inputs on the GHG inventories. Their comments and suggestions have been largely considered and reflected in the SNC.

Last but not least, a great deal of gratitude goes to H.E. Mr. Mohamad Rahal, for his support throughout the project and for pushing forward the climate change portfolio at the national level.

List of Acronyms

ACSAD	Arab Center for the Studies of Arid Zones and Dry Lands
AFDC	Association for Forestry Development and Conservation
AMR	Automatic Meter Reading
AR4	Fourth Assessment Report
AUB	American University of Beirut
AUM	Animal Unit Month
Avg	Average
B-RHIA	Beirut Rafic Hariri International Airport
CBD	Central Beirut District
CCGT	Combined Cycle Gas Turbine
CDM	Clean Development Mechanism
CDR	Council for Development and Reconstruction
CoM	Council of Ministers
CREEN	Centre Régional de l'Eau et de l'Environnement de l'Université Saint-Joseph
DF	Distant Future
DGUP	Directorate General of Urban Planning
DJF	December January February
EDL	Electricité Du Liban
EE	Energy Efficiency
EEWRC	Energy Environment and Water Research Center
EI	Energy Industries
ELARD	Earth Link and Advanced Resources Development
ESCWA	Economic and Social Commission for Western Asia
ESU	Epidemiological Surveillance Unit
ETP	Evapotranspiration
EU	European Union
EWARS	Early Warning Alert and Response System
FAO	Food and Agriculture Organization
GB	Green Building
GBA	Greater Beirut Area
GCM	Global Climate Model
GDP	Gross Domestic Product
GEF	Global Environment Facility

GHG	Greenhouse Gas
GIS	Geographic Information System
GoL	Government of Lebanon
GPG-LULUCF	Good Practice Guidance for Land Use, Land Use Change and Forestry
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
GW	Gigawatt
GWh	Gigawatt-hour
GWP	Global Warming Potential
HEV	Hybrid Electric Vehicle
HFO	Heavy Fuel Oil
HRC	Higher Relief Council
ICARDA	International Center for Agricultural Research in the Dry Areas
IEA	International Energy Agency
IMF	International Monetary Fund
INC	Initial National Communication
INSEE	National Institute of Statistics and Economic Studies
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated Pest Management
IUCN	International Union for Conservation of Nature and Natural Resources
IWRM	Integrated Water Resources Management
JICA	Japan International Cooperation Agency
JJA	June July August
KP	Kyoto Protocol
kVA	Kilovolt amperes
kW	Kilowatt
kWh	Kilowatt-hour
LARI	Lebanese Agricultural Research Institute
LAU	Lebanese American University
LBP	Lebanese Pounds
LCC	Lebanese Commuting Company
LCEC	Lebanese Center for Energy Conservation
LEAP	Long-range Energy Alternatives Planning system
LEDO	Lebanese Environment and Development Obvservatory
LFG	Landfill Gas

LMS	Lebanese Meteorological Station
LNG	Liquified Natural Gas
LPG	Liquified Petroleum Gas
LRA	Litani River Authority
LU	Lebanese University
LUCF	Land Use Change and Forestry
LULUCF	Land Use, Land Use Change and Forestry
MAM	March April May
MENA	Middle East and North Africa
MIC	Manufacturing Industries and Construction
Mm^3	Million cubic meters
MoA	Ministry of Agriculture
MoE	Ministry of Environment
MoEW	Ministry of Energy and Water
MoF	Ministry of Finance
MoIM	Ministry of Interior and Municipalities
MoPH	Ministry of Public Health
MoPWT	Ministry of Public Works and Transport
MoSA	Ministry of Social Affairs
MoT	Ministry of Tourism
MSW	Municipal Solid Waste
MW	Megawatt
MWh	Megawatt-hour
NA	Not Available
NAPPA	National Action Plan for Protected Areas
NCCCD	National Committee for Climate Change and Desertification
NCMS	National Center for Marine Sciences
NCSR	National Council for Scientific Research
NDU	Notre Dame University
NF	Near Future
NGO	Non Governmental Organization
NPMPLT	National Physical Master Plan for the Lebanese Territories
NS	Not Specified
O&M	Operations and Maintenance

OCGT	Open Cycle Gas Turbine
OEA	Order of Engineers and Architects
OWL	Other Wooded Land
P	Precipitation
Pa	Active Precipitation
PHC	Primary Health Care
PM	Particulate Matter
PRECIS	Providing REgional Climates for Impacts Studies
Q	Quotient of Emberger
RCM	Regional Climate Model
RE	Renewable Energy
RP	Recent Past
SES	Socio-economic Status
SLM	Sustainable Land Management
SLR	Sea Level Rise
SNC	Second National Communication
SON	September October November
SRES	Special Report on Emissions Scenarios
SST	Sea Surface Temperature
SWDS	Solid Waste Disposal Sites
T_{max}	Maximum Temperature
T_{min}	Minimum Temperature
T_{MM}	Minimum mortality temperature
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific, and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollars
USEK	Université Saint-Esprit de Kaslik
USJ	Université Saint Joseph
WHO	World Health Organization

EXECUTIVE SUMMARY

1. National Greenhouse Gas Inventory

The national inventory of Lebanon's anthropogenic emissions by sources and removals by sinks for the year 2000 of all GHGs covered by the Kyoto Protocol (CO_2, CH_4, N_2O, HFCs, PFCs and SF_6) in addition to the indirect GHGs (CO, NO_x, SO_2, and NMVOCs) has been calculated.

The inventory is based on the revised 1996 Intergovernmental Panel on Climate Change guidelines for National Greenhouse Gas Inventories and on the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Tier 1 approach is adopted in calculating the GHG emissions where the appropriate default emission factors are selected from the guidelines. Tier 2 approach is only used for the calculation of emissions from the cement industry where precise data allowed the development of a national emission factor.

The activity data for the various sectors are collected from various sources (public and private institutions) by conducting sectoral tailored surveys, and complemented by secondary sources such as scientific reports/publications, and academic studies. Estimations, interpolations and extrapolations are made for the sectors characterized with data gaps. Choice of activity data is validated through thorough stakeholders' consultations engulfing the public and private sectors, as well as academic and NGO communities.

Greenhouse Gas inventory by Sector and Gas

In the year 2000, Lebanon's total GHG emissions recorded 18,507 Gg (18.5 Million tonnes (Mt)) of CO_2 equivalent (CO_2 eq.), recording an average of 2.77% per year increase from 1994 (15,901 Gg CO_2 eq.). The energy sector is the main source of GHG emissions, accounting for 74.86% of the national emission (53.45% energy production and 21.41% transport). This is followed by industrial processes and waste sectors which account for 9.62% and 9.40% respectively. Emissions from agriculture and land use change and forestry make up 5.76%, and 0.36% of total CO_2 eq. respectively.

Carbon dioxide is the main emitted GHG with 84.13% of emissions in 2000, while CH_4 and N_2O constitute 10.19% and 5.68% respectively. The main contributors of CO_2 emissions are energy production and transport with 63% and 25% respectively whereas the waste sector constitutes the main source of CH_4 emissions (88%). The main contributor to N_2O emissions is the agriculture sector with 88%.

GHG Emissions by sector

Energy sector

The energy sector is the most important contributor to GHG emissions. In 2000, energy industries emitted 5,773 Gg CO_2 eq. (42% of total emission from the energy sector and 31% of total national emissions), manufacturing industries and construction generated some 2,830 Gg CO_2 eq. in 2000, comprising 20% of total emissions from the energy sector, and 15% of total national GHG emissions. The energy industries subsector contributed to 61.19 Gg of SO_2 in 2000 or 66% of the total SO_2 emissions from the energy sector and 65% of national SO_2 emissions, while MIC's SO_2 emissions accounted for 25% of total national SO_2 emissions.

Transport is a major sub-sector contributing to GHG emissions from fuel combustion. In 2000, 3,962.64 Gg CO_2 eq. were emitted into the atmosphere from transport in Lebanon, comprising 28.6% of total emissions from the energy sector, and 21% of total national GHG emissions. The transport sector is also the main source of CO, NO_x and NMVOC emissions from this category. The other sectors category, which includes emissions from commercial, institutional, residential and agriculture/forestry/fishing sub-categories, generated 1,280 Gg of CO_2 eq., representing 9% and 7% of the emissions from the energy sector and of total national GHG emissions respectively.

Industrial Processes

In 2000, emissions from the industrial processes sector amounted to a total of 1,781Gg of CO_2 eq. at 9.62% of Lebanon's total GHG emissions. The emissions primarily entail the CO_2 gas, with the largest contributor being cement production with 91.6%, followed by iron and steel production with

7.2%. The emissions from steel production may be over or underestimated since a simple approach was used in the calculation due to the absence of data on the consumption of reducing agents in this industry. Since direct and indirect emissions from the industrial processes sub-categories are insignificant, they are not reported in the inventory.

Refrigeration and air conditioning are the only sources of HFC gas emissions recorded in Lebanon since HFC 134a is serving as an alternative to ozone depleting substances being phased out under the Montreal Protocol. The total HFC emissions in 2000 are insignificant in absolute terms (0.01 Gg) but amount to approximately 11 Gg CO_2 eq. when converted to CO_2 eq. emissions since they have a high global warming potential. However, they were not reported as part of this national inventory.
As for SF_6 emissions for the year 2000, they are estimated to be null since SF_6 has only been imported to Lebanon starting the year 2002.

Cement industries are also the main emitters of SO_2 within this sector while road paving and food production the main emitters of NMVOCs.

Solvents and Other Product Use

In the year 2000, NMVOC emissions generated from solvents and other products use amount to 3.97 Gg or around 3% of Lebanon's total NMVOC emissions. Degreasing and dry cleaning are the major source of NMVOC with 2.47 Gg, followed by paint application (0.98 Gg) and printing industries (0.54 Gg).

Agriculture

The agricultural sector is a significant contributor to national GHG emissions, with 1,065.5 Gg CO_2 eq., representing 5.76% of national emissions in 2000. The main source of GHG emissions is "agricultural soils" with 77.1% of the sectoral emissions, and 4.4% of total national emissions, followed by enteric fermentation (11.9% sectoral and 0.7% national emissions), and manure management (10.9% sectoral and 0.63% of national).

Emissions of NO_x and CO result from field burning of agricultural residues, where it is estimated that 10% of the residues of wheat, barley and oats are burned every year. Other residues are not taken into account since they are collected and used either as a source of energy in rural areas (could not be estimated) or as animal feed and bedding. The NO_x and CO emissions from field burning of residues are estimated at 0.03 Gg and 0.77 Gg respectively.

Land Use Change and Forestry

Due to unavailability of data to accurately estimate how changing land use patterns affects CO_2 emissions and removals, the Good Practice Guidance for Land use, Land-use Change and Foresty could not be used in this inventory. The only available and complete national information is the land-use land-cover map which is not sufficient to make a comparative analysis on land changes for the year 2000. Therefore, the CO_2 removal data presented in this category must be treated with caution.

In Lebanon, the land use change and forestry sector acts as both a source and a sink where results of the year 2000 show that 807.6 Gg CO_2 are removed by sinks and 663.73 Gg CO_2 are emitted from forest fires. The net result labels this sector as a sink with -143.87 Gg CO_2 as a net removal. Emissions of CO_2, CH_4, N_2O, NO_x and CO are emitted as GHGs and precursors from biomass burning, which emanates mainly from natural and man-made forest fires.

Waste

The emissions from the waste sector are calculated using the mass balance approach which results in an overestimation of the emissions since it does not account for time factors in the waste accumulation and decomposition.

The waste sector is the largest source of CH_4 emissions in Lebanon, accounting for 87.5% of the total national CH_4 emissions. The sector generated 1,739.36 Gg CO_2 eq. in 2000, or 9.4% of the total GHG emissions for the same year. Solid waste disposal on land remains the highest emitting category, constituting 94.3% of waste emissions in 2000, or 1,640 Gg CO_2 eq., with CH_4 being the main gas emitted.

Emissions from wastewater handling emitted 96.3 Gg CO_2 eq. in 2000, where 59.3% of wastewater is estimated to be discharged directly in the sea, 26.1% is collected in septic tanks, and 14.6% is discharged in rivers.

As for waste incineration, although open burning of municipal waste is commonly practiced in Lebanon, data on such practices are unavailable. Therefore, this inventory only records emissions from the controlled incineration of medical waste, which constituted in 2000 0.2% of all waste GHG emissions, or 3 Gg CO_2 eq.

2. Greenhouse Gas Mitigation Strategy

The purpose of this chapter is to provide an analysis of the measures to reduce GHG emissions and enhance carbon sinks in Lebanon. The analysis is based on 2 types of scenarios: the baseline scenarios and the mitigation scenarios.

The baseline scenarios are constructed based on the current sectoral plans, policies and projected trends and are different from the business-as-usual scenario since the government of Lebanon has committed itself to long-term plans which introduce major changes to the existing structure of the economy. Some of these changes may be considered as a baseline scenario, such as in the energy sector while some plans are considered as a mitigation scenario such as the national waste management plan that still needs time for its execution. The GHG abatement analysis is made for 20 years, i.e. till the year 2030. The projection of trends uses 2004 as the base year and project forecasts the values to 2030, taking into account demographic, social, and economical assumptions available in official documentation.

The mitigation scenarios are proposed plans and projects that have a potential for sectoral emission reduction or sink enhancing. Mitigation options are selected and analyzed according to their direct and indirect economic impact, consistency with national development goals, economical feasibility, and compatibility with implementation policies, sustainability and other specific criteria. Various methods and tools are used to evaluate each mitigation option in terms of technological and economical implications.

Baseline and mitigation scenarios for the different sectors

Electricity

The energy baseline scenario is based on the MoEW's Energy policy paper. The most important points are found below:

- Increase installed capacity to 4,000 MW by 2014 and 5,000 MW thereafter to meet projected demand corresponding to an annual load growth of 7%, and 15% of peak load reserve;
- Possibility of renting 250 MW (barges, small generators or imports) between 2010 and 2013;
- 2/3 of the fuel mix is based on natural gas with multiple sources of supply;
- More than 12% of the fuel mix to be supplied by renewable energy sources;

Projected emissions are expected to reach 32,569 Gg CO_2 eq. by 2030 under the baseline scenario.
Two mitigation scenarios have been developed. Mitigation scenario 1 consists of the implementation of MoEW's latest policy paper for the electricity sector, in addition to capacity expansion (around 3,500 MW between 2015 and 2030 based on the 2/3 natural gas fuel mix, in addition to 11.4% of renewable energy by 2030) post-2015 to keep up with demand. Mitigation scenario 2 consists again of implementation of MoEW's policy paper but with a full switch of oil-fired power plants to natural gas by 2030, an increase in the penetration rate of renewable energy technologies (17% by 2030) and no electricity imports.

The emissions reduction from the mitigation scenario 1 adds up to 177,912 Gg of CO_2 eq. between 2011 and 2030, while the reduction resulting from the implementation of the mitigation scenario 2 adds up to 204,768.3 Gg of CO_2 eq. between 2011 and 2030.

Manufacturing Industries and Construction

The manufacturing industries and construction sector covers private self-generation of electricity which accounts for around 33% of the total electricity generation. Since a significant amount of private generation is derived from manufacturing industries, this chapter addresses measures to increase the efficiency of power generation in the industrial sector, especially in cement industries which constitute one of the major energy intensive industries in the country, the baseline scenario being business-as-usual. Two mitigation scenarios have been developed. Scenario 1, which is based on waste heat recovery and utilization for power generation in cement plants, has a potential reduction of CO_2 emission in the order of 230-380 Gg. The mitigation scenario 2 is based on partial substitution of fossil fuels with alternative fuels or less carbon intensive fuels. The potential emission reduction of scenario 2 has not been calculated.

Transportation

Baseline scenario is the business-as-usual, under which the projected number of vehicles will reach 1,600,000 by 2030, whereas the average number of daily motorized trips per person, and the share of passenger-trip by private vehicles, will both grow by almost 60% and 90% respectively. Two mitigation scenarios have been developed, the first being the revitalization of the public transport system whereby the distribution of passenger-trips traveled by bus and car would be reversed (more than half of personal trips to be traveled by bus). The second mitigation scenario developed is the implementation of a car scrappage program, which would reduce the overall energy intensity of the vehicle fleet, and consequently GHG emissions from the sector.

Building Envelops

The baseline scenario is the business-as-usual, while there is only one mitigation scenario developed, which stipulates the implementation of the already developed thermal standards for buildings in Lebanon. Unfortunately, the standards are still not mandatory. The impact of the application of the thermal standards on GHG emissions at the macroeconomic level was forecasted. Over a 20-year period (2010-2029), the application of the Thermal Standards for Buildings can lead to the avoidance of around 7,000 Gg of CO_2 (or around 343.5 Gg of CO_2/yr).

Industry

The cement industry is the most important industrial source of CO_2 emissions in Lebanon, and therefore two baseline scenarios (2% growth against a 4% growth projection) are suggested to portray possible future clinker production and CO_2 emissions from the cement industry in Lebanon until year 2030, where the emissions are projected to be 3,607 Gg of CO_2 eq. and 5,976 Gg of CO_2 eq. for scenario A and scenario B respectively. The only mitigation scenario proposed for the cement industry relates to the increase of additive blend in cement production which can reduce CO_2 emissions by an estimated average of 1.32%.

Agriculture

The baseline scenario assumes that the trend in the number of livestock and poultry will stay stable and expected emissions by 2030 will reach 244 Gg of CO_2. Emissions from agricultural soils and field burning of agricultural residues are not expected to increase either. By 2030, GHG emissions from agriculture soils could be at 60% less than the emissions in the baseline year, without taking into consideration CO_2 emissions or sequestration.

Two parallel mitigation scenarios are proposed: 1) field level measures such as farm manure management which would reduce some 79 Gg of CO_2 in 2030, plowing which would reduce emissions by 60%, and efficient irrigation, and 2) research, education, assistance, infrastructure, and institutional measures.

Forestry

The baseline scenario is based on the existing reforestation/afforestation plans which would increase the total carbon uptake increment to 347.32 kt by 2030. Three mitigation scenarios have been developed. Mitigation scenario 1 consists of maintaining and conserving existing forest carbon sinks which would bring the total CO_2 uptake increment to 1,273.5 kt. Mitigation scenario 2 consists of measures proposed under afforestation and reforestation while mitigation scenario 3 proposes substitution of fossil fuels by forest-based biofuels. The latter two scenarios' emission reduction potentials have not been developed.

Waste

The baseline scenario considers that the infrastructure and installations are being set up to realize the national solid waste management plan of 2006, which consists of establishing regional sanitary landfills, sorting and composting facilities while rehabilitating existing dumpsites. The emissions from the waste sector are expected to reach 5,969 Gg of CO_2 eq. by 2030. The proposed mitigation options tackle both the waste and energy sectors as it considers energy recovery as an alternative waste management option. Mitigation scenario 1 deals with gas recovery for electricity generation which would result in 2,984 Gg CO_2 eq. reduction in 2030. Mitigation scenario 2 deals with waste incineration and energy production. The effective cumulative avoided emission is calculated to be 11,771 Gg of CO_2 eq. for the period extending from 2015 to 2030.

3. Vulnerability and Adaptation

Future climate risks for Lebanon

Climate change scenarios have been developed for Lebanon through application of the PRECIS model. According to the model and in relation to the present climate, by 2040 temperatures will increase from around 1°C on the coast to 2°C in the mainland, and by 2090 they will be 3.5°C to 5°C higher. Comparison with LMS historical temperature records from the early 20th century indicates that the expected warming has no precedent. Rainfall is also projected to decrease by 10-20% by 2040, and by 25-45% by the year 2090, compared to the present. This combination of significantly less wet and substantially warmer conditions will result in an extended hot and dry climate. Temperature and precipitation extremes will also intensify. In Beirut, hot summer days (T_{max} > 35°C) and tropical nights (T_{min} > 25°C) will last, respectively, 50 and 34 days more by the end of the century. The drought periods, over the whole country, will become 9 days longer by 2040 and 18 days longer by 2090.

Agriculture

Agriculture in Lebanon is one of the most vulnerable sectors to climate change due to the limited availability of water and land resources and the pressure exerted by population growth and urbanization. The results of the assessment conducted show that higher temperature, reduced precipitation and high evapotranspiration will decrease soil moisture and increase aridity, which will affect the overall agricultural yield of crops. A decrease in productivity is expected for most of the crops and fruit trees especially for wheat, tomatoes, cherries, apples and olive. Chilling needs for mountainous fruit trees such as cherries and apples will not be met, leading to a risk of failure of blossom pollination and fecundation by up to 50%. High temperatures and reduced precipitation may also affect the quality of grapes, thus jeopardizing the quality of wine produced. Changes in climate will also lead to increased infestation of fungi and bacterial diseases for most of the crops. Irrigated crops will face water shortages due to increased water demand and decreased water availability for irrigation. Rainfed crops will show either no change or a decrease in their surface area or productivity (e.g., olive, wheat and cherry). Changes in temperature and rainfall will also affect the grazing period and the quality of the pastures, changing the species composition in favor of woody less palatable plants. However, increase in temperature will lead to an expansion of the coastal plantations such as banana and tomatoes to higher altitudes and herders would benefit from a longer pasture season in the mountains due to the reduced thickness and residence time of snow cover.

In order to reduce the consequences of climate change and increase the resilience of the agriculture sector, it is necessary to implement the following adaptation measures: 1) select and introduce more drought and heat-resistant species and hybrids; 2) change planting dates and cropping patterns; 3) adopt sustainable agricultural practices and integrated pest management techniques; 4) elaborate a national rangeland program; 5) enhance genetic selection of local breeds; 6) and promote mixed exploitations. Proposed adaptation measures include policy and legislation options, research topics for improved vulnerability assessment and monitoring, and adapted infrastructure.

Electricity

The forecasted rise in ambient temperatures would lead to higher cooling demand in summer, driving the peak load up in addition to the increase resulting from the natural growth in population, consumption rates and oil prices. This would in turn put pressure on the power production and supply system to meet the additional increase in demand, and consequently drive the cost of power production up. The increase in total consumption from increased cooling consumption will be 1.8% for a 1°C increase in temperature, and 5.8% for a 3°C increase in temperature. This will consequently necessitates an expansion of installed capacity between 87 and 438 MW. As for the forecasted reduction in precipitation, it would limit the hydropower generation potential, which would jeopardize the government's plans to increase this capacity. However, the predicted insignificant changes in wind speed and cloud cover are not likely to lead to any potential change in solar and wind energy.

Efforts of the power sector to adapt to the impacts of climate change converge and complement mitigation measures that entail ensuring a 24-hour supply of electricity, reducing budget deficit, and reducing dependence on imported oil consumption. Therefore, adaptation efforts should mainly be directed at implementing the Policy Paper of the Ministry of Energy and Water and the thermal standards for buildings proposed by Directorate General of Urban Planning.

Water

The effect of climate change on water resources is expected to be significant as a result of decrease in precipitation and projected changes in its spatial and temporal distribution, in addition to an increase in evapotranspiration. Droughts are predicted to occur 15 days to 1 month earlier, which will negatively affect the existing water shortage due to urbanization and population growth. The already dry regions such as the Bekaa, Hermel and the South will be mostly affected. A reduction of 6 to 8% of the total volume of water resources is expected with an increase of 1°C and 12 to 16% for an increase of 2°C. In addition, a decline in total and active precipitation is forecasted as well as a shift in rainfall consisting of higher precipitation in November and December, and a steep reduction from January onward.

Climate change will induce a reduction of 40% of the snow cover of Lebanon with an increase of 2°C in temperature and will reach 70% decrease in snow cover with an increase of 4°C. This will have adverse impacts on rivers and groundwater recharge, especially that snow melt will occur in early spring, which does not coincide with high demand for irrigation water such as the summer season. In addition, snow will shift from 1,500 m to 1,700 m by 2050 and to 1,900 m by 2090, affecting the recharge of most springs. The change in rainfall regimes will increase the manifestation of extreme events: winter floods can increase up to 30%, and hot summer days and tropical nights can last at least two months longer. This combination of significantly less wet and substantially warmer conditions will result in an extended hot and dry climate and in an intensification of the temperature extremes.

The main adaptation measures of the water sector include 1) the protection of groundwater from salinization in coastal areas; 2) the implementation of water demand side management strategies to reduce water demand in the domestic, industrial and agriculture sectors; 3) the development of watershed management plans; and 4) the implementation of pilot initiatives to demonstrate the feasibility of alternative sources of water supply and develop necessary standards and guidelines.

Coastal zones

The main climate change factors affecting costal zones are the potential increases in sea level and sea surface temperature due to the projected higher temperatures. Sea levels have been continuously rising at an average rate of approximately 20 mm/yr in the Levantine basin. If it were to continue in the future, it can reach up to 30-60 cm in 30 years, which will have an impact on the sand beaches in the south, and on the coastal natural reserves such as the Palm Islands and the Tyre nature reserves. This will also lead to seawater intrusion into aquifers which will affect not only urban areas but also coastal irrigated agriculture. The potential impacts of climate change on the coastal zone include coastal flooding and inundation during storms, sea water intrusion and salinization of coastal aquifers, coastal erosion and loss of sand beaches, degradation of coastal ecosystems and nature reserves and economic losses in coastal and marine activities such as tourism, agriculture, fisheries, transportation and other essential services.

The main adaptation strategy for coastal zones is the adoption of integrated coastal zone management to organize and control the urbanization of the coast. More specific measures against sea level rise consist of pulling back human activities from the coast through the creation of buffer zones, moving sources of urban, industrial and agriculture pollution away from the coast, introducing effective early warning systems for coastal hazards, and creating protective structures to limit potential damage.

Forestry

Forests in Lebanon will be adversely affected by climate change, especially that forest stands suffer from fragmentation, pest outbreaks, forest fires and unsuitable practices that already challenge their capacity to survive and develop. The expected changes in temperature and rainfall are expected to be accompanied by a significant change in bioclimatic levels in Lebanon. The Oromediterranean level is projected to disappear from Lebanon by 2080, while the Arid bioclimatic level is expected to increase from 5 to 15 % in area. The most vulnerable forest stands are the upper zone coniferous forests (*Cedrus libani; Abies cilicica*) and high mountain formations (*Juniperus excelsa*) and the most vulnerable areas are North Lebanon (Akkar) and Hermel, where a shift in bioclimatic level from sub-humid to semi-arid is expected. Moreover, Tannourine and Arz el Chouf nature reserves will severely be impacted by increased temperatures as they are mainly composed of cedar forests. Horsh Ehden will be less impacted due to diversity of its tree communities. Prolonged drought periods will increase the frequency and periodicity of fire events, especially for *Pinus halepensis* and *Juniperus* stands. The regeneration rate, overall area and population density of *Juniperus excelsa*, *Cedrus libani*, *Abies cilicica* as well as *Quercus cerris*, *Fraxinus ornus* and *Ostrya carpinofolia* are also expected to decrease.

Adaptation measures are targeted to assist the natural resilience of forests, anticipate future changes and promote landscape scale and mainly consist of 1) strengthening the legal and institutional framework to integrate climate change needs; 2) integrate landscape levels planning in local/regional development plans; 3) strengthen awareness and education and support research and 4) develop forest management plans for most vulnerable ecosystems.

Public Health

The direct and indirect effects of climate change include the outbreak of infectious diseases from changing temperatures, increased morbidity and mortality from heat and other extreme weather events, malnutrition from droughts and floods that affect agriculture and other water-borne and rodent-borne diseases related to scarcity of clean water. In addition, changing patterns in rainfall and temperature can cause the proliferation of vector-borne diseases such as Malaria and Dengue fever. The average mortality caused by increases in temperatures is expected to range between 2,483 and 5,254 additional deaths/year between 2010 and 2030. Vulnerable population groups, especially the elderly and people living in socio-economically deprived areas, in semi-arid areas and in areas with lower access to health services are more at risk as a result of their high sensitivity and low adaptive capacity.

The main adaptation measures to be taken in Lebanon include 1) strengthening the epidemiological surveillance system and surveillance for temperature-related mortality and morbidity; 2) developing and implementing an emergency heat warning system; 3) improving access to health care and proper sanitation; and 4) enhancing the Early Warning Alert and Response System (to improve the capacity of the current system to respond to unexpectedly occurring disasters.

Tourism

Climate change affects the tourism sector by inflicting damage on a wide range of environmental resources that are critical attractions for tourism. Warmer temperatures and reduced precipitation are expected to lead to a decrease in the intensity, residence time (from 110 days to 45 days with a warming of 2°C) and thickness of the snow cover in the mountains of Lebanon thus shortening the skiing season, which is the key attraction for tourism during winter. Climate change can also provoke the loss of natural attractions, reduce ecotourism activities and impinge on the livelihoods of the communities. In addition, sea level rise may inflict damage on the touristic attractions located on the shore and sandy public beaches and can cause coastal erosion and structural damage to national archaeological heritage.

General adaptation measures are mainly targeted to strengthening the role of related public institutions, creating financial incentives to encourage investment in more sustainable touristic activities and facilitating communication between the private and public sector. More specific measures include: 1) moving ski areas to higher altitudes or to colder north slopes; 2) improving insurance coverage in the face of extreme events for high mountain areas and winter tourism destinations at risk; 3) implementing soft and hard protection measures for coastal and island destinations and 4) developing and promoting alternative and sustainable types of tourism, supporting protected area management, and enhancing and restoring the forest cover in order to promote sustainable tourism for natural areas at risk.

Human Settlements and infrastructure

The most likely impacts of climate change on infrastructure and human settlements are caused by changing patterns in precipitation, sea level rise and increased frequency and intensity of storms which inflict significant damages to buildings and public infrastructure. These impacts can cause inundation of coastal settlements and buildings, disruption of operation at the airport and damages in the transport infrastructure, water and wastewater networks. They can also increase the risk of floods, mudslides and rockslides. The related socio-economic impacts include a reduction of the quality of life due to financial losses in the infrastructure supporting the different economic activities, and an increase in the cost of living in urban agglomerations.

Adaptation measures require the adjustments of current settlements and infrastructure to future climatic changes. These include 1) integrating the transportation and land-use planning at the level of planning of new infrastructure or rehabilitation of those affected by climate change; 2) adopting protective measures against sea level rise and other extreme weather events and 3) anticipating floods in vulnerable areas through hard and soft engineering measures.

4. Other Information: Public Awareness, Education and Capacity Building

Within this section, a description on existing institutional and policy framework pertaining to climate change is done. In order to strengthen the loose or even non-existing coordination among the ministries, the creation of a National Committee for Climate Change and Desertification is proposed.

In terms of access to technology, barriers are identified and policy options to overcome these barriers are proposed.

The existing climatic observation network is described, spanning the entire spectrum of organisations (governmental and academic) that contribute in conducting and providing information related to primarily meteorological information. In general, the country lacks proper funding within this area.

In terms of research, education, training and awareness, the role of higher education is highlighted, where the lack of funds and proper research in the climate change arena remains a main hindrance.

5. Constraints, gaps and related financial, technical and capacity needs

Several barriers need to be overcome in order to enable Lebanon to comply with the fundamental principles of the Convention. At present existing main barriers can be categorized into three groups: constraints for the preparation of national communications, difficulties in implementing the proposed mitigation and adaptation measures, and financial constraints.

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National Circumstances

1. National Circumstances

1.1 Geographic Profile

Lebanon is located on the eastern basin of the Mediterranean Sea (Figure 1-1) with a surface area of 10,452 km^2, characterized by mostly mountainous areas constituted of the following parts (Walley, 2001):

- A narrow coastal plain composed of 2 plains, one in the north (Aakar) and one in the south (Tyre) and a succession of little narrow plains separated by rocky headlands in the center.
- The Mount Lebanon chain with an average elevation of about 2,200 m. Cut by deep canyons, and composed essentially of Jurassic thick carbonate sediments, the northern part of the chain is the higher region.
- The Anti Lebanon chain - subdivided into two massives: Talaat Moussa (2,629 m) in the north and Jabal el Sheikh or the Mount Hermon (2,814 m) in the south.
- The Beqaa valley - a flat basin with a length of about 120 km, located between the Mount Lebanon and the Anti Lebanon chains. Its elevation averages at 900 m, peaking at 1,000 m at its center.

Figure 1-1 Geographical location of Lebanon

1.2 Government Structure

Lebanon is a republic, with the official language being Arabic, while French and English are the two locally used languages. The country's institutional authorities consist of:

1. The Legislative authority: represented by the General Assembly of the Parliament (whose role is to issue and update legislations);
2. The Executive authority: represented by the Council of Ministers (CoM) and its support institutions;
3. The Judiciary authority: represented by the Higher Council of Justice (whose role is to apply the legislations).

The Head of the State is the president of the Republic, who is elected by the Parliament and supervises the functions of each of the individual authorities. With the consultation of the members of the Parliament, the President appoints the Prime Minister which in turn forms a government. The appointment of cabinet ministers is ratified by the Parliament.

Administratively, Lebanon is divided into 8 mohafazat, divided into 25 Caza (Figure 1-2). The administrative center of each Caza is principally located in the most important town of the region. Each Mouhafaza is headed by a Mouhafez, who represents the national government administration and each Caza is headed by a Qaimmacam.

The Municipalities and the Councils of Elders make up the local government in Lebanon. The Mayor heads the municipality enjoying a vast authority over local affairs, while the Moukhtar heads the Council of Elders and provides services related to civic personal certifications.

Figure 1-2 Administrative boundaries of Lebanon

The Ministry of Environment (MoE) is the main governmental body concerned with environmental issues in the country. It was established in 1993 under Law 216/93 to meet Lebanon's environmental challenges, and articulate environmental policy principles and strategy objectives. MoE and other government agencies (the Ministry of Water and Energy (MoEW), Ministry of Public Works and Transport (MoPWT), Ministry of Agriculture (MoA), Council for Development and Reconstruction (CDR), the Directorate General for Urban Planning (DGUP), etc.) dispose of a growing arsenal of legal and regulatory instruments to protect the environment. Policies are addressed by the highest Executive level (through the Minister of Environment at the Council of Ministers) as well as by the Legislative Branch (through the Environmental Committee of the Parliament). Lebanon has passed as many as 750 texts related to environmental issues, including in order of increasing importance: circulars, ministerial decisions, decrees, laws and international treaties.

Lebanon has signed the United Nations Framework Convention on Climate Change (UNFCCC) in June 1992 and has ratified the convention on August 11^{th} 1994 by virtue of Law 359, and acceded to the Kyoto Protocol on November 13^{th} 2006 by virtue of Law 738.

1.3 Demographic Profile

The only population census ever conducted in Lebanon dates back to the year 1932, where the total number was estimated to 793,000. Since then, demographical data are obtained from estimations which differ from one source to another. In addition, massive emigration and the presence of Palestinian refugees in camps make the convergence to a single population value a daunting task.

Although the country experienced a significant population growth (3.01%/yr) between 1945 and 1975, the pace slowed down to an annual growth rate of 2.08% in 1997 with a resident population of 4 million people (CAS, 1997), among which 350,000 Palestinian refugees, as estimated by UNRWA. However, with a significant reduction in fertility rate, the natural growth of population is taking a slower rate and national projections estimate an annual growth of 1% between 2000 and 2030 (CDR, 2005).

The population of Lebanon is estimated at 4.16 million inhabitants in 2000 and 4.29 million in 2004 (based on an annual growth rate of 1% to the CDR population record of 1997 of 4 million), 27.3% of which are under 15 years of age and 7.4% are over 65. The country is witnessing a demographic transition. The infant mortality rate has decreased from 33.5/1,000 in 1996/97 to 18.6/1,000 in 2004. This could not have been achieved without substantial reduction of the high mortality rates recorded in 1999 in the North and the Bekaa, and the lowering of regional disparities. Indicators showing the demographic transition in Lebanon between 1996/97 and 2004 are shown in Table 1-1.

Lebanon is classified as a highly urbanized country with more than 85% of its residents living in urban areas, while sustainable urbanization remains a key national development challenge (UN, 2009).

The population in Lebanon is unevenly distributed among regions where one third of the population resides in the Greater Beirut Area (GBA), and only 12.5% of the population resides in the governorate of Bekaa, which is the largest administrative region by surface area (Figure 1-3). The country has one of the highest population densities in the world ranking 11^{th} with 391 persons/km^2, and the city of Beirut has the highest density among all governorates with 21,938 persons/km^2 (CAS, 2004; MoE, 2005).

Table 1-1. Indicators of the demographic transition in Lebanon

	1996-1997	2004
Crude birth rate (per 1,000 mid-year population)	25	16.9
Crude death rate (per 1,000 mid-year population)	7	4.1
Infant Mortality Rate (per 1,000 Live Births)	33.5	18.6
Population <15 years (%)	28	27.3
Population >65 (%)	6.5	7.4
Dependency Rate (%)	62.8	53.3
Total Fertility Rate (Live Births per 1,000 women of childbearing age)	2.5	1.9

Source: Ammar, 2009

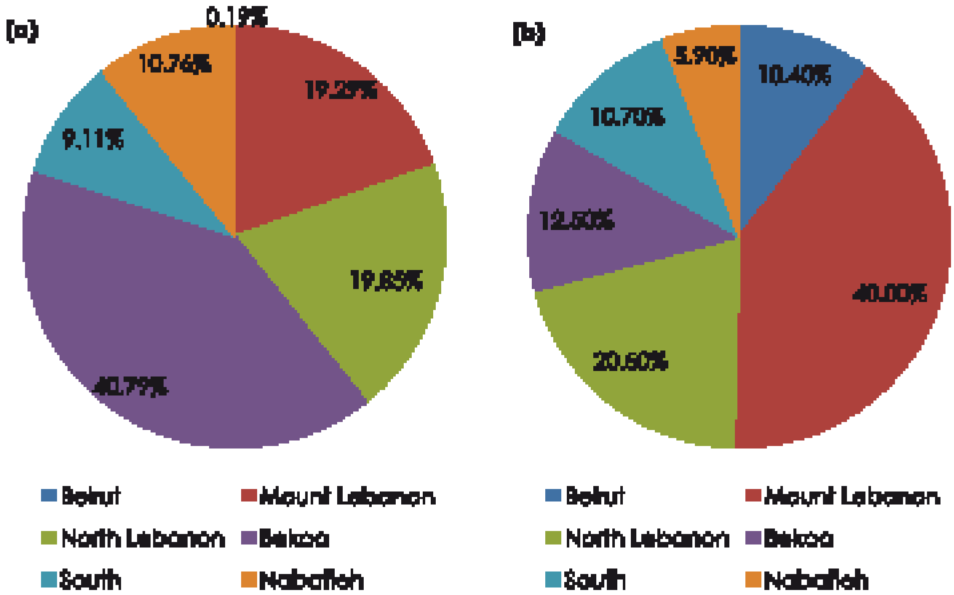


Figure 1-3 (a) Share of the total area by governorate (b) Percent distribution of individuals per governorate

1.4 Economic Profile

1.4.1 GDP evolution

Lebanon is considered a country of "medium high" income with a GDP of USD 16.3 billion in 2000 and USD 22.7 billion in 2006 (Figure 1-4) (MoF, 2008).

The average GDP growth for the period 2000 - 2006 is about 2.9% (Figure 1-4), with a major growth showing for the years 2003 and 2004 at GDP growth rates of 4.1 and 7% respectively. In 2005, growth witnessed a slowdown following the aftermath of Prime Minister Hariri's assassination, with real GDP growth at 1.1%. The first half of 2006 was characterized by a strong revival of the Lebanese economy with real GDP growth estimated by the Lebanese Ministry of Finance to 5 to 6%. However, the July 2006 War and the numerous political tensions in the country had a significant impact on the economy, slowing the real GDP growth down to 0%.

The GDP composition (Figure 1-5) from 2000 to 2006 shows similarities with a dominance of the tertiary sector. The service sector includes commerce, tourism, financial services, health care, higher education, market and non-market services, transport and communication and trade. The primary commodity shares of the economy for the years of 2000 and 2006 are 15.3% and 13.8% respectively.

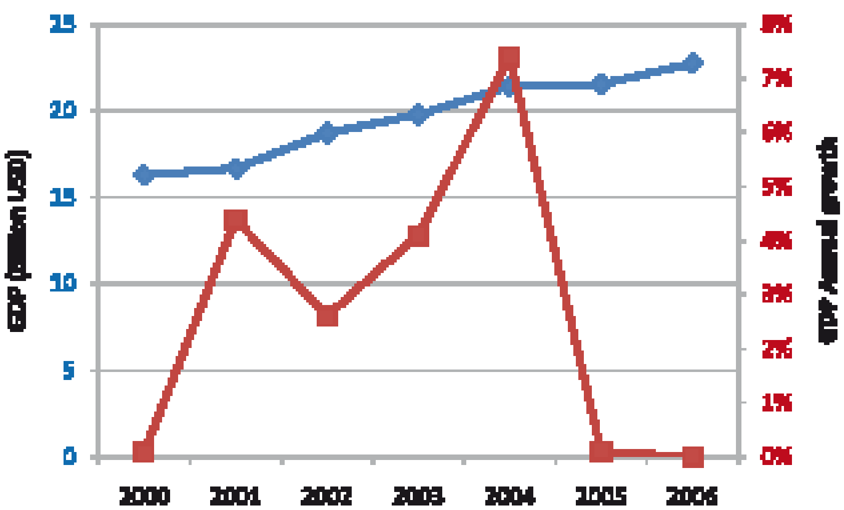


Figure 1-4 GDP evolution and annual growth
Source: MoF, 2008

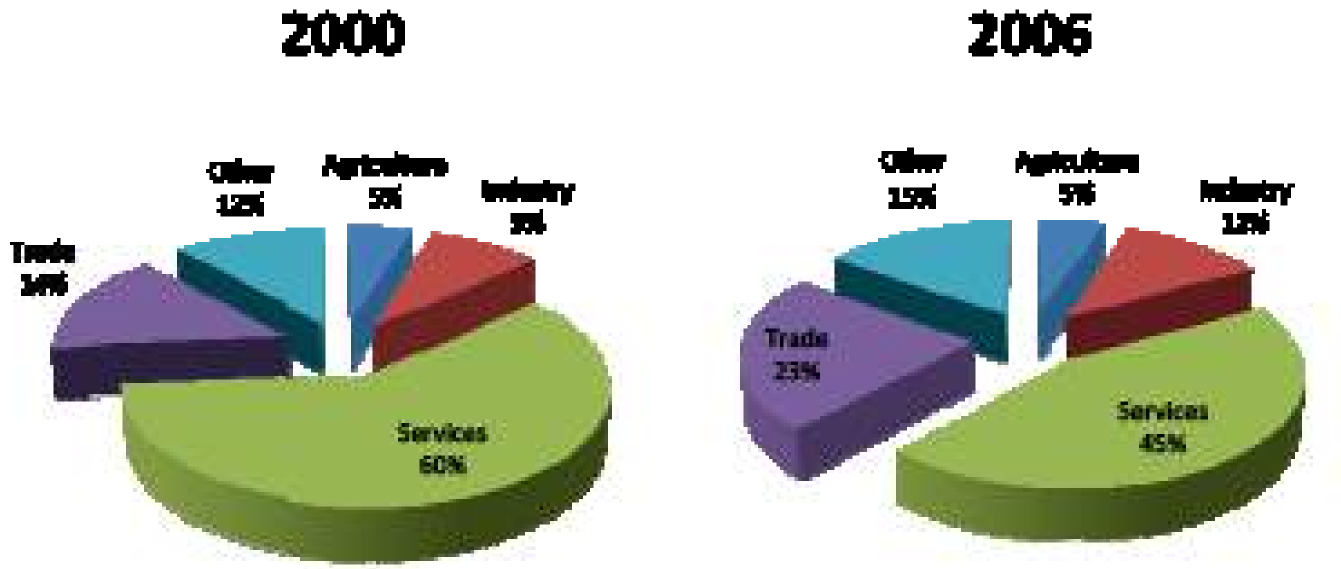


Figure 1-5 Percentage of GDP from agriculture, industry, services in Lebanon for 2000 and 2006
Source: MoF, 2008

1.5 Climate Profile

1.5.1 Precipitation

Lebanon is typically characterized by a Mediterranean climate with precipitation mainly occurring 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.

The topography of the Lebanese territories allows for a wide distribution of precipitation. As a result, five distinct agro-climatic zones are present in the coastal strip, low and middle altitudes of Mount Lebanon, west, central and north Bekaa. Records over 50 years from over 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 1-2), with the lowest and highest levels of precipitation of 80 mm and 3,010 mm respectively (Hajjar,1997). Coastal areas experience precipitation ranging from 600 to 1,100 mm reaching as high as 1,400 mm on the peaks of Faraya and Becharreh, and as low as 300 to 400 mm recorded inland (Figure 1-6, Figure 1-7).

Table 1-2 Precipitation levels records

	Number of Stations	Station Altitude		Precipitation (mm/year)		
		Low	High	Yearly Average	Min	Max
Beirut	4	15	34	891.75	393	1,600
North	25	2	1,925	1,055.00	425	1,890
Mount-Lebanon	36	45	1,840	1,210.16	421	3,010
South	26	5	1,150	933.27	342	2,139
Beqaa	36	650	1,510	705.42	80	2,374
Lebanon	105	5	1,840	787.00	80	3,010

Source: Hajjar, 1997

Figure 1-6 Mean annual precipitation over Lebanon

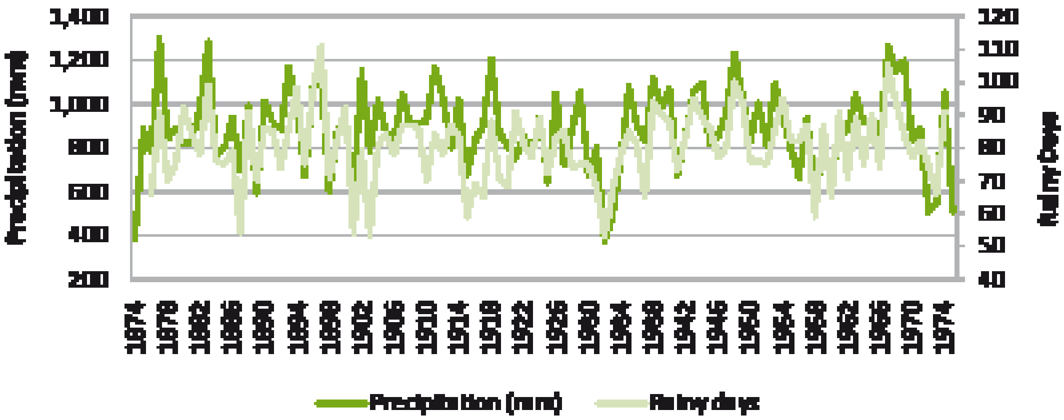


Figure 1-7 Total yearly precipitation levels observed at the American University of Beirut station between 1874 and 1975

Source: adapted from Farajalla et al., 2010

1.5.2 Temperature

Climate in the East Mediterranean is characterized by mild rainy winters from the westward moving cyclonic activity (Maheras, 2001; Alpert et al., 2004) and long, hot dry summers brought about by persistent atmospheric subsidence influenced by the Asian monsoon (Ziv et al., 2004). Lebanon's climate is further shaped by its unique topography with the coastal strip, the Lebanon and Anti-Lebanon mountain ranges, and the inland Bekaa plateau. Thus the coastal area and the western side of the Lebanon mountain range exhibit maritime characteristics, while the climate of the eastern side is more continental (LMS, 1977).

The yearly average temperature pattern (Figure 1-8) in Lebanon ranges from 5°C and 10°C for the region located above 1,800 m altitude except for a small area in the Bekaa plateau where the 10°C line extends to a lower altitude near the town of Serghaya. The region located between 1,100 m and 1,200 m enjoys 15°C yearly average temperature. A slight portion of the littoral benefits from the dampening effect of the sea and has a yearly average temperature above 20°C.

1.6 Water Resources

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.

1.6.1 Water Balance

Yearly precipitation results in an average yearly flow of 8,600 million m^3 (Mm^3), giving rise to 40 streams and rivers and over 2,000 springs. About 1,000 Mm^3 of this flow comes from over 2,000 springs with an average unit yield of about 10–15 l/s (FAO, 2008). Since Lebanon is at a higher elevation than its neighbors, it has practically no incoming surface water flow (FAO, 2008).

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 8%) and groundwater seepage (12%). 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) consisting of 1,500 Mm^3 of surface water and 700 – 1,165 Mm^3 of groundwater (MED EUWI, 2009). Table 1-3 shows the total annual water balance and water uses as reported in different sources.

1.6.2 Surface Water Resources

The flows in water courses are estimated at 3,400 Mm^3 approximately for an average year, including flows from both national and transboundary rivers. Surface water outflow to the Syrian Arab Republic is estimated at around 425-510 Mm^3 through the El Assi River and about 160 Mm^3 to the north of the occupied territories through the Hasbani/Wazani complex (FAO, 2008; Plassard, 1971). Table 1-4 shows flows in watercourses by Mohafaza during different periods of the year. Lebanon comprises 17 perennial and 23 seasonal rivers and streams (Table 1-5), with 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).

Figure 1-8 Mean annual temperature over Lebanon

Table 1-3 Summary of water balance

<table>
<tr><th colspan="2">Description</th><th>MED EUWI (2009)</th><th>MoEW (2004)</th><th>World Bank (2003)</th><th>UNDP (1970)</th><th>Geadah (2002)</th><th>Plassard (1971)</th></tr>
<tr><td colspan="2">Precipitation (mm)</td><td>800 – 1,000</td><td>820</td><td>820</td><td>940</td><td>-</td><td>-</td></tr>
<tr><td colspan="2">Evapotranspiration (mm)</td><td>500 – 600</td><td>430</td><td>380</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td colspan="2">Precipitation (Mm³)</td><td>8,320 – 10,400</td><td>8,600</td><td>8,600</td><td>9,800</td><td>8,600</td><td>8,600</td></tr>
<tr><td colspan="2">Evapotranspiration (Mm³)</td><td>4,300 – 6,240</td><td>4500</td><td>4,000</td><td>-</td><td>4,300</td><td>4,300</td></tr>
<tr><td colspan="2">Total flow of the 40 major streams (Mm³)</td><td>3,673 – 4,800</td><td>3680</td><td>3,800</td><td>4,300</td><td>1,774</td><td>1,800</td></tr>
<tr><td colspan="2">Surface flow to neighboring countries (Mm³)</td><td>300 – 670</td><td rowspan="2">945</td><td>700</td><td>~ 680</td><td>670</td><td>160 (Palestine)
510 (Syria)</td></tr>
<tr><td colspan="2">Groundwater flow to neighboring countries (Mm³)</td><td>310</td><td>200</td><td>-</td><td>300</td><td>150 (Palestine)</td></tr>
<tr><td colspan="2">Flow of submarine sources (Mm³)</td><td>385 – 1,000</td><td>385</td><td>700</td><td>711</td><td>880</td><td>880</td></tr>
<tr><td rowspan="2">Total resources (Mm³)</td><td>Average year</td><td>2,600 – 4,800</td><td>-</td><td>-</td><td>-</td><td>-</td><td></td></tr>
<tr><td>Dry year</td><td>1,400 – 2,200</td><td>-</td><td>-</td><td>-</td><td>-</td><td></td></tr>
<tr><td rowspan="3">Exploitable resources (Mm³)</td><td>Surface water</td><td>1,500</td><td>-</td><td>-</td><td>-</td><td>-</td><td>1,800</td></tr>
<tr><td>Groundwater</td><td>700 – 1,165</td><td>-</td><td>-</td><td>-</td><td>-</td><td>800</td></tr>
<tr><td>Total</td><td>1,400 – 2,200</td><td>-</td><td>-</td><td>-</td><td>2,000</td><td>-</td></tr>
</table>

Major surface storage structures such as reservoirs are not abundant in Lebanon. The major reservoir on a river is the Qaraoun Lake which is formed by a rockfill dam constructed on the Litani river with a total reservoir capacity of 220 Mm³ and an effective storage of 160 Mm³. It supplies three hydroelectic power plants and provides every year a total of 140 Mm³ for irrigation purposes and 20 Mm³ for domestic purposes to the South. A second artificial reservoir and dam was inaugurated in 2007 in Shabrouh, with a static storage capacity of 8 Mm³ and a dynamic reserve of 15 Mm³. It is located in 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) (MoEW, 2010).

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).

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).

Table 1-4 Flows in watercourses in Lebanese Mohafa

Flows in water courses (average values) (in Mm³)	North Lebanon	Mount Lebanon	North Bekaa	Central and Southern Bekaa	South Lebanon	Total
Entire Year	670	990	480	830	430	3,400
May to October (6 months)	270	305	240	240	25	1,080
July to October (4 months)	115	95	155	115	10	490
September	22	18	38	27	2	107

Source: Comair, 2006

Table 1-5 Annual flow of the most important perennial rivers and streams of Lebanon

Region	River	Length (km)		Flow (Mm³/year)		
		MoE (2001)	Jaber (1993)	MoE (2001)	Bakalowicz (2009)	Jaber (1993)
North	El Kabir	58	58	190	131	190
	Ostuene	44	NA	65	67	65.1
	Araqa	27	NA	59	70	65
	El Bared	24	24	282	72	281.9
	Abou Ali	45	42	262	205	262.4
	Kousba	NA**	NA	NA	NA	NA
	Asamra	NA	NA	NA	NA	NA
	El Jawz	38	25	76	40	75.7
Mount Lebanon	Ibrahim	30	22	508	319	507.9
	Janin	NA	NA	NA	NA	NA
	Khadira	NA	NA	NA	NA	NA
	El Kalb	38	28	254	117	252.6
	Beirut	42	20	101	65	101.4
	Damour	38	30	307	157	256.5
South	El Awali	48	50	299	371	284.4
	Joun	NA	NA	NA	NA	NA
	Saitaniq	22	NA	14	111	NA
	El Zahrani	25	NA	38	13	38.6
	Abou Assouad	15	NA	11	3	NA
Bekaa	Litani	170	NA	793	689	NA
	Upper Qaraon	NA	NA	NA	NA	404
	Lower Qaraon	NA	NA	NA	NA	NA
	Khardali – Sea	NA	170	NA	NA	129.9
	Yammouneh	NA	NA	NA	NA	58.7
	El Assi	46	45	480	656	414.5
	Hasbani	21	NA	151	85	138.3
Total*				3,890	3,171	3,527

*Total figures exclude certain river flows when relevant data is not available.
** Not Available.

1.6.3 Groundwater

Groundwater recharge is estimated around 3,200 Mm³, of which 2,500 Mm³ 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, 2008).

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. 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% of wells are illegal due the lack of enforcement of licensing requirements (World Bank, 2003).

Groundwater quality is 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 42,000 private wells) (CAS, 1997; CDR, 2005; and MoEW, 2010). This pollution has direct effects on public health and health-related expenditures. The costs of the health impacts of water pollution are estimated at USD 7.3 million/year and the costs of excess bottled water consumption at

Table 1-6 Comparison of water consumption by sector in Lebanon

Sector/Activity		Consumption on %			
	Jaber (1997)		World Bank (2010)	Comair (2006)	JICA, et al., (2003)
Domestic	Cooking	45	26	25	53
	Washing				
	Shower				
	Backyard Irrigation				
Services	Hotels, restaurants & pools	8.5	-	-	-
	Hospitals & health institutions				
	Schools				
	Commercial				
Public	Public Institutions	12	-	-	-
	Military (Caserns)				
	Parks and Municipal				
Agriculture	Cattle	4	65	69	-
	Horses				
Industrial	Light Industries	7.5	9	6	10
Losses		23	-	-	37
Total		100	100	100	100

about USD 7.5 million, noting that these are conservative estimates that do not account for all associated direct and indirect costs (MoE, 2001).

1.6.4 Snow cover

Lebanon, with about 60–65% of mountainous terrain, receives a considerable amount of snow (Shaban et al., 2004). The Mount Lebanon mountain range, at altitudes between 1,700 m and 3,000 m is covered, for around 3 months every year, with an average yearly precipitation of around 3 Mm^3 in the form of snow, with the snowpack reaching its peak in March. Starting February, temperatures are sufficiently high to cause snowmelt at altitudes lower than 2,000 m (Najem, 2007).

The snow that covered Mount Lebanon during the 2000-2001 winter contributed an equivalent of 1,250 Mm^3 (± 10%), 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, 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, 2009). Water from melting snow contributes 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.

1.6.5 Water Consumption by Sector

General estimates exist for water demand and water consumption by sector, with water demand values ranging from as low as 445 Mm^3 (JICA et al., 2003) to 985 Mm^3 (Comair, 2006), and as high as 1,338-2,280 Mm^3 (Amery, 2000). Table 1-6 illustrates water consumption by sector in Lebanon.

Greater Beirut has the highest water demand and loss rate, followed by Mount Lebanon. Public supply provides 83% of national water supply, necessitating an additional private supply in all regions amounting to 17% (JICA et al., 2003).

Further studies have assessed agricultural water withdrawal assessment based on 11,200 m^3/ha/yr from surfacewater and 8,575 m^3/ha/yr from groundwater resources (FAO, 2008). The use of groundwater for irrigation has increased during recent years. This situation has encouraged individual farmers to cope with water shortages by increasingly relying on private wells (Hreiche, 2009).

Table 1-7 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

Source: MoE, 2001

1.6.6 Stresses on the water sector

The water sector currently undergoes several environmental stresses resulting from different socio-economic activities and practices, as summarized in Table 1-7.

1.7 Agriculture

The agriculture sector's share of GDP, between 1999 and 2007, averaged 5.8% of the total value-added. For the same period, agriculture's share of employment of the total economically active population has been steadily declining, from 3.9% in 1999 to 2.2% in 2005.

Despite a beneficial variation in temperature and rainfall over the Lebanese territories, under-investment in the agricultural sector has contributed to retraction in its contribution to the national economy and a lack of interest from investors and the young workforce. Only 1% to 3% of the annual public budget is allocated to agriculture services. Another issue which is influencing the decrease in productive lands is the decrease in the average plot size due to inheritance laws, thus rendering agricultural exploitation unprofitable.

The varied elevation offers Lebanon the possibility of extending to an extremely diversified agriculture; from quasi-tropical products on coastal plains to orchards in high-altitude mountains, with a full range of possible intermediary crops in between. Physical configurations of terrains (vast plains, narrow plains, basins, slopes, etc.) determine the possibilities for automation or mechanization, industrial and semi-industrial exploitation (CDR, 2005).

Almost half of Lebanon's total surface area could be cultivated, although with different levels of productivity. The country's "real" arable land resides in large areas, representing altogether around one third of its total land mass (CDR, 2005). The main crop production regions are distributed as follows (Saade, 1994):

- The coastal strip: citrus fruits, bananas, horticulture products and vegetables (predominantly grown in plastic greenhouses);
- The Akkar plains: cereals, potatoes, grapes and vegetables;
- The central Bekaa valley: potatoes, vegetables, grapevine, stone fruits and grains;
- The mountainous region: fruit orchards and vegetables;
- The western slopes of the Mount Hermon and Anti-Lebanon range: grapes, olive and cherry;
- The hills in the South: olives, grains, tobacco and almonds.

Agricultural production is concentrated in the Bekaa valley, which accounted for 42% of total cultivated land in 2005 (Figure 1-9) and the highest percentages of essential crop types such as cereals and vegetables (Figure 1-10).

The most important cereals cultivated are wheat, barley and corn (MoA, 2007) which play an important role in food self-sufficiency. Production of cereals reached 394,400 tonnes in 2005 with a total value of LBP 92.9 billion (MoA, 2007). Durum wheat (used in the local food industry – borghul, freek, kishek, pasta, etc.),

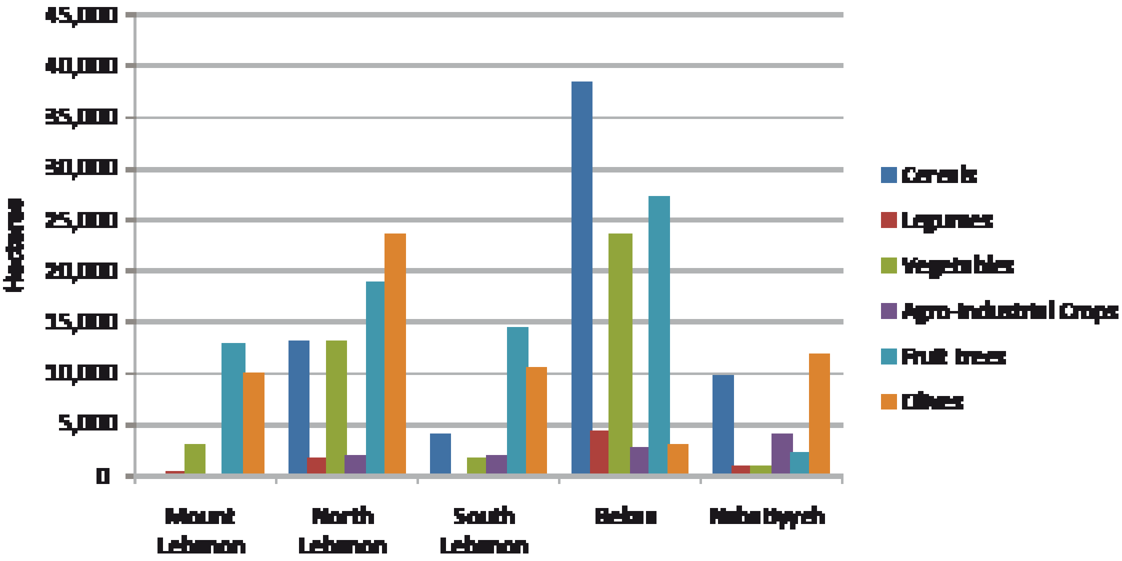


Figure 1-9 Distribution of crop area by governorate
Source: MoA, 2007

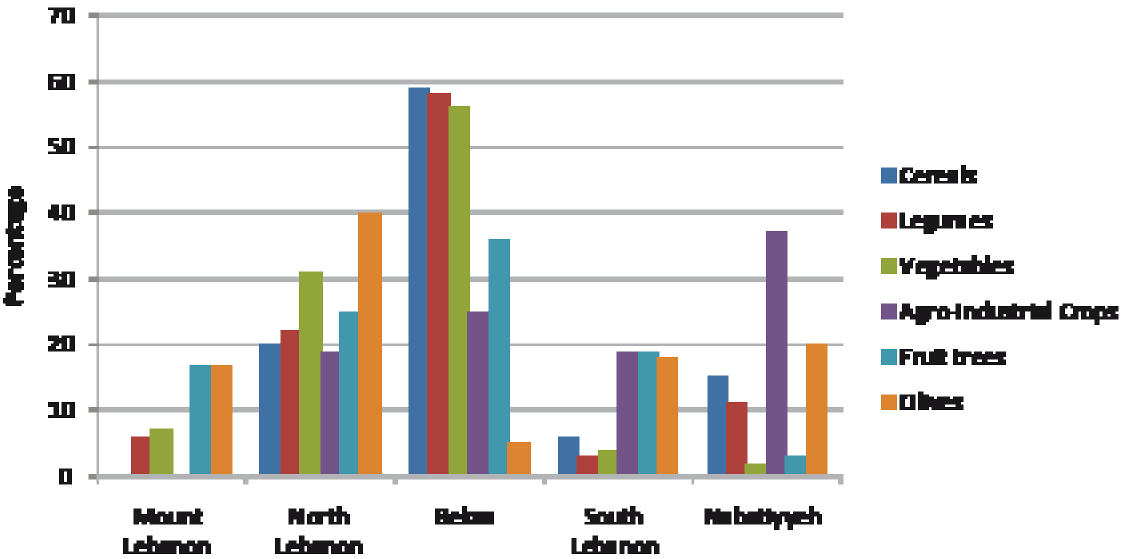


Figure 1-10 Percentage distribution of crops grown by governorate
Source: MoA, 2007

although not suitable for bread production, is the most widely grown cereal crop, and the only type of wheat cultivated in Lebanon, producing 143,700 tonnes valued at 60% of the total value of cereal production in 2005 (FAO, 2009a). Lebanon is a net importer of wheat, with import value reaching LBP 201 billion in 2005. The price of imported wheat is much lower than the farm gate price of locally-grown wheat (MoA, 2007). The government supports wheat cultivation as a strategic crop for food security, and to maintain the value of rainfed arable land.

Lebanon's vegetable production is divided into leafy vegetables (e.g., artichokes, cauliflowers, cabbages, lettuce and salad greens), tuber vegetables (e.g., potato and carrot), and fruit-bearing vegetables (e.g., peppers, cucumbers, eggplants, tomatoes, melons and watermelons). Potato constituted almost half of the total vegetable cultivation in 2005, covering 19,700 ha (or 46.8% of vegetable-cultivated area) and 7.2% of the total cultivated area, followed by tomato (covering 8.8% of the vegetable-cultivated area). Lebanon is a net exporter of potato (Figure 1-11), and a net importer of tomato (Figure 1-12). Despite the decrease in the harvested area of tomato, the yield has been increasing, mainly due to the use of good quality seeds and mechanization in tomato cropping and harvesting.

Fruit (citrus, pome fruits, stone fruits, tropical fruits including, carobs, almonds and nuts) cultivation is one of the most

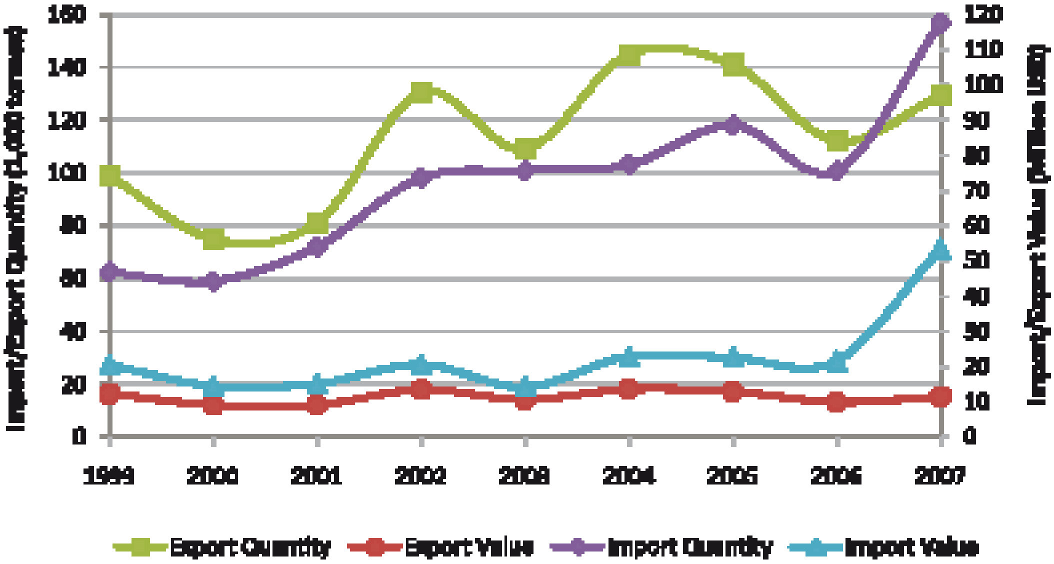


Figure 1-11 Potato import and export quantities and value
Source: FAO, 2009a

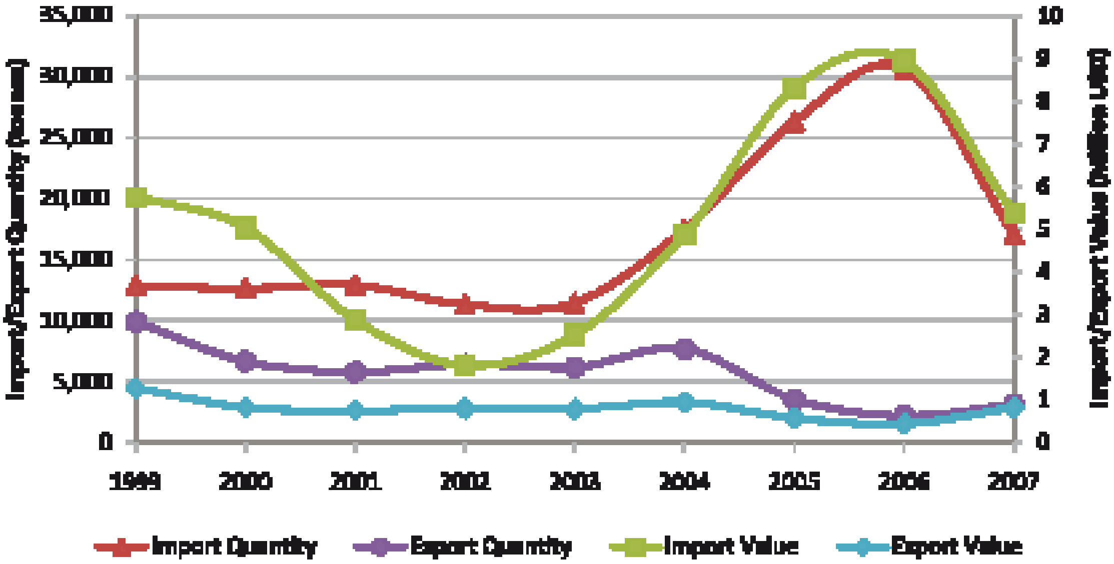


Figure 1-12 Tomato import and export quantities and value
Source: FAO, 2009a

important elements of agricultural income with 40% of total crop production quantity (in 2005), 36.5% of the agricultural value-added (in 2005) and 28% of the total productive agricultural area (FAO, 2009a and MoA, 2007). Fruit trees cultivation is concentrated in the Bekaa (36%), followed by North Lebanon (25%), South Lebanon (19%), Mount Lebanon (17%) and Nabatiyyeh (3%) (MoA, 2007).

Lebanon is a net regional exporter of oranges, apples, bananas, grapes and cherries (FAO, 2009a), thus maintaining a positive trade balance in fresh fruit products. Lebanon grows grapes as an industrial crop for wine making. The local wine industry produces one of the major agricultural exports by value (USD 10.4 million in 2005) (FAO, 2009a).

Although olive trees are technically fruit-bearing trees, the agricultural census of Lebanon considers this crop in a stand-alone category due to its local economic importance. Olives, largely non-irrigated, are the single largest crop by total surface area, grown over 21.5% of the total productive agricultural areas, or 58.8 thousand hectares, in 2005 (MoA, 2007). The North Lebanon governorate retains the largest production areas (40%), followed by Nabatiyeh (20%), South Lebanon (18%), Mount Lebanon (17%) and Bekaa (5%) (MoA, 2007). Olive fruit bearing is not consistent across the years; in 2004, the production reached 167,000 tonnes while it reached 76,500 tonnes in 2005 (MoA, 2007). Olive oil is rapidly becoming an important export commodity; Lebanon exported 29% of its production of

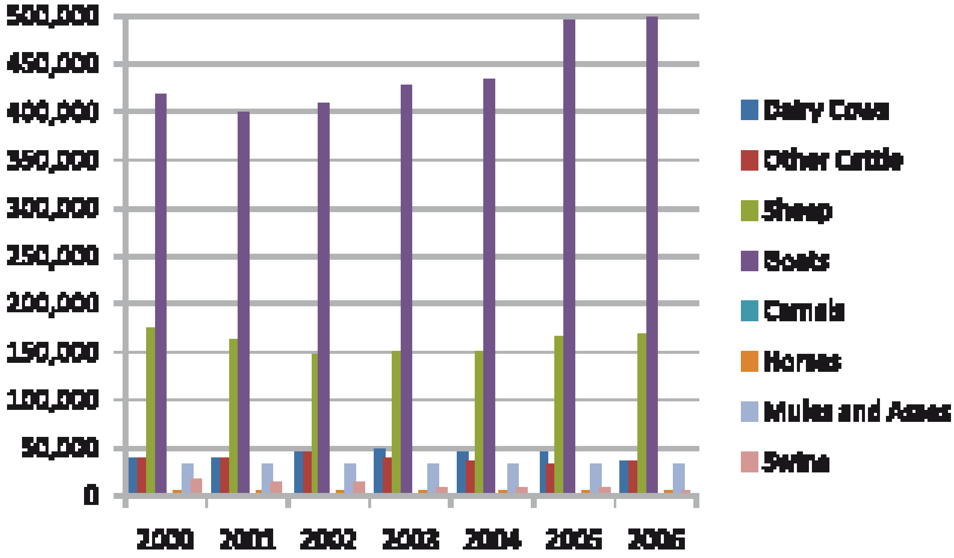


Figure 1-13 Number of livestock heads by type
Source: FAO, 2009

olive oil in 2005 (FAO, 2009a). However, it must be noted that not all of the production is from locally-grown crops. In the same token, imports of virgin olive oil are rapidly increasing due to the removal of trade barriers between Lebanon and the EU.

The livestock sector in Lebanon faces difficulties on the levels of production and marketing. Main livestock products include red meat of different varieties, poultry meat, in addition to milk and its derivatives, eggs, honey and fish. The quantities produced meet a small part of the local consumption demand. Consequently, the country relies on the import of animal products to meet the overall consumption demand. The exception, however, is the poultry sector where national poultry meat and egg production meet the overall demand for these products. Small ruminants include goat and sheep and constitute the largest livestock number (by stock heads) (Figure 1-13). Most of the herds are found in the Bekaa governorate, followed by North Lebanon (MoA, 2007).

Livestock production is an important activity, particularly in the mountains and in the Baalbeck-Hermel area on the eastern mountain chain where soil fertility is relatively low. In recent years, livestock production, especially goats and sheep, has increasingly relied on feed blocks and feed supplements, thereby reducing dependence on wild grazing and ultimately leading to more sedentary animal production (MoE, 2001). Goat meat supply meets the local consumption needs; however, Lebanon imports 65% of the sheep meat consumed. In general, the country is a net importer of dairy products as well (MoA and FAO 2005a).

The local milk production meets more than one-third of Lebanon's consumption needs (in fresh milk equivalent), including butter and cheese (MoA, 2007). The largest amount of milk is produced from farms in the Bekaa region (Figure 1-14). Cow milk represented 75% of the total quantity of milk produced in 2005, while goat and sheep milk represent 16% and 9% respectively. In 2000, sheep and goats produced 23,000 tonnes and 27,000 tonnes of milk respectively, or 25% of the local milk production.

In Lebanon, agriculture is the most water-demanding sector (about 65-70% of water resources) with irrigation being applied in 50% of all agricultural areas (MoA, 2007). The majority of irrigation techniques are gravity (or surface) irrigation, constituting 57.2% of all irrigated lands, while localized irrigation, including drip techniques, represents 7.7% of all irrigated lands (FAO, 2010). It is generally noted that sprinkler and drip irrigation are more commonly used when irrigation relies on groundwater and for specific crops such as potato, sugar beet and cereals.

Commensurate with the decrease in the total agricultural labor force, the agricultural population and its density are also on a decreasing trend. The average annual decrease in the agricultural population between 1999 and 2007 has been estimated at 5.4% (FAO, 2010). The agricultural population density, measured by the agricultural population per hectare of arable and permanent crops, has decreased from 0.7 in 1990-1992 to 0.3 in 2003-2005, despite a decrease in the area of arable and permanent cropland by 7.2% between 1990 and 2005 (FAO, 2010).

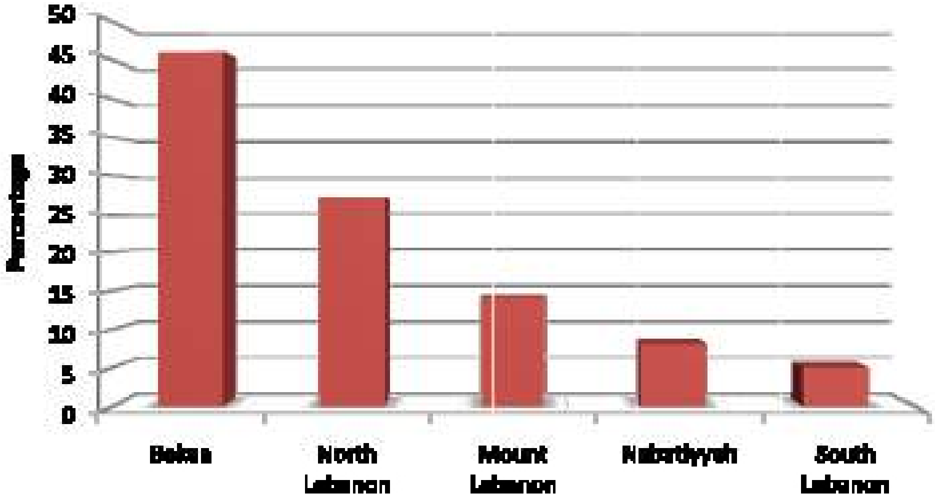


Figure 1-14 Milk production by governorate
Source: MoA, 2007

Population growth has affected the agriculture sector by further increasing urban pressure on agricultural lands, specially that converting agricultural fields to built-up, residential or commercial districts provides a faster return on investment to land owners particularly in coastal and peri-urban areas.

1.8 Forestry

Forests in Lebanon are very particular in their variation and characteristics and represent a unique feature in the arid environment of the Eastern Mediterranean.

In 2000, forests covered 13% (136,348 ha) of the country's overall surface and Other Wooded Lands (OWL) covered 10%. Other lands with trees (including fruit and olive trees) also covered 10% of the surface of the country (Figure 1-15) (MoA and FAO, 2005b).

The main forest species widespread in Lebanon are *Quercus calliprinos*, *Quercus infectoria*, *Quercus cerris, var. pseudocerris* (mostly referred to as *Quercus spp*), *Juniperus excelsa*, *Cedrus libani*, *Abies cilicica*, *Pinus pinea*, *Pinus halepensis*, *Pinus brutia* and *Cupressus sempervirens*. In addition, Lebanese forests contain a wide range of aromatic, wild and medicinal plants (Asmar, 2005). Oak woodlands (*Quercus spp*) constitute the major parts of Lebanese forests and OWL (41.61%), followed by pine forests (*Pinus spp*) (20.28%) while the *Cedrus libani* constitutes a mere 1.6% of the forest cover (MoA and FAO, 2005b).

As a result of unsustainable forest practices and neglect of forested lands, and as a result of the decline of controlled grazing in forest understory, oak and pine forests have become highly susceptible to fire events. In contrast, cedar forests have received national, regional and international attention due to their historic, symbolic and biological value (Sattout et al., 2005). Grazing has always been considered not only as an interesting economic activity related to forested lands, but also a powerful management tool that has shaped and defined the structure of Mediterranean forests. Grazing activities in and around forests occur in Lebanon during summer. Shepherds traditionally move their sheep and goats to the coast in winter (AFDC, 2007).

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

The forestry sector remains a relatively small employer nationwide; it only contributes to 0.02% of the total labor-force and 0.93% of GDP in 2001 (Sattout et al., 2005). Forest provides several economic resources: forest flora exploitation, beekeeping (USD 14,670,000 (MoA, 2007)), pine nuts production (USD 5,808,000 (Masri et al., 2006)), wood collection and charcoal production (AFDC, 2007), medical and aromatic plants (USD 29,600,000 (MoE et al., 2009), and carob pods (MoA, 2007). The economic value of the different forest ecosystems in Lebanon is estimated at about USD 131,500,000 (Sattout et al., 2005).

Table 1-8 Distribution of vegetation in Lebanon on the different vegetation levels

<table>
<tr><th rowspan="2">Floristic ensemble</th><th rowspan="2">Vegetation level</th><th colspan="3">Mother-rock</th></tr>
<tr><th>Limestone</th><th>Marl and Marly limestone</th><th>Sandstone</th></tr>
<tr><td rowspan="5">Mediterranean</td><td>Thermomediterranean
(0-500 m)</td><td>Ceratonia siliqua & Pistacia lentiscus series
Thermophilic series of Quercus calliprinos</td><td>Thermomediterranean series of Pinus brutia & Cupressus sempervirens</td><td>Thermomediterranean series of Pinus pinea</td></tr>
<tr><td>Eumediterranean
(500 m – 1,000 m)</td><td>Mediterranean series of Quercus calliprinos
Mediterranean series of Quercus infectoria</td><td>Mediterranean series of Pinus brutia & Cupressus sempervirens</td><td>Mediterranean series of Pinus pinea</td></tr>
<tr><td>Supramediterranean
(1,000 m – 1,500 m)</td><td>Supramediterranean series of Quercus Calliprinos, normal series of Quercus Calliprinos, Series of Ostrya carpinifolia & Fraxinus ornus, Series of Quercus cerris</td><td></td><td>Supramediterranean series of Pinus pinea, Series of Quercus infectoria sandstone variety, Series of Quercus cerris sandstone variety</td></tr>
<tr><td>Mountainous Mediterranean
(1,500 m – 2,000 m)</td><td>Series of Cedrus libani & Abies cilicica
Mountainous Mediterranean series of Quercus cedrorum & Quercus brantii ssp. Look
Mountainous series of Juniperus excelsa</td><td></td><td></td></tr>
<tr><td>Oromediterranean
(> 2,000 m)</td><td>Oromediterranean series of Juniperus excelsa</td><td></td><td></td></tr>
<tr><td rowspan="5">Mediterranean presteppic</td><td></td><td>Formation of Hammada eigii</td><td></td><td></td></tr>
<tr><td>Mediterranean presteppic (1,000 m –1,500 m)</td><td>Presteppic series of Quercus calliprinos</td><td></td><td></td></tr>
<tr><td>Presteppic supramediterranean
(1,400 m – 1,800 m)</td><td>Mixed presteppic series of Quercus calliprinos & Quercus infectoria</td><td></td><td></td></tr>
<tr><td>Presteppic mountainous Mediterranean
(1,800 m –2,400 m)</td><td>Mountainous presteppic series of Juniperus excelsa</td><td></td><td></td></tr>
<tr><td>Presteppic oromediterranean
(>2,400 m)</td><td>Presteppic oromediterranean series of J. excelsa</td><td></td><td></td></tr>
</table>

Source: Abi Saleh and Safi, 1988

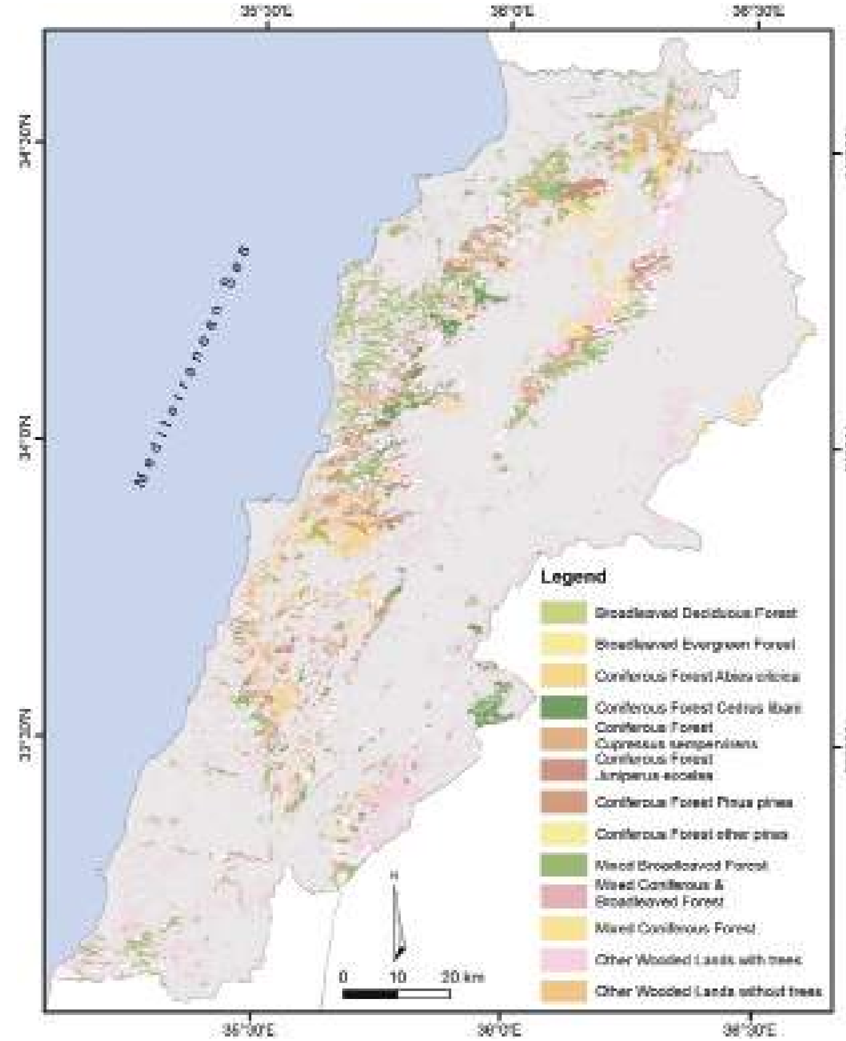


Figure 1-15 Lebanon's derived forest map
Source: MoA and FAO, 2005b

1.9 Energy

1.9.1 Electricity

The Lebanese electricity sector is at the heart of a deep crisis. The sector is unable to supply the reliable electricity needed by homes, offices and industries. It is a massive drain on government finances, crowding out more valuable expenditures on education, infrastructure, social protection, and health, and putting macroeconomic stability at risk. The state of the sector has reached a critical stage, with a massive drain on public resources (estimated at 4% of GDP for 2007 and 4.3% of GDP in 2009), significant revenue loss for industry and commerce, and exorbitant spending on back-up generation by the general population.

Electricity in Lebanon is supplied through Electricité du Liban (EDL), an autonomous state-owned entity under the authority of the MoEW. EDL is responsible for the generation, transmission, and distribution of electrical energy in Lebanon.

Lebanon figures among the countries with high coverage of electric power in the region. In 2002, access to electricity grew to be 96% in Lebanon (IEA, 2004) and it reached 99.9% in 2005 (IEA, 2006).

Demand figures are difficult to estimate for Lebanon, given that total production by existing power plants does not meet actual demand, therefore necessitating imports and self-generation to compensate for the deficit. It is estimated that 33% of the total electricity demand is met through self-generation (World Bank, 2008).

The peak electric load in Lebanon climbed from 1,666 MW in 2000 to 1,936 MW in 2004 (Figure 1-16). In 2009, average demand was 2,000 - 2,100 MW, and the instantaneous peak load in summer was 2,450 MW (MoEW, 2010). However, these figures do not account for the 33% self-generation mentioned above and

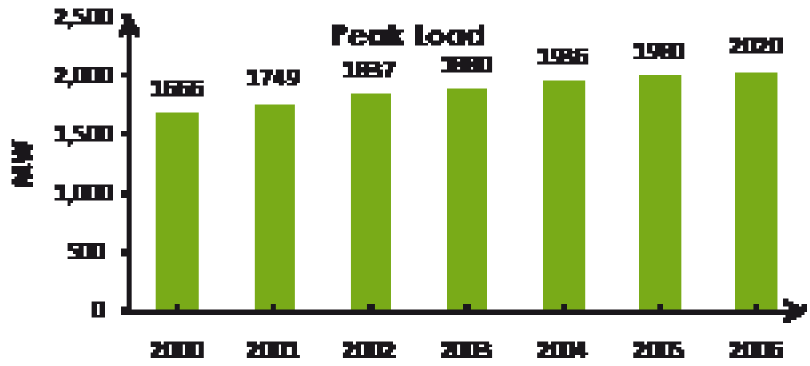


Figure 1-16 Electric Peak Load
Source: OAPEC, 2001-2007

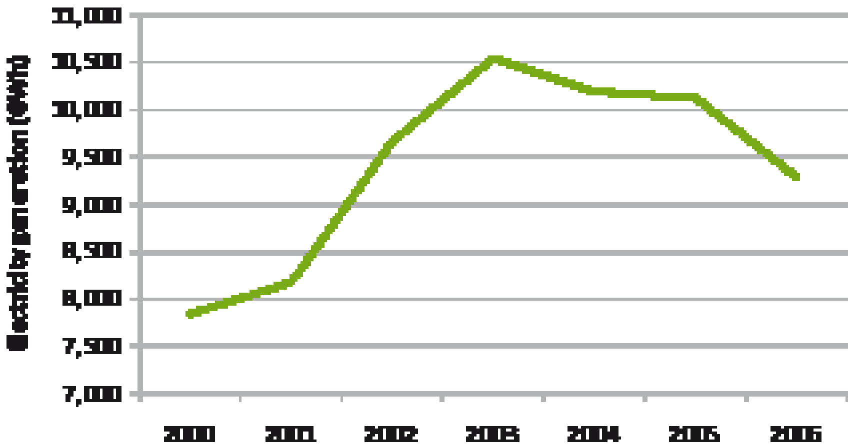


Figure 1-17 Electricity generation from 2000 to 2006.
Source: EDL, 2000 to 2009

when taken into account (i.e., inflate by 33%), the adjusted values show a load of 2,215 MW and 2,575 MW in 2000 and 2004 respectively. Figure 1-16 presents the electric peak load from 2000 to 2006.

Electricity demand met by EDL grew from 7,839 GWh in 2000 to 10,191 GWh in 2004. This represents an increase of around 30% over that period. The trend of electricity generation by EDL from 2000 to 2006 is represented in Figure 1-17.

It is worth noting that the decrease in demand met by EDL in 2006 is partially explained by the destruction of the electricity infrastructure caused by the hostilities with Israel during the July-August 2006 war.

Electricity is produced through 7 power plants and 5 hydropower plants (Table 1-9 and Table 1-10). While public data indicate that the total available capacity amounts to 90% of installed capacity, it is generally accepted that the available thermal power plant capacity currently varies from 1,600 to1,800 MW, i.e., around 70-80% of installed capacity (around 2,200 MW), due to the fact that many power plants are operating below their optimal efficiency. In 2009, installed capacity was 2,038 MW and available capacity 1,685 MW (MoEW, 2010). The total Lebanese hydropower capacity amounts currently to 274 MW, with an actual generation capacity of 190 MW (MoEW, 2010). Hydropower is generated mainly from the three plants installed on the Qaraoun Lake where the three installed turbines have a capacity of 34 MW, 108 MW and 48 MW respectively. The Bared and Nahr Ibrahim plants have an installed capacity of 17 and 33 MW respectively. All the hydropower units are between 40 and 70 years old, but they are not expected to be retired in the near future (CDR, unpublished).

Thermal capacity is divided into Heavy Fuel Oil-fired steam turbines at Zouk, Jiyeh and Hreysheh; diesel-fired Combined Cycle Gas Turbine (CCGT) at Beddawi and Zahrani; and diesel-fired Open Cycle Gas Turbine (OCGT) at Tyre and Baalbeck. As of October 2009, the Beddawi power plant has been operating on natural gas from Egypt, thus reducing demand for gas oil (MoF, 2010).

As already noted, self-generation plays a large role in electricity supply and demand. Power outages are a daily occurrence in Lebanon and in some regions of the country the quality of electricity supply is particularly poor.

Table 1-9 Total capacities and efficiency of thermal power plants in Lebanon

Unit Name	Total installed capacity (MW)	Available capacity (MW)	Efficiency (%)
Thermal			
Zouk	607	520	38
Jiyeh	346	295	33
Tyre	70	70	38
Baalbeck	70	70	38
Zahrani	435	435	48
Deir-Ammar (Baddawi)	435	435	48
Hreisheh	75	N/A*	N/A
Total thermal capacity	2,038	1,770	

* Not available.
Source: EDL, 2009 and World Bank, 2008

Table 1-10 Installed capacity and annual energy of hydropower plants in Lebanon

Unit Name	Installed capacity (MW)	Capacity factor (%)	Annual energy (GWh)
Litani	190	47	775
Al Bared	17	34	50
Safa	13	22	25
Nahr Ibrahim	33	35	100
Qadisha	21	41	75
Total capacity	274	43	1,025

Source: CDR, unpublished

No new power generation capacity has been added since the two combined cycle plants were installed in the 1990s. This has led to a massive investment by low-voltage consumers (households and commerce) and industry in back-up arrangements.

The reason for this is the inability of EDL to meet demand effectively due to insufficient generation capacity, high levels of lost electricity and poor load management. Hence, 33% of total electricity demand in 2003-2004 was met through self-generation, in addition to suppressed demand that is reported to be around 8.8%. Figure 1-18 shows estimated consumption figures for 2006, where self-generation accounts for 33.6% of total consumption, and suppressed demand for 5.3%. Self-generation was reported to increase between 1998 and 2006, and is inflating consumers' electricity bills up to 25% for the sake of "security of supply" (World Bank, 2008).

Electricity has also been imported from Syria for over a decade, and recently (starting 2009) from Egypt, in order to compensate for the shortfall in production. More than 8,000 MWh have been imported since 1998, and the monthly imports usually depend on the availability of surplus in Syria (Byblos Bank, 2010). Table 1-11 shows the annual import figures from 2000 to 2009. In 2006, Lebanon imported up to 200 MW at a price of approximately 12 US¢/kWh (World Bank, 2008), which is cheaper than the cost of electricity generation in Lebanon. Purchases from both countries constitute 7.5% of the total energy production (MoEW, 2010).

Of the electricity supplied by EDL, a significant portion is lost either due to technical losses in the network or due to theft. Technical losses are reported to be in the order of 15% and non-technical losses – which essentially comprise non-billed consumption of electricity through illegal connections on the distribution network – are reported to be about 18%. This 18% of non-billed electricity translates into USD 150 million in lost revenue per year for EDL and is partly explained by a weak billing system within EDL, but also by political interference in the operation of the utility. Over the years, EDL has sought to reduce its non-technical losses, and a decline of about 3% was achieved during 2004-05. As a result of these two types of losses, over 30% of produced electricity is not billed (World Bank, 2008).

In addition, the poor electricity service provided by the public sector is costing the government massive amounts in the form of generalized subsidies required to cover oil bills. These low levels of revenues are caused by the tariffs being set far below cost recovery (as well as an inefficient

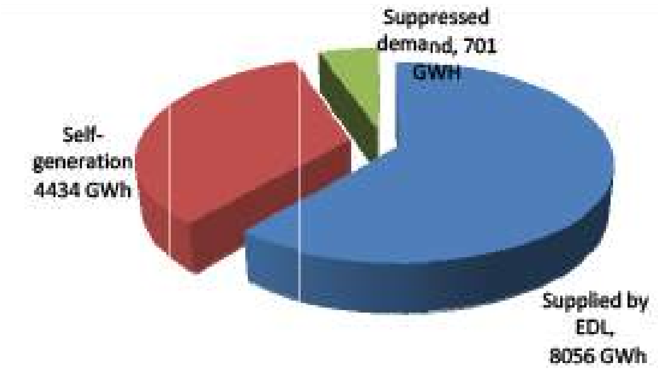


Figure 1-18 Estimated total consumption of electricity in 2006

Table 1-11 Electricity Imports from Syria throughout the years

Year	Imports (GWh)
2000	1,397
2001	1,263
2002	532
2003	-
2004	216
2005	455
2006	929
2007	972
2008	561
2009	1,116*

*** 589 GWh from Syria and 527 GWh from Egypt.**
Source: (EDL, 2000 to 2009)

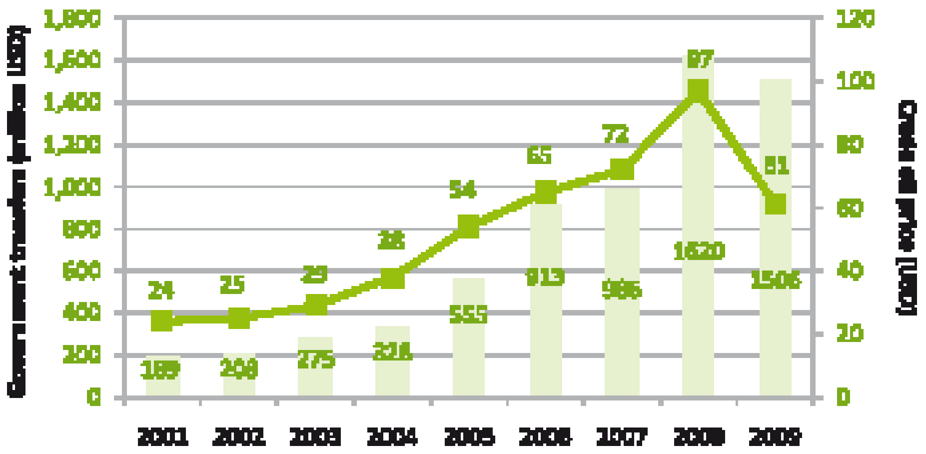


Figure 1-19 Transfers to EDL and crude oil prices (2001-2009)
Source: MoF, 2010

tariff structure), as well as low billings and collections. With the huge increases in international oil prices in recent years, the lack of tariff adjustment since 1996 (when the oil price was USD 21/barrel) has become a clear and present cause of the fiscal drain of the sector (World Bank, 2008).

Moreover, despite the abundance of natural gas in the region, gas-oil (diesel) continued to be used in two major power plants designed to use natural gas, as well as in the gas turbines designed as peaking plants. These turbines were used as base load plants due to insufficient capacity to serve demand, until the end of 2009 when natural gas arrived from Egypt via Jordan and Syria. The high O&M cost of all power plants caused by insufficient regular maintenance, lack of spare parts, and high technical losses, result in very high production costs. Indeed, Lebanon's electricity tariff level is high by regional standards and in relation to service quality, but too low to cover EDL's costs. As a result of the continued service un-reliability, any tariff increase is likely to be met by protest by consumers and a significant decline in the billing and collections (World Bank, 2008).

Given the mismatch between its inlays and outlays, EDL relies considerably on government transfers, aimed primarily at covering the deficit – rather than investment activities – through contributing to the repayment of fuel oil and gas oil bills. The government's financial support to the electricity company dates back to the civil war – although back then, the frequency and structure of transfers was not systematic, as is currently the case (Figure 1-19). The substantial increase in recent years reflects the rise in international oil prices, coupled with growing demand for oil. In 2008, transfers reached USD 1.6 billion, which translates roughly to USD 400/person/year. If total expenditures are taken into account, transfers to EDL constitute the third largest public expenditure item, after interest payments and personnel cost (MoF, 2010).

1.9.2 Transport

The transportation system in Lebanon encompasses land transport, marine transport, and air transport subsystems. The transport infrastructure consists of the road and rail networks, the Beirut-Rafic Hariri International Airport (B-RHIA) and the main sea ports of Beirut, Tripoli, Saida and Tyre. As the existing railway has become idle for the transport of passengers and goods, the land transport infrastructure is practically characterized by the national road network, the vehicle fleet and the public transport system. The government plays an exclusive role in the development, maintenance and management of the transport infrastructure and a limited role in the operation of transport services, namely in the operation of public transport and the currently non-operational railway. The Lebanese road network consisted of 22,000 km of roads in 2001, out of which only 6,380 km (about 30%) were classified as paved roads while the remaining 70% were un-classified roads which are governed by municipalities (MoE, 2005) Classified roads are usually subdivided into international, primary, secondary and local roads and fall under the authority of the MoPWT. The road network suffers from inadequate maintenance and low traffic capacity leading to slow traffic flows, congestion, and poor road safety conditions.

The land transport in Lebanon suffers from major problems including lack of organization. The major cities, particularly the Greater Beirut Area (GBA), suffer from severe congestion and chaotic traffic conditions. Travel demand is growing more rapidly than the transport system's ability to accommodate; in the GBA alone, daily passenger trips are expected to rise to 5 million in 2015 (from 1.5 million in 1995). Major arterial roadways, highways, and intersections suffer from severe under-capacity and delays. The current transport system is dominated by the automobile, which constitutes more than 86% of the fleet. Vehicle kilometers traveled are low, reflecting the fragmentation and the localization of the economy. Private passenger cars account for the majority of intra-city trips (approximately 70%), and both automobile ownership and usage are growing. The total cost of urban congestion in GBA and other major cities and towns is estimated at over USD 2 billion annually, which represents up to 10% of GDP. This, together with other external costs, such as accident and pollution costs, has serious impacts on the economy (MoE, 2005). Road traffic growth in Lebanon from 2003 to 2004 was estimated to be 6.8%, which corresponds to a rate well beyond economic growth, and is expected to remain stable over the coming years. Traffic problems are evident at the entrances to the city of Beirut where bottlenecks develop and long delays are experienced. The coastal highway leading from the north carries a daily traffic volume in both directions of close to 180,000 vehicles while the southern coastal highway has a volume of a little more than 50,000 vehicles. The average speed during the day along the major axes in the GBA ranges between 15 and 30 km/hr, dropping to 10 km/hr and less in the commercial districts within the city at peak times (MoE, 2005).

Intra-city public transport is dominated by service-taxis (shared taxis), with an increasing number of buses, mini-buses, and mini-vans. Most of these vehicles are owner-operated as private enterprises, and function in the absence of regulated schedules or routes. Governmental decisions have resulted in almost a threefold increase in the number of licensed public transport vehicles between 1994 and 2004 (MoE, 2005).

The Lebanese vehicle fleet is dominated by poorly maintained private cars. The vehicle inspections procedure was interrupted for over 15 years up until 2004, which further contributed to poor conditions of the vehicle fleet. In spite of the annual inspection that is undertaken, unlike for trucks and buses, there is no legislation governing passenger vehicle emissions. Decree 6603/1995 sets emission standards for diesel vehicles (trucks and buses) relating to CO, NO_2, hydrocarbons and Total Suspended Particles, but is not enforced.

The fleet size reported in 2003 in Lebanon was 1,081,477 vehicles (MoE, 2005). Figure 1-20 shows the vehicle fleet size between 1997 and 2005 and projections for 2015, when the total size is expected to reach 1,406,103 vehicles – from 1,219,224 in 2005 (MoE, 2005).

The Lebanese vehicle fleet is relatively old and outdated where 60% of the fleet is older than 13 years. Around 40,000 public transport vehicles are distributed between shared-taxis (service-taxis), taxis, buses and minivans, which constitutes an oversupply at very low quality levels. These vehicles are increasing traffic congestion, transport delays and air pollution (MoE, 2005). The occupancy rate of service-taxis is 1.2 passengers/car.

The shared taxi category average age is estimated at 30 years, which consists mainly of Mercedes 200/230 series (1975 to 1979 models) (MoE, 2005). This probably leads to a proportionately higher percentage of emissions released into the atmosphere per vehicle-kilometer or vehicle-hour of congestion than otherwise. Some of the reasons that leads to the conditions above can be attributed to 1) the non-restricted import of vehicles prior to 1995, after which the Lebanese authorities imposed

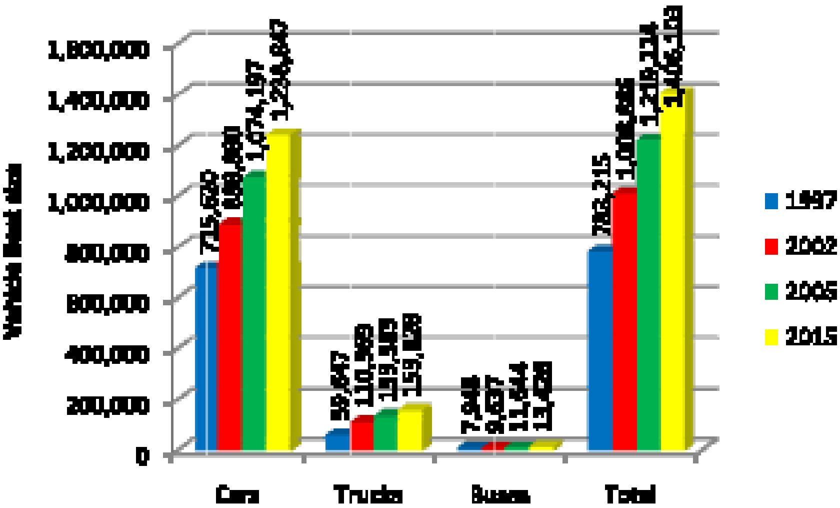


Figure 1-20 Vehicle fleet size between 1997 and 2005 and projections for 2015.
Source: MoE, 2005

new regulations banning the import of vehicles above 8 years old, 2) the existing tax system which imposes higher import taxes on newer (and more expensive) vehicles, 3) the cost of vehicle registration and of the annual license which decreases with vehicle age.

Lebanon has a very high car ownership reaching to around 526 cars/1,000 persons, with car imports in the range of 100,000 annually, out of which 50% are new cars. The high car ownership may be attributed to 1) a weak and unreliable public transport system, 2) weak urban planning practices, 3) socio-cultural stigma associated with bus riding and car ownership, 4) availability and affordability of old vehicles, as well as of credit facilities for the purchase of newer cars (MoE, 2005).

The public transport sector in Lebanon suffers from major organizational and technical problems, including 1) the lack of government planning, regulation and enforcement, and efficient, reliable, clean and cost-effective mass transport system where safety regulations are applied, 2) oversupply of vehicles resulting in low ridership and low revenues among operators, which in turn leads to the neglect of vehicle maintenance and insurance.

Goods distribution in GBA has no clear logistics setup: the location of make-shift warehousing in residential buildings poses a serious safety as well as logistical concern. The chaotic loading and unloading procedures in urban streets are increasing exacerbating roadway congestion. Issues impeding the development of efficient and competitive freight movement also include complex procedures across international borders, licensing requirements, high fees and lack of coordination among authorities. This results in a serious lack of competitiveness and impedes the growth of the Lebanese economy (MoE, 2005).

1.10 Waste

1.10.1 Solid Waste

Lebanon annually generates an estimated 1.56 million tonnes of municipal solid waste. A daily average of 0.75 to 1.1 kg/capita is generated in urban areas, while the daily average in rural areas stands at 0.5 to 0.7 kg/capita (MoE-METAP, 2004). The average annual growth in municipal solid waste (MSW) generation is estimated at 3.62%.

Proper MSW management systems are operational in the GBA, in Zahle and to some extent in Tripoli. Illegal dumping and open burning of MSW are common where most towns or cities operate open dumps within their jurisdictions. The illegal dumping and uncontrolled burning of MSW endangers flora and fauna and their habitats, deteriorates local air quality and creates a nuisance thereby decreasing the quality of life in neighboring areas (MoE, 2005). Table 1-12 indicates the different management systems of MSW by region.

In the GBA, MSW management services are contracted out to the private sector, including street sweeping, collection, sorting, treatment and disposal of waste. The GBA generates 12% of the total MSW stream in Lebanon, of which only 15% are composted and 5% are recycled (EC, 2006). The remaining MSW of GBA (80%) is disposed of by landfilling in the Bsalim landfill (for bulky waste) and

Table 1-12. Summary of MSW management systems in Lebanon by region

Governorates	MSW Management System
North Lebanon	Open dumping and burning, except in five municipalities of Greater Tripoli
Akkar	Open dumping and burning
Mount Lebanon	Covered under the Greater Beirut Area contract except for: the entire District of Jbeil and parts of Aley, Kesrouan, Baabda and Metn
Beirut	Entirely covered under the GBA contract
South Lebanon	Open dumping and burning
Nabatiyeh	Open dumping and burning
Baalbek-Hermel	Open dumping and burning
Bekaa	Open dumping and burning except for 15 municipalities in the District of Zahle which dispose of their MSW in the Zahle landfill

Source: MoE, 2005

in the Naameh landfill (for inert material), dramatically reducing the projected lifetime of the sanitary landfill in Naameh.

Outside the GBA, the MSW management is the responsibility of municipalities. At the national level, recycling rates of MSW remain low (7.7% in 2004) (CAS, 2007).

1.10.2 Wastewater

Lebanon generates an annual average of 250 Mm^3 of domestic wastewater (0.68 Mm^3/day) (UoB, 2004). Less than 68% of dwellings have access to public sewage networks. Beirut has the highest rate of connection to public sewage network while Nabatiyeh has the lowest rate (Table 1-13) (CAS, 2004). Most towns and villages lack public wastewater drainage and infrastructure.

Table 1-13 Percentage of housing connected to the sewage network

Governorate	Percentage (%)
Beirut	99.1
Mount Lebanon	74.9
North Lebanon	61.1
South Lebanon	65.7
Nabatieh	17.9
Bekaa	45.7
Average	67.4

Source: CAS, 2004

The most commonly used wastewater disposal methods at the household level are traditional concrete-lined sanitary pits and unlined boreholes that are dug into the bedrock, which poses a high risk of groundwater aquifer contamination through seepage (EC, 2006; UoB, 2004).

As of 2000, some 30 wastewater treatment plants were planned to be installed in different regions. Wastewater treatment plants are now at various stages of execution: under construction/under preparation/secure funding, which are expected to solve the untreated wastewater problem and to improve the quality of surface water, sea water and groundwater (CDR, 2009).

1.11 Health Profile

While being in the midst of demographic transition, Lebanon is towards the end of its epidemiological transition phase: the health and financial impacts of infectious diseases are declining, whereas the incidence and cost of chronic non-communicable diseases are on the rise (Ammar, 2009), putting the traditional health system under stress.

Health services are abundantly available in Lebanon and the majority of the population has access to an outpatient facility within a 10-minute walk, and a hospital within a 20-minute drive (Ammar, 2009).

By the end of the civil war, only half of the 24 public hospitals were operational, with an average number of active beds not exceeding 20 per hospital. The Government's 1993 Reconstruction Plan aimed at rehabilitating and building public hospitals in order to have at least one in each governorate.

On the other hand, the development of the private hospital sector was relatively less affected by the civil disturbances and continued to grow both in number and capacity to represent more than 90% of the total number of hospital beds in the 1990s, and decreased to 80% with the operationalization of new public hospitals (Ammar, 2009).

In the period between 1975 and 1995, UN agencies played a major role in conducting essential health programs in joint coordination with NGOs. Ever since, NGOs have been successfully providing health services by contributing to joint preventive programs carried out by the MoPH and UN agencies. Furthermore, some NGOs have been playing a meaningful supporting role in the health system by conducting surveys or training workshops, or by providing logistical support through purchasing, stocking and distributing essential medical

Table 1-14 Distribution of health providers by governorate in 2006

	Beirut	Mount Lebanon	South Lebanon	Nabatiyeh	North Lebanon	Bekaa	Total (100%)
Private Hospitals	21	64	24	10	34	38	189
Public Hospitals	2	6	4	6	7	5	30*
PHC Centers	136	402	219	113	63	152	1,085

*Only 23 are operational.
Source: Ammar, 2009

Table 1-15 Budgetary resources in the public health sector

Indicator (Year 2004)	Amount
MoPH allocated budget (as % of total government budget)	3.67
Public expenditure on health (as % of GDP)	2.35
Annual MoPH budget (USD per capita)	63.97

Source: Ammar, 2009

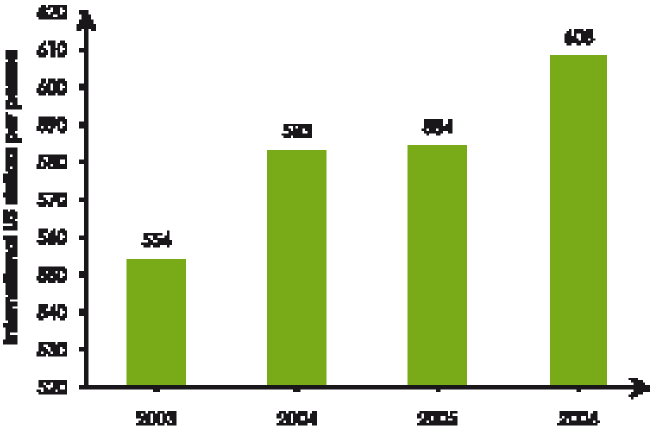


Figure 1-21 Total expenditure on health per capita in Lebanon.
Source: WRI, 2006

supplies to a vast network of primary health care centers (health centers and dispensaries). In 2006, the number of such centers reached 1,085, distributed throughout Lebanon, out of which 142 are affiliated with the MoPH. Each health center has a defined catchment area and provides general medical care including pediatrics, cardiology, reproductive health and oral health.

The distribution of the different types of health service providers by governorate is shown in Table 1-14.

With an allocation that never exceeded 4% of the total government budget, the MoPH has to cover the hospitalization cost of uninsured patients and provide them with expensive treatments that cannot be afforded by some households. In fact, the share of health spending as a percentage of total household spending reached 9.23% per household in 2004 and the households' out-of-pocket direct payments were estimated at 44% of the total health expenditures by households and intermediaries in 2005. Indicators for budgetary resources for the year 2004 are presented in Table 1-15. These allocations have been growing over years with the development of the MoPH's financing function, leaving scarce resources to prevention, public health and regulation functions (Ammar, 2009).

On the overall, public expenditures on health, as a percentage of total expenditure and total expenditures on health per capita in Lebanon have been increasing reaching USD 583/capita in 2004 (Figure 1-21).

After the July War of 2006, the MoPH initiated the Early Warning Alert and Response System (EWARS) in the areas that were most affected by the war. Consisting of mainly health centers and the dispensaries in the South, following it success, it was expanded throughout 2007 to 2009 to cover all regions in the country. The objectives of EWARS are to:

- Establish a surveillance network for the early detection and monitoring of infectious diseases with epidemic potential or those targeted for elimination/eradication, as well as for other, new emerging and re-emerging infectious diseases;
- Enhance the role of health institutions in preventive health activities, by involving them in disease surveillance;
- Strengthen the district, regional and central capacity to respond to potential outbreaks of new emerging and re-emerging diseases through the formation of rapid response teams at each level;
- Enhance communication of public health information about communicable diseases within the health system institutions and at the level of the population (WHO, 2010a).

1.12 Tourism

Lebanon boasts a diverse culture, distinctive geography and rich history on which it has relied to promote its touristic image in the domestic and international tourism and recreation markets. The country receives international tourists from all over the world, but particularly from neighboring Arab states and European countries. Despite having a typical Mediterranean climate, the country faces tough competition from other eastern Mediterranean states over European tourists. Nevertheless, Lebanon's temperate climate relative to that of many Arab states serves to boost its touristic image among Arab tourists.

There are different forms of tourism and recreation that are influenced differently by climate and climatic changes. Touristic activities and infrastructure in Lebanon are concentrated in the high mountains where ski resorts and winter chalets are located, and in the hills overlooking Beirut and the coast where "country clubs" are found (MoE, 2005) (Figure 1-23). The tourism sector in Lebanon is active throughout the year, but peaks during the summer months of July and August (Table 1-16).

In recent years, Lebanon has registered a significant increase in the number of ecotourism providers and in 2004, 56,000 visitors entered Lebanon's nature reserves (MoE, 2008), a growth of around 56% from the year 2000.

The number of international arrivals of non-resident tourists grew steadily between 2000 and 2004, but has been fluctuating since 2005, mainly due to the weak security situation that has prevailed in 2005 and 2006. Tourism is a driving force for the local economy, generating USD 6,000 million in international receipts in 2004, up from USD 742 million in 2000 (Figure 1-22). In 2003, tourism accounted for 34.2 % of GDP, compared to 27.6% in 2004 (UNWTO, 2009).

Table 1-16 Percentage distribution of total arrivals by season between 2000 and 2008

	Percentage of Arrivals								
Season	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Winter	18	20	17	17	17	19	22	22	19
Spring	25	26	24	24	25	26	33	25	22
Summer	34	34	36	38	36	39	21	27	30
Autumn	22	20	22	21	21	35	24	26	29
Total Number of Arrivals* (in Million)	2.7	2.8	3.3	3.5	4.0	3.6	2.0	5.5	6.5

* Figures include arrivals of Lebanese and Syrian nationals
Source: (CAS, 2000-2008)

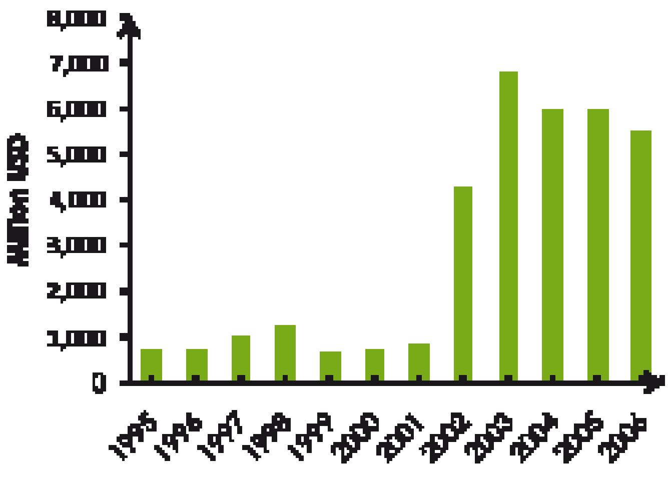


Figure 1-22 International tourism receipts between 1995 and 2006
Source: WRI, 2008

Figure 1-23. Map of the main touristic attractions and areas in Lebanon

National Greenhouse Gas Inventory

2. National Greenhouse Gas Inventory

2.1 Introduction

In accordance with Article 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCCC), parties are required to develop and report national inventories on national emissions and removals of greenhouse gases (GHG) using comparable methodologies. As a Non-Annex I party to the UNFCCC, Lebanon has prepared and submitted its Initial National Communication (INC) in 1999, with the year 1994 as the baseline for its national GHG inventory.

This chapter updates the national inventory by summarizing Lebanon's anthropogenic emissions by sources and removals by sinks for the year 2000 of all GHGs covered by the Kyoto Protocol (KP) (CO_2, CH_4, N_2O, HFCs, PFCs and SF_6) in addition to the indirect GHGs (CO, NO_x, SO_2 and NMVOCs). It also presents the trend analysis of the national GHG inventory for the period 2000 to 2004, with a revision of the results of the first inventory to allow a complete assessment of trends in national GHG emissions.

The inventory is based on the revised 1996 Intergovernmental Panel on Climate Change (IPCC) guidelines for National Greenhouse Gas Inventories and on the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories that provides methodologies for calculating national inventories and estimating uncertainties (IPCC, 1997 and IPCC, 2000). Tier 1 approach is adopted in calculating the GHG emissions where the appropriate default emission factors are selected from the guidelines. Tier 2 approach is only used for the calculation of emissions from the cement industry where precise data allowed the development of a national emission factor. The reference approach is used for the estimation of the CO_2 emissions from the overall fuel consumption figures. In addition, the sectoral approach is used to estimate the GHG emissions and removals for the following sectors:

- Energy
- Industrial processes
- Solvent and other product use
- Agriculture
- Land-use change and forestry
- Waste

The activity data for the different sectors are collected from various sources (public and private institutions) by conducting sectoral tailored surveys, and complemented by secondary sources such as scientific reports/publications, and academic studies. Estimations, interpolations and extrapolations are made for the sectors characterized with data gaps. Choice of activity data is validated through thorough stakeholders' consultations engulfing the public and private sectors, as well as academic and NGO communities.

2.2 Greenhouse Gas inventory in 2000

In the year 2000, Lebanon's total GHG emissions recorded 18,507 Gg (18.5 Million tonnes (Mt)) of CO_2 equivalent (CO_2 eq.), recording an average of 2.77% per year increase from 1994 (15,901 Gg CO_2 eq.) (Table 2-1). The energy

Table 2-1 GHG Emissions – year 2000

Total GHG Emissions (Gg)	**18,507**
Increase based on 1994 value (Gg)	2,606
Growth rate per year (%)	2.77
Net GHG Emissions (Gg)	**18,363**
Increase based on 1994 value (Gg)	2,462
Growth rate per year (%)	2.58
Removals of GHG (Gg)	**144**

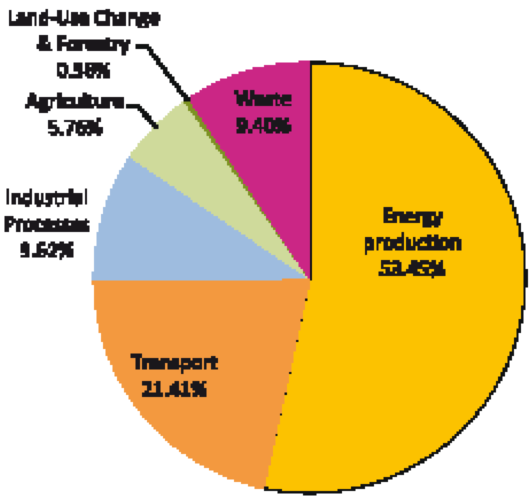


Figure 2-1 GHG emissions by source Energy production or Energy Production

sector is the main source of GHG emissions, accounting for 74.86% of the national emission. This is followed by industrial processes and waste sectors which account for 9.62% and 9.40% respectively. Emissions from agriculture and land use change and forestry make up 5.76%, and 0.36% of total CO_2 eq. respectively. Figure 2-1 shows the GHG emission shares of each of the sectors – the energy sector is divided into its two main subcomponents: energy production and transport. The CO_2 removals from forests and croplands is estimated at -143.87 Gg for the year 2000

Carbon dioxide is the main emitted GHG with 84.13% of emissions in 2000, while CH_4 and N_2O constitute 10.19% and 5.68% respectively. As shown in Figure 2-2, the main contributors of CO_2 emissions are energy production and transport with 63% and 25% respectively whereas the waste sector constitutes the main source of CH_4 emissions (88%). The main contributor to N_2O emissions is the agriculture sector with 88%.

In terms of key categories, the two activities contributing most to Lebanon's emissions are consumption of fuel oil for energy production and land road transport, which account for 43.5% of total emissions in 2000. Energy production in other sectors and solid waste disposal, cement industries and agricultural soils are also among the key categories amounting to 97% of total emissions, as presented in Table 2-2.

Table 2-3 summarizes Lebanon's emissions of CO_2, CH_4 and N_2O for all sectors presented in terms of CO_2 eq. and using the IPCC Second Assessment Report's 100-year Global Warming Potential (GWP) of 21 for CH_4, and 310 for N_2O. Table 2-4 and Table 2-5 present Lebanon's direct and indirect emissions with proper notations as required by decision 17/CP.8.

Table 2-2 Analysis of key categories for the year 2000

Sector	Source Categories	GHG	Emission Estimate (non-LULUCF) (Gg CO_2 eq.)	Total absolute estimate incl. LULUCF (Gg CO_2 eq.)	Percent of total (%)	Cumulative level incl LULUCF (%)
Sum	Sum		12,681.3	12,681.3		
1.A.1 Energy	Stationary Combustion: Fuel oil	CO_2	4,091.5	4,091.5	22.2%	22.2%
1.A.3 Energy	Mobile Combustion: Road Vehicles	CO_2	3,929.4	3,929.4	21.3%	43.5%
1.A.2 Energy	Emissions from Manufacturing Industries and Construction	CO_2	2,830.6	2,830.6	15.4%	58.9%
1.A.1 Energy	Stationary Combustion: Gas diesel oil	CO_2	1,661.4	1,661.4	9%	67.9%
6.A Waste	Emissions from Solid Waste Disposal Sites	CH_4	1,640.0	1,640.0	8.9%	76.8%
2.A Industrial Processes	Emissions from Cement Production	CO_2	1,630.9	1,630.9	8.8%	85.6%
4.D Agriculture	(Direct and Indirect) Emissions from Agricultural Soils	N_2O	820.5	820.5	4.5%	90.1%
1.A.4 Energy	Other Sectors: Agriculture/Forestry/ Fishing	CO_2	493.1	493.1	2.7%	92.7%
1.A.4 Energy	Other Sectors: Residential	CO_2	443.5	443.5	2.4%	95.2%
1.A.4 Energy	Other Sectors: Commercial	CO_2	336.7	336.7	1.8%	97%

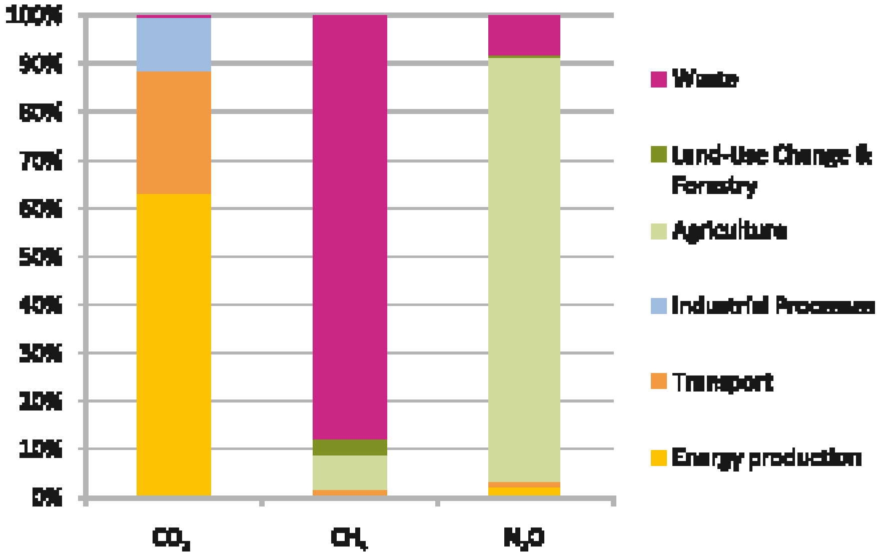


Figure 2-2 GHG emissions by gas

Table 2-3 Lebanon's GHG emissions summary for the year 2000

Greenhouse gas source and sink categories	CO_2 Emissions (Gg)	CO_2 Removals (Gg)	CH_4 (Gg)	CH_4 (Gg CO_2 eq.)	N_2O (Gg)	N_2O (Gg CO_2 eq.)	Total emissions (Gg CO_2 eq.)
Total National Emissions and Removals	15,570.13	-143.87	89.82	1886.22	3.39	1050.90	18507.25
Energy	13,786.19		1.62	34.02	0.11	34.10	13,854.31
Energy Industries	5,752.89		0.23	4.83	0.05	15.50	5,773.22
Manufacturing Industries and Construction	2,830.60		0.06	1.26	0.02	6.20	2,838.06
Transport	3,929.40		1.14	23.94	0.03	9.30	3,962.64
Other Sectors	1,273.30		0.19	3.99	0.01	3.10	1,280.39
Industrial Processes	1,780.98		-	-	-	-	1,780.98
Mineral Products	1,652.98			-	-	-	1,652.98
Metal Production	128.00		-	-	-	-	128.00
Agriculture			6.60	138.60	2.99	926.90	1065.50
Enteric Fermentation	-		6.03	126.63	-	-	126.63
Manure Management	-		0.51	10.71	0.34	105.40	116.11
Agricultural Soils	-			-	2.65	821.50	821.50
Field Burning of Agricultural Residues	-		0.06	1.26	-	-	1.26
Land-Use Change & Forestry		-143.87	2.90	60.90	0.02	6.20	67.10
Changes in Forest and Other Woody Biomass Stocks	-	-807.60	-	-	-	-	-
Forest and Grassland Conversion	663.73		2.90	60.90	0.02	6.20	730.83
Waste	2.96		78.70	1,652.70	0.27	83.70	1,739.36
Solid Waste Disposal on Land	-		78.10	1,640.10	-	-	1,640.10
Wastewater Handling	-		0.60	12.60	0.27	83.70	96.30
Waste Incineration	2.96		-	-	-	-	2.96

Table 2-4 National greenhouse gas inventory of anthropogenic emissions of HFCs, PFCs and SF_6

Greenhouse gas source and sink categories	HFCs (Gg)		PFCs (Gg)		SF_6 (Gg)
	HFC-23	HFC-134	CF_4	C_2F_6	
Industrial processes	NO	0.01	NO	NO	NO
A. Mineral products	NO	0.01	NO	NO	NO
B. Chemical industry					
C. Metal production					
D. Other production	NO	NO	NO	NO	NO
E. Production of halocarbons and SF_6					
F. Consumption of halocarbons and SF_6	NO	NO	NO	NO	NO
G. Other (please specify)	NO	0.01	NO	NO	NO

Table 2-5 Lebanon's National GHG inventory of anthropogenic emissions by sources and removals by sinks of all GHGs not controlled by the Montreal Protocol and GHG precursors

GHG source and sink categories	CO_2 emissions (Gg)	CO_2 removals (Gg)	CH_4 (Gg)	N_2O (Gg)	NO_x (Gg)	CO (Gg)	NMVOCs (Gg)	SO_x (Gg)
Total national emissions and removals	15,570.15	-143.87	89.82	3.39	58.69	481.49	128.56	93.43
1. Energy	13,786.19	NA	1.62	0.11	57.95	455.38	85.68	92.59
A. Fuel combustion (sectoral approach)	13,786.19		1.62	0.11	57.95	455.38	85.68	92.59
1. Energy Industries	5,752.89		0.23	0.05	15.22	1.14	0.38	61.19
2. Manufacturing industries and construction	2,830.60		0.06	0.02	6.43	0.32	0.16	23.46
3. Transport	3,929.40		1.14	0.03	34.46	453.55	85.05	2.56
4. Other sectors	1,273.30		0.19	0.01	1.84	0.37	0.09	5.37
5. Other (please specify)	NO	NO	NO	NO	NO	NO	NO	NO
B. Fugitive emissions from fuels	NO	NO	NO	NO	NO	NO	NO	NO
1. Solid fuels			NA		NA	NA	NA	NA
2. Oil and natural gas			NO		NO	NO	NO	NO
2. Industrial processes	1,780.98	0.00	0.00	0.00	0.00	0.00	38.91	0.84
A. Mineral products	1,652.98				NA	NA	36.12	0.84
B. Chemical industry	NE		NE	NE	NE	NE	NE	NE
C. Metal production	128.00		NE	NA	NE	NE	NE	NE
D. Other production	NA		NA	NA	NA	NA	2.78	NA
E. Production of halocarbons and SF_6								
F. Consumption of halocarbons and SF_6								
G. Other (please specify)	NO	NO	NO	NO	NO	NO	NO	NO
3. Solvent and other product use	NA			NA			3.97	
4. Agriculture			6.60	2.99	0.03	0.77	NA	NA
A. Enteric fermentation			6.03					
B. Manure management			0.51	0.34			NA	
C. Rice cultivation			NO				NO	
D. Agricultural soils				2.65			NA	
E. Prescribed burning of savannahs			NO	NO	NO	NO	NO	

GHG source and sink categories	CO_2 emissions (Gg)	CO_2 removals (Gg)	CH_4 (Gg)	N_2O (Gg)	NO_x (Gg)	CO (Gg)	NMVOCs (Gg)	SO_x (Gg)
F. Field burning of agricultural residues			0.06	0.00	0.03	0.77	NA	
G. Other (please specify)			NO	NO	NO	NO	NO	
5. Land-use change and forestry	0.00	-143.87	2.90	0.02	0.72	25.34	0.00	0.00
A. Changes in forest and other woody biomass stocks	0.00	-807.60						
B. Forest and grassland conversion	663.73	NA	2.90	0.02	0.72	25.34		
C. Abandonment of managed lands		NO						
D. CO_2 emissions and removals from soil	NO	NO						
E. Other (please specify)	NO	NO	NO	NO	NO	NO		
6. Waste	2.96		78.70	0.27	NA	NA	NA	NA
A. Solid waste disposal on land			78.70		NA		NA	
B. Wastewater handling			0.60	0.27	NO	NO	NO	
C. Waste incineration	2.96				NA	NA	NA	NA
D. Other (please specify)			NO	NO	NO	NO	NO	NO
7. Other (please specify)	NO	NO	NO	NO	NO	NO	NO	NO
Memo items								
International bunkers	408.12		0.00	0.01	2.16	0.90	0.34	NO
Aviation	381.55		0.00	0.01	1.62	0.54	0.27	NO
Marine	26.56		0.00	0.00	0.54	0.36	0.07	NO
CO_2 emissions from biomass	NO							

NA: Not Applicable - NE: Not Estimated - NO: Not Occurring

2.3 GHG Emissions by sector

2.3.1 Energy sector

The energy sector is the most important contributor to GHG emissions, with its sub-categories that include:

- Energy industries: combustion of fuel by power plants for public electricity production
- Manufacturing industries and construction (MIC): combustion of fuel by private generators for energy generation for industrial use and electricity generation for domestic use.
- Transport: combustion of fuel in land transport. Fuel combustion in civil aviation and water-borne navigation are not reported as part of the national inventory but as international bunkers.
- Other categories: fuel combustion for energy generation in the Commercial/institutional/residential sector as well as in agriculture/forestry/fishery.

The fuel types taken into consideration in this section are: gasoline, gas oil, diesel oil, fuel oil, jet kerosene, LPG, and coking coal. The activity data are based on the official amounts of fuel imports for the year 2000 as provided by the Directorate General of Petroleum, cross-checked with information provided by the Association of Petroleum Importing Companies, EDL, and the MoPWT, Directorate General of Land and Maritime Transport. The amounts of coking coal were retrieved from the International Energy Agency database.

In 2000, emissions from the energy sector accounted for 74.86% of the total emissions, reflecting Lebanon's heavy reliance on imported petroleum products to meet its energy requirements. As shown in Table 2-6, the energy industries category is the main source of emissions, followed by land transport. The transport sector, with 28.6% of energy emissions, is also considered a major emitter due to the high per capita car ownership, the age of the fleet and the absence of an efficient public transport system.

Table 2-6 Greenhouse Gas emissions from the Energy Sector per sub-category

Energy sub-sectors	GHG emissions (Gg CO_2 eq.)	Share of total energy emissions	Share of total national emissions
Energy Industries	5,773	42%	31%
Manufacturing Industries and Construction	2,830	20%	15%
Transport	3,963	29%	21%
Other Sectors	1,280	9%	7%
Total	13,854	100%	75%

Energy Industries

The reference approach was also used to estimate the CO_2 emissions of the energy sector based on the Revised 1996 IPCC Guidelines. No difference was detected in the calculations, where both approaches showed CO_2 emissions of 13,786 Gg in the year 2000.

In 2000, 5,773 Gg CO_2 eq. were emitted into the atmosphere from the electric energy production. Heavy fuel oil (HFO) and diesel oil are the major source of energy in Lebanon, with a small share of hydropower generation. HFO with a sulfur content of about 2% by weight is the main fuel used for public electricity generation, constituting 71% of total fuel consumption by this category. Consequently, the energy industries subsector contributed to 61.19 Gg of SO_2 in 2000, or 66% of the total SO_2 emissions from the energy sector and 65% of national SO_2 emissions.

Manufacturing industries and construction

This category covers the emissions resulting from combustion of fuel in industries and construction sites, use of lubricants and private power generation. In fact, due to the interrupted supply and rationing of the electricity supplied by the government, most of the industries generate their own electricity through private power generators. The use of these types of supply is also prominent among households, where individual or community-based back-up generators are used when EDL's supply is unable to meet the demand. These generators are distributed throughout the Lebanese territory and are used by a significant proportion of the population. However, since they are not regulated by any governmental agency, it is difficult to estimate their number and the amount of fuel (diesel oil) used annually. Therefore, the fuel consumption of these generators is accounted for in this sector as an aggregated figure, along with the fuel used by industries and construction sites.

The fuel types used in the manufacturing industries and construction sectors are gas/diesel oil, fuel oil, LPG and coking coal (The use of LPG in this sector is estimated at 15% of the total LPG import to Lebanon). Combustion of these fuels generated 2,830 Gg CO_2 eq. in 2000, comprising 20% of total emissions from the energy sector, and 15% of total national GHG emissions. Figure 2-3 depicts the share of GHG emissions from the MIC by fuel type. This sub-sector also occupies the second place in terms of SO_2 emissions, accounting for 25% of total national SO_2 emissions.

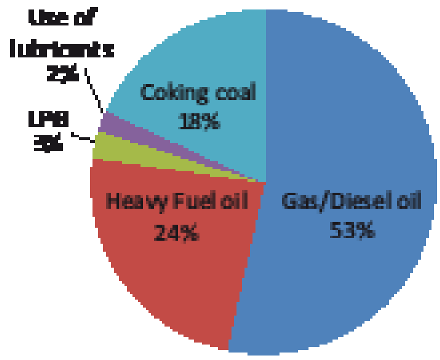


Figure 2-3 Share of GHG emissions by fuel type under MIC

2.3.1.1 Road Transport

Transport is a major sub-sector contributing to GHG emissions from fuel combustion. The GHG emission includes only land transport, since rail transport is inexistent, and both domestic aviation (fleet composed of only 10 light aircrafts) and water-borne navigation are negligible. Road transportation includes all types of light duty vehicles such as automobiles and light trucks, and heavy duty vehicles such as tractor trailers and buses, in addition to on-road motorcycles. These vehicles operate on gasoline (98.8%) while only heavy duty vehicles are allowed to run on diesel (1.2% of transport fuel consumed in Lebanon).

In 2000, 3,962.64 Gg CO_2 eq. were emitted into the atmosphere from transport in Lebanon, comprising 28.6% of total emissions from the energy sector, and 21% of total national GHG emissions. The transport sector is also the main source of CO, NO_x and NMVOC emissions, as presented in Figure 2-4.

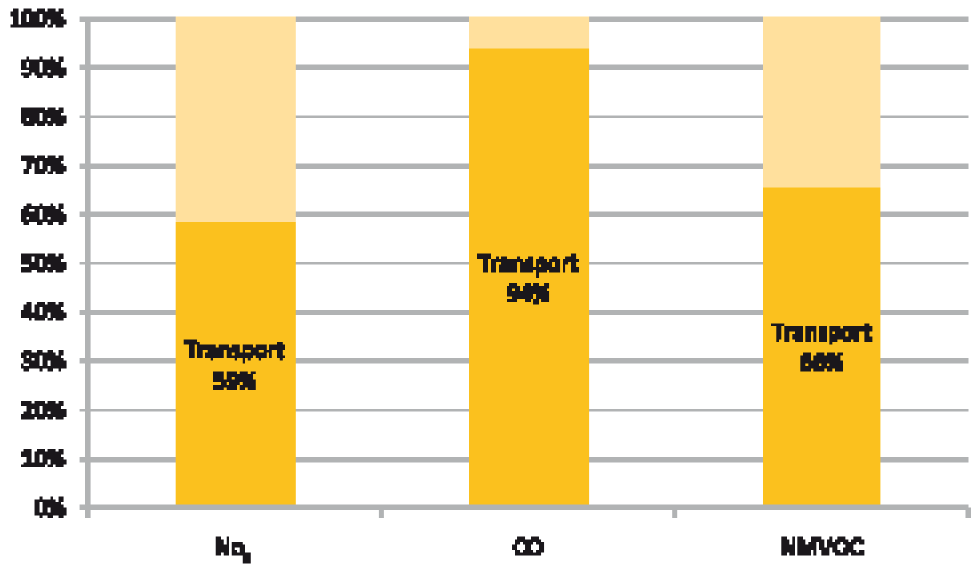


Figure 2-4 Share of emissions of NO_x, CO and NMVOC from the transport sector

2.3.1.2 International Bunkers

International bunkers include international aviation and marine navigation. Emissions of CO_2 accounted for 408 Gg of which 93.6% is from aviation. These emissions are not counted in Lebanon's national inventory.

2.3.1.3 Other sectors

The other sectors category includes emissions from commercial, institutional, residential and agriculture/ forestry/fishing sub-categories where the consumption of diesel oil (for space heating), LPG (for cooking), and kerosene (for space heating and cooking) are considered. Since no accurate data on the share of fuel consumption by the different sectors are available for analysis, it is estimated that 21% of total gas/diesel import, 85% of total LPG import and 100% of total kerosene is used in these sectors.

In the year 2000, the emissions generated from these sectors are estimated to be 1,280 Gg of CO_2 eq., with CO_2 being the major GHG (99.7%). This represents 9% and 7% of the emissions from the energy sector and of total national GHG emissions respectively. Figure 2-5 presents the share of emission by fuel type.

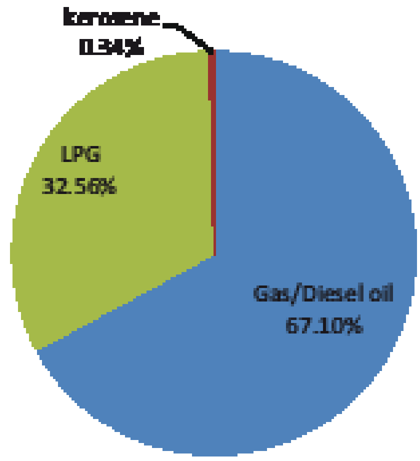


Figure 2-5 Share of GHG emissions by fuel type under other sectors

2.3.2 Industrial Processes

GHG emissions from this sector are produced from a variety of industrial activities that are not related to energy generation and use. The main emission sources are industrial production processes which chemically or physically transform materials. Emissions related to energy generation activities within the industrial sector are covered under the energy sector (manufacturing, industries and construction section). The main sources of emissions from industrial processes in Lebanon are:

- Cement production
- Lime production
- Soda ash production and use
- Asphalt roofing production
- Road paving with asphalt
- Glass production
- Iron and steel production
- Food and alcoholic beverages production

- HFC Emissions from Refrigeration and Air Conditioning
- Consumption of halocarbons and SF_6

Activity data were collected directly from the relevant industries and from the Directorate General of Customs, complemented with secondary data whenever primary data were unavailable. Tier 1 default emission factors are used for emission calculation estimations except for cement industries where the appropriate data were available, therefore allowing the use of the Tier 2 approach, thus establishing a local emission factor. Emissions of some industries such as chemicals industries were not taken into account due to the absence of activity data.

In 2000, emissions from the industrial processes sector amounted to a total of 1,781Gg of CO_2 eq. at 9.62% of Lebanon's total GHG emissions. The emissions primarily entail the CO_2 gas, with the largest contributor being cement production with 91.6%, followed by iron and steel production with 7.2%. The emissions from steel production may be over or underestimated since a simple approach was used in the calculation due to the absence of data on the consumption of reducing agents in this industry. Cement industries are also the main emitters of SO_2 within this sector while road paving and food production the main emitters of NMVOCs (Figure 2-6). Since direct and indirect emissions from the industrial processes sub-categories are insignificant, they are not reported in the inventory.

Refrigeration and air conditioning are the only sources of HFC gas emissions recorded in Lebanon since HFC 134a is serving as an alternative to ozone depleting substances

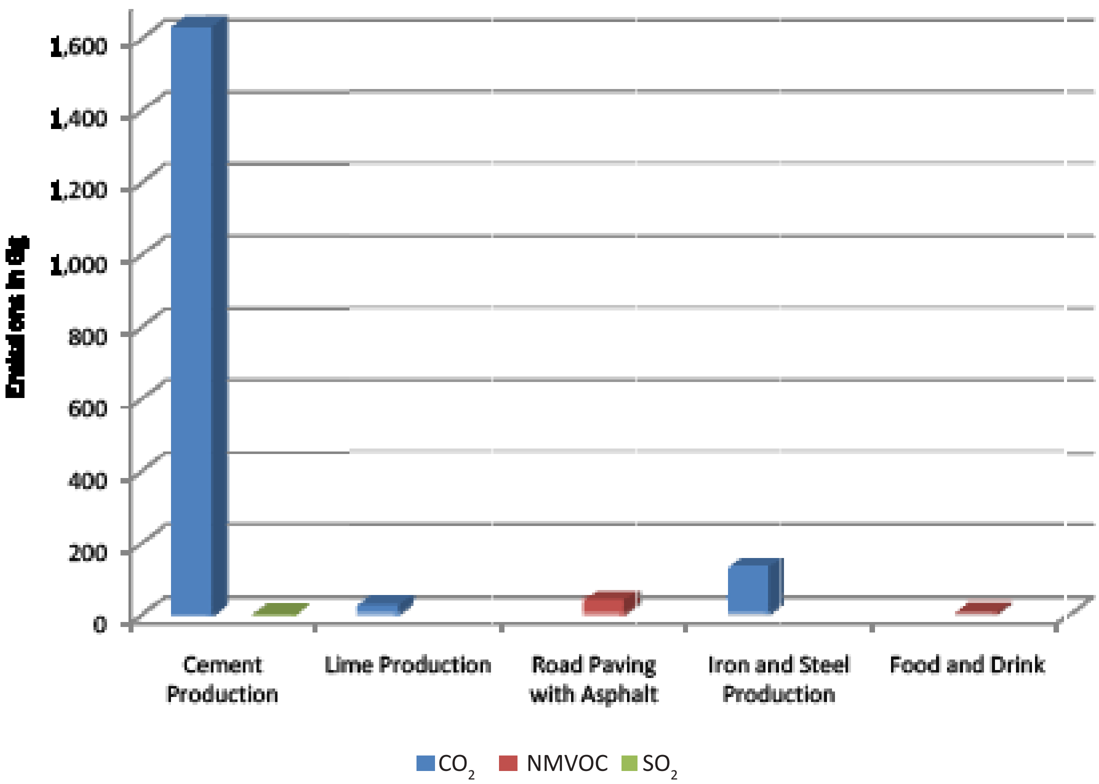


Figure 2-6 GHG direct and indirect emissions from industrial processes

Table 2-7 GHG emissions from the sub-categories of the Lebanese industrial sectort

Industrial processes sub-sectors	GHG emissions (Gg CO_2 eq.)	Share of total industrial processes emissions	Share of total national emissions
Cement Production	1,631	91.58%	8.81%
Lime Production	22	1.24%	0.12%
Iron and Steel Production	128	7.19%	0.69%
Total	1,781	100.00%	9.62%

being phased out under the Montreal Protocol. The total HFC emissions in 2000 are insignificant in absolute terms (0.01 Gg) but amount to approximately 11 Gg CO_2 eq. when converted to CO_2 eq. emissions since they have a high global warming potential. However, they were not reported as part of this national inventory.

As for SF_6 emissions for the year 2000, they are estimated to be null since SF_6 has only been imported to Lebanon starting the year 2002.

2.3.3 Solvents and Other Product Use

This category covers the emissions resulting from the use of solvents and other products containing volatile compounds. The major sub-categories of this sector in Lebanon are:

- Paint application
- Degreasing and dry-cleaning
- Printing industries

Other activities such as textile finishing, leather tanning, etc. are thought to be insignificant at the national level (less than 1% of national emissions) therefore emissions resulting from these activities are not reported in this inventory (EEA, 2005). Since these subcategories only emit NMVOC, the methodology and emission factors used for estimating these emissions are taken from the EMEP/CORINAIR Emission Inventory Guidebook (EEA, 2005). Activity data are based on the values of imports/exports of white spirit, paint and ink from the Lebanese Customs.

In the year 2000, NMVOC emissions generated from solvents and other products use amount to 3.97 Gg or around 3% of Lebanon's total NMVOC emissions. Degreasing and dry cleaning are the major source of NMVOC with 2.47 Gg, followed by paint application (0.98 Gg) and printing industries (0.54 Gg).

2.3.4 Agriculture

Despite the limited land area under agricultural uses, the agricultural sector is a significant contributor to national GHG emissions, with 1,065.5 Gg CO_2 eq., representing 5.76% of national emissions in 2000. This sector includes the following emission sources:

- Enteric fermentation - CH_4
- Manure management - CH_4, N_2O
- Agricultural soils - N_2O
- Field burning of agricultural residues- CH_4, NO_x and CO

As shown in Table 2-8, the main source of GHG emissions is "agricultural soils", where N_2O is directly and indirectly generated, as a result of biological nitrogen fixation and nitrogen input to the soils through the application of synthetic fertilizers, animal waste, crop residues or (sewage sludge). Activity data on the consumption of synthetic fertilizers are retrieved from the International Fertilizer Industry Association (IFA, 2008). The values of the animal population used for the estimation of the nitrogen excreted from animal waste and the values used for the estimation of N-fixing and Non-N fixing crops, are retrieved from FAO (FAO, 2008).

Methane emissions from the agricultural sector are produced mainly from the enteric fermentation in livestock, accounting for 11.88% of the total emissions from the sector, followed by manure management and field burning of residues.

Manure management produces both CH_4 and N_2O during the storage, treatment and disposal of manure. Based on experts' consultations, the portion of manure managed in each management system for each representative livestock category has been identified and taken into account in the calculations (Table 2-9).

Emissions of NO_x and CO result from field burning of agricultural residues, where it is estimated that 10% of the residues of wheat, barley and oats are burned every year. Other residues are not taken into account since they are collected and used either as a source of energy in rural areas (could not be estimated) or as animal feed and bedding. The NO_x and CO emissions from field burning of residues are estimated at 0.03 Gg and 0.77 Gg respectively.

2.3.5 Land Use Change and Forestry

The GHG emissions and removals of Land Use Change and Forestry in Lebanon are calculated for the year 2000 according to the Revised 1996 IPCC guidelines (IPCC, 1997). Due to unavailability of data to accurately estimate how changing land use patterns affects CO_2 emissions and removals unavailability, the Good Practice Guidance for Land use, Land-use Change and Forestry (GPG-LULUCF) could not be used in this inventory. The only available and complete national information is the land-use land-cover map which is not sufficient to make a comparative analysis on land changes for the year 2000. Therefore, the CO_2 removal data presented in this report must be treated with caution.

Table 2-8 GHG emissions from the Agriculture sector.

Agriculture sub-sectors	CH_4 emissions	N_2O emissions	GHG emissions (Gg CO_2 eq.)	Share of total agriculture emissions	Share of total national emissions
Enteric Fermentation	6.03	-	126.70	11.88%	0.68%
Manure Management	0.51	0.34	115.62	10.90%	0.63%
Agricultural soils	-	2.65	629.03	77.10%	4.44%
Field burning of agricultural residues	0.06		1.00	0.12%	0.01%
Total	6.60	2.99	872.35	100.00%	5.76%

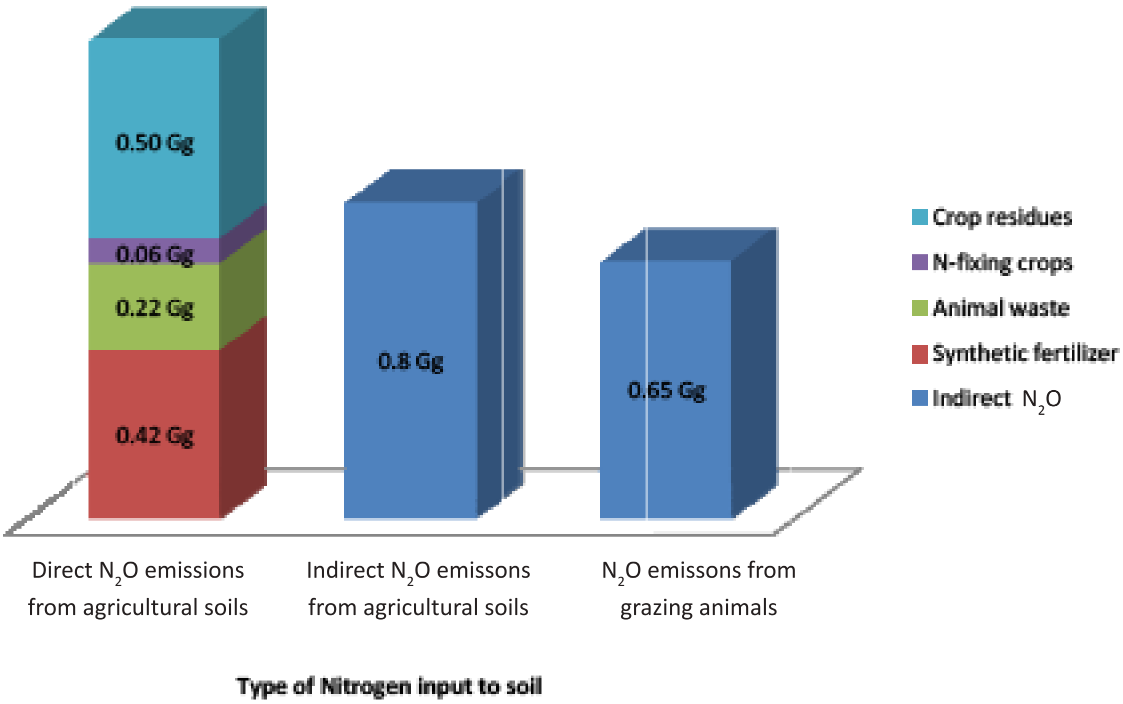


Figure 2-7 presents N_2O emissions according to the type of nitrogen input to the soil.

Table 2-9 Fraction of Manure Nitrogen per Animal Waste Management System

	Anaerobic Lagoons	Liquid systems	Solid storage and drylot	Pasture range and paddock
Dairy Cows	0.05	-	0.85	0.1
Other Cattle	-	-	0.9	0.1
Sheep	-	-	-	1
Swine	0.17	0.14	0.69	-
Poultry	-	-	1	-

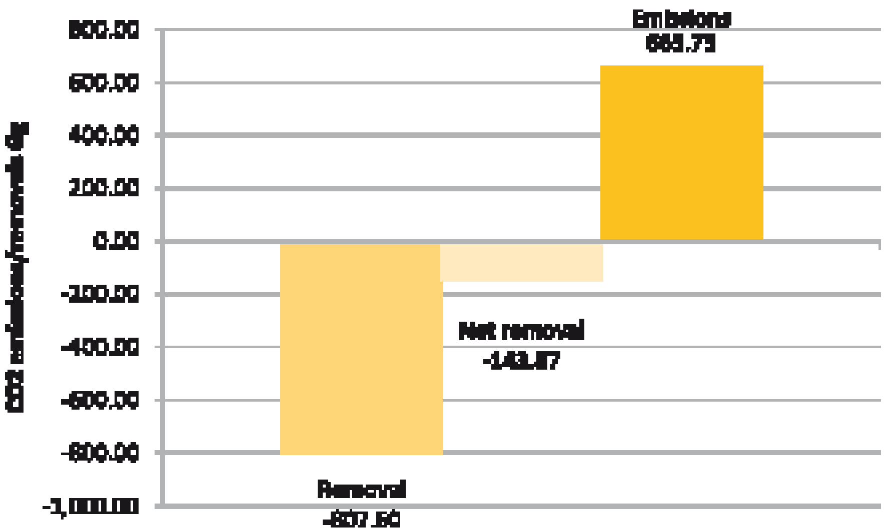


Figure 2-8 Emissions and removals from LUCF for 2000

The emission assessment is based on the idea that the flow of CO_2 from or to the atmosphere is equal to the changes in carbon stocks existing in biomass or soils and that the changes in carbon stocks can be estimated by establishing the rates of change in land use and the practice used to bring about these changes (burning, clear-cutting, etc.). Accordingly, this inventory examines changes in carbon stocks caused by 1) changes in changes in forest and other woody biomass stocks and 2) forest and grassland conversion.

The estimate of CO_2 removals from forests and changes in carbon stocks due to logging and fuelwood extraction presented in this report are based on the forest report assessment (MoA and FAO, 2005c) and the FAO's statistical database (FAO, 2008). Due to the absence of disaggregated data on the nature of fires (natural or anthropogenic) and the type of forest affected (managed or unmanaged), a total value of the area ravaged by forest fires is used from the Association for Forest Development and Conservation (AFDC) and the MoE database. In order to ensure consistency in calculations, the values of annual growth rate of forest used in the INC were used (MoE et al., 1999).

In Lebanon, the land use change and forestry sector acts as both a source and a sink where results of the year 2000 show that 807.6 Gg CO_2 are removed by sinks and 663.73 Gg CO_2 are emitted from forest fires (Figure 2-8). The net result labels this sector as a sink with -143.87 Gg CO_2 as a net removal.

Removals of CO_2 from changes in forest and other woody biomass stocks are caused by the changes in carbon stocks as a result of increase in forested areas or number of trees and decrease in commercial harvest of roundwood and fuelwood. Table 2-10 presents the values used for the calculations of the emissions and removals from this category for the year 2000.

Emissions of CO_2, CH_4, N_2O, NO_x and CO are emitted as GHGs and precursors from biomass burning, which emanates mainly from natural and man-made forest fires. It is estimated that fires have ravaged an area of 3,337 ha in 2000, made of 38.45% of coniferous and 61.55% broadleaf trees (MoA and FAO, 2005c; AFDC, 2007).

2.3.6 Waste

The emissions from the waste sector are calculated using the mass balance approach which estimates the Degradable Organic Carbon (DOC) content of solid waste. It is worth noting that this default methodology results in an overestimation of the emissions since it does not account for time factors in the waste accumulation and decomposition.

The categories of waste for which emissions are accounted for consist of:

- Solid waste disposal on land: emissions resulting from managed semi-aerobic sites (landfills such as Nehmeh and Zahleh), unmanaged deep sites (open dumpsites with a depth of more than 5 m such as Tyre, Saida, and Tripoli dumpsites) and other disposal methods on land. Activity data on the annual amount of Municipal Solid Waste (MSW) disposed in Solid Waste Disposal Sites (SWDS) use a population of 4.12 million in 2000 with an average urban MSW generation rate of 339.62 kg/cap/yr and a percent disposal in SWDS of 77%.

Table 2-10 Activity data for LUCF calculations

Activity data		CO_2 Uptake (Gg)	CO_2 release (Gg)	Balance (Gg)
Temperate commercial Evergreen (kha)	131.24	-601.5		
Temperate commercial Deciduous (kha)	5.11	-14.1		
Non-Forest Trees- evergreen fruits and olive trees (banana, citrus, olive) (1000 trees)	24024	-181.68		
Deciduous fruit trees (apple, cherries, peaches, pears, plums, etc.) (1000 trees)	19349	-87.8		
Roundwood commercial harvest (Kt dm)	9.19		16.9	
Fuelwood and charcoal consumed (kt dm)	21		38.5	
Other wood use (sawnwood, roundwood non-commercial) (kt dm)	12.05		22.1	
Total		-885.1	77.5	-807.6

- Wastewater handling: emissions resulting from the biodegradation of domestic and commercial wastewater disposed in water bodies or collected in septic tanks. Emissions from Industrial wastewater handling are not considered due to the absence of industrial wastewater treatment in Lebanon.
- Waste incineration: emissions resulting from the incineration of clinical waste.

The waste sector is the largest source of CH_4 emissions in Lebanon, accounting for 87.5% of the total national CH_4 emissions. The sector generated 1,739.36 Gg CO_2 eq. in 2000, or 9.4% of the total GHG emissions for the same year. Figure 2-9 illustrates the relative share of the different GHG emissions from the waste sector while Table 2-11 presents the contributions of the different categories to GHG emissions.

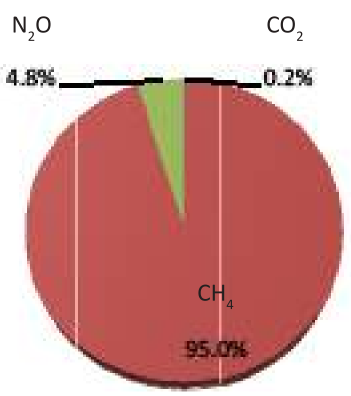


Figure 2-9 Composition of GHG emissions from the waste sector

Solid waste disposal on land remains the highest emitting category, constituting 94.3% of waste emissions in 2000, or 1,640 Gg CO_2 eq., with CH_4 being the main gas emitted. For calculation purposes, and based on an analysis of compiled data on waste generation in the Greater Beirut Area, the solid waste generated in Lebanon for the year 2000 is estimated to amount to 1,400,567 tonnes, of which 77% is being discharged in solid waste disposal sites. Since no information on the amount of gas flared in Zahle and Tripoli landfill are available for the year 2000, CH_4 flaring is only considered for the Nehmeh landfill, amounting to 3.9 Gg CH_4 (Table 2-11).

Emissions from wastewater handling emitted 96.3 Gg CO_2 eq. in 2000, where 59.3% of wastewater is estimated to be discharged directly in the sea, 26.1% is collected in septic tanks, and 14.6% is discharged in rivers.

As for waste incineration, although open burning of municipal waste is commonly practiced in Lebanon, data on such practices are unavailable. Therefore, this inventory only records emissions from the controlled incineration of medical waste, which constituted in 2000 0.2% of all waste GHG emissions, or 3 Gg CO_2 eq.

Table 2-11 GHG emissions from the waste sector.

Waste sub-sectors	GHG emissions (Gg CO_2 eq.)	Share of total waste emissions	Share of total national emissions
Solid Waste Disposal on Land	1,640.1	94.29%	8.86%
Wastewater Handling	96.30	5.54%	0.52%
Waste Incineration	2.96	0.17%	0.02%
Total	1,739.36	100.00%	9.40%

2.4 GHG Emissions by Gas

Carbon dioxide is by far the most important GHG emitted in Lebanon in 2000, accounting for 84% of total CO_2 eq. emissions. The major emitter of CO_2 is fuel combustion (energy industries, manufacturing industries or transport), constituting 88% of total CO_2 emissions. Industrial processes, namely cement industries, are also a significant source of CO_2 with 11% of emissions in 2000 (Figure 2-10).

Methane emissions have the second largest share of Lebanon's GHG emissions, with 89.82 Gg at 10.19% of the total GHG emissions in 2000. The waste sector, and namely solid waste disposal on land, is the largest contributor to these emissions with approximately 87% of emissions. This is followed by enteric fermentation and forest and grassland conversion (forest fires) with 6.7% and 2.3% respectively (Figure 2-11).

Nitrous oxide emissions have the smallest share of emissions in Lebanon, amounting to 3.39 Gg CO_2 eq. at 5.68% of total GHG emissions. In 2000, the main emitter of N_2O was the agriculture sector, namely agricultural soils and manure management, at 78% and 10% of total N_2O emissions respectively. This is followed by wastewater handling with 8% of N_2O emissions (Figure 2-12).

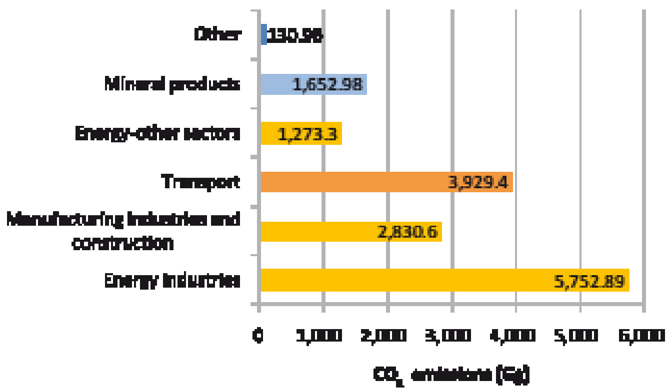


Figure 2-10 CO_2 emissions from major sources

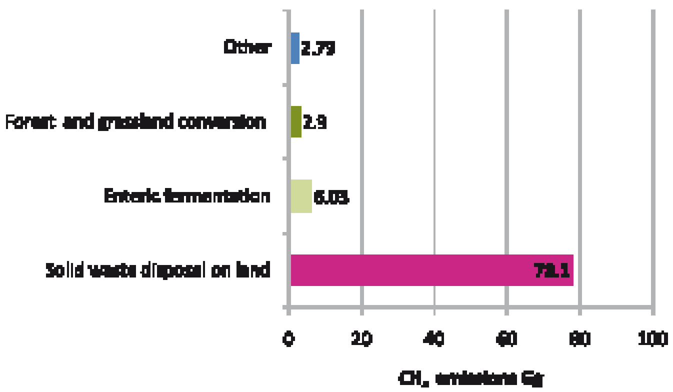


Figure 2-11 CH_4 emissions from major sources

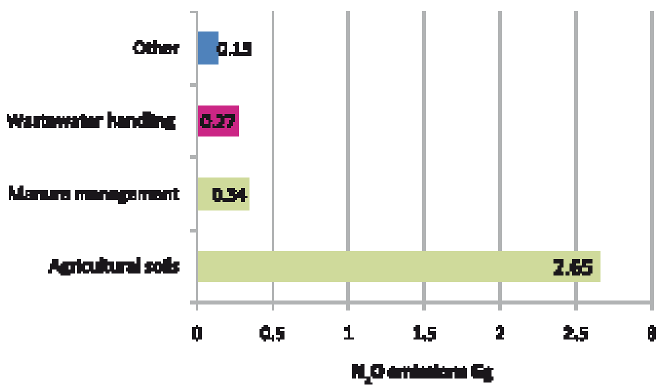


Figure 2-12 N_2O emissions from major sources

2.5 Trend in Lebanon's GHG Emissions: 1994-2004

An inventory of greenhouse gas emissions for the years 1994-2004 is undertaken in order to allow a complete assessment of trends in national GHG emissions and accordingly, design appropriate mitigation measures. The emissions of 1994 reported in the INC are used as the baseline for the extrapolation of results for the period 1994-1999. Emissions of the years 2000 to 2004 are calculated using the revised 1996 IPCC guidelines and based on recently collected activity data. For analysis purposes, the energy sector is divided between Energy production (EI, MIC, other) and transport. Table 2-12 and Figure 2-13 show the percent change and trend of GHG emissions during 1994-2004 for all sectors under study.

Table 2-12 Trend of emissions during the period 1994-2004

	Total GHG emissions (Gg CO_2 eq.)	Energy (Gg CO_2 eq.)	Transport (Gg CO_2 eq.)	Industry (Gg CO_2 eq.)	Agriculture (Gg CO_2 eq.)	Land Use and Forestry (Gg CO_2 eq.)	Waste (Gg CO_2 eq.)
1994	15,901	7,743	3,991	1,924	1,130	210	902
2000	18,507	9,892	3,963	1,781	1,066	67	1,739
2004	20,299	10,979	3,976	2,178	925	12	2,227
% change 1994-2004	27.66%	41.79%	-0.39%	13.19%	-18.12%	- 94.42%	146.99%
Average % change/yr	2.77%	4.18%	-0.04%	1.32%	-1.81%	-9.44%	14.70%

Lebanon's GHG emissions have increased by 27.6% since 1994, when total emissions were approximately 15,901 tCO_2 eq. This represents an average annual growth rate of 2.77%. As can be seen in Table 2-12, the fastest rate of growth occurred in the waste sector followed by the energy and industrial sector. A significant decrease in emissions is noted in the Land Use and Forestry sector in addition to a slight decrease in the agriculture sector.

As shown in Figure 2-13, the trend of increase in total GHG emissions closely follows the trend of emissions from the energy sector, which constituted 49 to 58% of total emissions during this period. This significant growth in emissions reflects the growing demand for electricity, due in part to the changing socio-economic conditions and to the expansion of the national grid. In fact, the sharp increase noticed between the 1994 and 2000 emissions is due to the increase in gas/diesel oil consumption (Figure 2-14) that accompanied the installation and operation of the Baalbeck, Tyre, Beddawi and Zahrani diesel power plants during this period.

As for the transport sector, GHG emissions have conserved a steady state throughout the 1994-2004 period. Despite a vehicle fleet increase during this period, the increased efficiency in fuel consumption of new cars, the ban to import cars older than 8 years that was introduced in Lebanon and the inspection system that was established in Lebanon in 2001 contributed to the stabilization of the emission trend from the transport sector.

The increasing emission trend is also caused by development of the industrial sector during this period, and namely the increase in cement and lime production by 40% and 32% respectively, with limited technological changes over the same period. Consequently, emissions from cement and lime industries increased by 45% and 37.5% respectively from 1994 to 2004. However, the soda ash use and steel production have witnessed a sharp decrease from their 1994 values, reaching a decrease in emissions of 90% for soda ash use, and 100% for steel production after the shutdown of the only steel plant in 2002. The averaged sectoral percent change during the 1994-2004 period is estimated at 13.19%.

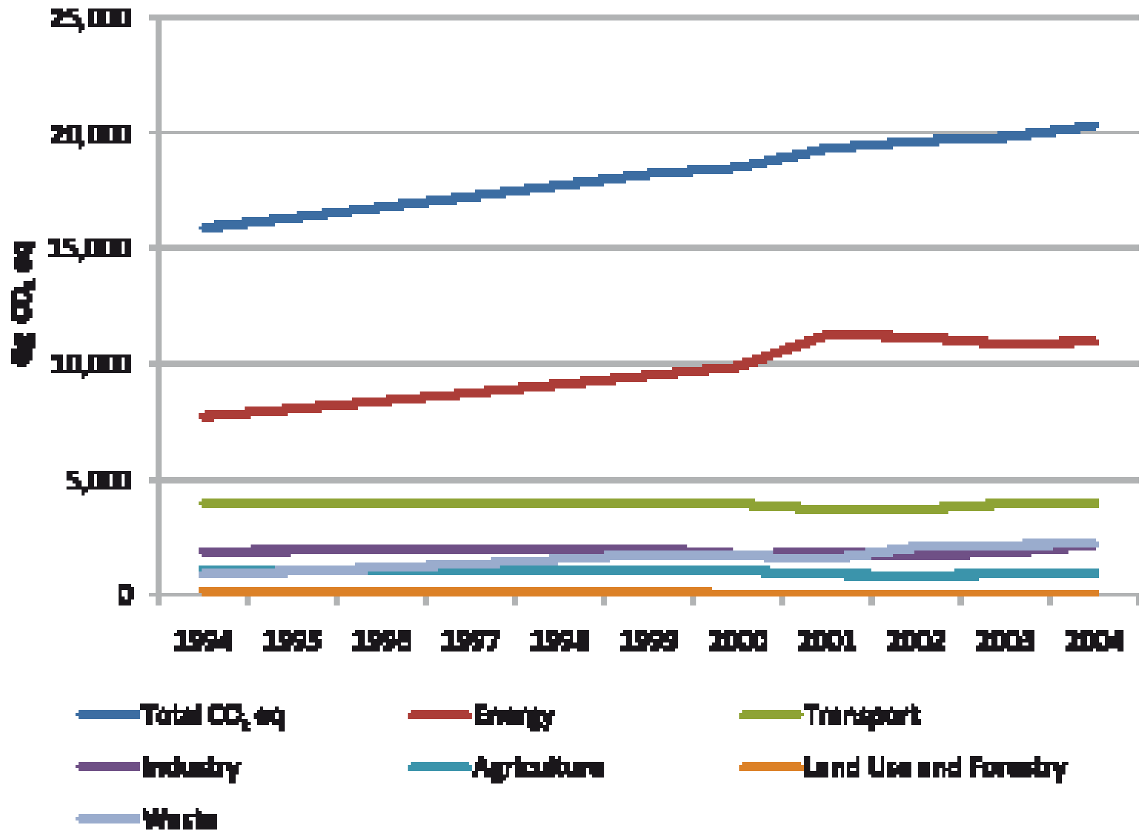


Figure 2-13 Trend in emissions

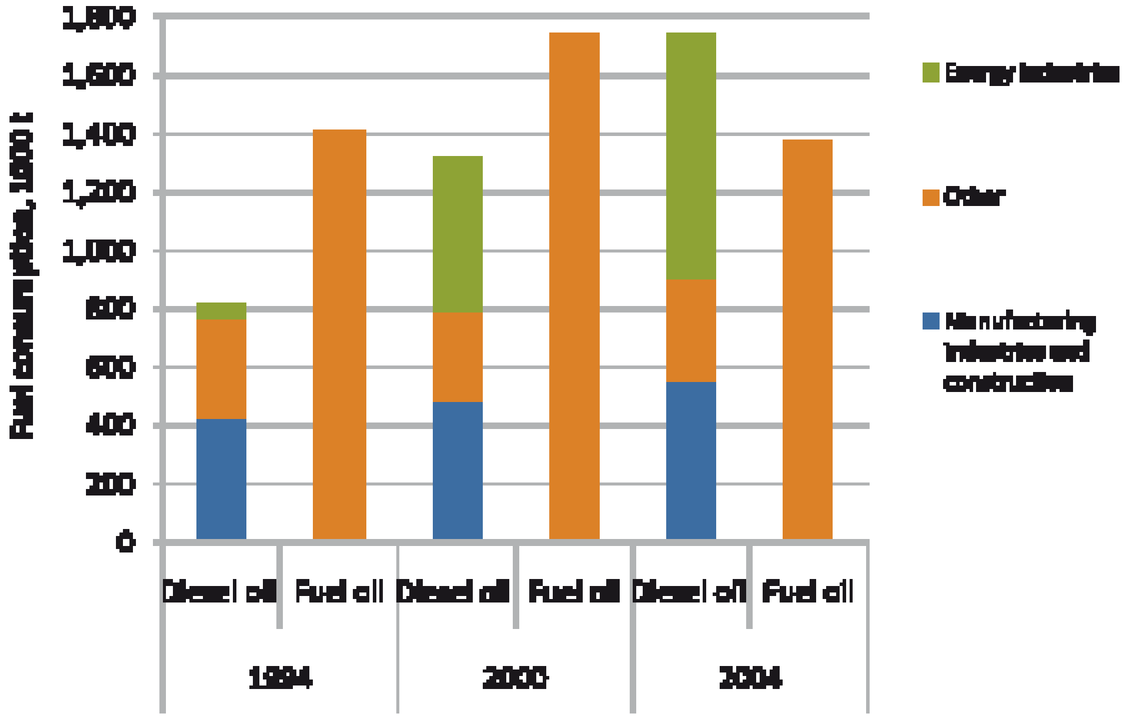


Figure 2-14 Consumption of fuel and diesel oil in the Energy sector

The sector with the most significant change in emissions is the waste sector with an increase of 147% from the 1994 values. With an increase in population, in waste generation and in percent of waste deposited in landfills, methane emissions from solid waste disposal on land have increased by 135% during the same period. Although flaring was introduced in 2000 with the establishment of the Naameh landfill, the amount of methane recovered is insignificant, constituting only 5% and 8% of the total annual methane generated from waste disposal on land in 2000 and 2004 respectively (Figure 2-15).

This sharp increase in emissions from the waste sector is countered by a decrease in emissions from agriculture and land use change and forestry. Indeed, during the 1994-2004 period, emissions from agriculture and LUCF decreased by 18% and 94.44% respectively. Possible causes for these changes in emissions are:

- Decrease in the population of livestock such as sheep, swine and other cattle. This decrease not only reduced the amount of CH_4 generated from manure management systems but also the N_2O emissions produced from the nitrogen excreted during grazing.
- Decrease in forest fires from 1994 to 2004, not only due to increase awareness of forest management from local communities but also due to increase wood harvesting during this period.

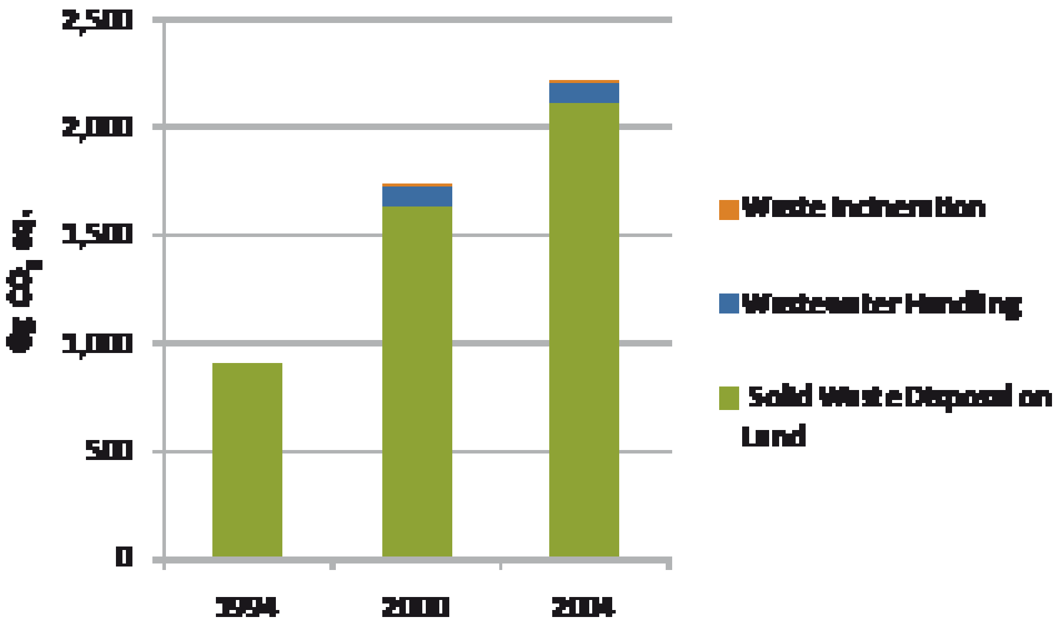
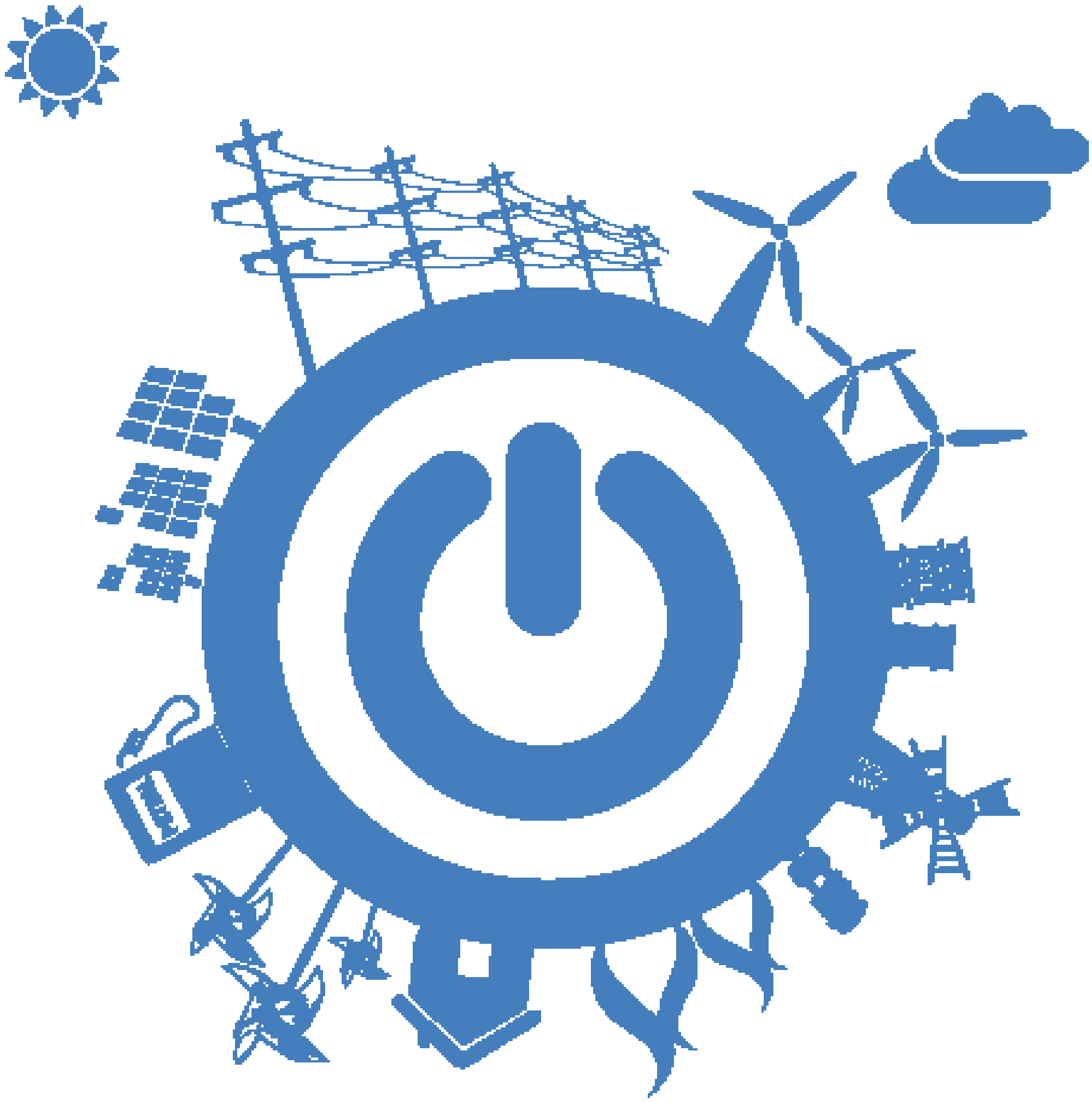


Figure 2-15 Trend in GHG emissions from the waste sector from 1994 to 2004

Greenhouse Gas Mitigation Analysis



3. Greenhouse Gas Mitigation Analysis

The purpose of this chapter is to provide an analysis of the measures to reduce GHG emissions and enhance carbon sinks in Lebanon. The analysis is based on 2 types of scenarios: the baseline scenarios and the mitigation scenarios.

The baseline scenarios are constructed based on the current sectoral plans, policies and projected trends. Baseline scenarios are different from the business-as-usual scenario since the government of Lebanon has committed itself to long-term plans which introduce major changes to the existing structure of the economy. Some of these changes may be considered as a baseline scenario, such as in the energy sector while some plans are considered as a mitigation scenario such as the national waste management plan that still needs time for its execution. The choice of baseline scenario is achieved through a thorough consultation process with all stakeholders and sectoral decision makers. The data used are derived from periodical reports, national and international studies and literature review. The GHG abatement analysis is made for 20 years, i.e. till the year 2030. The projection of trends uses 2004 as the base year and project forecasts the values to 2030, taking into account demographic, social, and economical assumptions available in official documentation. When faced with major lack of data, projections are developed in close cooperation with the relevant institutions to determine the most appropriate political and economical development of a specific sector.

The mitigation scenarios are proposed plans and projects that have a potential for sectoral emission reduction or sink enhancing. Mitigation options are selected and analyzed according to their direct and indirect economic impact, consistency with national development goals, economical feasibility, and compatibility with implementation policies, sustainability and other specific criteria. Various methods and tools are used to evaluate each mitigation option in terms of technological and economical implications. It should be noted that due to major lack of data, most of the values used in the analysis are based on international applications and studies.

3.1. Energy Sector

3.1.1. Electricity

Electricity in Lebanon is supplied through Electricité du Liban (EDL) that is responsible for the generation, transmission, and distribution of electrical energy in Lebanon. The sector has faced many challenges and difficulties, mainly the inability of meeting demand over the last few decades, as well as a considerable budget deficit necessitating continuous government transfers (reaching USD 328 million, equivalent to 1.5% of GDP in 2004). Electricity generation is the main emitter in Lebanon, with 5,773 Gg CO_2 eq. in 2000 or 31% of total emissions in 2000.

3.1.1.1. Baseline scenario

A number of plans and strategies for the electricity sector have been formulated to date, as different governments with different political inspirations and views have changed former plans. However, no plan has been implemented, and the gap between demand and supply has kept increasing as a result of the increasing demand, leading to an increase in rationing year after year. Table 3-1 presents the main components of the Ministry of Energy and Water's (MoEW) latest policy paper for the electricity sector released in June 2010, endorsed by the Council of Ministers, which, if implemented with the necessary additional investments for capacity expansion until 2030, will have very significant influence in keeping up with growing demand (MoEW, 2010).

3.1.1.2. Projected Emissions

The energy sector releases mainly CO_2 emissions from fuel combustion. Figure 3-1 illustrates the breakdown of the total installed capacity of power plants in Lebanon under the baseline scenario using Long-range Energy Alternative Planning system (LEAP). LEAP is a scenario-based energy-environment modeling tool. Its scenarios are based on comprehensive accounting of how energy is consumed, converted and produced in a given region or economy under a range of alternative assumptions on population, economic development, technology, price and so on. LEAP serves several purposes: as a database, it provides a comprehensive system for maintaining energy information; as a forecasting tool, it enables to make projections of energy supply and demand over a long-term planning horizon; as a policy analysis tool, it simulates and assesses the effects - physical, economic,

Table 3-1 Main components of MoEW policy

Infrastructure
- Target of total installed capacity of 4,000 MW by 2014 and 5,000 MW thereafter to meet a load of 2,500 MW (summer 2009), the 500 MW of demand currently supplied by self generation, and future demand corresponding to an annual load growth of 7%, and 15% of peak load reserve.
- Possibility of renting 250 MW (barges, small generators or imports) between 2010 and 2013
- Rapid increase of the installed capacity by 600-700 MW using CCGT (400 MW) and/or Reciprocating Engines using diesel starting 2011 and over a period of 3 years
- Rehabilitating, maintaining, replacing, or upgrading existing plants to increase their overall capacity by about 245 MW
- Increasing installed capacity by 1,500 MW immediately and 1,000 MW after 2014 using the modality of Independent Power Producer (IPP) in collaboration with the private sector. Increasing the share of hydropower production between 2012 and 2015 Introducing wind power via the private sector by building wind farms (60-100 MW) between 2011and 2013.
- Use "waste to energy" or geothermal energy if possible to add a capacity of 15-25 MW between 2013 and 2014
- Removing bottlenecks, reducing transmission losses, completing a control facility to ensure adequate connection between power plants and load centers together with high reliability and stability at the lowest cost
- Improving the distribution services in 2010 and equalize respectively the supply and collection between regions
- Subcontract company for the upgrade/ rehabilitation of the distribution system
- Developing a center able to monitor automatic meter reading, perform remote connection/ disconnection of supply and demand management functions between 2012 and 2014
- Introducing new services, payment facilities and new tariff structures and mechanisms
- Developing a Distribution Management Center (DMC) to be implemented between 2012 and 2014
Supply and Demand
- 2/3 of the fuel mix is based on natural gas with multiple sources of supply
- More than 12% of the fuel mix to be supplied by renewable energy sources
- Developing an infrastructure plan to supply and distribute natural gas
- Completing a prefeasibility study and construct a Liquefied Natural Gas (LNG) marine terminal in Selaata or Zahrani between 2011 and 2013
- Building a gas pipeline along the coast to feed all power plants between 2011 and 2013
- Completing a wind atlas for Lebanon and launch IPP wind farms with the private sector
- Starting a prefeasibility study on Photovoltaic (PV) farms
- Encouraging initiative of waste to energy
- Save a minimum of 5% of the total demand from demand side management and energy efficiency
- Adopting the Energy Conservation law, institutionalizing the Lebanese Center for Energy Conservation (LCEC) and launching a national plan for energy conservation
- Widely spreading the use of Compact Fluorescent Lamp (CFL)
- Increasing the penetration of Solar Water Heaters (SWH) and devising innovative financing schemes
- Encouraging the use of energy saving public lighting
- Setting up the National Energy Efficiency and Renewable Energy Account (NEEREA) and developing the ESCO (Energy Service Company) business
- Gradually increasing tariff in conjunction with improvements in the electric service provision
- Implementing Time of Use (TOU) tariffs in conjunction with the implementation of Automatic Meter Reading (AMR) schemes
Legal Framework
- Developing rules and laws that promote the largest penetration of "Green Buildings (GB)" and "Energy Efficiency (EE)"
- Comply and respect international norms and standards in the energy efficiency, environmental and public safety domains
- Increasing the human resource capacity of EDL
- Updating the legal due diligence needed to corporatize EDL as per the three functions of generation, transmission and distribution
- Using Service Providers, independent power production, Operation & Maintenance (O&M) contracts
- Initiating the process of revising Law 462 with concerned parties
- Beginning with the current legal status of EDL governed by Decree 4517
- Adopting a Law for the new power plants and encouraging all kinds of Public Private Partnership to facilitate the transition and ensure proper continuity between current and future legal status

Source: MoEW, 2010

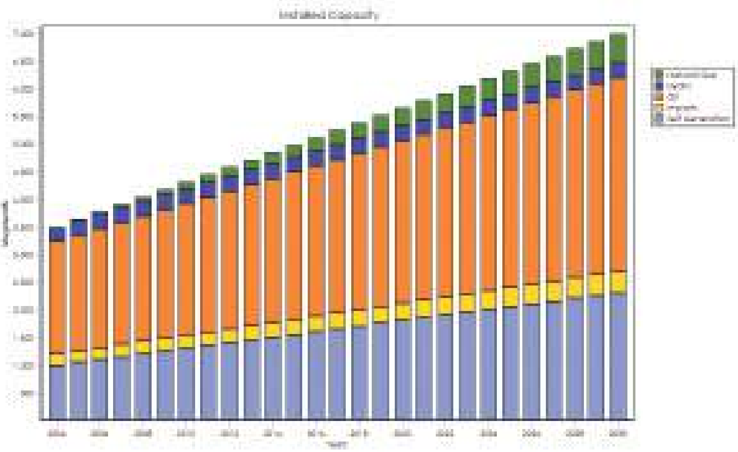


Figure 3-1 Breakdown of total installed capacity under the baseline scenario

and environmental - of alternative energy programs, investments, and actions (SEI, 2006).

GHG emissions for the year 2004 amount to around 7,261 Gg of CO_2 eq., which is lower than the value obtained in the GHG inventory. This can be attributed to differences in the approach used in the IPCC guidelines and in LEAP, differences in the efficiencies of power generation, and differences in emission and conversion factors. Projected emissions are expected to reach 32,569 Gg CO_2 eq. by 2030 under the baseline scenario, including self-generation (Figure 3-2). The emissions from the electricity imports from neighboring countries are not reported as they do not account for national emissions.

3.1.1.3. Mitigation scenarios

Mitigation scenario 1: Implementation of MoEW's latest policy paper for the electricity sector, in addition to capacity expansion (around 3,500 MW between 2015 and 2030 based on the 2/3 natural gas fuel mix, in addition to 11.4% of renewable energy by 2030) **post-2015 to keep up with demand.**

Mitigation scenario 2: Implementation of MoEW's policy paper but with a full switch of oil-fired power plants to natural gas by 2030, an increase in the penetration rate of renewable energy technologies (17% by 2030) and no electricity imports.

The data and assumptions for these scenarios are summarized in Table 3-2 and the breakdown of total installed capacity of power plants is illustrated in Figure 3-3 and Figure 3-4.

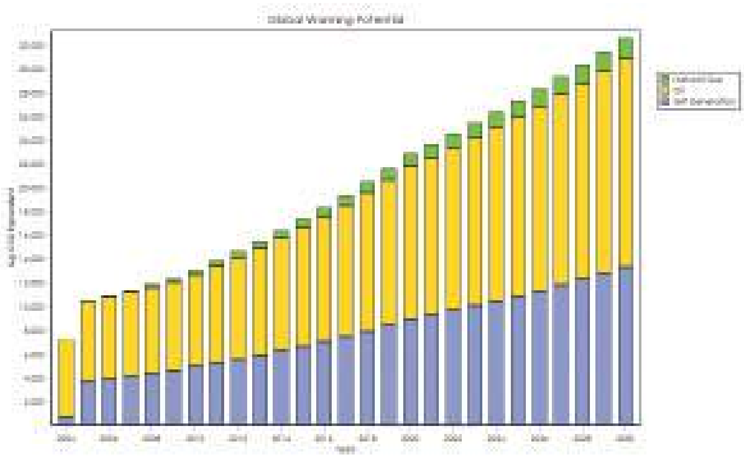


Figure 3-2 GHG emissions from the electricity sector under the baseline scenario

Table 3-2 Data and assumptions for Mitigation scenario

	Exogenous capacity (MW)	
	Mitigation Scenario 1	Mitigation Scenario 2
Oil	2004: 2,038 2014: 2,538 2030: 1,230	2004: 2038 2014: 2538 2030: 0
Diesel	2004: 0 2014: 300 2030: 0	2004: 0 2014: 300 2020: 0
NG	2004: 0 2014: 1,617.5 2030: 4,690	2004: 0 2014: 1617.5 2030: 5,850
Hydro	2004: 274 2015: 310 2030: 400	2004: 274 2015: 310 2030: 600
Wind	2004: 0 2015: 80 2030: 253.8 (8% growth as of 2016)	2004: 0 2015: 80 2030: 334.2 (10% growth as of 2016)
Solar	2004: 0.5 2015: 0.5 2030: 81.4 (5% growth between 2021 and 2030)	2004: 0.5 2015: 0.5 2030: 129.7 (10% growth between 2021 and 2030)
MSW	2004: 0 2015: 20 2030: 63.4 (8% growth as of 2016)	2004: 0 2015: 20 2030: 129.7 (10% growth as of 2021)
Imports	2004: 200 2011: 300 2030: 300	2004: 200 2011: 300 2030: 0
Self-Generation	2004: 1,000 2015: 0 2030: 0	2004: 1,000 2015: 0 2030: 0
Total in 2030	7,019 MW (11.4% renewable)	7,044 MW (17% renewable)

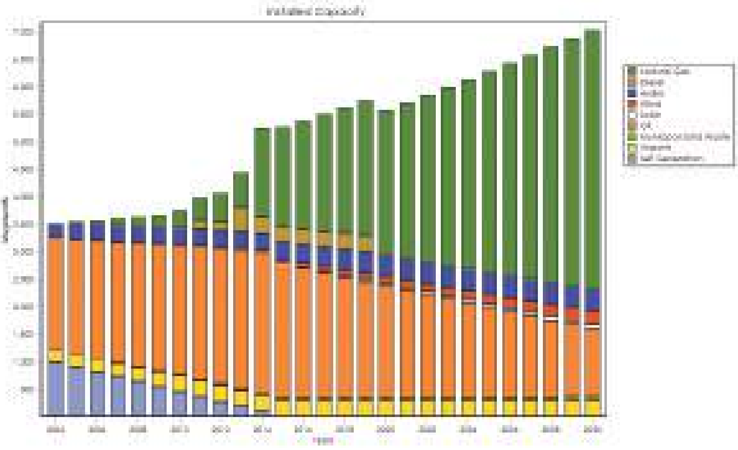


Figure 3-3 Breakdown of total installed capacity under mitigation scenario 1

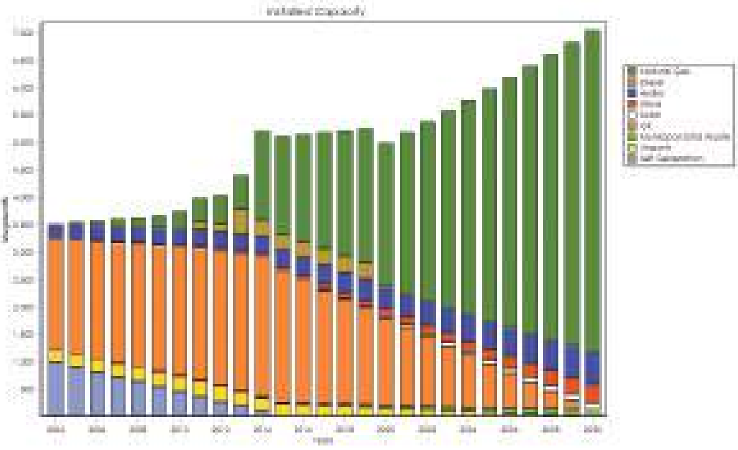


Figure 3-4 Breakdown of total installed capacity under mitigation scenario 2

3.1.1.4. Emissions reduction and costs of mitigation scenarios

Mitigation scenario 1: The cumulative reduction in GHG emissions from mitigation scenario 1 adds up to 177,912 Gg of CO_2 eq. between 2011 and 2030, or a 33% reduction from 2004. The emissions reduction in 2030 is around 41.6%, as in Figure 3-5.

The cost of implementation of mitigation scenario 1 is estimated at USD 8.14 billion, which includes the implementation cost of MoEW's plan (USD 4.87 billion). The additional investments amount to USD 3.27 billion, assuming that all added CCGT capacity consist of new power plants rather than conversion of old oil-fired power plants and that the investment is made at once in 2016 and not gradually (Table 3-3). The resulting unit cost of emissions reduction from mitigation scenario 1 is USD 42.9/tCO_2 eq. Discounted unit costs are calculated at 10% and 15% discount rates (Table 3-3 and Table 3-4).

Mitigation scenario 2: The cumulative reduction in GHG emissions from mitigation scenario 2 adds up to 204,768.3 Gg of CO_2 eq. between 2011 and 2030, or a 38% reduction from 2004, which is higher than scenario 1. Emissions reduction reaches 43.6% in 2030.

The total cost of mitigation scenario 2 is around USD 11.0 billion, with the cost of additional investment being USD 6.12 billion, as shown Table 3-3. The resulting unit cost of emission reduction is USD 57.6/tCO_2 eq., which is higher than scenario 1 since a greater fraction of existing installed capacity (oil-fired) has to be replaced by CCGT and renewable technologies.

A comparison of scenarios 1 and 2 reveals that scenario 2 reduces GHG emissions by 26,856 Gg more than scenario 1, or 7.5% more between 2004 and 2030.

It should be noted that these figures are not meant to be compared merely for scenario selection purposes, and the two scenarios were mainly considered to illustrate the

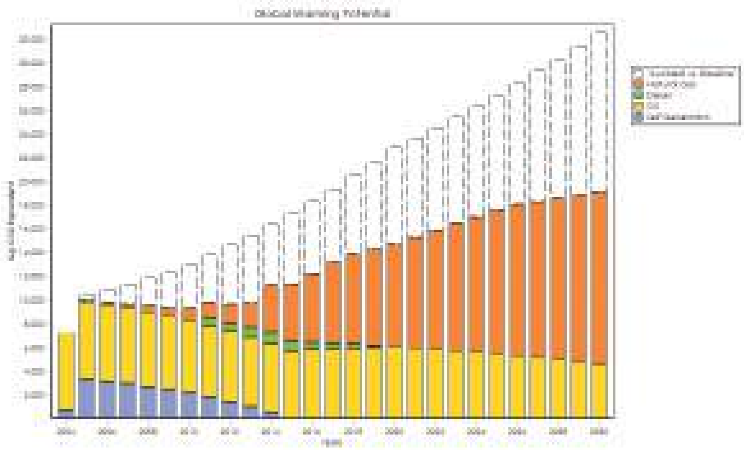


Figure 3-5 GHG emissions and avoided emissions under mitigation scenario 1

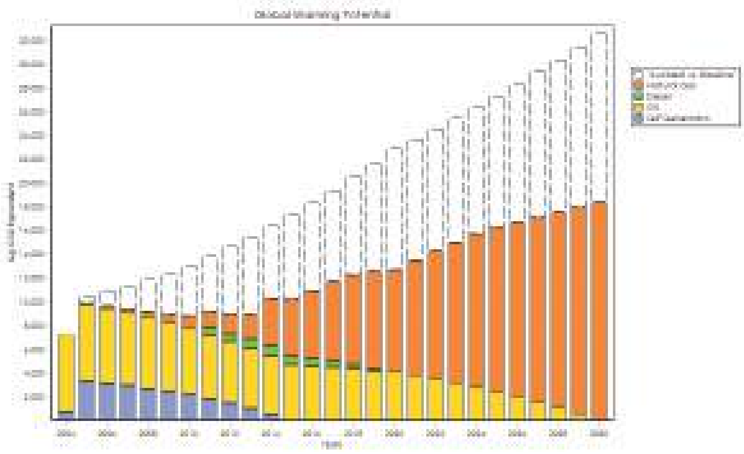


Figure 3-6 GHG emissions and avoided emissions under mitigation scenario 2

Table 3-3 Cost of installed capacity expansion needed in addition to MoEW's plan

Technology	Cost/MW (USD million)	Mitigation scenario 1		Mitigation scenario 2	
		Capacity to be added (MW)	Total Cost (USD million)	Capacity to be added (MW)	Total Cost (USD million)
CCGT	1.00	2,072	2,000	3,232.5	3,200
Hydropower	5.80	90	522	290	1,700
Wind	1.95	173.8	339	254.2	496
Solar	4.00*	80.9	324	129.2	517
Waste to energy	1.90	43.4	82.5	109.7	208
Total	-	2,460.1	3,270	4,015.6	6,120

* Expert opinion. Cost figures for the other technologies are taken from MoEW, 2010.

Table 3-4 Discounted total cost and unit cost at different discount rates

Discount rate	Mitigation scenario 1		Mitigation scenario 2	
	Discounted total cost (USD billion)	Discount unit cost (USD/tCO_2 eq.)	Discounted total cost (USD billion)	Discount unit cost (USD/tCO_2 eq.)
10%	6.94	41.08	8.68	44.59
15%	6.53	38.63	7.92	40.69

extent of emissions reduction possible and associated costs. It is expected that the greater the shift to cleaner technologies, the cost is greater, as indicated in scenario 2. The more funds can be secured, the greater the possible investment to increase the proportion of clean fuels (natural gas and renewable) in power generation – as in scenario 2 – and thus reduce GHG emissions.

3.1.1.5. Mitigation Strategy

The mitigation strategy consists mainly of implementing the elements elaborated in the policy paper for the Electricity Sector (MoEW, 2010), which addresses the problem in a comprehensive, integrated manner.

Regarding the diversification of fuel supply and the proposed expansion of CCGT capacity to generate most of the capacity needed, LNG can offer important relief in the medium to longer term by (Poten and Partners, 2009) by significantly reducing generation cost.

Two options were advocated for the supply of natural gas to the power plants:

- A gas pipeline along the coast between Baddawi and Tyre advocated in the MoEW policy paper to feed all power plants falling along that coastal strip. This option would be expensive (Poten and Partners, 2009), in addition to the fact that gas volumes coming to Baddawi would not suffice.

- A permanently moored offshore Floating Storage and Regasification Unit (FSRU) with ship to ship LNG transfer, linked to the coast by a subsea gas pipeline in the case of the Zahrani power plant (Poten and Partners, 2009).

With an FSRU, LNG solution at Zahrani would result in USD 75 – 80 million/ year total saving, an Internal Rate of Return (IRR) of more than 90%, and investment payback in one or two years. Expanding Zahrani can be a good proposition in the longer term, given LNG's comparable life cycle generation costs to coal without the environmental drawbacks.

In the current surplus market conditions, Lebanon could secure long term prices of around USD 7/million BTU (assuming oil prices of around USD 65/barrel). However, EDL might not qualify as a creditworthy LNG buyer, which might require additional government guarantee and potentially a World Bank partial-risk guarantee from the supplier.

A site-specific feasibility study to determine the feasibility of such a project is needed, followed by a Front End Engineering and Design (FEED) study. Another important pre-requisite for such a project is the finalization of a gas/LNG import law to clarify the regulatory and fiscal regimes governing the import terminal and the various participants including EDL, terminal developer and LNG supplier. Finally, a long term LNG supply procurement strategy needs to be developed and finalized (Poten and Partners, 2009).

3.1.2. Manufacturing Industries and Construction

The manufacturing industries and construction sector covers private self-generation of electricity which accounts for around 33% of the total electricity generation. Total emissions from this sector reached 2,838.06 Gg of CO_2 eq. in 2000. Since a significant amount of private generation is derived from manufacturing industries, this chapter addresses measures to increase the efficiency of power generation in the industrial sector, especially in cement industries which constitute one of the major energy intensive industries in the country.

3.1.2.1. Mitigation scenarios and costs

Mitigation scenario 1: Waste heat recovery and utilization for power generation in cement plants

The objectives of this option are to meet the electrical supply needs of cement plants and to reduce GHG emissions through the recovery and use of waste heat from the rotating kiln of the cement clinker production line. Additionally, this option has the potential to significantly reduce harmful emissions (including SO_x, NO_x and floating particles), and thus improve the local environment.

Based on figures of heat recovery and utilization reported in UNFCCC 2007, 2008a, 2008b, and 2009, the following assumptions (Table 3-5) are considered concerning the case of Lebanon and the results are presented in Table 3-6 and Table 3-7.

Mitigation option 2: Partial substitution of fossil fuels with alternative fuels or less carbon intensive fuels

Since the majority of the industries in Lebanon use fossil fuel sources for their production processes and operations (petroleum coke, diesel oil and residual fuel oil), a main option to reduce the related CO_2 emissions is to reduce the carbon content of the fuel by using fossil fuel types

Table 3-5 Assumptions considered for the case of Lebanon

Parameter	Value
Average Gg CO_2 eq. reduced/Gg of cement produced	0.033
Average amount of electricity generated (MWh/ year)	97,817
Capital Cost per MWh of electricity generated (USD/MWh)	10.98
Expected operational lifetime of the project (years)	20
Operational cost	20% of investment cost
Growth rate in clinker production under scenario A	2%
Growth rate in clinker production under scenario B	4%

Table 3-6 Results of mitigation option 1 under scenario A and scenario B for selected years

Year	2010	2020	2030
Scenario A			
Production of Cement (tonnes)	4,666,602	5,688,562	6,934,325
Amount of electricity generated (MWh/year)	168,835	205,809	250,881
Amount of CO_2 eq. reduced (Gg CO_2 eq.)	155	189	230
Scenario B			
Production of Cement (tonnes)	5,243,240	7,761,277	11,488,585
Amount of electricity generated (MWh/year)	189,698	280,799	415,652
Amount of CO_2 eq. reduced (Gg CO_2 eq.)	174	258	381

Table 3-7 Breakdown of the cost of mitigation option 1 under scenario A and scenario B for the period 2010-2030

	Investment Cost (USD million)	Operational Cost (USD)	Total Cost (USD million)	Total Discounted Cost (10%) (USD million)	Cost (USD/Gg CO_2eq.)	Total Discounted Cost (15%) (USD million)	Cost (USD/Gg CO_2 eq.)
Scenario A	1,854	370,909	2.22	2,658	693	2,537	661
Scenario B	2,083	416,741	2,50	3,624	672	3,288	610

Table 3-8 CO_2 emissions per type of fuel

Fuel Type	Net calorific value (TJ/Gg)	Effective CO_2 emission factor (Gg/TJ)	CO_2 Emissions per Gg of fuel (g CO_2/g of fuel)
Fuels already in use			
Petroleum Coke	32.5	0.097	3.152
Residual fuel oil	40.4	0.077	3.126
Diesel oil	43	0.074	3.182
Alternative Fuels			
Natural Gas	48	0.0561	2.692
Municipal waste	10 - 11.6	0.0917 - 0.1	0.971 - 1.16

Source: IPCC, 2006

with a lower CO_2 emission factor on a net calorific value basis (tCO_2/GJ) such as natural gas (Table 3-8).

Another option is the application of waste-derived alternative fuels such as wastes originating from fossil sources or biomass residues. In considering using waste-derived fuels in cement industries specifically, a number of issues should be considered such as energy efficiency of waste combustion in cement kilns, fuel quality, generation of trace elements and heavy metals and production of secondary waste (Hendriks et al., 2004).

3.1.3. Transportation

In comparison with developed nations, Lebanon has a larger percentage of older vehicles, which probably leads to a proportionately higher percentage of emissions released into the atmosphere per vehicle-kilometer or vehicle-hour of congestion than in developed countries. The transport sector accounts for 19.5% of Lebanon's GHG emission (3,976 Gg of CO_2 eq.), and around 98.5% of total CO emissions. This section focuses on land transport of passengers, which is the largest contributor to GHG transport emissions in Lebanon.

3.1.3.1. Baseline scenario

The main existing transport legislation relevant to the mitigation of GHG emissions comprises:

- Decree 6603 (4/4/1995) that defines standards for operating diesel trucks and buses, as well as the implementation of a monitoring plan and permissible levels of exhaust fumes and exhaust quality (particularly for CO, NO_x, hydrocarbons and TSP).
- Decision 9, issued by the Council of Ministers on 5/4/2000, which calls for the reform and re-organization of the Land Public Transport Sector in Lebanon and the reduction of the number of public transport vehicles from 39,761 to 27,061 vehicles.
- Law 341(6/08/2001) that lays the legal framework for reducing air pollution from the transport sector and encouraging the use of cleaner sources of fuel. Specifically, the law bans the import of minivans operating on diesel engines, as well as old and new diesel engines for private passenger cars and minivans. The law empowered the GoL to retrieve 10,000 public license plates operating on diesel.

Numerous transport studies and policies and legislative texts are available, but little has been effectively implemented to date, leaving the sector in a chaotic situation. Table 3-9 presents a number of formulated and on-going projects and studies which, if implemented will have very significant influence in enhancing the sustainability of the transport system and reducing GHG emissions.

3.1.3.2. Projected growth in the vehicle fleet

The projected demographic growth in Lebanon from a total population of 4.29 million to around 5.2 million over the coming 25 years would inevitably be translated into growing demands for the various urban services, including transport. The vehicle population is expected to grow to 1,400,000 in 2015 (MoE, 2005). Moreover, it is estimated that, in 25 years, the vehicle fleet as well as the average number of daily motorized trips per person will both grow by almost 60%.

Given the relatively affordable car prices, available credit facilities, and the lack of a reliable and efficient public transport system, it is expected that the current trend would remain constant in the coming years under the baseline scenario; i.e., the share of passenger-trips traveled by private vehicles would keep increasing until it reaches 90% in 2030. The share of passenger-trips traveled by buses would remain constant, while that for vans would decline. Buses are assumed to operate on diesel, and vans on gasoline as mandated by law 341/2001. Fuel types and associated energy intensity would remain unchanged for all modes of passenger transport.

3.1.3.3. Mitigation scenarios

Mitigation scenario 1: Revitalization of the Public Transport System

This option consists of creating an efficient and reliable public transport system, whereby the distribution of passenger-trips traveled by bus and car would be reversed (more than half of person trips to be traveled by bus). This will entail the introduction of 637 buses countrywide with 507 buses in GBA, 85 in Tripoli, and 45 to serve intercity (between Mohafaza centers). The total non-recurring investment in vehicles, infrastructure, terminals, depots, etc., is estimated at USD 400 million (based on unpublished data from the MoPWT). The GBA public transport will require an annual subsidy of USD 100

Table 3-9 Summary of formulated and on-going projects and studies relevant to the transport sector

Study/ Project	Status and comments
Urban Transport Development Plan (UTDP) for the city of Beirut Funded jointly by the World Bank and the Republic of Lebanon, and implemented by the CDR	The corridor improvement component has been suffering serious impediments and delays attributed to slow expropriation procedures on the Government side. Around 60% of this component has been implemented
Revitalization of the Public Transport and Freight Transport Industries Launched by the MoPWT	The background assessment for this study has been launched
Restructuring of the Directorate General for Land & and Marine Transport Launched by the MoPWT	No implementation to date
The Road User Charges Study	No concrete action has been taken to date in order to establish neither a Road Fund nor a Transport Fund, and the study is now outdated, especially with the unexpected rise in oil prices
The Proposed National Transport Policy Prepared by the DGLMT and submitted to the Government of Lebanon in 2002	No concrete implementation to date
The National Physical Master Plan for the Lebanese Territories (NPMPLT)	Although the MPMPLT was endorsed by the Council of Ministers in 2009, no application decrees were issued for its application into land use, urban planning, or development schemes and projects
The Beirut Suburban Mass Transit Corridor Study	This project is also not considered financially viable by the government due to the costs it entails and to the present loss of the rail right-of-way by urban encroachment on the existing track in many locations
Setting up of the Traffic Management Organization (TMO)	The TMO was created by Decree No.11244 dated October 25, 2003, but has had an administrative rather than a more technical traffic management role, which has held the TMO from fulfilling the actual objectives and tasks it was created for. The current TMO needs restructuring – including hiring traffic experts
Regulation of the Public Transport Industry in Lebanon Carried out by the MoPWT-DGLMT (2002)	No concrete implementation to date

Source: MoE, 2005

million, which is modest compared to what is currently paid to employees as transport allowance. This cost should be considered starting 2011, with an additional USD 200 million in 2020 for the renewal of the bus fleet and its expansion by around 25% up to a size of 800 buses, in addition to upgrading and maintenance of infrastructure.

The cost-effectiveness of this mitigation scenario in terms of USD/tCO_2 eq. reduced would be too high in absolute terms since such a project is usually not carried out merely for GHG mitigation purposes, but is rather a basic infrastructure project that needs to be implemented for more general and broader purposes, and that would have additional advantages. Thus, its total cost cannot be considered as the mitigation cost.

Mitigation scenario 2: Implementation of a car scrappage program

This option consists of developing and implementing a complementary, integrated program to reduce emissions from the existing fleet through carrying out a car scrappage program whereby illegal private public transport vehicles which are old, highly emitting and carry duplicate license plates would be bought by the Government and scrapped.

A scrappage program would reduce the overall energy intensity of the vehicle fleet, and consequently GHG emissions from the sector. A number of recent scrappage programs make GHG emissions reduction an ancillary goal by setting fuel economy or g CO_2 eq./km requirements on the replacement vehicles. These upgrades range from a fuel economy improvement of 2.13 – 3.83 km/L to 120 g CO_2 eq./km (Allan et al., 2009). However, since newer cars are driven further per year than older ones, prematurely retiring a vehicle may reduce short-term GHG emission reduction benefits if the replacement vehicle is driven considerably farther than the scrapped vehicle.

The implementation of a car scrappage program in Lebanon can be considered a top priority measure that needs to be undertaken within an integrated framework. The estimated size of the vehicle fleet to be targeted is around 30,000 to 40,000 vehicles. Strict control needs to be exerted simultaneously in order to enforce the ban on old cars and therefore prevent any illegal import or smuggling. In parallel, strict emission standards need to be defined and enforced, and control made more stringent so as to identify those "legal" cars that are non-compliant and need repair or maintenance. In a second stage, once illegal vehicles have been scrapped, incentives would be provided to promote the replacement of non-compliant old vehicles that are too costly to repair and maintain, thus sustaining the renewal of the fleet throughout the years.

The promotion of technology measures such as hybrid vehicles would only be advocated once the above-mentioned measures, which are a pre-requisite to any other plan, less costly and lead to higher emission reductions, have been implemented and sustained. The introduction of hybrid and efficient vehicles to replace the taxi fleet has been advocated but is still controversial and will depend on its affordability, governmental support and provision of adequate subsidies.

3.1.3.4. Mitigation strategy

In addition to the scenarios presented above, the main strategy for the transport sector should include the following:

- Improve specifications relating to vehicle efficiency and fuel economy at the import stage;
- Provide incentives for increasing the share of new vehicle technologies in the fleet (e.g., HEV);
- Issue and enforce new vehicle emission control standards for imported used vehicles;
- Implement decree 6603/1995 relating to standards for operating diesel trucks and buses, monitoring and permissible levels of exhaust fumes and exhaust quality;
- Restructure, empower and enhance the role of the traffic management organization;
- Promote the creation of a transport fund and foster increased public/private partnership in order to reduce the financial burden of the transportation system on the budget of Lebanon;
- Adopt knowledge-intensive high-tech management approaches for solving complex urban transport problems;
- Amend vehicle taxation system and registration fees into a more environmentally oriented scheme;
- Endorse road network development and apply conventional traffic flow improvements;
- Discourage private car use in CBD areas through a reduction of road space for private vehicle operation and parking, coupled with a supporting fiscal structure that makes car use in CBD more expensive, assuming that a proper (efficient) alternative of transportation mode is provided;
- Proper training of drivers passing their license test so as to promote adequate driving habits that reduce emissions from cars;
- Redefine scarce urban road infrastructure for an increased (and partially exclusive) use of public transport means;
- Improve logistics and fleet management including upgrading and enforcing the car inspection program requirements and mandating the presence of catalytic converters;
- Introduce fuel taxation and parking fees, coupled with supporting awareness campaigns with respect to sustainable transport practices;
- Reduce the average number and length of vehicle trips through decentralization of public,

medical, academic and other institutions; as well as improved logistics and simplification of routine official procedures;

- Promote mass transit of freight through the introduction of electric rail in the long term;
- Reduce congestion in urban areas by reducing the penetration of trucks into urban areas, controlling loading/unloading operations, preventing the location of warehouses in the basements of buildings, etc.;
- Introduce legislative reforms, particularly in relation to urban planning laws, expropriation laws, taxes and tariffs, traffic laws.

3.1.4. Building Envelops

This section focuses on the thermal performance of buildings based on heating and cooling energy consumption. Thermal standards for buildings in Lebanon were developed by the "Capacity Building for the Adoption and Application of Thermal Standards for Buildings" project in 2005 by the General Directorate of Urban Planning (DGUP) and UNDP where the impact of the application of the thermal standards on GHG emissions at the macroeconomic level were forecasted, based on an estimation of the area of buildings which will be constructed on a 20-year horizon (MoPWT et al., 2005). Unfortunately, the standards are still not mandatory.

3.1.4.1. Application of Thermal Standards in new buildings

The proposed thermal standards for buildings suggest standards for walls, roofs and windows for residential and office buildings (commercial, institutional). These standards tackle:

- U-value for roofs and walls for the various climatic zones of Lebanon;
- U-value for windows for the various climatic zones of Lebanon;
- Maximum Effective Fenestration Ratio determined based on an analysis of several parameters that the building designer may act upon in order to reduce the solar heat gain of the proposed building, such as the orientation of the building, the glass shading coefficient, and the architectural shading factor (fins and overhang).

Over a 20-year period (2010-2029), the application of the Thermal Standards for Buildings can generate a reduction in energy use at building input (office and residential) consisting of around 56 million GJ of avoided heating energy and around 8 million GJ of avoided cooling energy. This leads to the avoidance of around 7 million tCO_2 over 20 years or around 343,500 tCO_2/year. The analysis is based on a merely fuel-based electricity supply mix; thus a change in the fuel mix towards cleaner fuel sources may result in a deeper reduction in emissions.

As for the cost of the reduction in GHG emissions from thermal insulation of buildings, the associated economic savings vary in magnitude depending on the price of fuel and diesel oil. Average estimations indicated savings in the range of USD 500 million in 2005, which can be considered as an underestimate as a result of the rise in fuel prices between 2005 and 2008 (peak price) and the inflation and rise in construction costs during this same period. The actual value of savings from the application of these standards can be assumed to be at least USD 1 billion/yr.

3.1.4.2. Retrofitting Existing Buildings

Regarding existing buildings, which represent the largest stock of buildings at any point in time, an Energy Performance Index (EPI) can be assigned to each building based on an assessment of its thermal performance. A development scheme can be put forward based on such an assessment with the aim of retrofitting existing buildings to improve their thermal performance. However, such a scheme would carry considerably high costs – higher than applying the standards to new buildings, and could only be effectively implemented if financing schemes and incentives are provided to the building owners.

Various efforts are being done to tackle existing buildings. The Lebanese Green Building Council and the International Finance Corporation have already launched activities to establish a voluntary green building rating system tailored to Lebanon to evaluate the "greenness" of existing non-residential buildings in comparison to similar buildings nationwide and provide structured guidelines to systematically improve resource and energy efficiency. A sustainable financing system is also being put in place to create incentives for retrofitting initiatives.

3.2. Industry

This section focuses on the mitigation of GHG emissions from cement industries, since they are the most important industrial source of CO_2 emissions reaching 92% of total industrial GHG emissions. In Lebanon, there are three Portland cement plants with a total production of clinker of 4,143,809 tonnes in 2004 and total emission of 2,156 Gg of CO_2 eq.

3.2.1. Baseline Scenario

Two baseline scenarios are suggested to portray possible future clinker production and CO_2 emissions from the cement industry in Lebanon until year 2030. Scenario A assumes a low growth rate of 2% in the cement industry while scenario B uses a higher growth rate of 4%. Figure 3-7 represents forecasts of cement production and CO_2 emissions under scenario A (3,607 Gg CO_2 eq.) and scenario B (5,976 Gg CO_2 eq.).

3.2.2. Mitigation scenario

Mitigation scenario: Increasing the additive blend in cement production

The production of clinker is the most energy-intensive step in the cement manufacturing process and causes large process emissions of CO_2. In blended cement, a portion of the clinker is replaced with industrial by-products. The reduction in clinker requirement in the production of cement results in reduction of CO_2 associated with calcination of limestone in kilns (UNFCCC, 2005).

The future potential for application of blended cement in Lebanon depends on the current application level, on the availability of blending materials, and on standards and legislative requirements. An increase of the share of additive (i.e., fly ash) from 27.66% to 35% would reduce the emissions by an estimated average of 1.32% of CO_2 emissions, at a cost between USD 15 and USD 30/Gg for fly ash and USD 24/Gg for blast furnace slag (UNFCCC, 2005).

3.2.3. Mitigation Strategy

Other mitigation measures could be applied or further explored in Lebanon to reduce GHG emissions from the cement sector such as:

- Substitution of conventional pre-calcination method by a pre-calcination method aimed at CO_2 production in a highly concentrated form;
- Replacing parts of the plant (motors, raw mill vent fan, preheater fan, kiln drives, etc.) by high efficiency ones;
- Applying energy management and process control in grinding;
- Modification of clinker cooler (use of mechanical flow regulator);

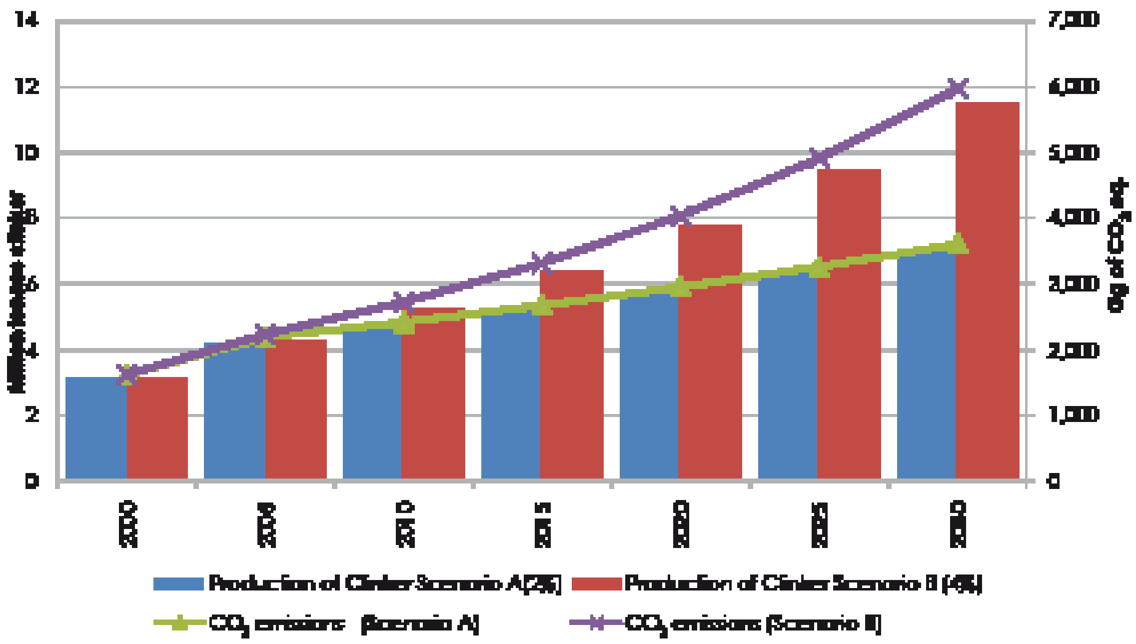


Figure 3-7 Projected clinker production and CO_2 emissions under scenario A and scenario B

- Optimization of heat recovery/upgrade clinker cooler;
- Using efficient transport system (mechanical transport instead of pneumatic transport);
- Establishment of annual targets for GHG emissions reduction in cement factories;
- Support to increase the flow of CDM revenues to encourage costly mitigation measures in the cement sector;
- Creation of a dialogue platform between the government and the cement factories management representatives.

3.3. Agriculture

The total GHG emissions from the agricultural sector do not constitute more than 3.7% of the national total emissions. The main GHGs are N_2O and CH_4, generated from agricultural soils, manure management and enteric fermentation. The 2004 total emissions from the agriculture sector amounted to 685 tCO_2 eq., distributed as follows: 131 tCO_2 eq. from enteric fermentation; 127 tCO_2 eq. from manure management; 426 tCO_2 eq. from agricultural soils; and 1 tCO_2 eq. from field burning of agricultural residues.

3.3.1. Baseline scenario

Many agricultural activities known to generate GHG emissions are not practiced in Lebanon (forest burning, rice cultivation, intensive fodder and leguminous species cultivation, intensive animal husbandry, etc.). Therefore, the limited development in agricultural practices and activities could be seen as an advantage for Lebanon in terms of limiting GHG emissions from the agriculture sector.

The number of animals in the farming sector has not considerably increased over the past years, except for poultry, and the trend is expected to remain stable by 2030 as shown in Table 3-10. The expected rise in emissions from the animal husbandry sub-sector is expected to be alleviated by improved breeding and feeding management, and thus higher food conversion efficiency that lowers emissions from manure (Smith et al., 2007).

Emissions from agricultural soils and field burning of agricultural residues are not expected to increase either, given the forecast that total agricultural area will fluctuate at the expense of other land uses (construction, land reclamation, forests) that vary with time. The national GHG emissions inventory shows a decrease of 3.5% in N_2O emissions between 2004 and 2006, while the IPCC report on mitigation measures in agriculture (Smith et al., 2007) estimates a potential of 0 to 10% annual decrease in N_2O emissions in warm dry climates. Since such reductions can be easily obtained from annual variability in cropping patterns and yields, it is estimated that N_2O, CH_4 and NO_x emissions from agriculture soils will decrease by 3.5% annually even if there is no clear policy for GHG reduction from the agriculture sector. Hence, by 2030, GHG emissions from agriculture soils could be at 60% less than the emissions in the baseline year, without taking into consideration CO_2 emissions or sequestration.

The National Action Plan (NAP) for Combating Desertification (MoA, 2003) developed by the Ministry of Agriculture (Table 3-11) is expected to help reduce GHG emissions from agricultural soils through the promotion of sustainable agriculture, improved rangeland management, and soil conservation practices. The implementation of the NAP for Combating Desertification could therefore count GHG emission reduction as a co-benefit, provided that more detailed and structured calculations add value to the NAP's contribution.

3.3.2. Mitigation scenarios

It is to be noted that the mitigation scenarios developed hereafter are to be considered as complementary.

Mitigation scenario 1: Field level measures

Improve Manure management: Large modern farms need to better manage their manure and other agricultural

Table 3-10 Poultry and livestock head numbers per year

	2000	2004	2006	2007	2030
Dairy cows	38,900	43,850	36,500	45,300	55,719
Other cattle	38,100	36,550	36,500	40,100	45,634
Poultry*	10,898,630	13,200,000	13,389,534	12,676,712	18,508,000
Sheep and goat	591,575	732,000	854,800	759,100	950,000

* Number of birds per year is adjusted from an average bird life cycle of 38 days.

Table 3-11 Principles advocated by the National Action Plan for Combating Desertification that contribute to the reduction of GHG emissions

Sustainable agriculture	Rangeland management	Soil conservation
- Implementation of a comprehensive land use plan - Development of a decision support system for farmers on trends and production techniques (including organic farming and low external inputs for sustainable agriculture - LEISA) - Adoption of a system approach to improve agricultural productivity and to identify needed interventions in terms of provision of necessary infrastructure, credit, training, post-harvest and marketing - Development and adoption of integrated and sustainable agriculture practices including certification programs and procedures	- Development of a comprehensive legislative and policy framework with the active participation of all rangeland users - Development of a national rangeland strategy - Provision of support for the establishment of proper land tenure systems so that users have long-term stake in sustainable use - Enhancement of biomass and vegetative cover of rangelands - Support for sustainable livestock production through the introduction of improved stock, animal husbandry, stock management, alternative feed resources and health programs; through the initiation of relevant pilot activities; and through the implementation of a participatory model for rangeland management in a pilot area - Support of research to develop a better understanding of rangeland dynamics, rehabilitation and management techniques - Support for technical trainings and efficient extension services for rangeland management, rehabilitation and sustainable livestock production	- Protection of prime agricultural lands from further misuse through the establishment of a proper land use planning and zoning system - Development and enforcement of a comprehensive legislative framework for sustainable agricultural production - Promotion of soil conservation practices - Development of a proper extension service - Development of a strategy for relevant applied research in soil conservation and management issues - Mainstreaming of soil conservation and management topics in the curricula of agricultural schools and relevant departments at universities

wastes by producing compost or biogas which would reduce GHG emissions considerably. Compost can be restituted to the soil as an organic fertilizer, which would increase water conservation and soil fertility (FAO, 2009b). Biogas could be used as an autonomous energy source for farms generating it, thus reducing their energy import from non-renewable sources. For instance, 1.7 cubic meters of biogas is equivalent to one liter of gasoline, thus 1 kg of cow manure will generate 388 watt-hour at 28°C. For a cow dung generation rate of around 25 kg per day, energy production can reach around 20 kilowatt-hours daily (Singh, 1971; Reidhead, 2010).

Manure management is an essential practice in minimizing GHG emissions caused by microbial activities during manure decomposition. The amount of gas emitted varies with: (1) the amount of manure, which depends on the number of animals and amount of feed consumed; (2) animal type, particularly the condition of the digestive tract, quality of feed consumed, etc., which in Lebanon consists of cattle and poultry; (3) manure handling method through solid or liquid disposal methods; and (4) environmental conditions such as temperature and moisture. Common mitigation measures for manure management are summarized in Table 3-12.

Calculations for the livestock sector in Lebanon show that improved breeding and feeding management can reduce up to 32% of tCO_2 eq. emissions from the livestock sector – dairy cows, other cattle and poultry – as shown in Table 3-13. However, such measures are not likely to be applicable for the traditional rearing of small ruminants (sheep and goat) from which emissions are not expected to change, and would be difficult to mitigate, since manure is mostly daily spread in rangeland, and small ruminants are mostly dependent on natural seasonal pastures. Small ruminants are mainly local breeds, put in small scale traditional shelters and their manure is stocked and sold to farmers to be used as organic fertilizer.

Plowed agricultural soils in areas prone to land degradation: Most agricultural soils in Lebanon are plowed. Even though plowing releases GHGs (N_2O, CO_2), these emissions vary according to several criteria such as purpose of plowing (land reclamation, tubers harvesting, etc.) and type of soil (plowing soil with excessive nitrogen fertilization or soils previously planted with legumes emits N_2O) and

Table 3-12 Common mitigation measures for manure management

General Management practices	Feed Management	Manure Storage, Handling and Treatment Technologies
- Avoid adding straw to manure as it acts as a food source for anaerobic bacteria - Avoid manure application on extremely wet soil - Animal grazing on pastures helps reduce emissions attributable to animal manure storage. Introducing grass species and legumes into grazing lands can enhance carbon storage in soils	- Select livestock to genetically improve food conversion efficiency - Increase the digestibility of feed by mechanical, chemical or biological processing - Feed less frequently - Feed cattle additives (ionophores) that act to inhibit methane production by rumen bacteria - Add edible oils that reduce methane emissions by rumen	- Covered lagoons: covers on the surface of the manure reduce the transfer of GHGs to the atmosphere. Methane under the cover is either flared and the emissions are released to the atmosphere, or burned in a generator to produce electricity. Methane emissions can be reduced by 80% - Digesters: wastes are fermented under anaerobic conditions to produce methane, generating heat and electricity as an alternative energy source - Filtering of exhaust from animal houses for GHG removal (still under research) - Composting of manure

Source: IFAD, 2009; Berg and Pazsiczki, 2006; AAFRD & UoA, 2003

Table 3-13 GHG emissions from manure and enteric fermentation for major animal husbandry activities for the baseline year, (2004), and 2030, with and without mitigation measures

	CH_4 (Gg)			N_2O (Gg)			Total CO_2 eq. (Gg)	
	2004	2030 without mitigation	2030 with mitigation	2004	2030 without mitigation	2030 with mitigation	2030 without mitigation	2030 with mitigation
Dairy cows	1.666	2.117	1.906	0.082	0.104	0.100	76.764	33.196
Other cattle	1.206	1.506	1.431	0.052	0.065	0.062	51.631	20.562
Poultry	0.238	0.333	0.293	0.249	0.350	0.335	115.189	111.194
Total	3.110	3.956	3.629	0.383	0.518	0.497	243.584	164.953

geographic area (soil texture in semi-arid areas is easily degraded). Mitigation measures include encouraging organic farming, with appropriate crop rotation, intercropping, the use of compost and green cover fertilization instead of chemical fertilizers, and encouraging no-till or conservation agriculture techniques that would reduce gas emission from soils by 40% and conserve soil fertility in semi-arid areas (GTZ-CoDeL, 2009).

Use efficient irrigation system: Agricultural cropping patterns that are irrigated using surface techniques suffer from low water efficiency and low production. This irrigation method boosts weed proliferation and requires plowing and soil management. As a result, the use of herbicides, pesticides and fertilizers increases as well. The adoption of localized efficient irrigation systems (e.g., drip irrigation) is a win-win solution where productivity, and thus carbon uptake, increase, water efficiency is enhanced, and GHG emissions are reduced through reduced plowing, reduced use of herbicides, pesticides and fertilizers and reduced water pumping.

Mitigation scenario 2: Research, education, assistance, infrastructure, and institutional measures

Research measures: Agricultural research institutions and programs in Lebanon should be strengthened and enhanced to elaborate research programs in fields related to adaptation to climate change. The existing governmental research institutions (LARI, NCSR, etc.) should join venture with local universities and regional institutions with long past experience in arid and semi-arid areas (ICARDA, ACSAD). Ultimately, a network of research institutions that address research on agriculture and climate change in Mediterranean countries could provide invaluable insight and direction on critical areas for action. Some topics to be studied include:

- Identifying appropriate agricultural practices (till, no-till, weed control, irrigation methods, etc.) and agricultural production systems (organic farming, conservation agriculture, crop rotations, etc.) which can lead to reduction in GHG emissions from soils;

- Adapting agricultural machinery to no-till practices;
- Modifying animal nutrition in order to cope with changing cropping patterns for fodder species, and minimize nitrogen losses in manure;
- Analyzing the economic feasibility for newly adopted agricultural systems.

Educational and assistance measures: Educational measures should be targeted at owners and employees of major modern farms, farmers in semi-arid areas, veterinarians, agricultural engineers, and technicians.

Infrastructure measures: The major infrastructure changes to be undertaken are among the private sector, and include the use of units for composting and/or recovering biogas manure in modern poultry and animal husbandry farms, the improvement of irrigation systems and the use of appropriate machinery for conservation agriculture techniques (for seeding, harvesting in no-till agriculture, etc.).

Institutional measures: The legislative framework related to agriculture and natural resources management should be reviewed and harmonized with the conventions that are ratified by the Government in relation to climate change, combating desertification, and biodiversity. The inter-linkages and conflicting mandates between different institutions should be resolved and responsibilities should be well defined and distributed. The human resources and organizational structure of the Ministry of Agriculture should be reviewed according to law amendments in order to provide the desired services related to adaptation measures.

Since most of the measures for adaptation and mitigation are linked, the major administrative institutions and departments to be reinforced are:

- The directorate of Animal Resources on manure management and fodder issues (as part of new legislation on organic agriculture);
- The directorates of Plant Resources and of Rural Development and Natural Resources on soil management and grazing/ rangeland management as well as organic farming;
- Research institutes; to achieve the research measures to be addressed;
- Green Plan; to implement the infrastructural mitigation/adaptation measures related to water;
- Extension services; to disseminate information to farmers.

Some of these major directorates and institutions, namely research and extension services, could be delegated or implemented in joint venture with the private sector (input and service providers, universities, etc.) and NGOs. Some international organizations are already involved in such measures (UNDP, GTZ, FAO, etc.). Financial incentives (such subsidies and loans) are crucial for all measures.

3.3.3. Cost of mitigation measures

Field and infrastructure measures could only be addressed at the level of individual, major poultry and animal husbandry farms, since the cost varies with the number of animals, and with the technologies used. Case studies could be undertaken in order to estimate the cost of processing the manure into compost, or for the production of biogas and then energy at the farm level.

The cost of each mitigation option can be estimated according to carbon price (USD/tCO_2eq./yr). For instance, livestock feeding and nutrient management costs USD 60 and USD 5/tCO_2 eq./yr respectively, while animal breeding costs USD 50/tCO_2 eq./yr (Smith et al., 2008).

Assuming that improved livestock feeding and animal breeding are implemented and have an equal impact on emission reduction, the cost per tCO_2 eq./yr will be the mean of two values, i.e. USD 55/tCO2-eq/yr. Improved nutrient management practices are expected to result in a reduction of 60% of baseline N_2O emissions, at an assumed cost of USD 5 /tCO_2 eq./yr (Smith et al., 2008) (Table 3-14).

The same approach could be used in order to estimate the cost of conversion of exploitations from conventional agriculture (for selected vulnerable crops like potato, tomato, wheat or olive) to conservation agriculture adopting no-till practices and eventual drip irrigation systems. In many cases, measures are almost costless. For example, the cost of adopting no-till agriculture in the MENA region has been estimated to around USD 88/ha to USD 600/ha according to the country (FAO, 2009b). Other more expensive measures include shifting from surface to drip irrigation which is estimated to cost USD 3,500/ha in Lebanon. Subsequently, in order to convert by 2030, 30,000 ha of cereals, legumes, and fruit orchards in the Baalback-Hermel area to no-till agriculture, a budget of USD 18 million is needed, (excluding the

Table 3-14 Emission reduction potential and cost of mitigation from the proposed measures

	Mitigation Option 1: Improved Breeding & Feeding Management	Mitigation Option 2: Nutrient Management
Emission Reduction (in tCO_2 eq.)by 2030	78,631	399,000
Cost (USD/tCO_2 eq.)	55	5
Total Cost (in USD million)	4.33	2.0

cost of machinery) while a budget of USD 105 million is needed to convert the same area to drip irrigation. The lack of information on the sequestration of CO_2 by soils in Lebanon limits the analysis of the sequestration potential from the shift to drip irrigation, and the calculation of the cost of this measure per tCO_2 eq.

3.4. Forestry

The land and forestry sectors are regarded as sinks for GHGs where in 2004 some 605 Gg CO_2 eq. were estimated to have been sequestered. Mitigation actions are designed to increase carbon sequestration by forests and soil by maintaining and conserving existing forest carbon sinks and increasing forest cover by reforestation and afforestation.

3.4.1. Baseline scenario

The MoE's and MoA's reforestation/afforestation plan aims at increasing the forest cover from 13% of Lebanon's land surface area to 20%. The net annual emissions of GHG from the forestry sector are negative since growing trees sequester carbon from the atmosphere, while adult trees lock the carbon sequestered in the bark. Table 3-15 shows the area of forests in kha and the number of fruit trees in Lebanon for the year 2004, as well as projections under a baseline scenario with a 2030 horizon. The GHG inventory has estimated the annual total carbon uptake increment in Lebanon for the year 2004 at around 249.19 kt of carbon.

3.4.2. Mitigation options and costs

Mitigation scenario 1: Maintaining and conserving existing forest carbon sinks

Maintaining forests and nature reserves can be achieved through:

- Adopting sustainable forest management practices such as grazing, Non Wood Forest Poducts (NWFP), and harvesting of wood in forests and other wooded lands (OWL) to address the possible threats to these ecosystems and improve their status;

Table 3-15 Forest area and number of trees in the baseline scenario

	Total for the year 2004		Expected trend	2030 Total expected	2030 projections
Area Evergreen stands (ha)	139,522	134,298	Increase from 13% to 20% cover	211,836	206,612
Area Deciduous stands (ha)		5,224			5,224
Number of non-forested evergreen fruit trees (1,000)		25,492	10% increase in number of fruit trees		28,041
Number of other fruit trees (1,000)		20,056	10% increase in number of fruit trees		22,061
Total Carbon uptake increment (kt)		249.19			347.32

- Preventing forest degradation and habitat fragmentation through sustainable management, land use management, insect and pest management and forest fire fighting strategies, which will provide stability for ecosystems to permit the establishment of ecological equilibrium, and therefore the reduction of habitat loss and degradation;

- Rehabilitating abandoned lands and degraded zones to ensure natural or assisted forest regeneration and development.

Additional activities for forest protection, management and leakage monitoring and their incurred costs between 2011 and 2030 are as follows (Table 3-16 and Table 3-17):

- Wood clipping and pruning of trees, including transportation of pruning residues, at a cost of 1,000 USD/ha. This measure would be repeated twice between 2010 and 2030 in case it is not already being undertaken by local people;

- Clearing of grass and weeds along the borders of all roads surrounding forests and OWL on a yearly basis for the purpose of fire protection, at a cost of around USD 100,000/year;

- Acquiring 40 vehicles equipped with water tanks and pumps for patrolling all forest and OWL areas throughout the country. The cost per vehicle would amount to USD 50,000, and these would serve for 10 years. The effective duration of operation is 6 months, from June until November, where the vehicles are used in forest protection. The operation costs of these vehicles (fuel, repair and maintenance, etc.) would be USD 600/month;

- Each vehicle will be run by 2 forest guards, who would be in charge of monitoring a specific region to prevent fires and control grazing and deforestation of newly reforested areas. Violations would be dealt with in coordination with the Internal Security Forces. The incurred costs are USD 1,000/month as salaries for the forest guards;

- Setting up a communication system between guards (e.g., mobile lines with internal extensions between guards) to ensure optimal coordination and supervision of green areas. The cost of such a system would be around USD 9,000 for 80 lines as a capital cost, and a monthly USD 4,000 as O&M cost;

- Managing pests in forests and OWL by spraying pesticides by plane (as currently practiced). This measure would have to be implemented every other year. The cost would amount to around USD 400,000 every year that spraying is carried out. However, research and implementation of other more environment-friendly pest management practices are recommended.

Table 3-16 Breakdown of the costs of forest protection and management measures

Measure	Average annual cost (USD million/year)
Clipping and pruning	18.27
Clearing of grass and weeds	0.10
Vehicles (capital cost)	0.10
Vehicles (fuel & maintenance)	0.28
Forest guards	0.96
Communication system	0.04
Pest management	0.40
Total	20.15

Table 3-17 Costs of forest protection and management for selected years

Year	2015	2020	2030
Area of forests (ha)	166,371	180,289	211,836
Total CO_2 Uptake Increment (tCO_2)	1,048,471	1,117,674	1,273,499
Cost (USD/ha)	111.4	108.3	107.1
Cost (USD/tCO_2)	17.7	17.5	17.8

The total present value cost (at different discount rates) of managing and protecting the existing forested areas and OWL, as well as managing reforested areas, to ensure that the stocks continue to sequester carbon, are presented in Table 3-18. The costs reflect the investment and operational costs to be incurred between the years 2011 to 2030 to implement the proposed mitigation scenario.

Table 3-18 Total discounted costs for forest protection and management

Discount Rate	PV (cost in USD) up to 2030	Cost (USD/t of incremental C sequestered) (up to 2030)	Cost (USD/ tCO_2 sequestered) (up to 2030)
5%	242,899,386	39.4	10.76
10%	162,550,434	26.3	7.20
15%	117,495,326	19.0	5.21

Mitigation scenario 2: Afforestation and reforestation including agroforestry and sylvo-pastoral systems

In order to optimize the success rate of reforestation campaigns, the National Reforestation Plan (NRP) in Lebanon stipulated the use of native species in each site according to the ecological criteria, the climate and soil characteristics in the related ecosystem and has banned the introduction of non-native species. However, very limited measures are currently taken to identify and prevent the introduction of alien species, ascertain the origin of the seedlings, encourage production of native species and monitor the establishment and development success of those reforestation campaigns. In addition to the control of the alien species, a forest genetic resources conservation and management strategy should be implemented, including the management of seeds provenances.

Reforestation success rate for coniferous, deciduous and mixed wood areas can be as low as 20-30% (Castro et al., 2004) in stressful environments such as Mediterranean ecosystems including Lebanon. Moreover, scientific evidence (Benayas et al., 2005; Castro et al., 2004) has shown that planting methods such as seeding or relying on bushes or species from the understory to initiate successful forest dynamics are more successful than direct planting, but require significantly more time to result in effective ecosystem development.

Any action aiming at replanting trees on barren or degraded areas that were previously covered by forests and would contribute to the overall carbon sequestration balance is identified as "reforestation". The action of establishing forests on sites that were not previously considered as forests is called afforestation. In this perspective, all efforts of agroforestry or even urban greening (recreation areas, urban parks, etc.) are included. Linking forests and OWL through corridors (forest trees, wild fruit trees and local species) is of utmost importance in enhancing the green cover and conserving existing stands. Spillover effects from creating contiguous forest lands include the reduced habitat fragmentation.

Mitigation scenario 3: Substituting fossil fuels by forest-based biofuels: a CDM option

In addition to their role in reducing global carbon equivalent rates, forests can positively contribute to mitigating climate change effects by substituting fossil fuels with forest-based fuels.

In Lebanon, the forest growth rate is relatively low when compared to the annual demand for wood fuel and unless sustainable forestry practices are adopted and implemented, a recommendation to increase the supply of forest-based fuels is hardly applicable and should be considered with care. OWL can serve as the main source of biofuel from wood clipping and sylviculture practices. The density of forests and OWL can also be reduced to provide biofuel while also reducing the fire risk.

In conclusion, even if the direct benefit of forests in Lebanon cannot be properly highlighted through their contribution to GHG emissions removal, the economic value of those forests in terms of ecosystem services and other secondary benefits (wellbeing, cultural, etc.) should be considered while valuing Mediterranean forests.

3.5. Waste

The waste sector, including wastewater, is the largest source of CH_4 emissions in Lebanon. The sector generated 2,227 Gg CO_2 eq. in 2004, or 11% of the total GHG emissions for the same year. Calculations for the years 2000 to 2004 indicate an increase of 28% in waste GHG emissions by 2004 (base year 2000).

The discussion on mitigation potential from the waste sector will focus on solid waste management which accounts for the majority of emissions in this sector.

3.5.1. Baseline scenario

With the absence of actual targets for waste reduction, sorting at the source, composting and landfilling, it is difficult to predict how the different waste streams are going to be managed by 2030. However, it is acknowledged that the infrastructure and installations are being set up to realize the national solid waste management plan of 2006, which consists of establishing regional sanitary landfills, sorting and composting facilities while rehabilitating existing dumpsites. The following assumptions are proposed for constructing a future baseline scenario:

- The current 2006 plan would be implemented over the next 20 years (2010-2030);

- The open dumpsites would be rehabilitated therefore transferring the waste from unmanaged sites to managed sites with CH_4 gas collection in the proposed sanitary landfills, and rehabilitation of the dumpsites through closure and collection of gas. Landfill gas recovery rates are projected to grow with the assumed increase in the proportion of waste going into 'managed' sites;

- Solid waste disposal on land would gradually decrease by an annual rate of 3.5%, thereby constituting 68% of the total waste generated by 2030 (compared to 84% in 2006). It is assumed that recycling and composting rates will increase to cover 32% of the total waste stream by 2030;

- The generated municipal waste stream that would be disposed of on land by 2030 is assumed to be managed;

- The per capita MSW generation rates are assumed to follow the GDP growth that is predicted for Lebanon at an annual average rate of 4.3% (IMF, 2009).

Based on these assumptions, the projected future baseline CH_4 emissions and corresponding waste inflows into solid waste disposal sites were calculated (reaching 6,000 Gg of CO_2 eq.), as presented in Figure 3-8.

3.5.2. Mitigation scenarios and costs

The proposed mitigation options tackle both the waste and energy sectors as it considers energy recovery as an alternative waste management option. However, it is highly recommended that in the implementation of any or both mitigation scenarios, strict control and enforcement of pollution emissions controls be applied to prevent adverse impacts on public health and the environment.

Mitigation scenario 1: Landfilling with gas recovery for electricity generation

Based on the assumptions of the baseline scenario for the different parameters mentioned, the amount of waste to be deposited on land was calculated, along with the volume of methane which could be used in the future

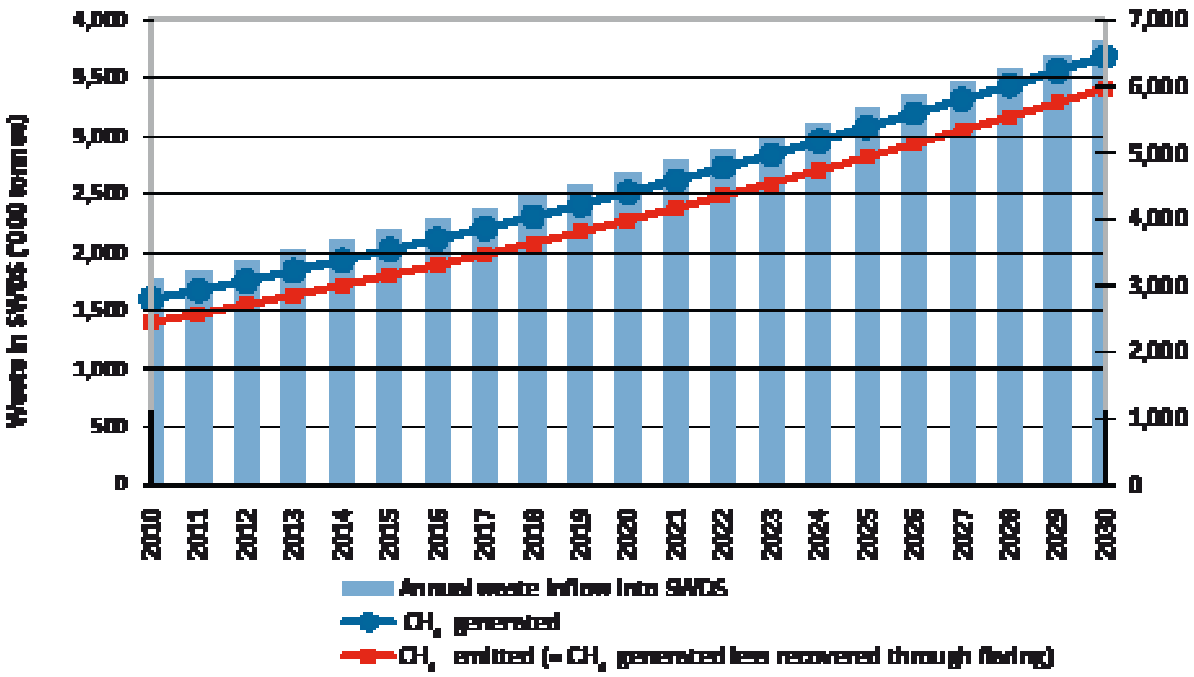


Figure 3-8 Projected baseline quantities of municipal solid waste in disposal sites and methane generation from SWDS

to generate electricity. The estimated methane volumes from solid waste disposal on land exclude the recovered volumes which would undergo flaring under the current policy. Thus, measures to capture the increasing volumes of methane emissions are considered to be 'additional' mitigation measures and their cost is accounted for accordingly.

For this mitigation scenario, gas recovery projects for electricity generation are assumed to apply to all current and future sanitary landfills and rehabilitated dumpsites. However, the economic feasibility of such projects would need to be scrutinized on a site-by-site basis. The amount and composition of waste deposited are key factors that help determine the methane generation potential, which in turn determines the economic viability of gas recovery projects. A landfill gas energy project may not be feasible for small waste quantities with low organic fractions or high moisture content. Most landfill gas recovery projects for energy use run on internal combustion engines with capacities in the range of 1-15 megawatts (MW) (Bogner et al., 2007). The determination of the engines' capacity needed for power generation from captured landfill gas is carried out by a series of conversions and assumptions of the portion of methane in landfill gas (50%), collection efficiency (50%), portion of captured methane used for power generation (90%) and other combustion engine parameters. Flares are installed even if the landfill gas is intended to be recovered for electricity generation in order to prevent accidental releases.

Regarding the collect and flare systems, the capital cost and operation and maintenance costs are driven by the amount of waste disposed. While absolute total costs increase with larger amounts, the unit costs per tonne of waste decrease reflecting economies of scale. Table 3-19 shows average costs of a collect and flare system for the generation of electricity. It should be noted that only additional costs represented by investments to utilise the methane gas for electricity production were taken into consideration. Table 3-20 shows the energy potential from the methane emissions and the power capacity needed to convert the thermal energy into electric energy. The methane emissions captured for energy generation are considered to be the emissions avoided. It is assumed that no CO_2 emissions from electricity production will be avoided, given that the current power generation rates do not meet the electricity demand. The installed

Table 3-19 Capital and operational costs of a collect and flare system and internal combustion engine for electricity generation from landfill methane gas

Parameter	Value
Capital Cost of a Collect and Flare system	USD 0.87/ tonne of MSW
Operation & maintenance cost	USD 0.13/tonne of MSW
Capital cost of an internal combustion engine/ generator	USD 1,791,000/MW
Operation & maintenance cost of an internal combustion engine/ generator	USD 181,000/MW
Depreciation period	10 years
Project Lifetime	20 years
Discount rate	10%, 15%

Source: USEPA, 1999. Estimated in 2004 USD

Table 3-20 Power capacity needed, energy potential from landfills' methane and methane emissions avoided for selected years

	2015	2020	2025	2030
Methane generated (Mm^3 CH_4)	209.85	264.65	327.89	396.52
Methane captured (Mm^3 CH_4)	104.93	132.32	163.94	198.26
Methane used for power generation (Mm^3 CH_4)	94.43	119.09	147.55	178.43
Energy content of "usable" methane (10^6 MJ)	3,563	4,493	5,567	6,732
Thermal energy generation potential (GWh_{th})	990	1,249	1,548	1,871
Electric energy generation potential (GWh_e)	225	284	352	426
Minimum engine capacity needed (MW)	29.0	36.6	45.3	54.8
Engine capacity to be installed (factoring in engine availability) (MW)	34.1	43.0	53.3	64.5
Methane emissions avoided (Gg CO_2 eq.)	1,579	1,992	2,468	2,984

capacity for electricity generation from landfill methane gas would start with 26.6 MW in 2010 and increase to 64.5 MW by 2030. It is assumed that the internal combustion engines will have to be replaced by 2020.

The marginal cost of the reduction in CO_2 eq. was calculated using the net present value of the capital and operating costs for the landfill gas collection and electricity generation system and the net present value of the annual benefits from electricity generation. The revenues from electricity generation were calculated based on an average electricity price of USD 0.09 /kWh, and hypothetical increases in the price of 10 to 50% over the 20-year period. It is considered that the GHG emissions saved (tCO_2 eq.) are those saved through the collection of 50% of the methane gas, as allows the technology. At current electricity prices, the marginal cost of reducing 1 tCO_2 eq. landfill methane emissions is USD 1.85 (at a discount rate of 10%) or USD 1.75 (at a discount rate of 15%) (Table 3-21).

Table 3-21 Marginal cost of abatement of landfill methane per tCO_2 eq. at varying electricity prices and discount rates

	Discount Rate = 10%	Discount Rate = 15%
Electricity Price (USD/kWh)	Marginal Cost (USD/ tCO_2 eq. saved)	
0.09	1.85	1.75
0.10	0.60	0.50
0.11	-0.65	-0.75
0.12	-1.90	-2.00
0.13	-3.15	-3.26
0.14	-4.41	-4.51

Mitigation scenario 2: Waste incineration and energy production

Given the relatively small and dispersed quantities of waste generated in Lebanon, it is assumed that three waste-to-energy plants could be installed in three urban poles: Beirut to serve Beirut and Mount Lebanon; Tripoli to serve urban Tripoli; and Saida to serve urban Saida. Given the current generated quantities in the three locations, it is assumed that two 300,000 tonnes/year plants would be built to serve Tripoli and Saida and one 600,000 tonnes/year would be built in the Greater Beirut Area to serve Beirut and Mount Lebanon.

It is assumed that the MSW quantity that would be diverted from landfills in 2015 in the event of adoption of waste incinerators (while maintaining the baseline recycling and composting rates) would be 935,195 tonnes, and would grow to 1,417,370 tonnes by 2030. Hence, the landfill methane emissions avoided would be 1,129,694 tCO_2 eq. in 2015 and would grow to 1,916,302 tCO_2 eq. by 2030. The cumulative avoided emissions would be 24,142,251 tCO_2 eq. for the entire period extending from 2015 to 2030. Deducting the CO_2 emissions from incineration from the avoided emissions, the effective cumulative savings would total 11,771,499 tCO_2 eq. (Table 3-22 and Figure 3-9).

Table 3-22 GHG emissions avoided through diverting MSW from landfilling to incineration in selected years

	2015	2020	2025	2030
Baseline emissions (Gg CO_2 eq.)	3,159	3,984	4,936	5,969
MSW amount eligible for incineration (thousand tonnes)	935.19	1,087.71	1,250.96	1,417.37
Avoided CH_4 emissions due to the diversion of MSW from landfilling to incineration (Gg CO_2 eq.)	1,130	1,370	1,636	1,916
CO_2 emissions from incineration (Gg CO_2 eq.)	617	718	826	935
CO_2 emission saving (Gg CO_2 eq.)	512	652	810	981

For Lebanon, the use of the grate technology with three different scenarios for flue gas treatment has been recommended (MoE-MSC-IPP, 2005). Average values on energy production from incinerators of different capacities using different flue gas treatment techniques are used in this analysis. Values used for the calculation of costs are based on the MSC-IPP study (2005) and are shown in Table 3-23. It should be noted that since this waste management option is not part of any decreed plans in the Lebanese government, the full costs of investment and operation were taken into consideration in the cost analysis to reflect the fact that a completely new technology for waste management would have to be adopted to allow reductions in GHG emissions.

The marginal cost of the reduction in CO_2 eq. was calculated using the present value of the capital and operating costs for the incineration technology with energy recovery and the present value of the annual benefits from electricity generation. The revenues from electricity generation were calculated similarly as in

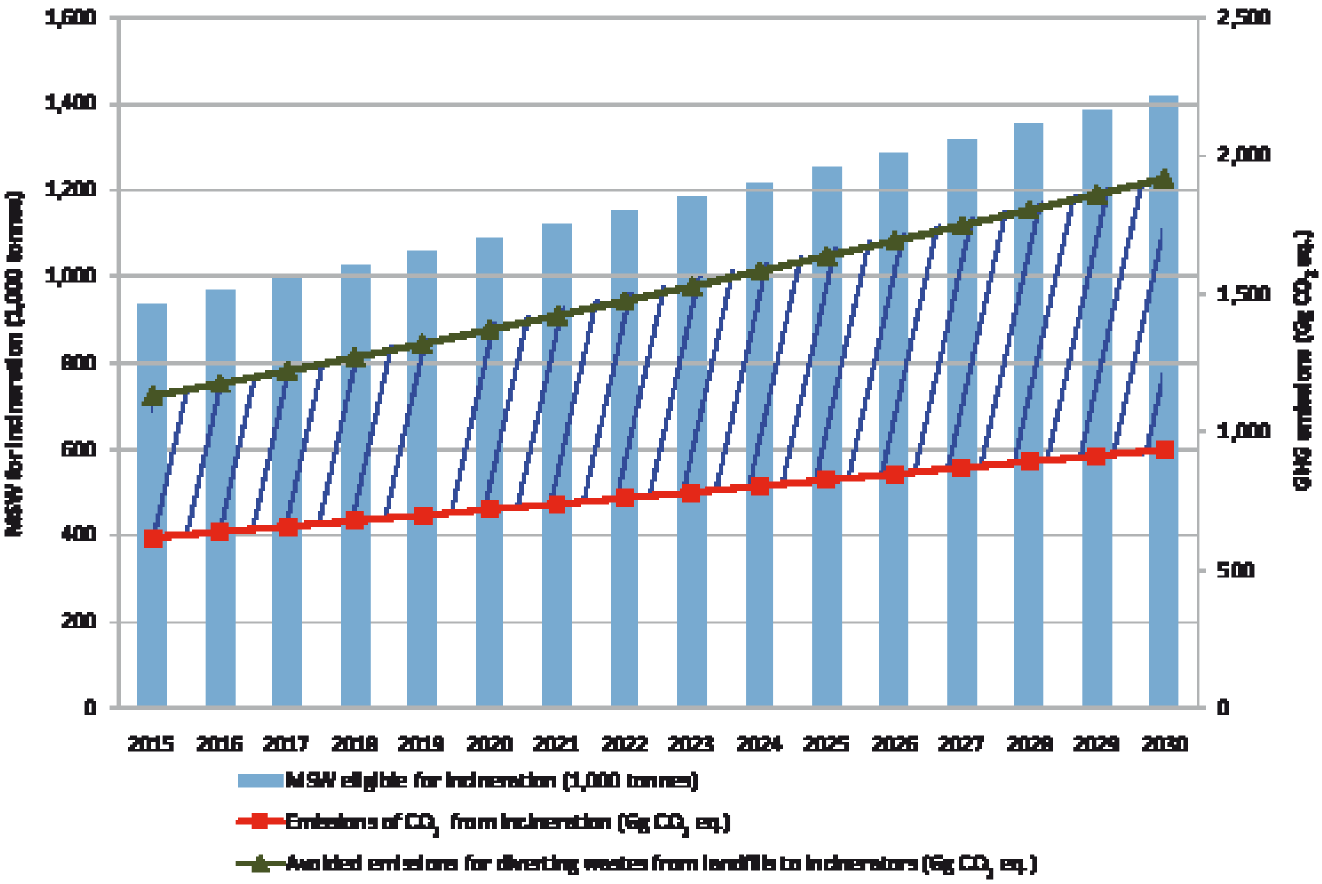


Figure 3-9 Projected quantities of municipal solid waste to be incinerated and avoided GHG emissions

Table 3-23 Energy potential from waste incineration and investment and operational costs of waste incineration for energy production

Parameter	Value
Average energy production from a 300,000 tonnes/yr facility	118,750 MWh
Average energy production from a 600,000 tonnes/yr facility	243,650 MWh
Average investment cost for all the proposed incineration capacity	USD 469.8 million
Average annual Operation & Maintenance cost for all the proposed incineration capacity	USD 92.9 million
Depreciation period	15 years
Project Lifetime	20 years

Estimated in 2004 USD
Source: MoE - MSC-IPP, 2005

mitigation scenario 1 above. It is considered that the GHG emissions saved (tCO_2 eq.) are those saved through the diversion of MSW from landfilling to incineration. At current electricity prices, the marginal cost of reducing 1 tCO_2 eq. of GHG emissions from solid waste using incineration ranges from USD 69.8 to USD 80.3 depending on the discount rate used (Table 3-24).

The marginal cost of abatement is significantly lower for landfill methane gas utilization given the larger potential to capture methane gas from the current waste management option in use in Lebanon. Waste incineration for energy production is an expensive mitigation option for Lebanon. Both mitigation scenarios can be applied successfully in settings with strict environmental and institutional controls to prevent any possible, inadvertent environmental pollution issues (Rand et al., 2000).

Table 3-24 Marginal cost of abatement of GHG emissions through incineration per tCO_2 eq. at varying electricity prices and discount rates

	Discount Rate = 10%	Discount Rate = 15%
Electricity Price (USD/kWh)	Marginal Cost (USD/tCO_2 eq. saved)	
0.09	80.33	69.80
0.10	77.21	67.34
0.11	74.09	64.89
0.12	70.98	62.43
0.13	67.86	59.97
0.14	64.74	57.52

3.5.3. Mitigation Action Plan

The two proposed mitigation scenarios can be grouped under one mitigation action plan which recommends an increase in the share of renewable energy (from waste) in electricity production due to the potential for energy recovery and the expected avoidance of future CH_4 emissions from landfills. Additional activities to complement the action plan should include the development of the necessary legislation to ease barriers and provide incentives for landfill operators to invest in electricity generation from LFG.

Climate Risks, vulnerability & Adaptation Assessment

4. Future climate risks

4.1 Future climate risks

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

4.1.1 Methodology

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

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

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

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

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

4.1.2 Projections uncertainties and limitations

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

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

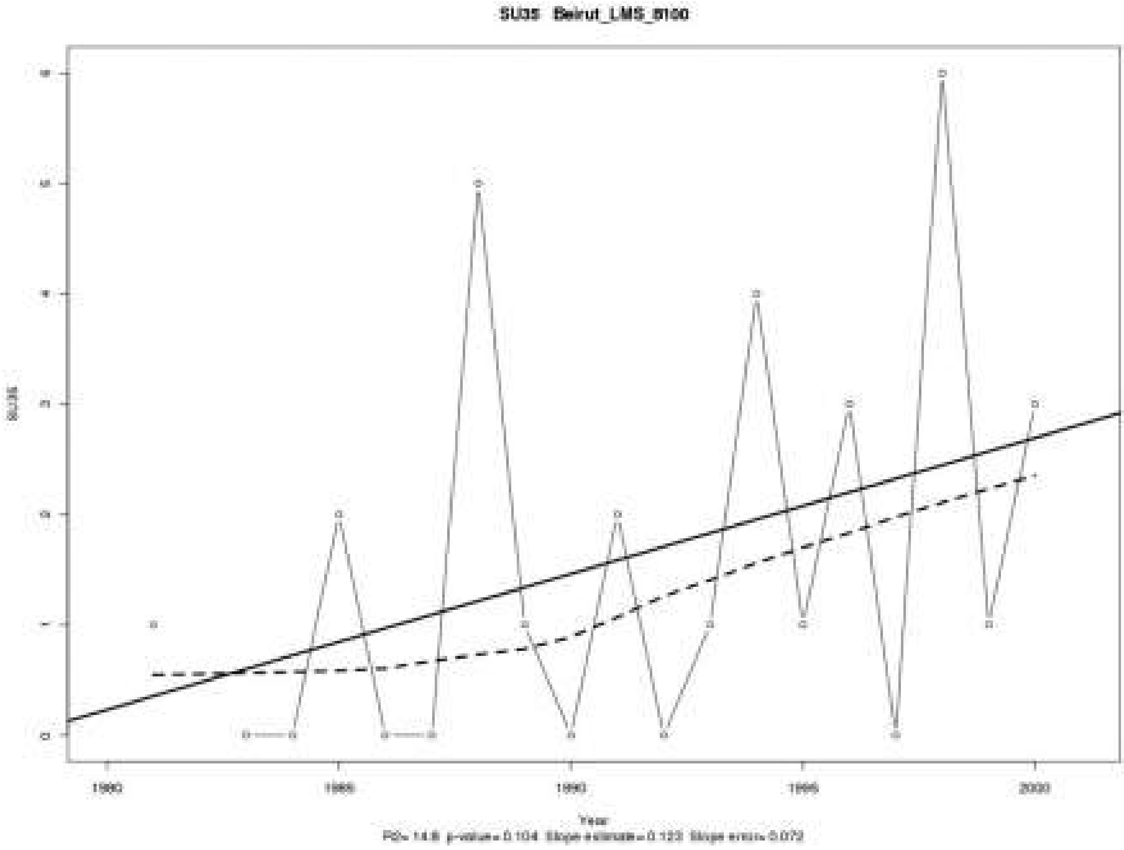
The RCM's uncertainty that ultimately provides the local climate projections can be quantified by taking an "ensembles" approach by averaging the projections from different models, something that is not possible to achieve in this assessment due to the lack of resources and scarcity of regional climate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

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

4.1.3 Model Evaluation- Recent Past Changes

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

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



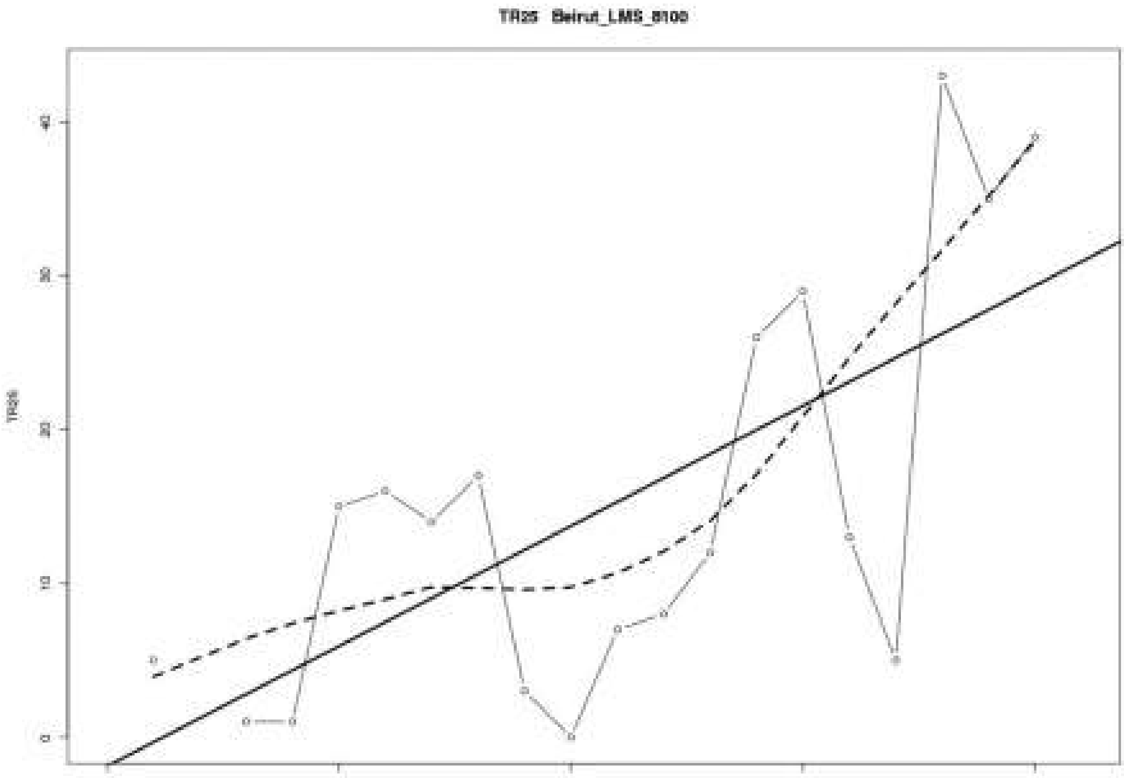
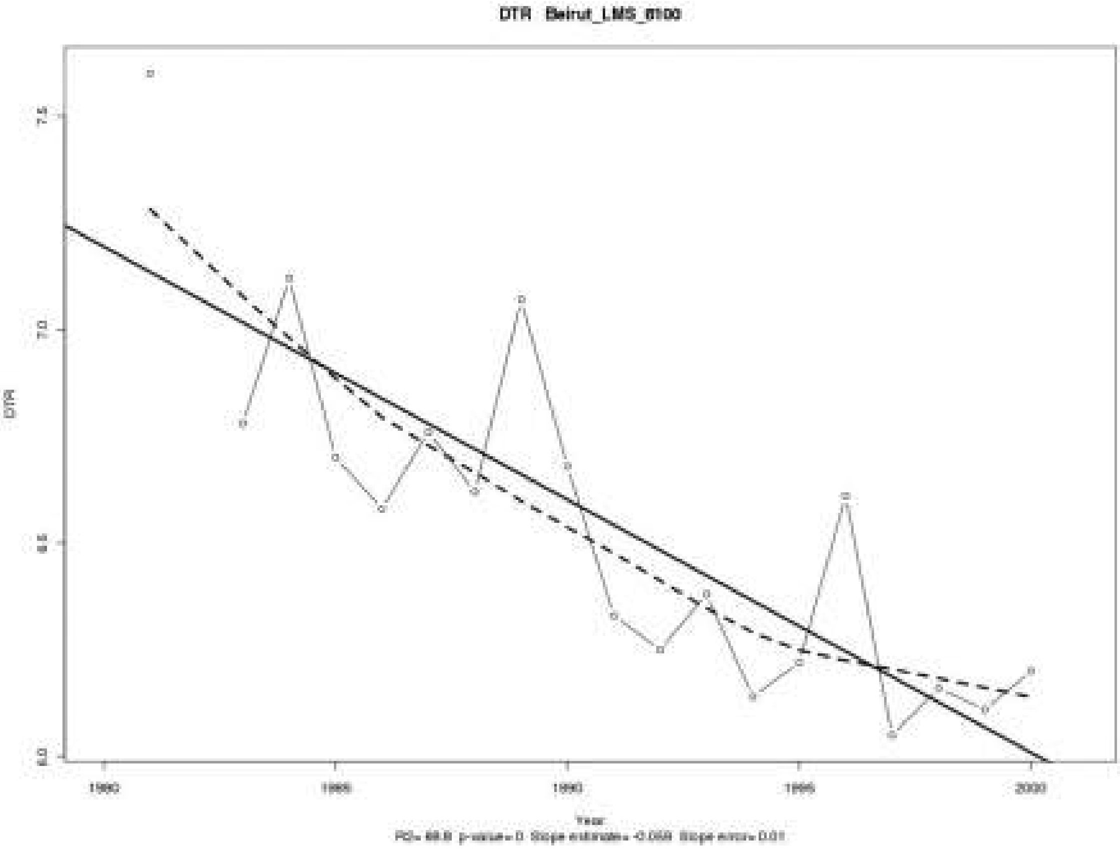


Figure 4-2a Temperature-related indices for Beirut for 1981-2000 derived from RClimDex



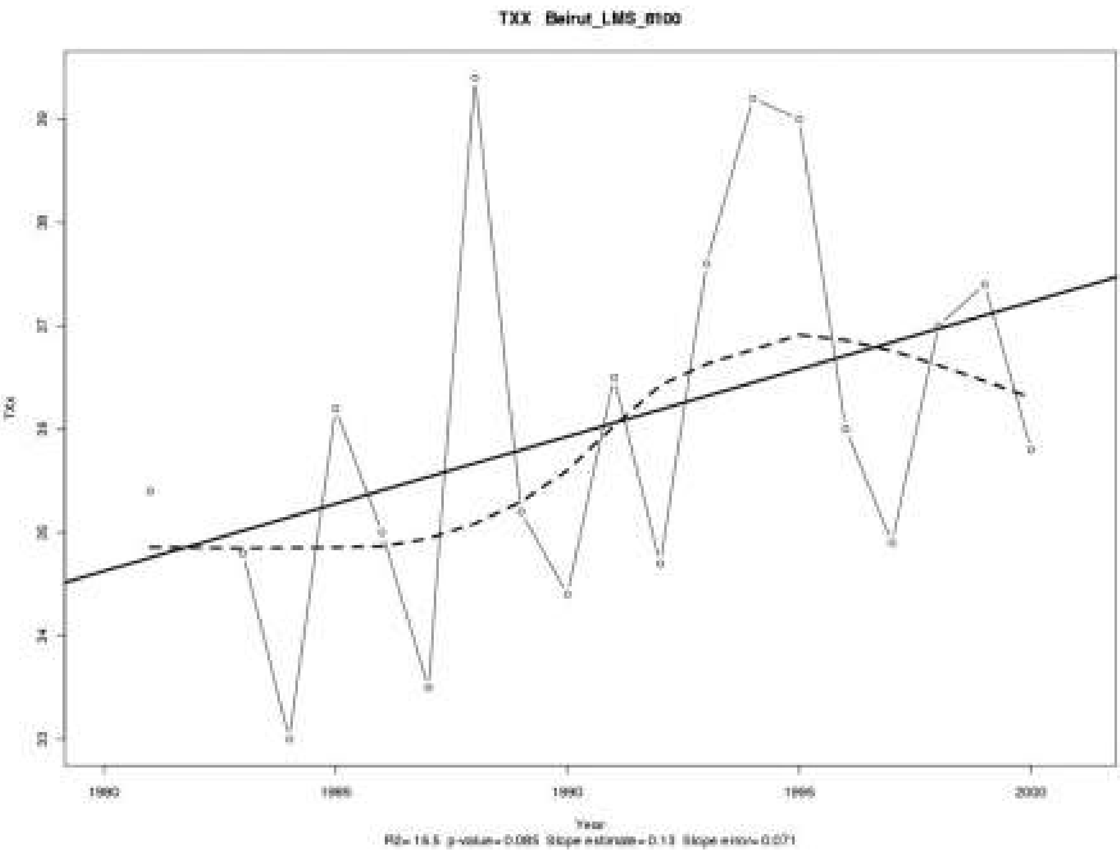
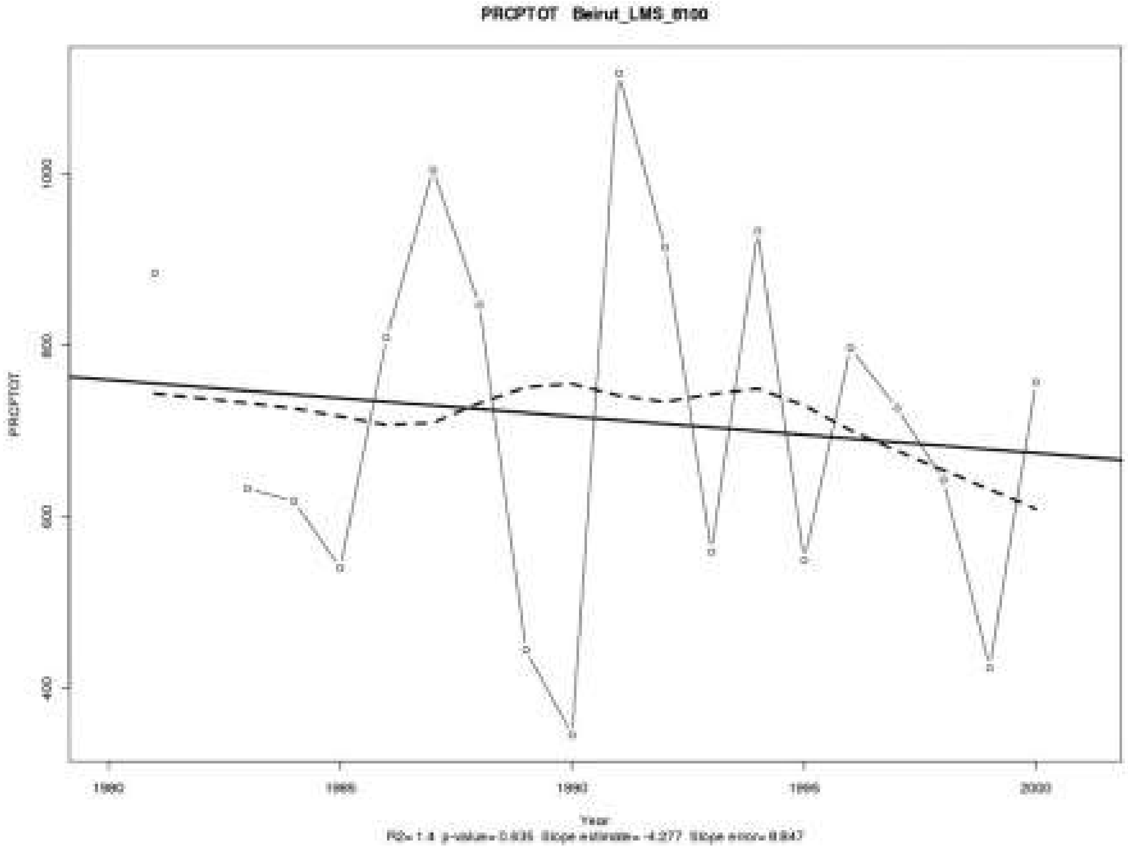


Figure 4-2b Temperature-related indices for Beirut for 1981-2000 derived from RClimDex



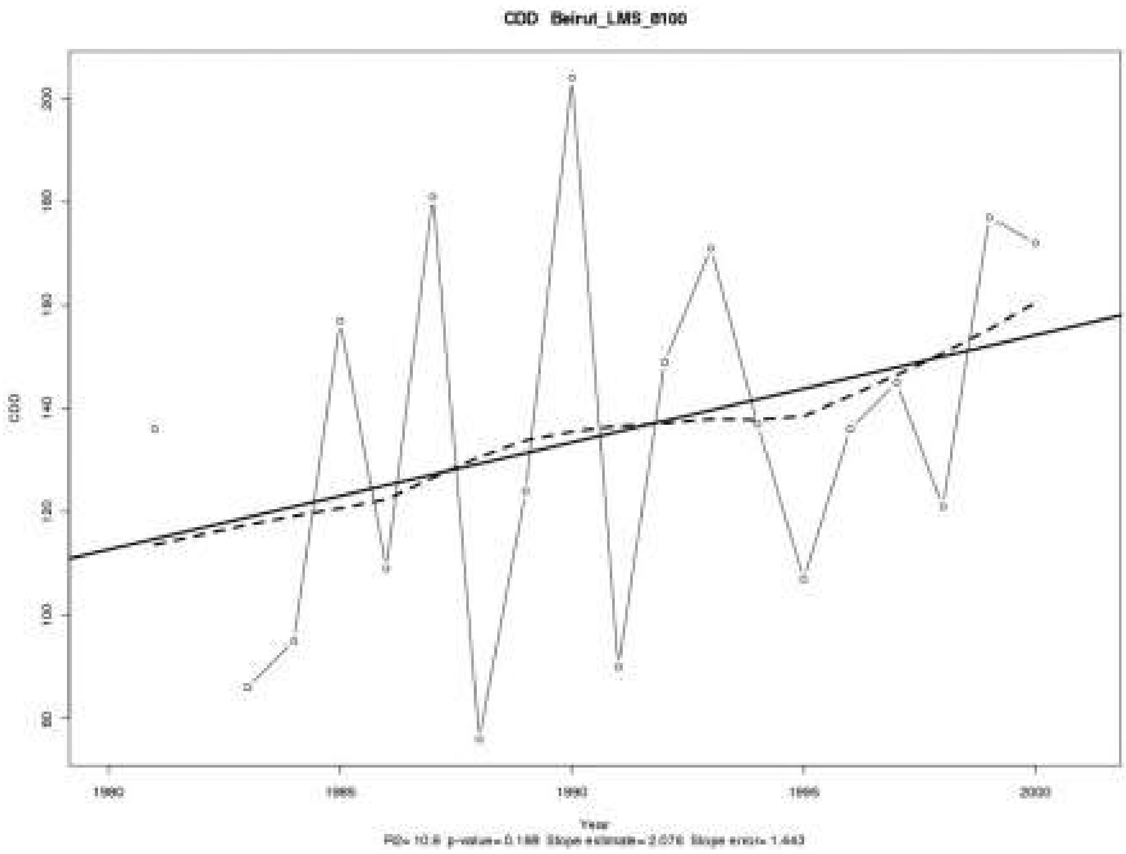
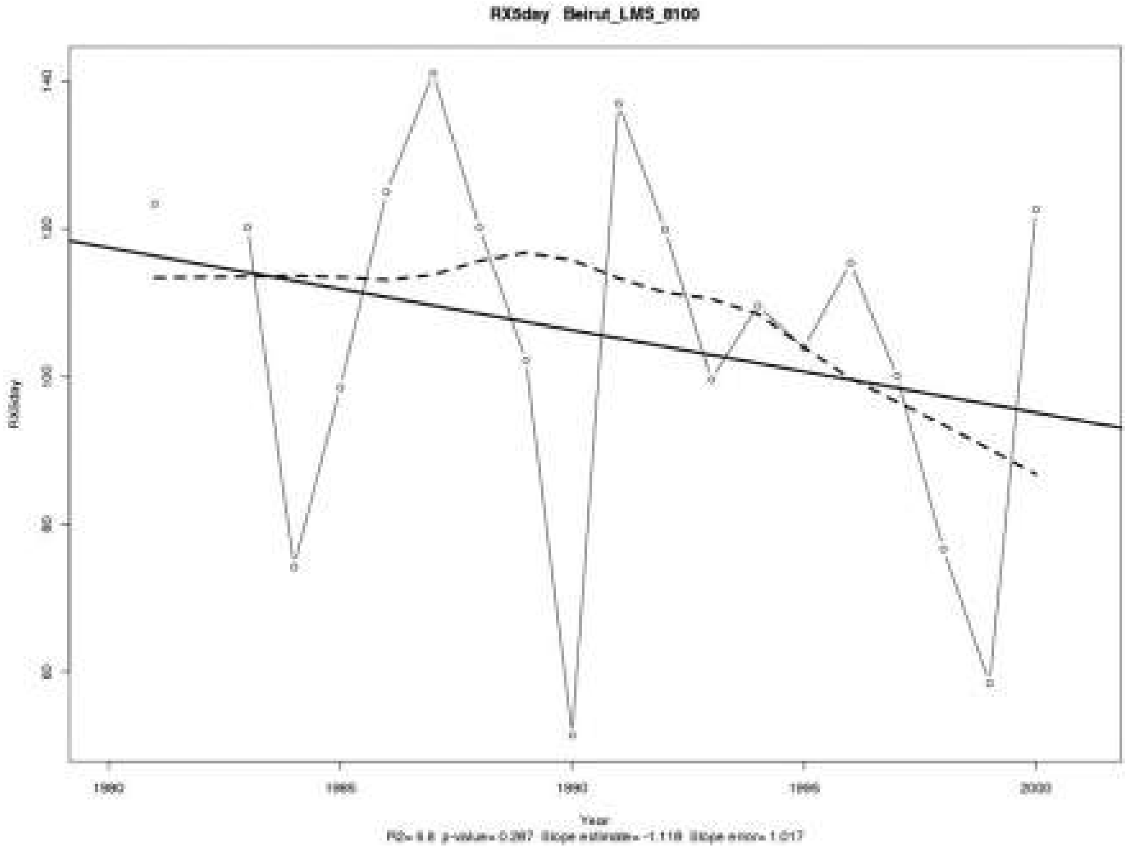


Figure 4-3a Precipitation-related indices for Beirut for 1981-2000 derived from RClimDex



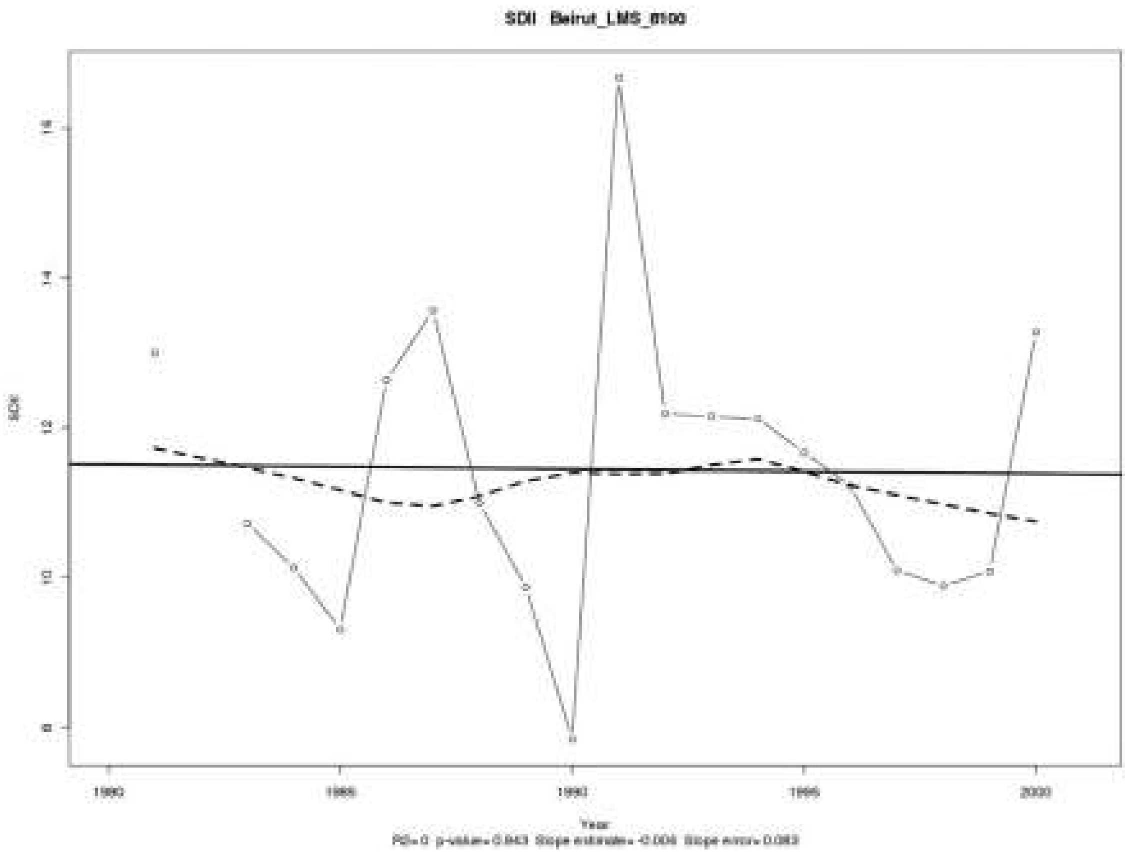


Figure 4-3b Precipitation-related indices for Beirut for 1981-2000 derived from RClimDex

4.1.4 Future Climate Projections

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

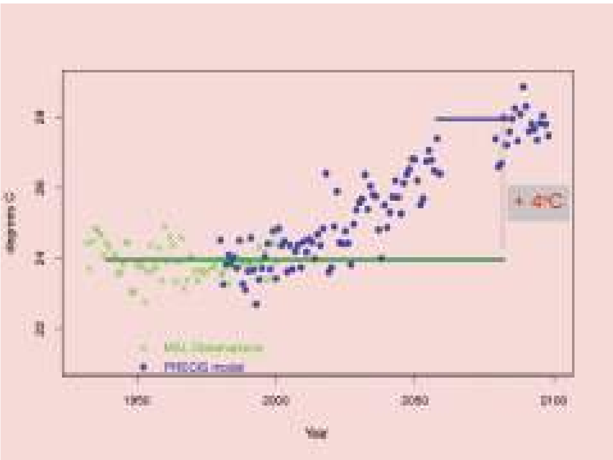


Figure 4-4 Long-term time-series of annual T_{max} over Beirut as observed by LMS and projected by PRECIS (adjusted)

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

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

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

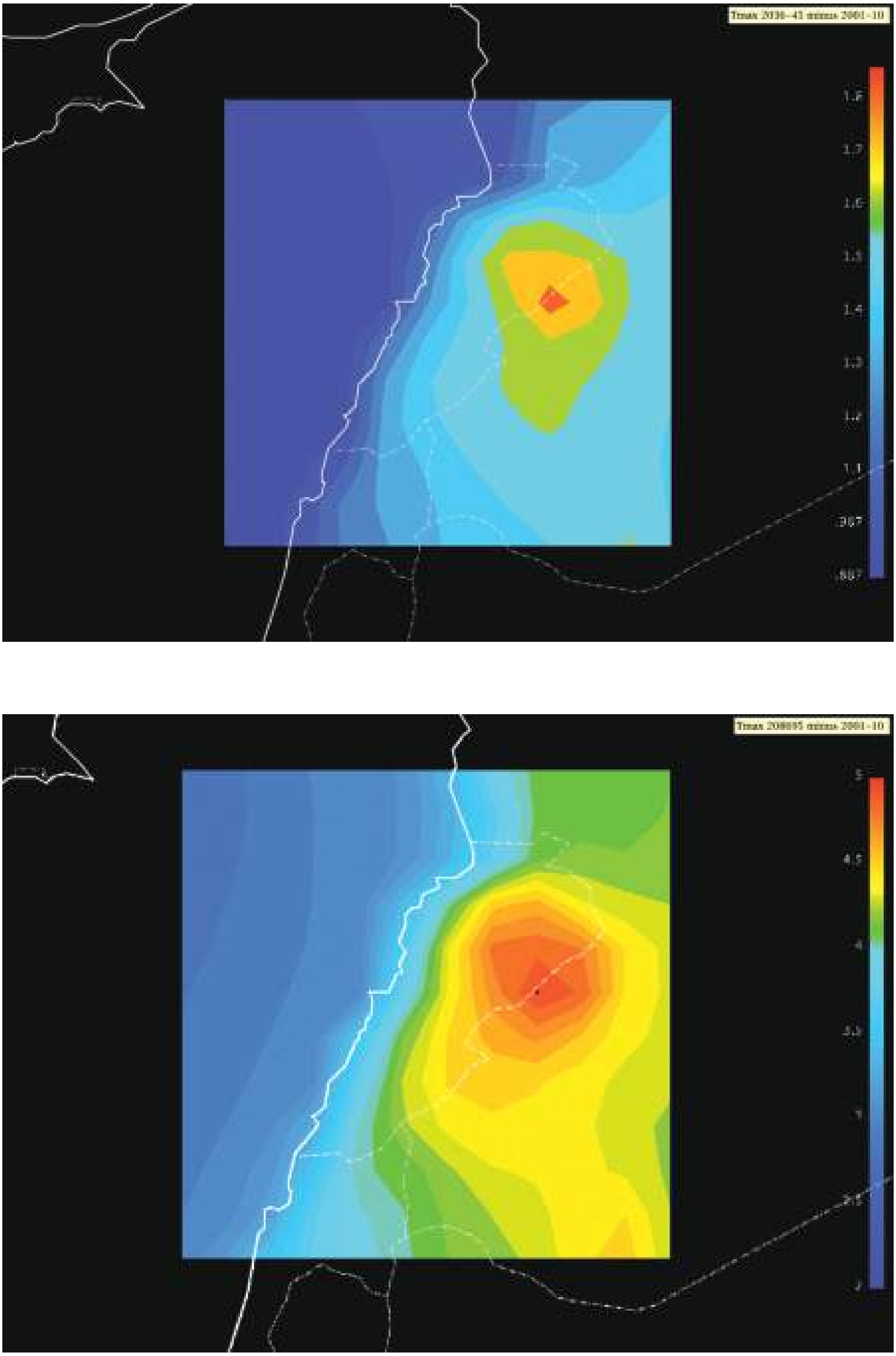


Figure 4-5 PRECIS projections of annual T_{max} over Lebanon as changes from the 2001-2010 average for 2036-45 (Top) and 2086-95 (Bottom)

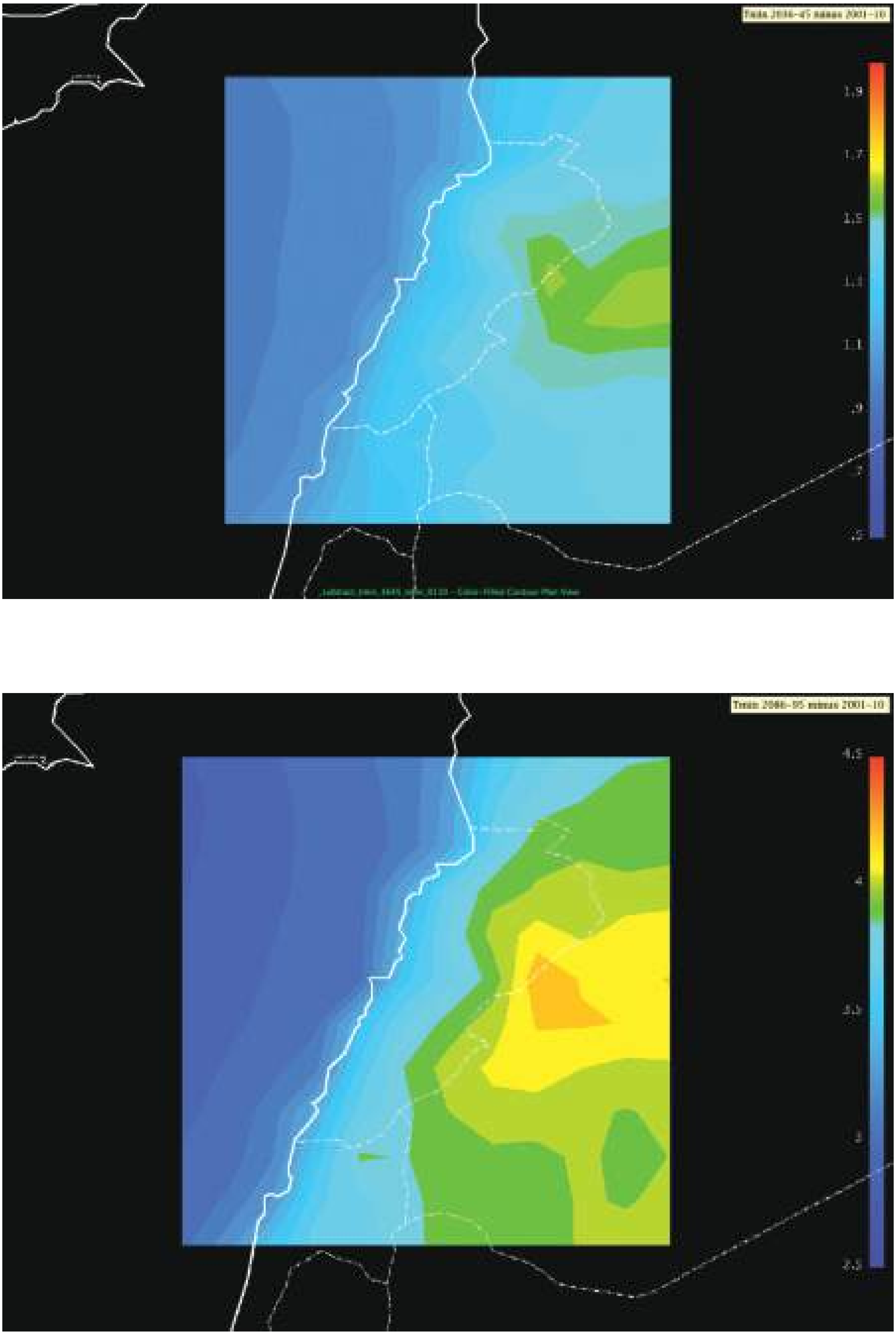


Figure 4-6 PRECIS projections of annual T_{min} over Lebanon as changes from the 2001-2010 average for 2036-45 (Top) and 2086-95 (Bottom)

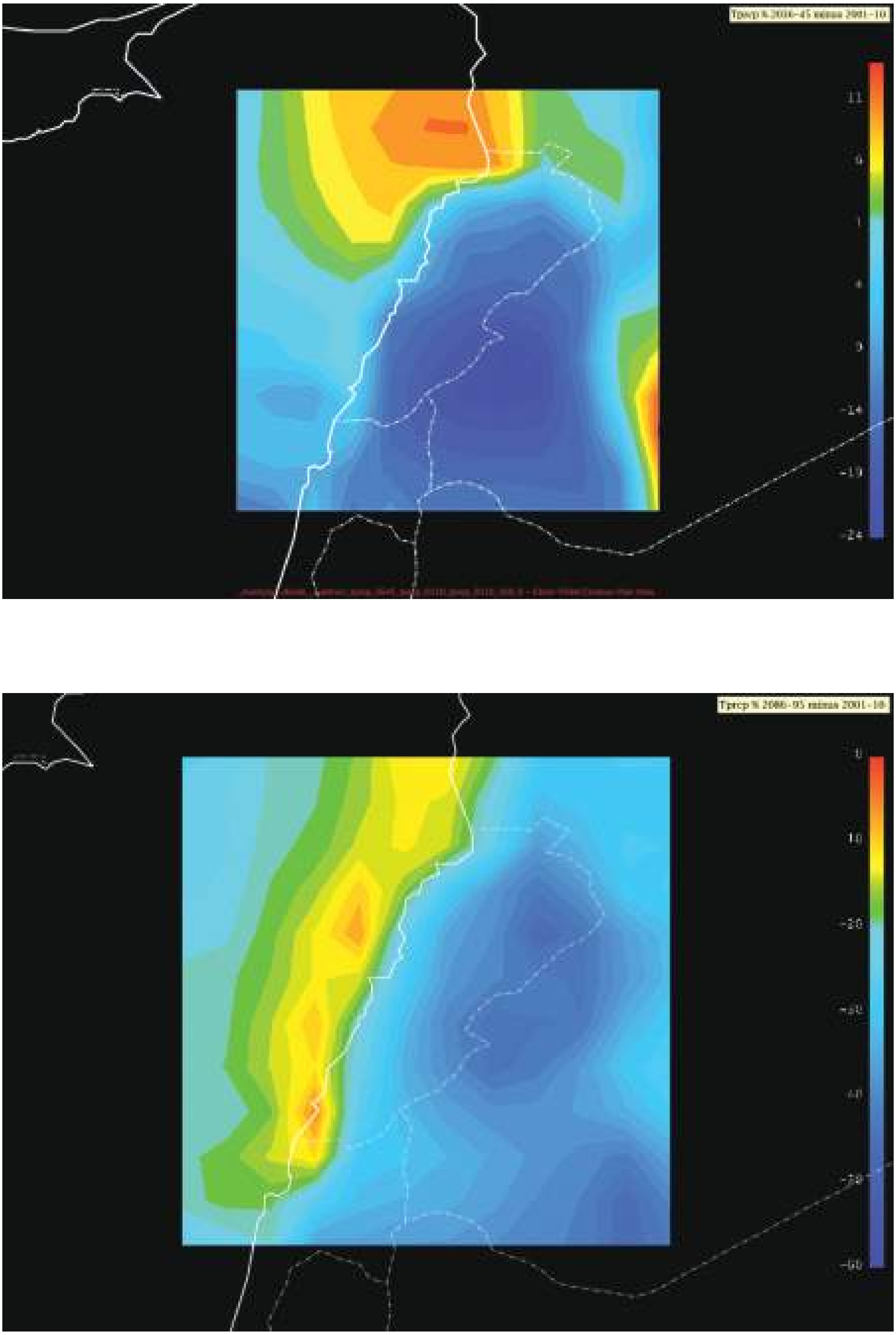


Figure 4-7 PRECIS projections of annual Precipitation over Lebanon as changes from the 2001-2010 average for 2036-45 (Top) and 2086-95 (Bottom)

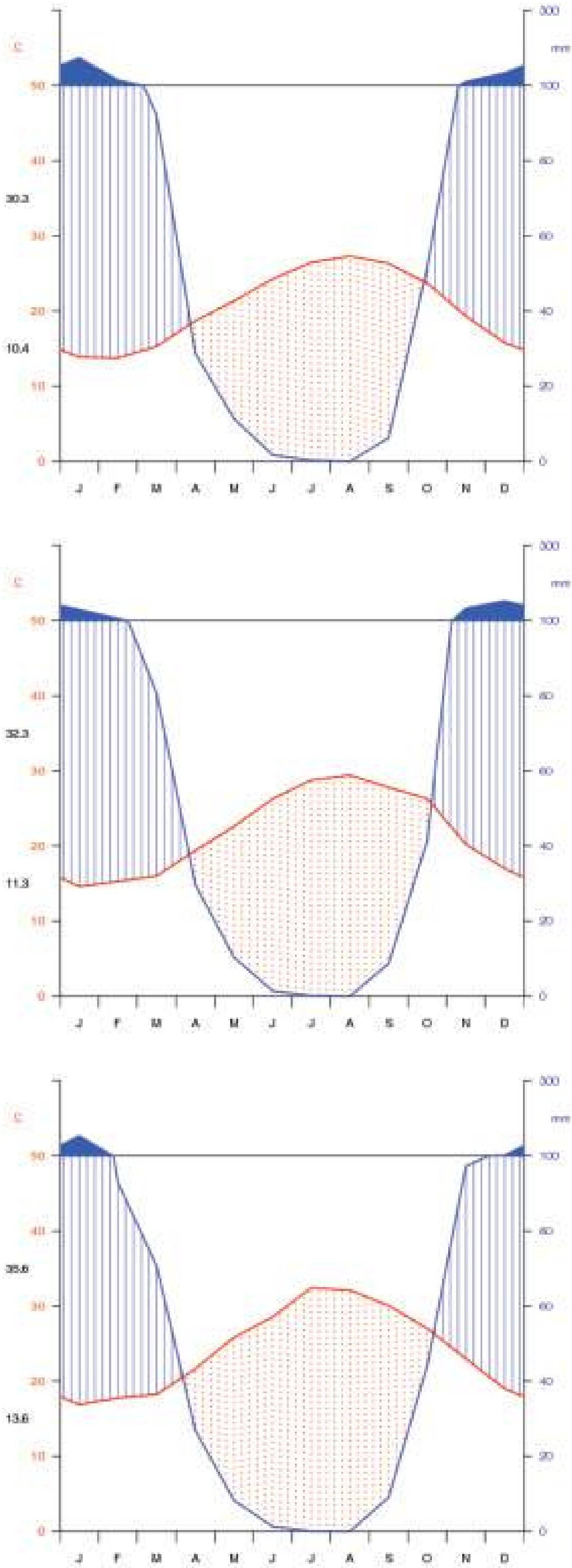


Figure 4-8 Walter & Lieth climate diagrams for Beirut observed by LMS in 1980-2000 and projected by PRECIS for 2025-2044 and 2080-2098

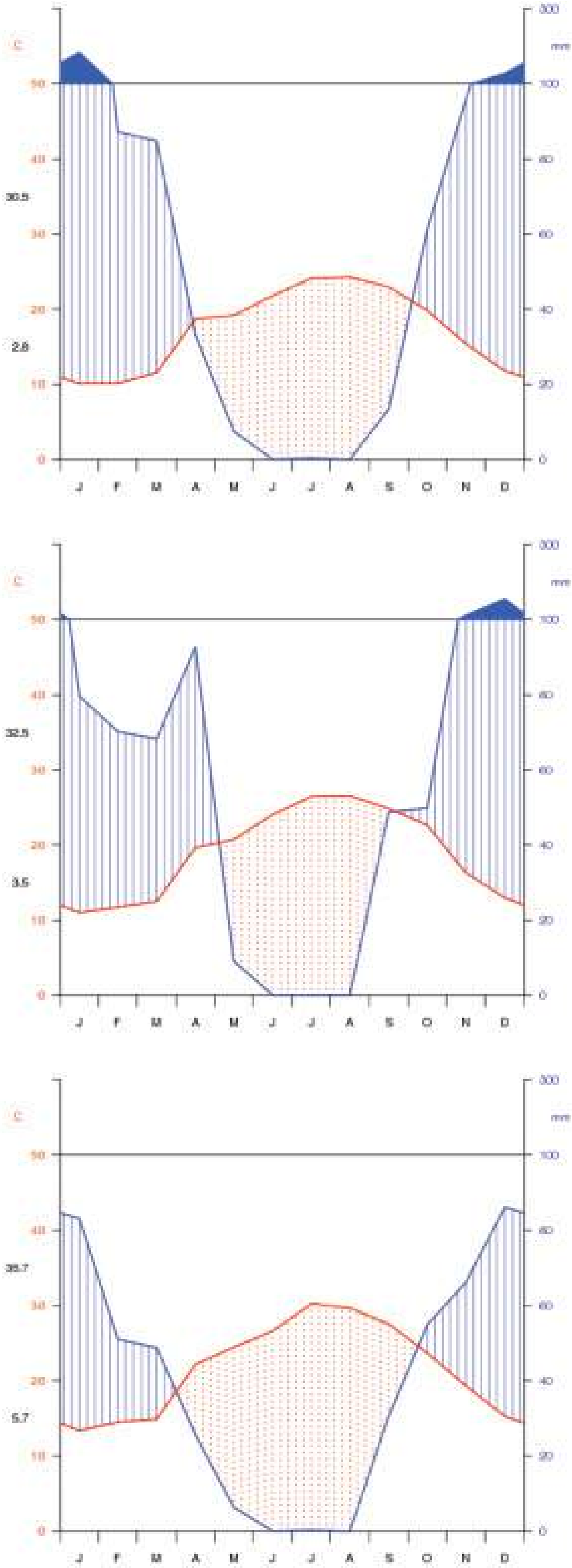


Figure 4-9 Walter & Lieth climate diagrams for Zahleh observed by LMS in 1980-2000 and projected by PRECIS for 2025-2044 and 2080-2098

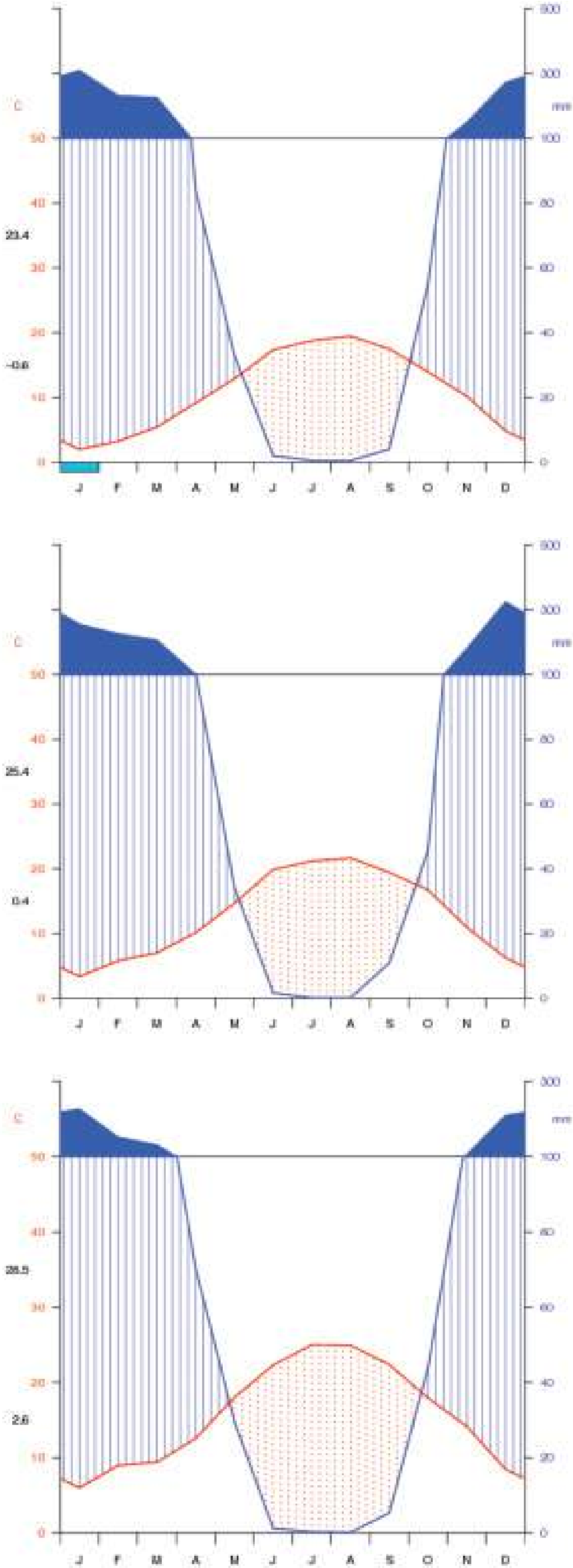


Figure 4-10 Walter & Lieth climate diagrams for Daher observed by LMS in 1980-2000 and projected by PRECIS for 2025-2044 and 2080-2098.

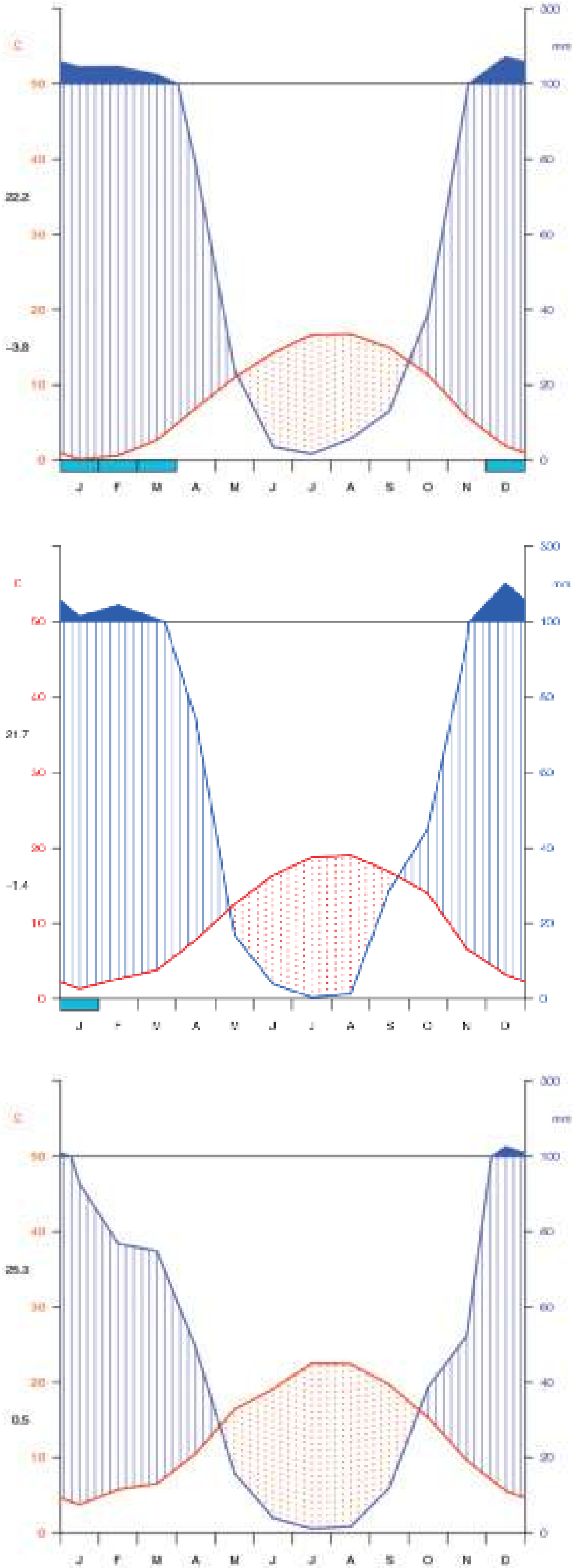


Figure 4-11 Walter & Lieth climate diagrams for Cedars observed by LMS in 1980-2000 and projected by PRECIS for 2025-2044 and 2080-2098

4.1.5 Indices of extremes

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

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

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

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

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

4.1.7 Further Work – Recommendations

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

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

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

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

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

4.2 Vulnerability and impact assessment

4.2.1 Method of assessment

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

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

4.2.2 Socio-economic scenarios

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

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

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

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

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

Table 4-2 Socio-Economic scenario

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

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

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

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

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

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

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

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

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

4.2.3 Climatic scenarios

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

4.2.4 Data Sources and Gaps

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

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

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

4.2.5 Main assumptions

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

However, the analysis does not account for internal and external security shocks which would severely impact growth, the population's livelihoods and vulnerability, hence intensifying any natural shocks from the projected climatic changes.

4.3 Vulnerability & Adaptation of the Agriculture Sector

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

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

4.3.1 Methodology

Scope of assessment

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

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

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

Development of the sector under socio-economic scenarios

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

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

4.3.2 Vulnerability and Impact Assessment

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

Wheat

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

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

Potato

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

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

Tomato

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

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

Cherries

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

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

Apples

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

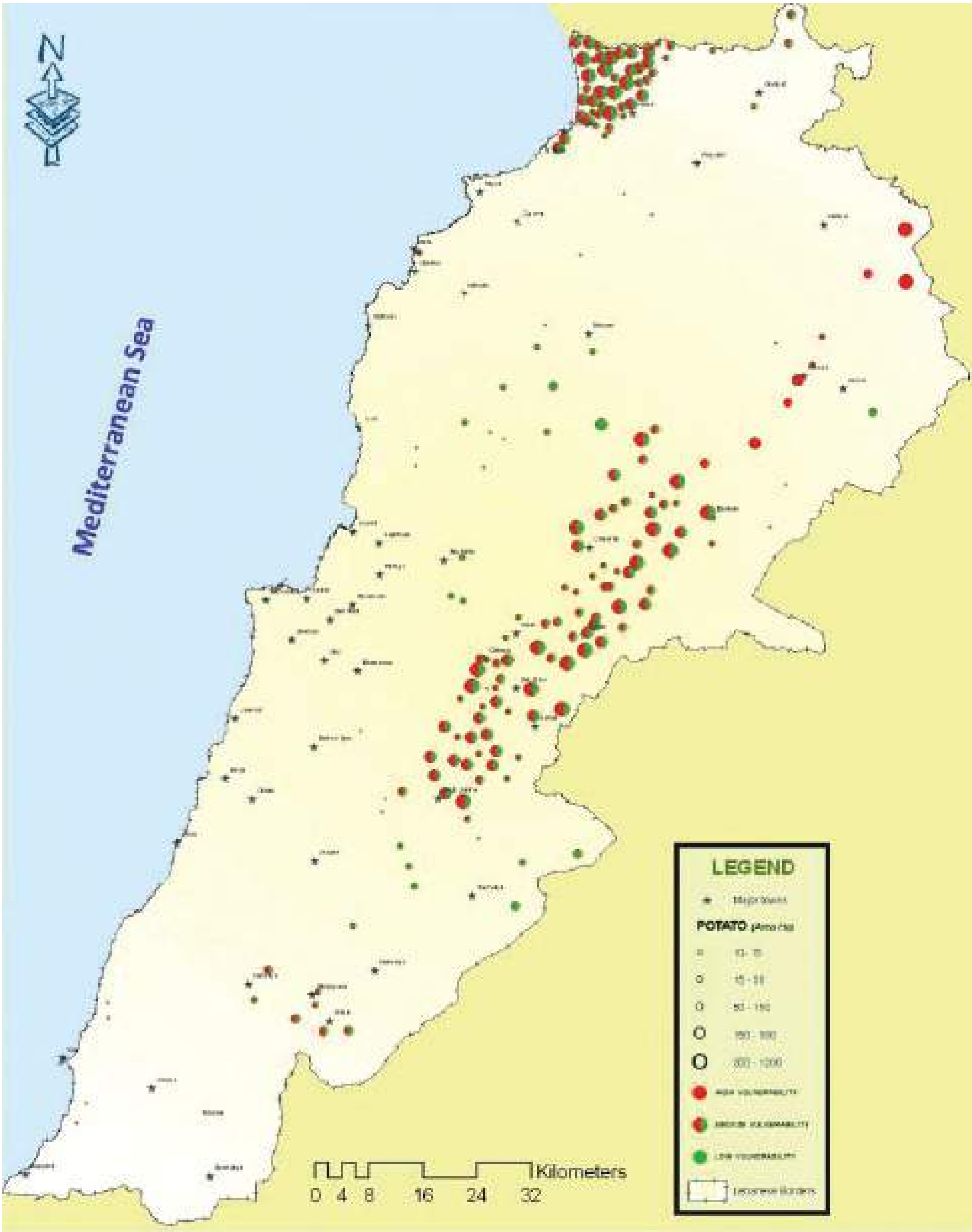


Figure 4-12 Potato cultivation areas and crop vulnerability

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

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

Grapevine

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

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

Banana

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

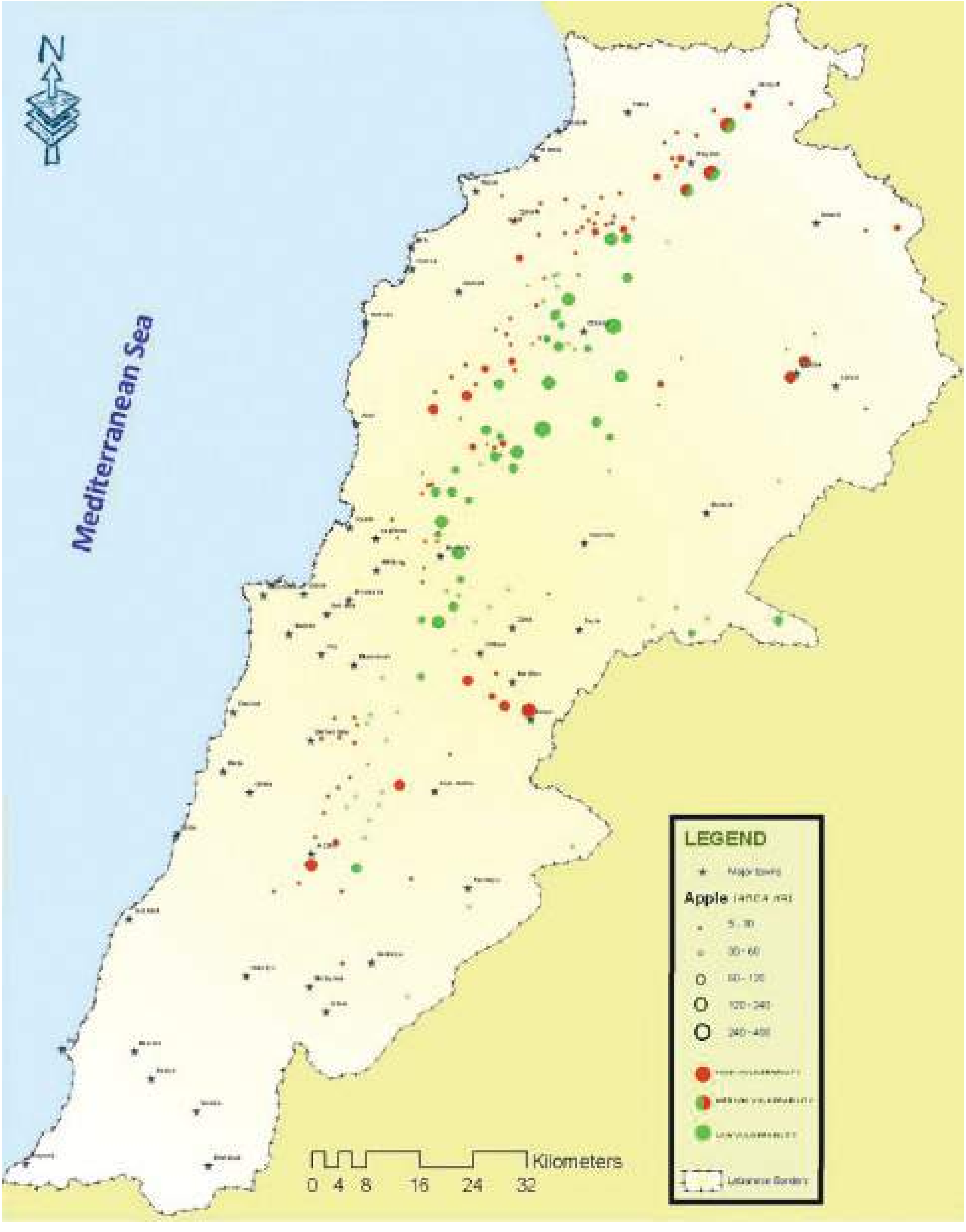


Figure 4-13 Apple cultivation area and crop vulnerability

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

Olive

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

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

Small ruminants

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

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

Adaptive Capacity: agriculture resilience and food security

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

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

4.3.3 Adaptation measures

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

4.3.3.1 Field level measures

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

Table 4-4 Specific field level adaptations measures

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

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

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

4.3.3.2 Research and infrastructure measures

Research measures

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

Infrastructure measures

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

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

4.3.4 Cost of adaptation

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

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

4.4 Vulnerability and Adaptation of the Electricity Sector

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

4.4.1 Methodology

Scope of Assessment

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

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

Methods of Assessment

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

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

Table 4-5 Adaptation action plan for the agriculture sector

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

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

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

Development of the sector under socio-economic scenarios

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

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

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

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

4.4.2 Vulnerability and Impact Assessment

Energy demand and consumption

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

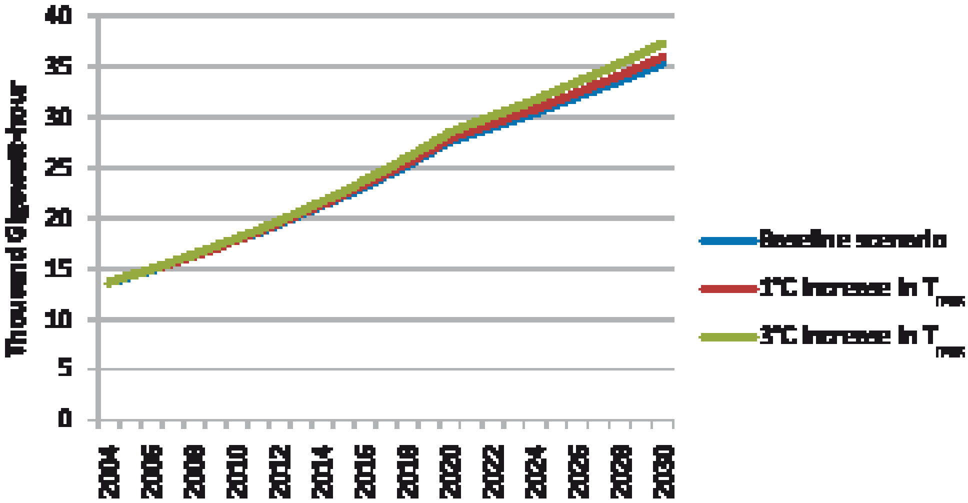


Figure 4-14 Forecasted increase in energy consumption resulting from a 1°C to 3°C increase in ambient temperature

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

Hydropower generation

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

Renewable energy

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

4.4.3 Adaptation Measures

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

4.5 Vulnerability and Adaptation of the Water Sector

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

4.5.1 Methodology

Scope of Assessment

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

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

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

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

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

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

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

Methods of assessment

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

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

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

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

Policies, plans and prospects

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

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

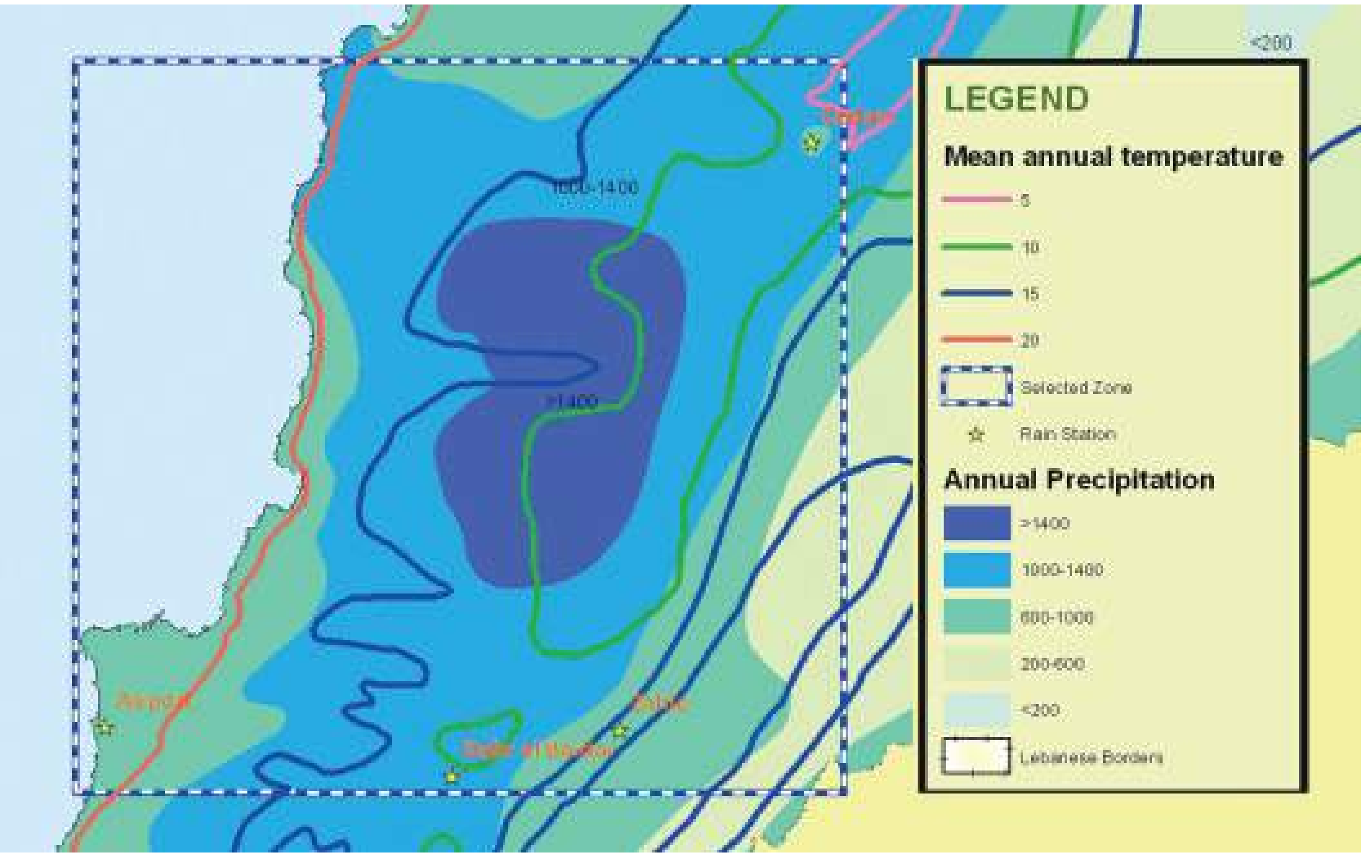


Figure 4-16 Temperature and precipitation isohyets in the study area

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

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

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

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

Table 4-6 Projections for domestic water demand by 2030

	2000	2030	Growth
Daily domestic water demand / person	200 liters	220 liters	+10%
Total domestic water demand / year	296 Mm^3	418 Mm^3	+41%

Source: CDR, 2005

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

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

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

	Yearly renewable water resources (m^3/capita)	Total yearly renewable water resources (billion m^3)
1997	766–1,287	
2015	336–979	
2025	262–809	2.00 – 3.94

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

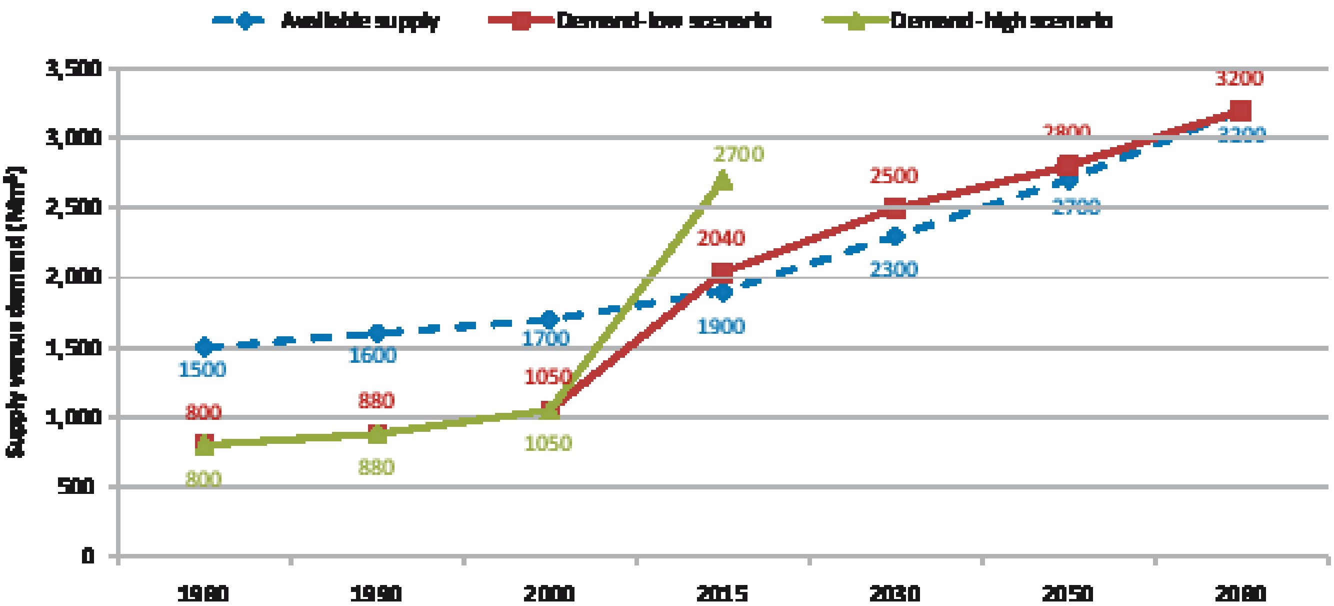


Figure 4-17 Baseline projections of supply and demand

Development of the sector under socio-economic scenarios

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

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

4.5.2 Vulnerability assessment

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

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

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

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

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

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

4.5.3 Impact assessment

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

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

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

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

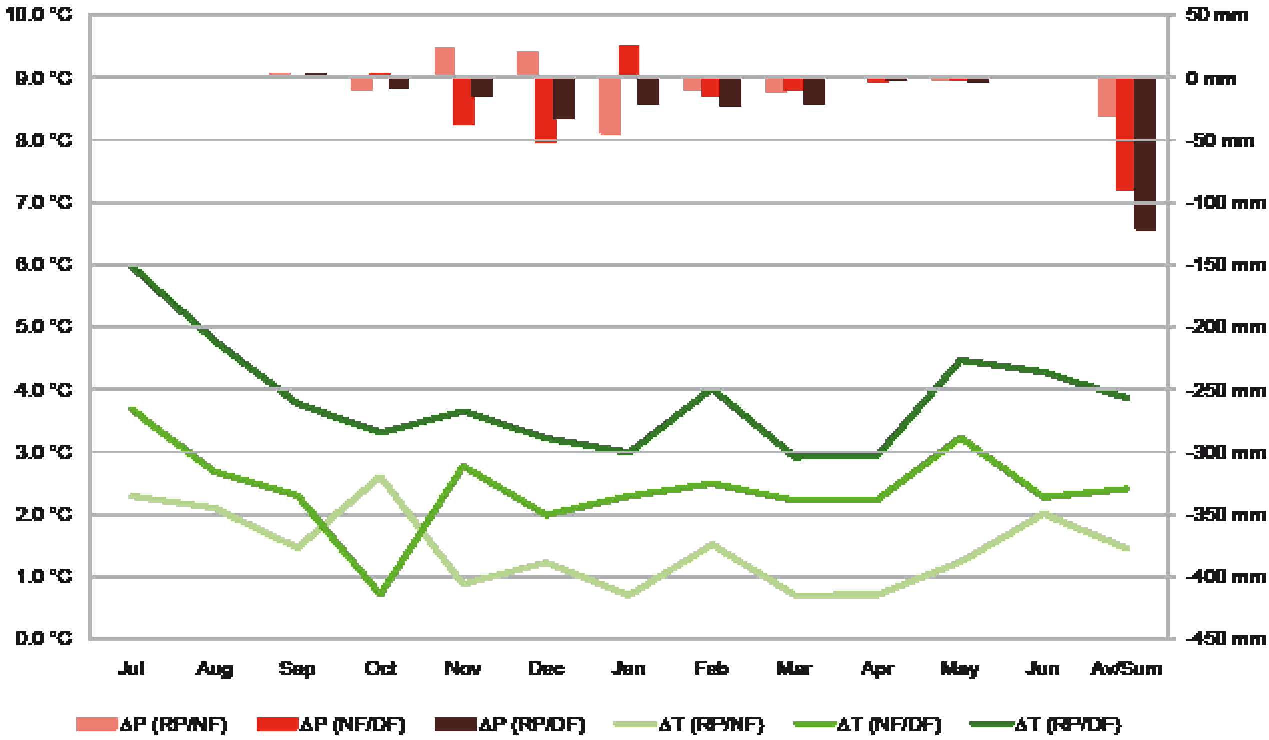


Figure 4-18 Projected changes in precipitation and average temperature – Beirut station

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

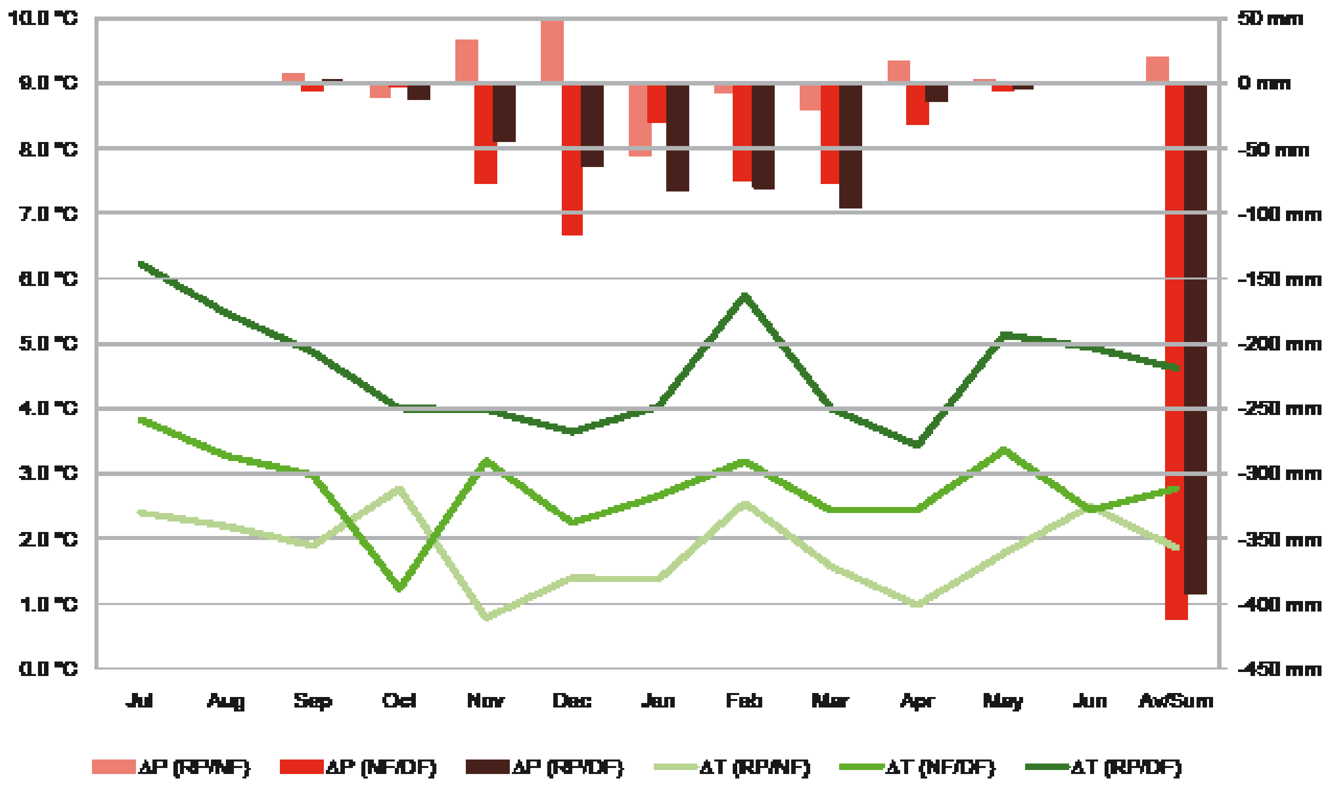


Figure 4-19 Projected changes in precipitation and average temperature – Daher-el-Baydar station

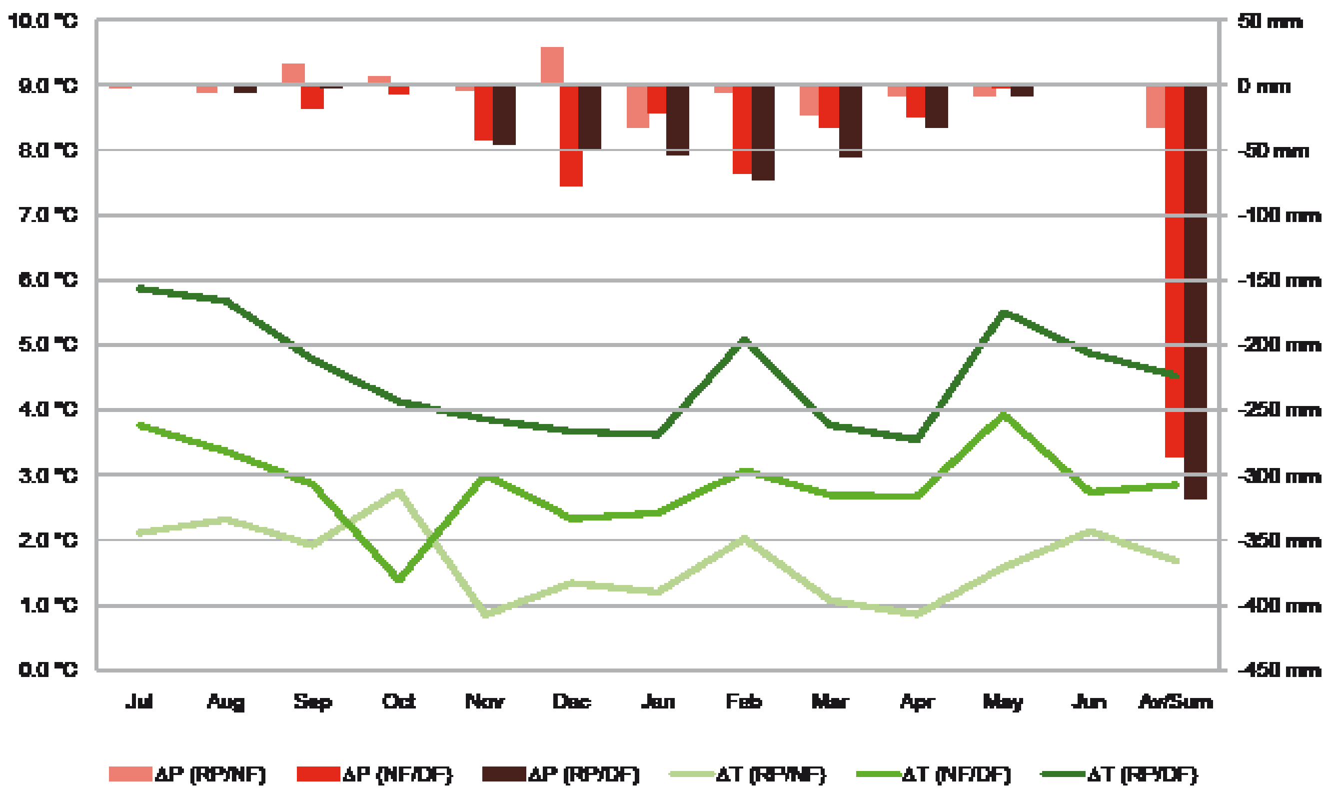


Figure 4-20 Projected changes in precipitation and average temperature – Cedars station

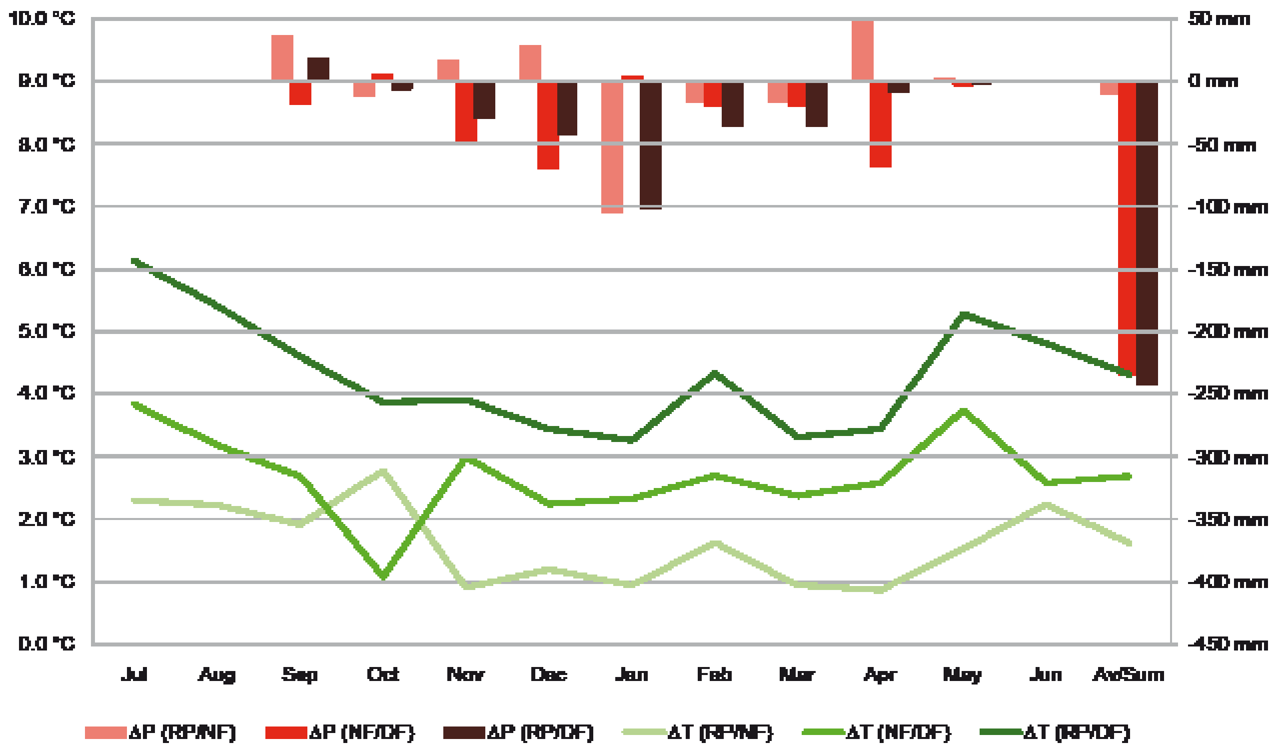


Figure 4-21 Projected changes in precipitation and average temperature – Zahleh station

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

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

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

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

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

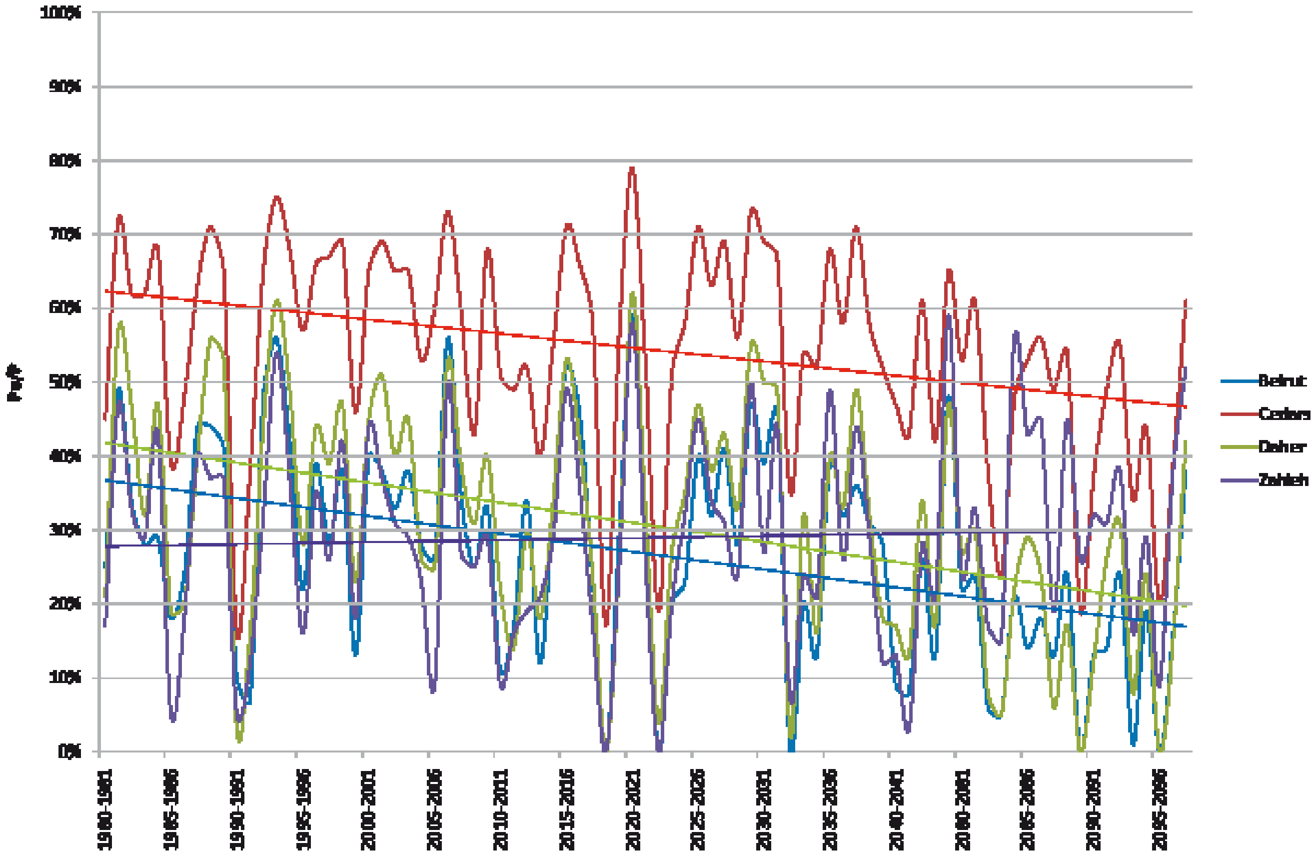


Figure 4-22 Trend pf the proportion of active precipitation out of total precipitation over time in the 4 grid boxes constituting the study area

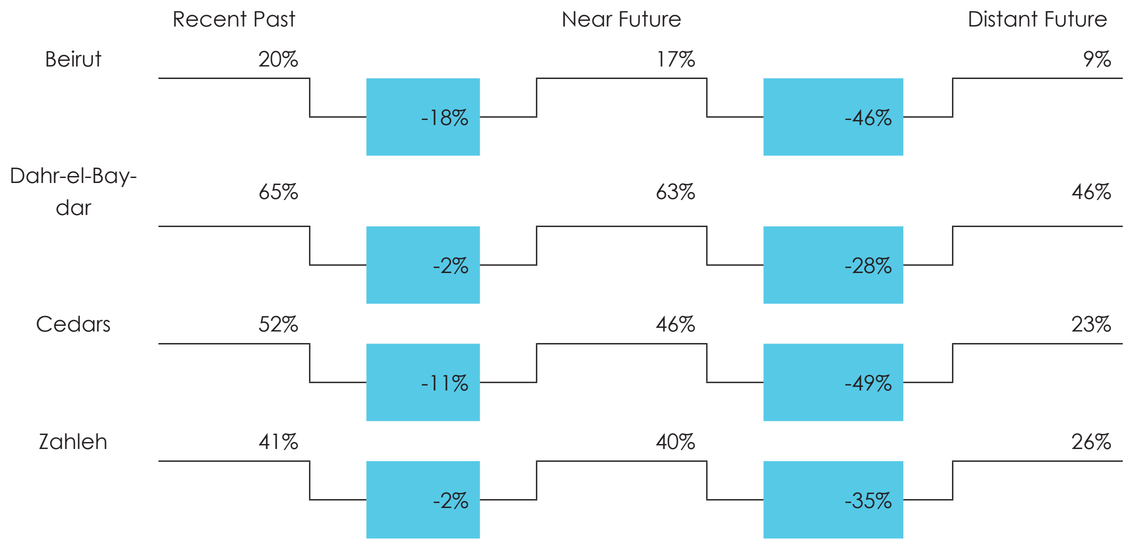


Figure 4-23 Decline in the proportion of active precipitation out of total precipitation in the different regions over time

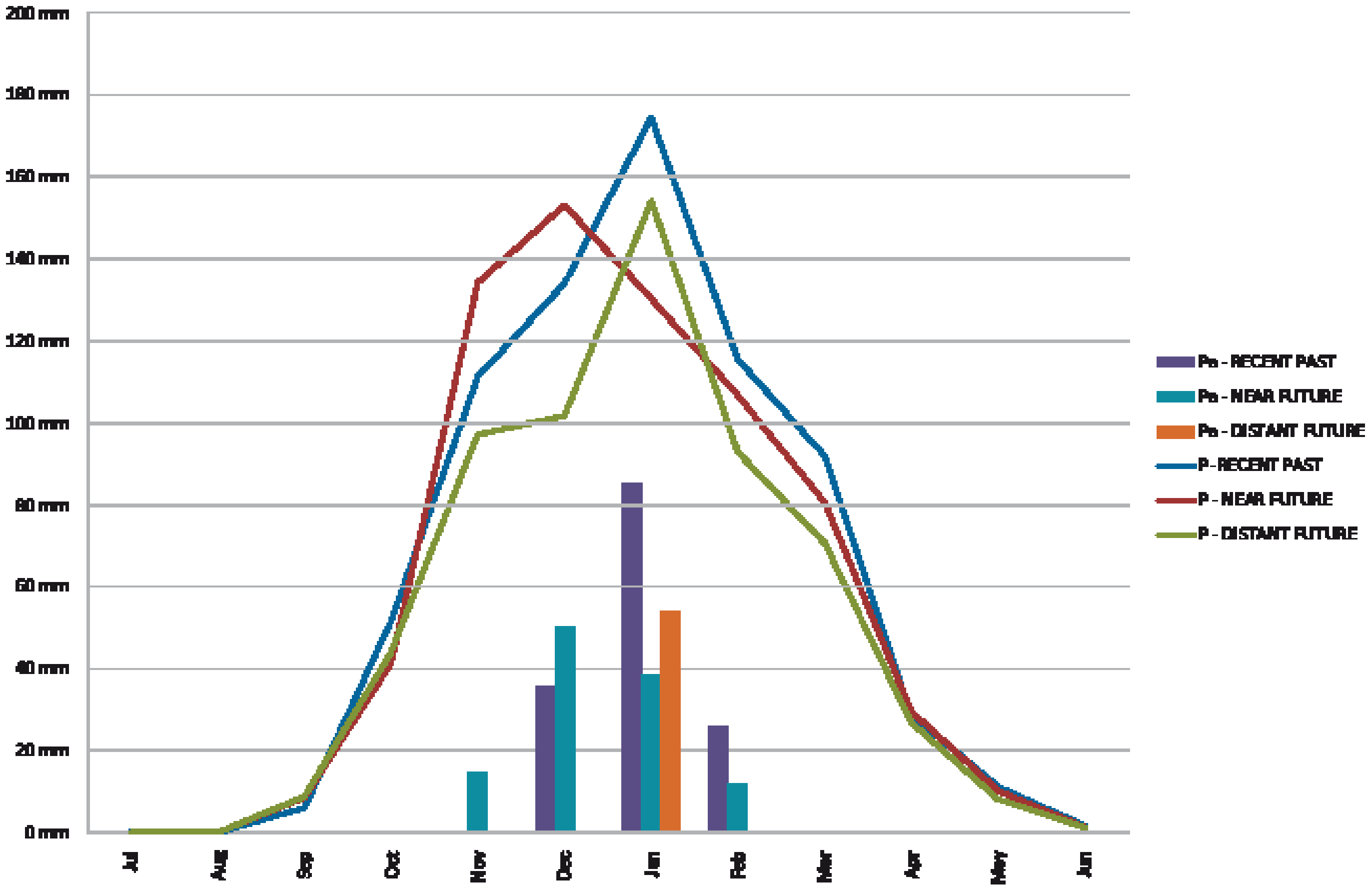


Figure 4-24 Monthly average of total and active precipitation in Beirut (past and projected)

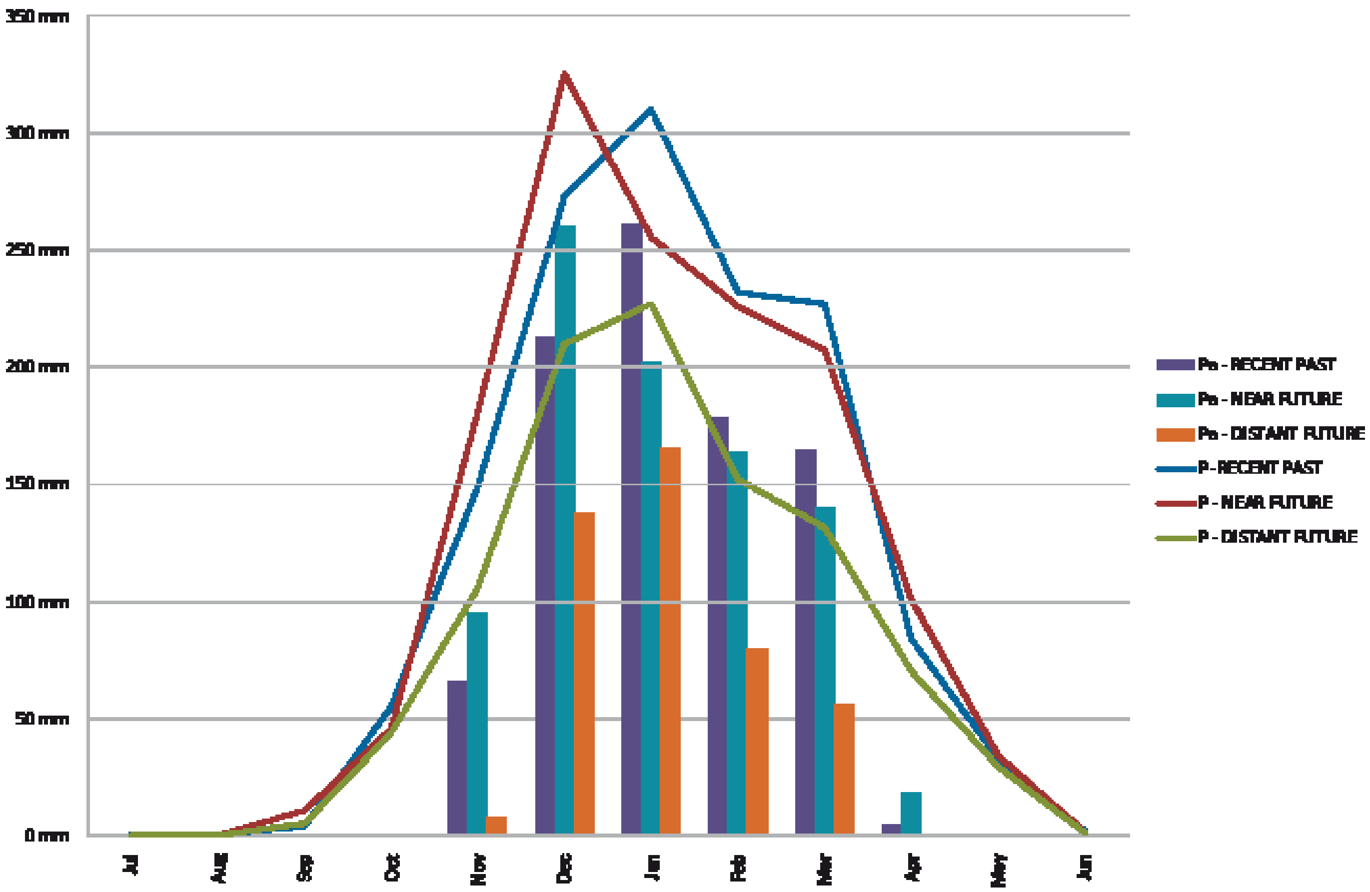


Figure 4-25 Monthly average of total and active precipitation in Daher-el-Baydar (past and projected)

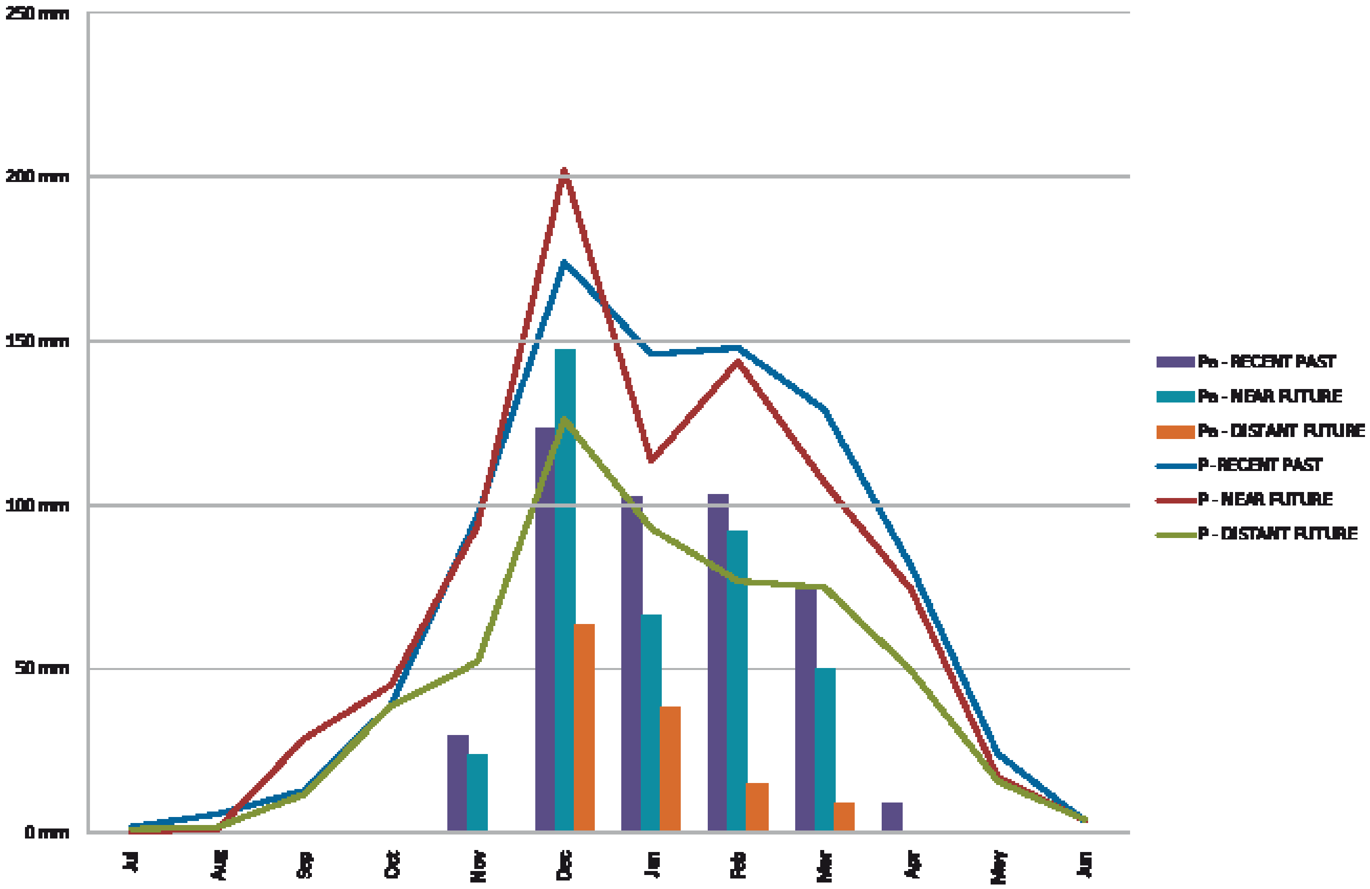


Figure 4-26 Monthly average of total and active precipitation in the Cedars (past and projected)

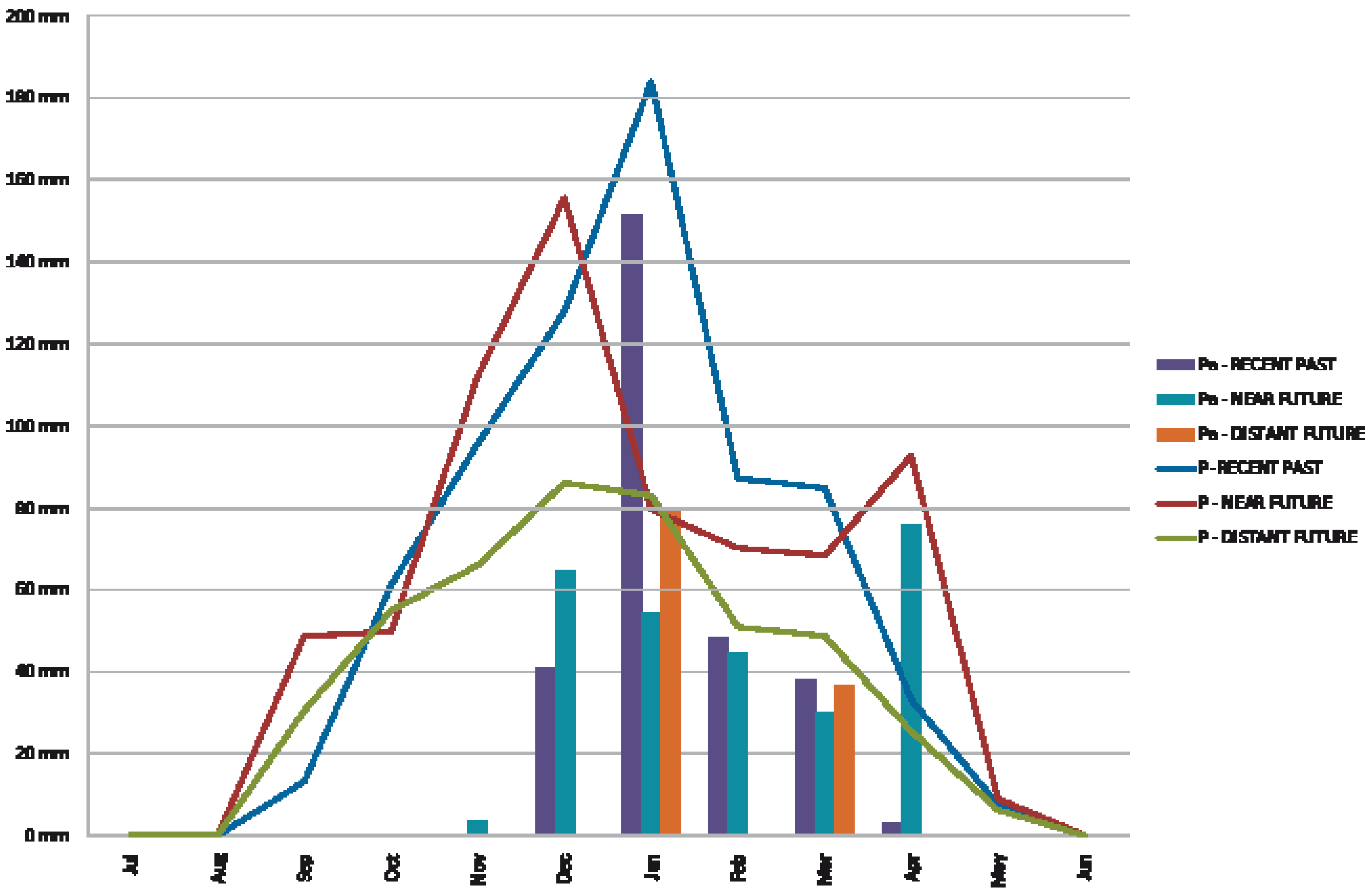


Figure 4-27 Monthly average of total and active precipitation in Zahleh (past and projected)

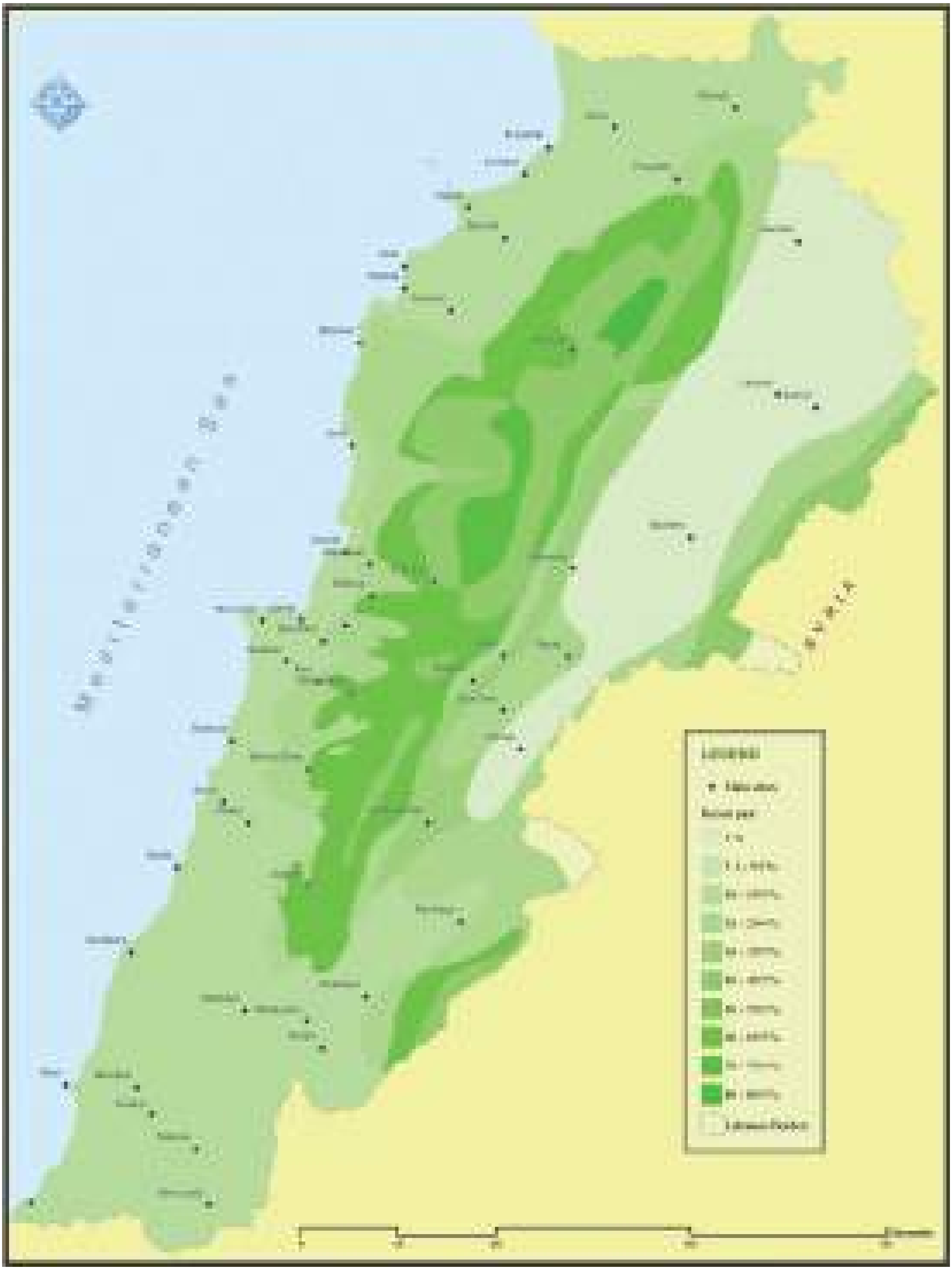


Figure 4-28 Proportion of active precipitation out of total precipitation for the recent past (1960-2000)

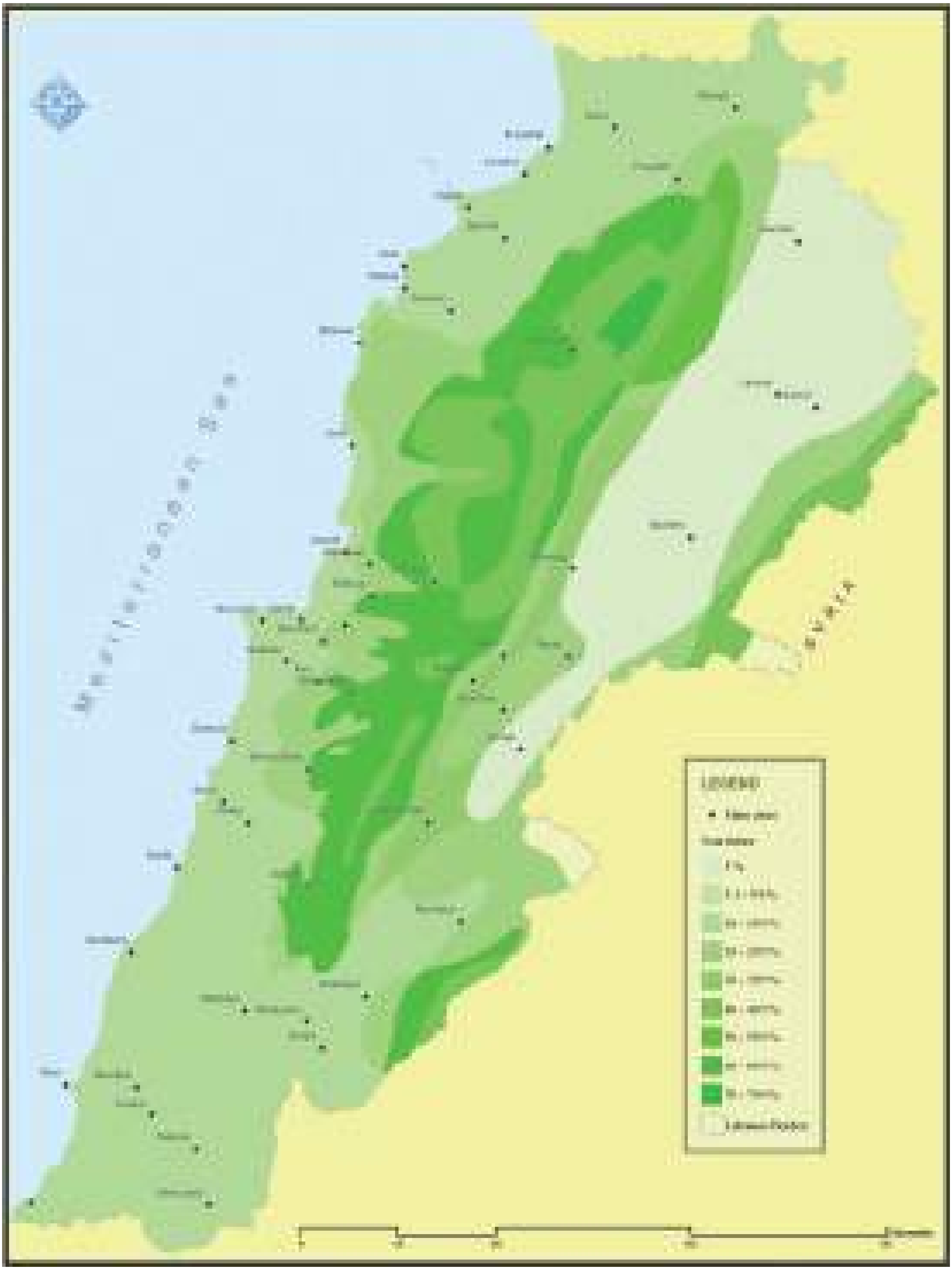


Figure 4-29 Proportion of active precipitation out of total precipitation for the near future (2025-2044)

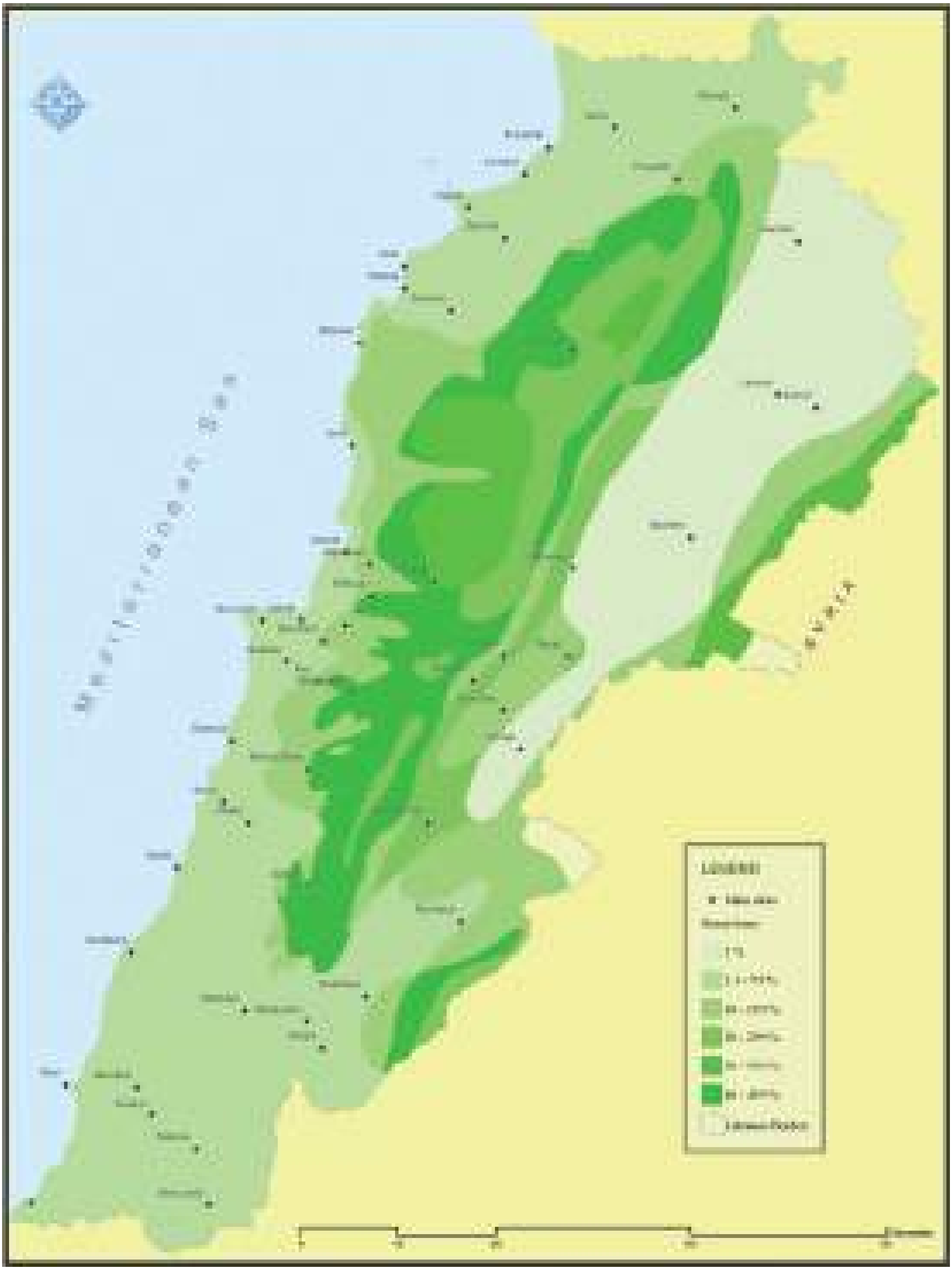


Figure 4-30 Proportion of active precipitation out of total precipitation for the distant future (2080-2098)

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

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

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

Potential impact on snow cover

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

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

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

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

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

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

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

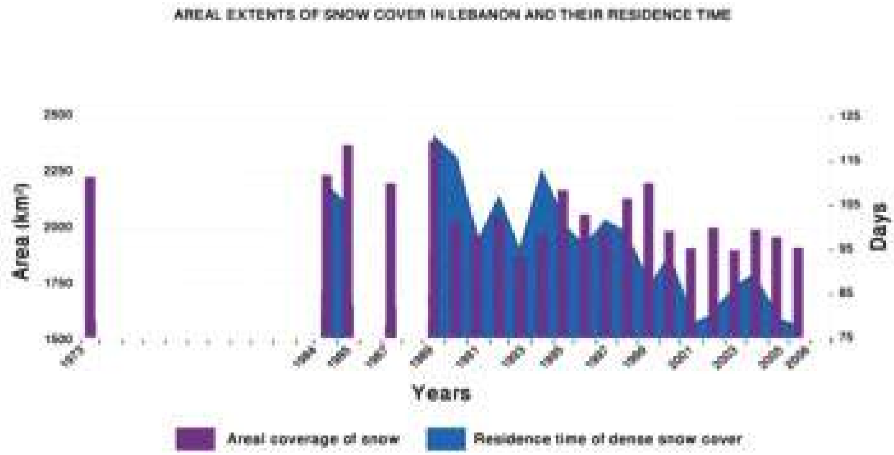


Figure 4-34 Areal extents of snow cover in Lebanon and their residence time Source: Shaban, 2009

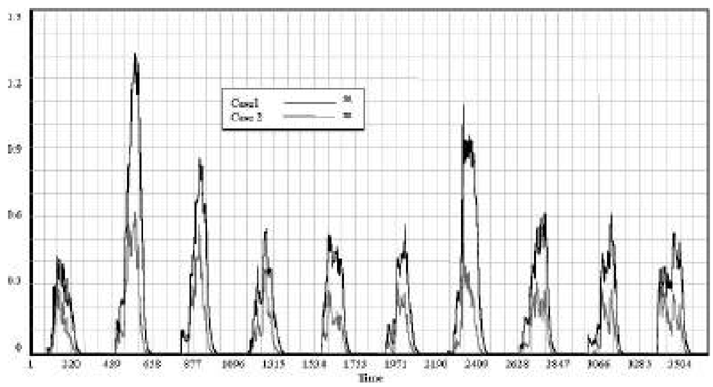


Figure 4-35 Mean snow width generated over 10 years (Case 1: reference simulation; Case 2: scenario of an increase by 2°C)

Source: Hreiche et al., 2007

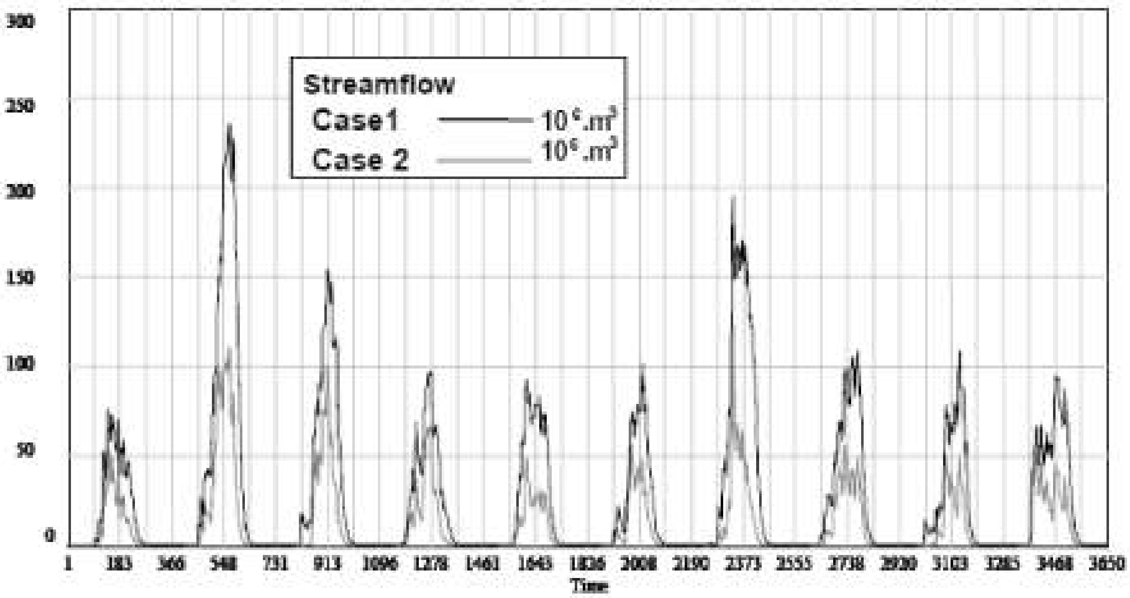


Figure 4-36 Evolution of the snowpack in Nahr Ibrahim catchment simulated over 10 years. (Case 1: reference simulation; Case 2: scenario of an increase by 2°C). Source: Hreiche et al., 2007

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

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

4.5.4 Adaptation Measures

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

Table 4-9 Water sector adaptation action plan

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

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

4.6 Vulnerability and Adaptation of Coastal Zones

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

4.6.1 Methodology

Scope of Assessment

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

Methods of Assessment

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

Development of the sector under socio-economic scenarios

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

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

4.6.2 Vulnerability assessment

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

Figure 4-37 Land use along the Lebanese coastal zone

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

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

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

4.6.3 Impact assessment

The impacts of climate change on coastal zones are:

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

4.6.4 Adaptation measures

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

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

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

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

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

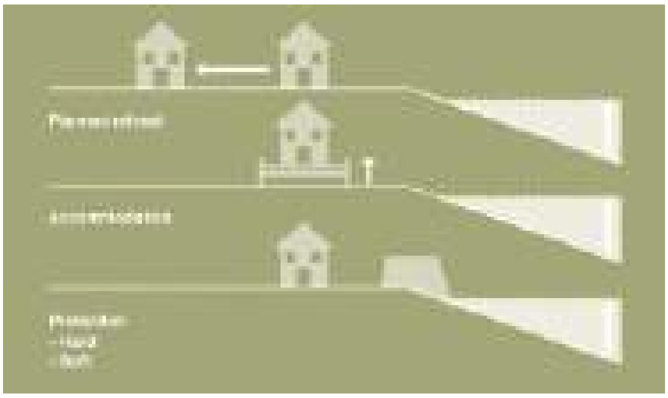


Figure 4-38 Illustration of the possible adaptation responses to sea-level rise. Source: Parry et al., 2009

4.7 Vulnerability and Adaptation of the Forestry Sector

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

4.7.1 Methodology

Scope of Assessment

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

Climatic factors

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

Mediterranean vegetation and specifically Mediterranean forests have adapted to prevailing climatic constraints and are typically represented by clear altitudinal leveling: the vegetation levels. In Lebanon, vegetation levels have been described and illustrated in the phyto-association map published by Abi Saleh & Safi (1988), in which 10 vegetation levels can be clearly distinguished with respect to altitude (Figure 4-39). These vegetation levels derive from the "Quotient pluviothermique" of Emberger (Quezel,1976), which reflect the tolerance of species within a range of precipitation, mean maximum

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

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

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

Methods of Assessment

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

- Overlaying the derived forest map (MoA and FAO, 2005b) on the grid map of Lebanon (25 km x 25 km);
- Identifying for each grid the dominant forest type (current - for the period 1960-2000), and the Quotient of Emberger (Q), for the periods 1961-1980; 2025-2044; and 2080-2098;
- Selecting the most vulnerable forest types with respect to Q, and their ability to withstand future climate change; i.e., the forest types were designated as "most vulnerable" when the shift in bioclimatic level would overbear the tolerance of the forest type with reference to climagramme of Emberger for Lebanon (Abi Saleh et al., 1996);
- Assessing the impact on vulnerable forest types with respect to the expected change in Q and therefore in the bioclimatic condition and the ability of the ecosystem (valence écologique) to cope with the projected change (Figure 4-40);
- Assessing for each forest type the margin of tolerance with respect to temperature and rainfall in reference to Table 4-11 adapted from Quezel (1976), Abi Saleh (1978) and M'Hirit(1999);
- Highlighting grids where the shift in bioclimatic level (Table 4-11) surpasses the ecological tolerance of the dominant forest type. In this case, the selected grids show the location of the most vulnerable forest types that would be most impacted by climate change. They represent grids where the

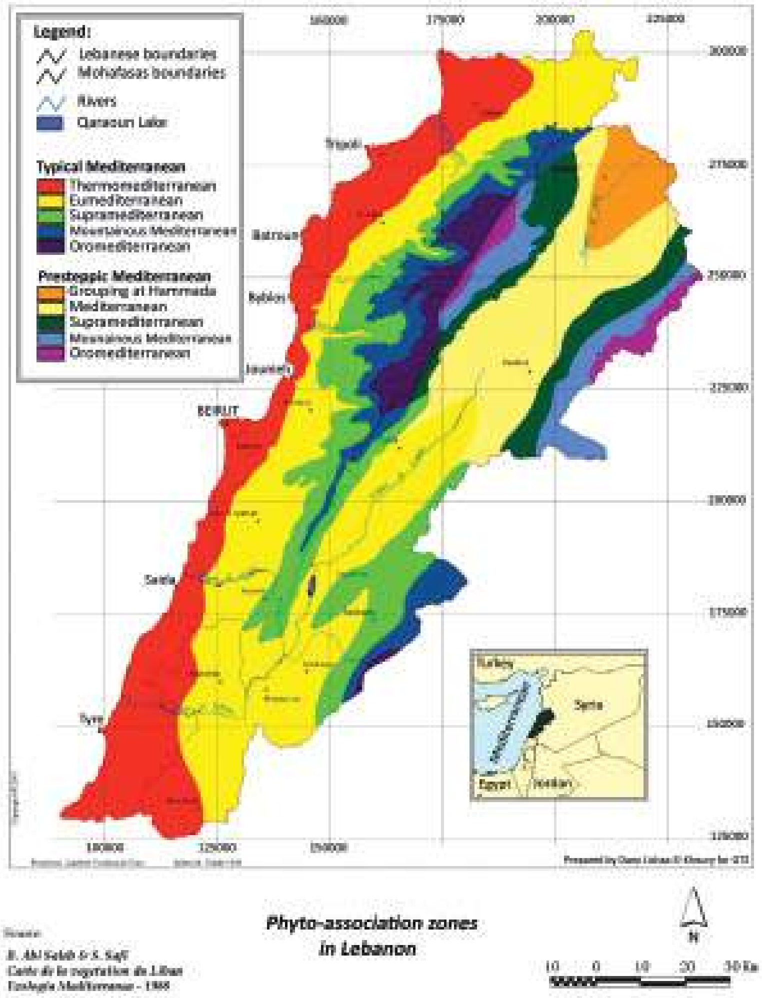


Figure 4-39 Phyto-association zones in Lebanon
Source: Abi Saleh and Safi, 1988

shift in bioclimatic level will be from humid or sub-humid to semi-arid, and subsequently areas where the survival of the species will be challenged (Figure 4-41);

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

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

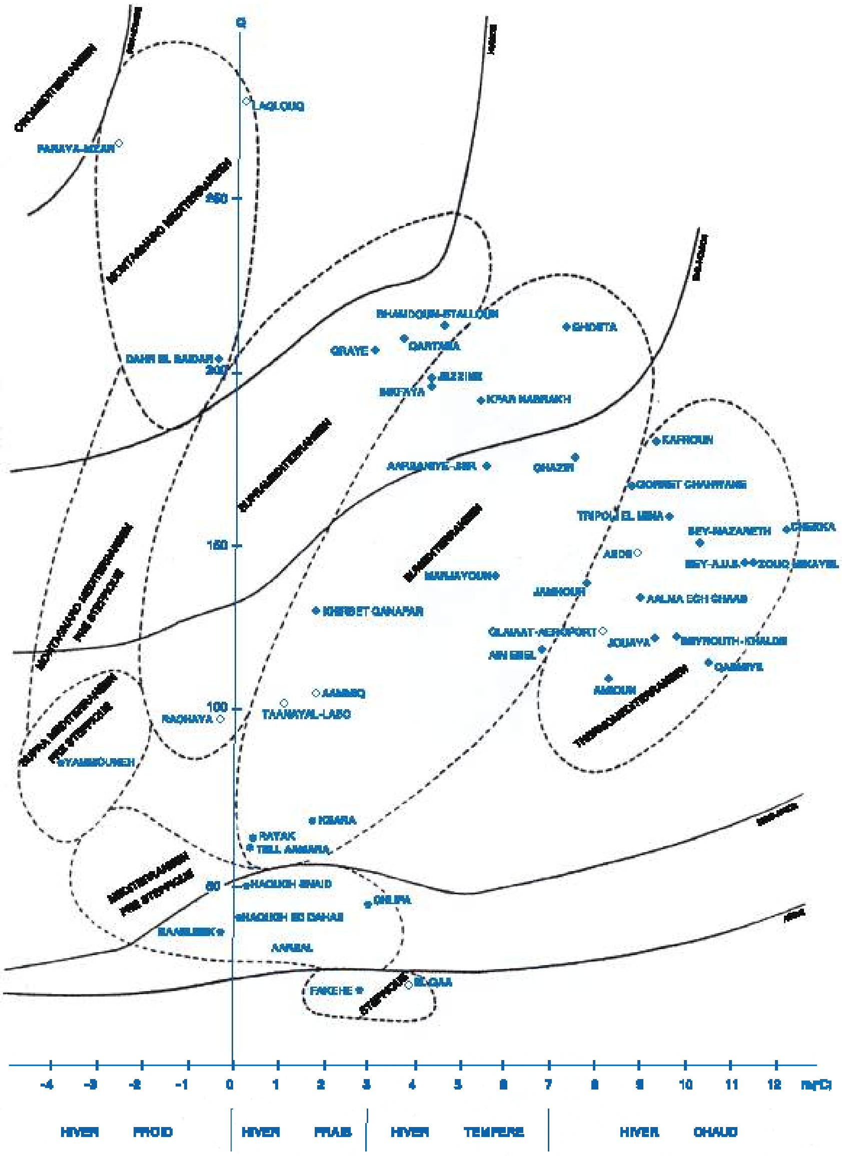


Figure 4-40 Distribution of bioclimatic levels in Lebanon with respect to Emberger Quotient
Source: Abi Saleh et al., 1996

Table 4-11 Forest types' tolerance to precipitation variability in Lebanon

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

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

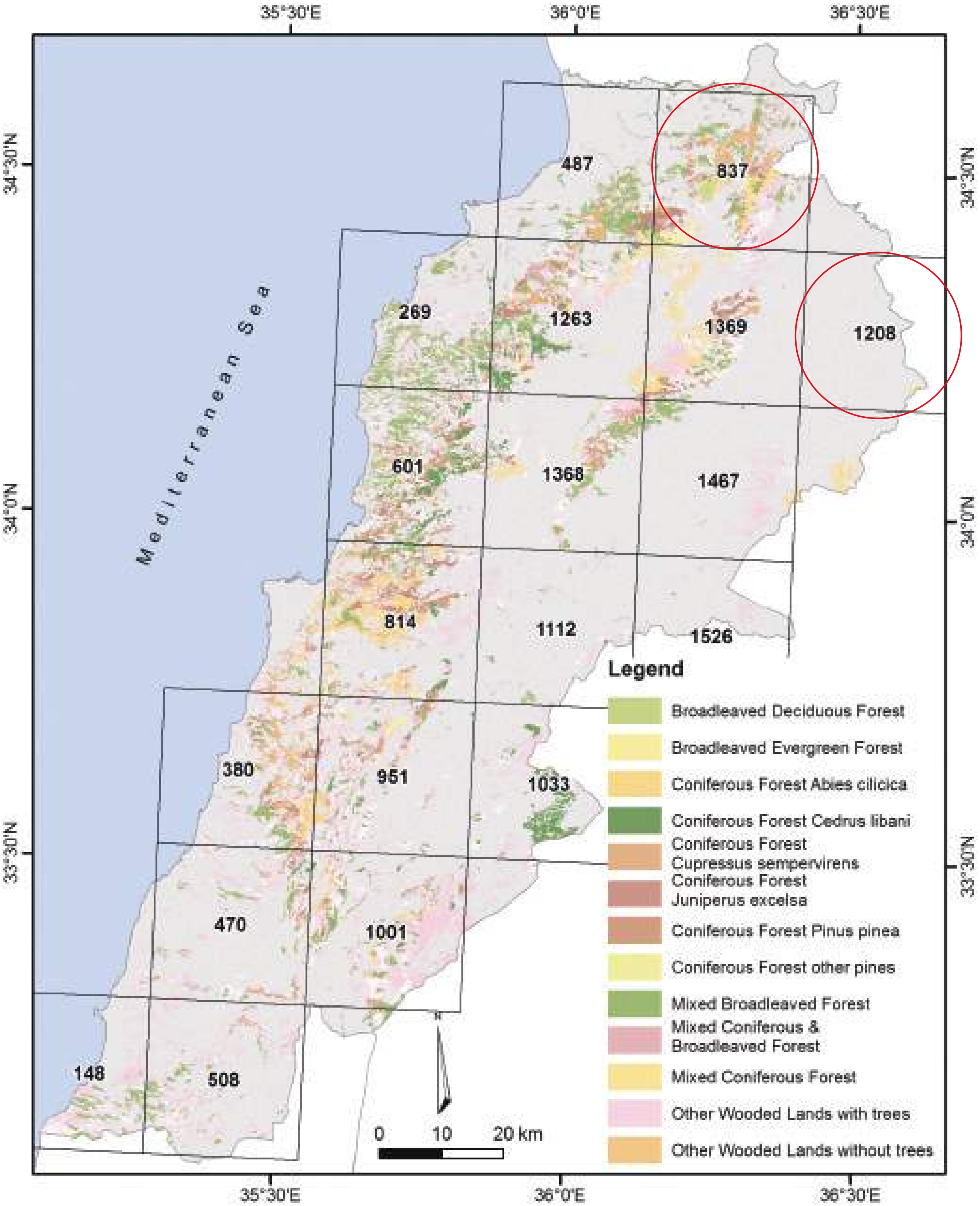


Figure 4-41 Areas (encircled) expected to be most impacted by climatic factors

Policies and strategies

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

Development of the sector under socio-economic scenarios

Under scenario A, forest development will replace abandoned agricultural lands. The expected rural migration under this scenario might benefit forest stands as pressure (illegal logging, over grazing/ undergrazing, unsustainable harvesting, collection of medicinal and aromatic plants) on existing forests will be reduced. Non-wood forest products resulting from agro-forestry products (such as pine nuts, carob pods and honey, etc.) might be negatively affected due to the lack of labor, open market strategies and absence of agro-forestry policies. Law enforcement and the increased awareness of the recreational value of forests will lead to a better interest in ecotourism and nature-based activities, as well as in the value and associated services such as landscape and biodiversity. The risk from forest fires will probably decrease with the adoption of improved and innovative integrated management practices (improved fire fighting techniques, pre- and post-fire management, sustainable grazing within forest areas, etc).

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

4.7.2 Vulnerability assessment

Various uncertainties exist on the extent and speed at which climate change will impact biodiversity and ecosystem services, as well as the thresholds of climate change above which ecosystems are irreversibly changed and no longer function in their current form. Therefore, there is a strong need to measure and model adequately land surface fluxes, soil moisture and vegetation dynamics for a sufficiently long time, including years characterized by different hydro-meteorological conditions, before being able to properly assess the effects of climate change on forest ecosystems.

The adaptive capacity of a forest ecosystem to changing environmental conditions is determined by its size, biological and ecological diversity, as well as by the condition and character of the surrounding landscape. Species migration as a response to climate change is not "new" as analysis of pollen deposits in sediments and vegetation macrorests have shown pronounced and sometimes rapid response (sometimes in less than 20 years) of terrestrial vegetation to past climatic changes, with sudden collapse of a number of species and the rapid expansion of others. However, species migration may not be fast enough to cover dispersal requirements under the predicted rate of climate change (Tinner and Lotter, 2001). The assessment of the adaptive capacity of different forest types in Lebanon, in terms of the impact of climate variability, socio economic importance, resilience to forest fires and pest attacks, ability to migrate upward, and the resources needed to adapt to climate change, reveal that the upper zone coniferous forests (*Cedrus libani; Abies cilicica*) and high mountain formations (*Juniperus excelsa*) have the lowest natural adaptive capacity to current and future trends (Table 4-12).

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

Table 4-12 Vulnerable hotspots in the Forestry sector

System	Sensitivity to climate change	Root cause	Natural Adaptive capacity	Overall vulnerability
Juniperus excelsa	Very high	Absence of effective protection, pressure of overgrazing and the demanding physiological requirements for regeneration	Low	Very High
Cedrus libani	High	Forest fragmentation and the location of forest stands on mountain crestline, which limits their ability the migrate upwards	Low-Moderate	High
Abies cilicica	High	Absence of pure fir stands, forest fragmentation and illegal logging	Low	High
Quercus cerris, Fraxinus ornus & Ostrya carpinifolia	High	Limited geographical extent and forest fragmentation	Low	High

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

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

Ecosystem fragmentation and land use changes: Urban expansion and road network development, human intervention by logging and overgrazing activities are the serious causes of ecosystem fragmentation in Lebanon where forests have been broken into isolated small pieces that are more susceptible to external disturbances. The number of forest patches on the eastern flank of Mount Lebanon has increased from 131 to 730 patches between 1965 and 1998. With the disappearance of the forest cover, rock outcrops have appeared within patches due to soil erosion. Almost 50% of the total forest cover has been lost in 33 years, mainly affecting juniper stands (Jomaa et al., 2007). In addition, the important fragmentation of forests and natural habitats is also seriously challenging the migration of the cedars forest upward or northward, especially that most of existing stands are already present at the mountain peak line (Hajar et al., 2010).

Pest attacks: Increased levels of CO_2 in the atmosphere prompt an increase in the C/N balance of plant tissues, which in turn results in a lower food quality for many defoliating insects which sometimes respond by increasing the level of leaf consumption and consequently damage trees. In addition, an increase in temperature may alter the mechanism by which the insects adjust their cycles to the local climate (diapause), resulting in faster development and a higher feeding rate. This has already been witnessed in Lebanon with the attack of Cedar stands in Tannourine forest by *Cephalcia tannourinensis*, an outbreak that has been closely correlated to the length of the snow cover period over the last

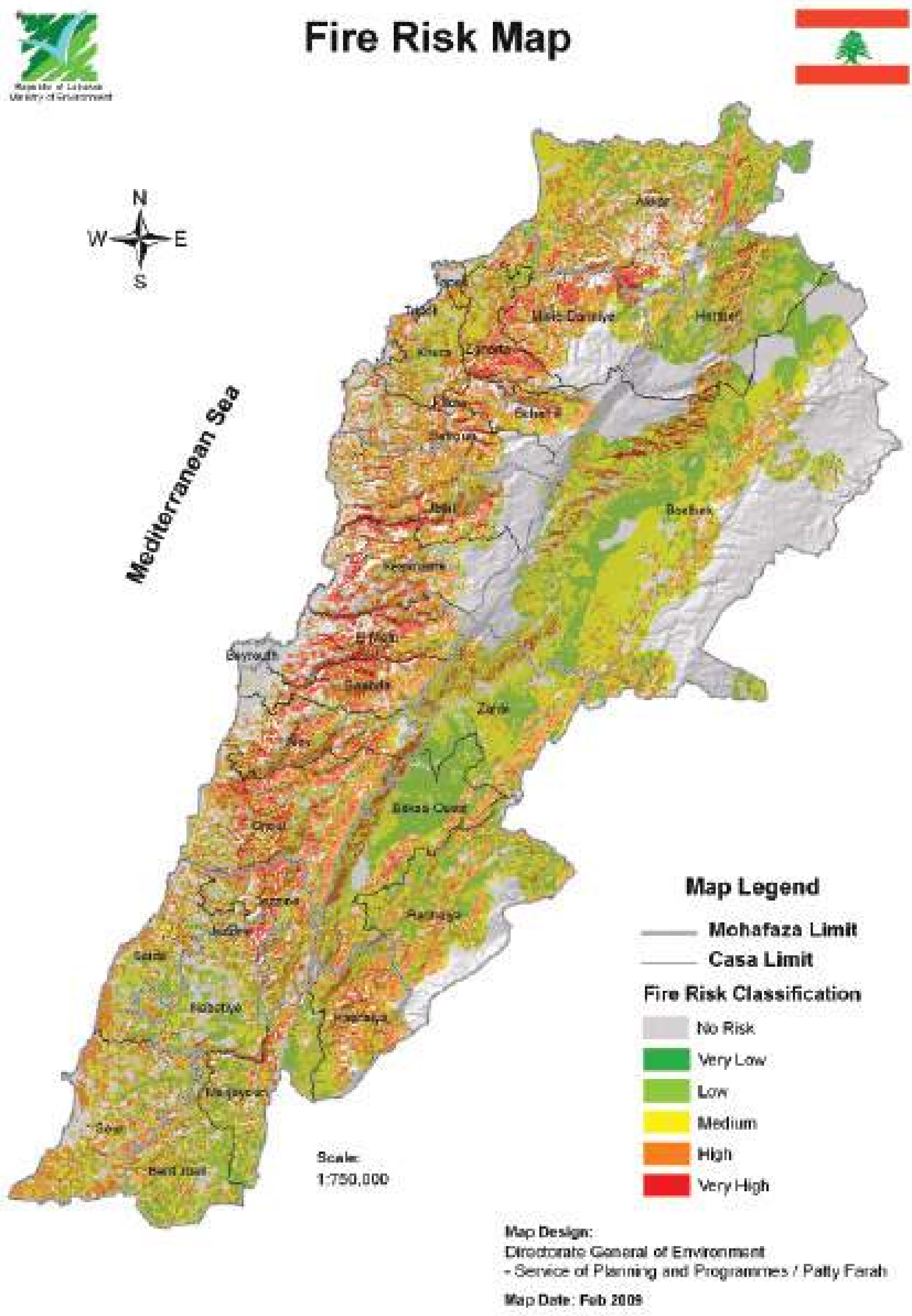


Figure 4-42 Forest fires risk map

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

Quarries: Between 1996 and 2005, the number of quarries increased from 711 to 1,278 with a simultaneous increase of quarried land from 2,875 to 195,283 ha. The majority of quarries in Lebanon are developed with no consideration for their environmental impact, thus causing the destruction of vegetation and important natural habitats and the permanent loss of biodiversity and natural resources, especially that 25% of existing quarries developed within forested land (Darwish et al., 2008; AFDC, 2007).

Grazing: The decline of grazing activities during the past decades has favoured uncontrolled development of forest understory which in turn has resulted in an increased fire risk on forests. The conservative policies (Law 558/1997: Forest code) aggravated the situation as grazing has been prohibited in forested areas, which increased the overgrazing pressure on OWL.

4.7.3 Impact assessment

The expected changes in temperature and rainfall are expected to be accompanied by a significant change in bioclimatic levels in Lebanon, particularly their geographical extent in terms of percent of total cover. The Oromediterranean level is projected to disappear from Lebanon by 2080, while the Arid bioclimatic level is expected to increase from 5 to 15 % in area (MoE et al., 1999; UNEP-MAP, 2009). In addition to the need for the species to migrate upward/northward, other impacts on forests in Lebanon related to climate change could be expected as follows:

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

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

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

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

4.7.4 Adaptation measures

As forest resilience refers to the capacity of a forest to withstand and absorb changes in the environment, adaptation will imply understanding and influencing these conditions to increase forest resilience (Regato, 2008), with the overall perspective of increasing and conserving forest ecosystem services. However, since the forestry sector is considered as a sink and a vulnerable sector, many measures proposed for mitigation (to increase carbon sequestration) can be applied for adaptation. Additional measures could be recommended to assist the natural resilience of forests, anticipate future changes and promote landscape scale in the adaptation options.

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

Grid box	Dominant forest type	Av Q1 1960-1981	Bioclimatic level	Av Q2 2020-2044	Bioclimatic level	Av Q3 2080-2098	Bioclimatic level
148	*Quercus spp.*	150	Humid	120	Humid	105	Humid
269	*Quercus, mixed pinus*	165	Humid	150	Humid	90	Sub-humid
380	*Quercus, Pinus pinea and Pinus brutia*	240	Humid	150	Humid	90	Sub-humid
487	*Juniperus, Quercus*	90	Sub-humid	90	Sub-humid	60	Sub-humid
837	*Juniperus, Cedrus, Abies, Mixed Quercus/ Pinus*	75	Sub-humid	75	Sub-humid	45	Semi-arid
951	*Juniperus, Quercus and Pinus brutia*	345	Perhumid	195	Humid	120	Humid
1001	*Quercus, Pinus brutia*	225	Humid	120	Humid	90	Sub-humid
1112	*Quercus*	404	Perhumid	330	Perhumid	180	Humid
1208	*Juniperus*	75	Sub-humid	49	Semi-arid	34	Semi-arid
1368	*Cedrus, mixed Juniperus and Quercus*	315	Perhumid	255	Perhumid	135	Humid
1526	*Juniperus*	240	Humid	195	Humid	120	Humid

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

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

The cost of vulnerability and adaptation in natural ecosystems is inherently problematic. The Lebanese government spends on nature conservation around USD 300,000 per year, mainly dedicated for the management of nature reserves, while the action plan for protected areas has foreseen a sum of USD 4,685,000 over 5 years (MoE, 2006) to encompass ecological conservation, extension of protected areas, diversification of protected area types as well as awareness, institutional capacity building and ecotourism promotion. This action plan aims to reduce the threat form habitat fragmentation and the vulnerability of ecosystems and species to the pressures of climate change. This cost, considered as vulnerability and adaptation costs, is underestimated as the adaptation activities adopted to reduce the vulnerability of species and ecosystems should account for different extra actions needed such as land acquisition for corridors and the fluctuation of land prices with time. It should also include the costs of pest management to fight pest infestation resulting from climate change implications on nature reserves in Lebanon.

Table 4-14 Forestry adaptation action plan

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

		- Promoting the protection of existing OWL to enable their future development into forest cover - Promoting landscape connectivity in terms of natural corridors between forests and OWL Emulate long distance dispersal through habitat restoration Diversify habitat type, forest types and land uses at landscape level Modify existing legislation to increase buffer zones around protected areas and to minimize the impact of future climate change
	Strengthen the awareness and education and support research	Increase awareness on ecosystem services and climate change to key target groups such as government agencies, order of engineers and architects, universities (introduction of related courses), schools (revision of curriculum) Collect, conserve and disseminate traditional and local knowledge, innovations and practices related to biodiversity conservation Promote research and implementation of soil conservation, as soil carbon not only constitutes a carbon sink, but also improves site productivity Promote and inform on forest ecosystems services
	Develop forest management plans	Prepare management plans for the most vulnerable ecosystems to climate change, with due consideration to the following needs: - Implement effective fire management strategies through forest management - Adopt an ecosystem/community philosophy for reforestation activities: tree and understory species should be reintroduced on carefully planned sites - Explore and cultivate drought tolerant ecotypes (when needed) - Increase genetic, species and landscape diversity within the limits of ecological composition (vegetation series) - Establish collections of seeds for the main forest tree species and understory species (seed/gene banks) - Establish natural and ecological corridors to promote protected areas networks - Adopt effective land management practices, such as sustainable grazing, to prevent large reductions in ground cover - Conserve and/or restore biotic dispersal vectors: birds, insects, and migratory species - Plan reforestation activities including future migration anticipation

4.8 Vulnerability and Adaptation of the Public Health Sector

4.8.1 Methodology

Scope of Assessment

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

- The direct effects result from changing temperatures that trigger the outbreak of infectious diseases; from heat waves that can increase morbidity and mortality; and other extreme weather events and their consequences such as floods, storms, and massive fires, which can cause an increase in the number of casualties;
- The indirect effects of climate change on human health include droughts and floods affecting agriculture and leading to malnutrition; scarcity of clean water, which widely impairs hygienic conditions; and migration due to changing environments, which makes humans vulnerable to a whole host of diseases.

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

Methods of Assessment

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

Development of the sector under socio-economic scenarios

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

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

4.8.2 Vulnerability assessment

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

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

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

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

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

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

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

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

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

4.8.3 Impact assessment

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

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

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

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

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

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

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

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

Table 4-15 Climate sensitive infectious diseases

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

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

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

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

4.8.4 Adaptation Measures

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

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

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

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

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

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

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

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

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

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

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

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

4.9 Vulnerability and Adaptation of the Tourism Sector

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

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

4.9.1 Methodology

Scope assessment

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

Development of the sector under socio-economic scenarios

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

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

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

4.9.2 Vulnerability assessment

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

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

4.9.3 Impact assessment

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

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

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

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

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

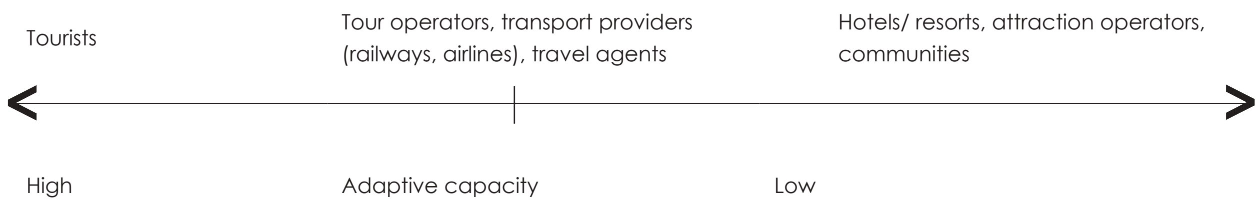


Figure 4-43 Relative adaptive capacity of major tourism sub-sectors

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

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

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

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

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

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

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

Source: UNWTO et al., 2008

4.9.4 Adaptation Measures

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

High mountain areas and winter tourism destinations at risk

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

Coastal areas at risk

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

Natural areas at risk

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

Other general adaptation measures include:

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

4.10 Vulnerability and Adaptation of Human settlements and Infrastructure

4.10.1 Methodology

Scope of assessment

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

Development of the sector under socio-economic scenarios

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

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

4.10.2 Vulnerability assessment

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

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

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

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

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

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

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

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

Figure 4-44 Flood risk areas versus population distribution

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

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

4.10.3 Impact assessment

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

Impacts on urban agglomeration

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

Impacts on buildings

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

Impacts on public and service infrastructure

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

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

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

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

Impacts in socio-economic systems

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

4.10.4 Adaptation measures

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

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

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

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

Other Information:
Public Awarness, Education
And Capacity Building

5 OTHER INFORMATION: PUBLIC AWARENESS,EDUCATION AND CAPACITY BUILDING

This section presents an analysis of the enabling environment for the effective implementation of climate change mitigation and adaptation measures. Existing conditions were reviewed, constraints and gaps identified, and measures to improve the enabling environment were proposed.

It is partly based on the review of previous national general and sector-specific studies (MoE et al., 1999; MoE et al., 2002a; MoE et al., 2002b; MoE et al., 2007), and analyzes aspects of the enabling environment such as the institutional and policy framework, access to technology, climatic systematic observation, climate research, education, training and awareness, capacity building and information sharing.

5.1 Institutional and Policy Framework

Law 690/2005 has stipulated the inclusion of climate change into the main mandate of the Ministry of Environment, specifically under the Service of Environmental Technology.

Apart from Law 359/1994 and Law 738/2006 relating to the ratification of the UNFCCC or the Kyoto Protocol respectively, no major legislation directly addresses climate change. However, a number of regulations have addressed issues that could be linked to climate change, such as the reduction of air pollution from transport (Law 341/2001), the reduction of energy import by developing local energy including renewable energies (Council of Ministers, decision No 13/2004), energy efficiency standards and labels, or other decisions relating to the ratification of conventions such as the UN Convention on Biodiversity or the UN Convention to Combat Desertification. Additionally, a draft law on the Protection of Air Quality is currently being reviewed by the Council of Ministers prior to enactment. It includes a section on emissions control which would positively reflect on GHG emissions in Lebanon.

Several climate change-related projects have been conducted primarily by the MoE, and other non-governmental and academic organizations. Nevertheless, only recently has the Lebanese context featured the necessary political awareness and will to start addressing climate change through an appropriate legal, institutional and policy framework. However, no inter-governmental and inter-institutional coordination and cooperation mechanisms are in place, which undermines the government's ability to carry out cohesive and synergetic response measures.

Whereas it is clear that most climate measures can only be effective if integrated into existing and planned policy frameworks and strategies, the mainstreaming process is still at its very early stages in Lebanon.

The idea of creating a National Committee for Climate Change and Desertification (NCCCD) has been brought forward in the 2009 Ministerial Declaration (under the Protection of the Environment section). Given the multi-sectoral nature of climate change policies, a way forward is for the NCCCD to be composed of line ministries, and other relevent national academic/research groups and NGOs whose activities and coordination mechanism will have to be further elaborated. Each ministry will work within its mandate as assigned by existing laws and regulations to mainstream to the extent required climate change concepts into sectoral development plans and policies. It is important to note that the MoE would remain the designated national focal point to the UNFCCC as well as the Designated National Authority (DNA) of the Clean Development Mechanism (CDM).

5.2 Access to Technology

In Lebanon, there is a significant need to upgrade existing technologies to achieve lower energy consumption and lower emissions (MoE et al., 2007). Major barriers to effective technology transfer identified include the outdated available policies and legislations that often preclude new technologies or restrict their market, the lack of funding for cost-intensive new technologies, the competitiveness with already well-established products, the immaturity of new technologies, the lack of skilled human resources and of technical resources, and the lack of public awareness.

Most technologies remain expensive and un-incentivized. Solar water heaters, however, have gained a competitive share of the Lebanese market, with several local dealers offering technical expertise and competitive prices, and several banks providing targeted loans. A Memorandum of Understanding (MoU) has been signed between the Central Bank and the United Nations Development Program (UNDP) for technical cooperation on launching a National Energy Efficiency and Renewable Energy Account (NEEREA). The MoU includes a complete funding mechanism that would allow organizations from different sectors to implement models of energy conservation at 0% interest rates with full risk guarantees.

However, direct and tangible incentives remain hard to perceive. The need to make economic incentives more obvious through tax adjustments and awareness raising is important.

The most significant policy options for accelerating technology transfer to Lebanon include the adjustment of energy prices through the development of suitable market based programs and development of proper regulation including incentives/taxing, customs policies processes, quality control systems and norms, etc. The engagement of private sector is highly encouraged.

5.3 Climatic Systematic Observation

Monitoring and observation are essential for establishing a proper understanding of climate change trends, contributions to climate change, and risks related to it. Lebanon still lacks a comprehensive national monitoring system within a cohesive climate research framework. A limited number of studies and reports have been made available in various sectors, however often serving specific interests and purposes without fitting into a nation-wide monitoring plan.

Existing systematic monitoring frameworks in Lebanon include a relatively modern network of meteorological and atmospheric monitoring systems, operated by the Lebanese Meteorological Service (LMS) (8 synoptic and 35 standard meteorological stations). Other networks are operated by the Lebanese Agricultural Research Institute (LARI), private universities and research institutes (AUB, USJ, ICARDA and TEDO). Lebanon is also equipped with a less modern oceanographic monitoring system (3 coastal moored buoys) installed by LMS that is in need of upgrading. Additionally, the National Center for Marine Sciences measures water quality parameters on a periodical basis. In addition, Lebanon has a terrestrial and ecological monitoring system, where some systematic monitoring is available for terrestrial observations (soil temperature by LMS, AUB and ICARDA, and radiation measurements by LMS), but practically none for ecological ones. The Litani River Authority (LRA) performs regular river flow measurements. Few researchers have been working on bio-indicators for climate such as reptiles and insects, but research has not yet been translated into systematic monitoring activities. This category is thus in need of an upgrade, financial resources to start generating appropriate homogenized information and proper centralized dissemination of data, increase expertise and proper coordination and cooperation among research and observatory bodies. It is also recommended to establish institutional and legal frameworks for systematic observation networks that comprehensively encompass all environmental media by identifying priority indicators as well as vulnerable areas.

5.4 Climate Research, Education, Training and Awareness

Lebanon still lacks comprehensive formal education directly addressing climate change, as no academic or vocational programs directly tied to climate change are available so far. However, several faculties and research institutes and departments within the different universities (AUB, USJ, LAU, NDU, LU) do offer programs indirectly related to climate change as part of environment-related curricula. Other non-academic research institutes (NCSR, NCMS, LARI, IRI) are also involved in research related to climate change.

Similarly to the case of systematic observation, academic and non-academic research in Lebanon is driven by the availability of funds, without clear national guidance and directions. Interdisciplinary research and coordination between researchers also remain limited.

Civic education within the school curricula already addresses environmental issues and could be extended to further focus on climate change. Similarly, technical and vocational institutes and programs need to integrate climate change science, especially with regards to specific skills in the fields of renewable energy technologies, water and energy efficiency techniques, green buildings, hybrid cars, etc.

On another front, public interest and awareness on the issue of climate change has been growing globally, regionally and nationally for the last several years. Wide media coverage had actually followed the recent developments in international negotiations and contributed to general awareness raising through further exposing the issue and its implications.

The Ministry of Energy and Water is playing a particular role in promoting awareness related to energy efficiency and conservation in Lebanon.

In addition to governmental initiatives, Non-Governmental Organizations (NGOs) play a key role in raising awareness. The work of NGOs covers a wide array of topics related to climate change, from policy papers (IndyAct) to activities concerned with reforestation, biodiversity conversation, etc. (AFDC, GeenLine, SPNL), and activities related to the development and promotion of renewable technologies (ALMEE). Stronger participation of civil society at international negotiations and in international events can also help raise local awareness and interest.

5.5 Capacity Building

Training of designers and technicians on the installation and maintenance of renewable energy systems is essential. Although experience has been gained in the country with regard to solar water heaters, more capacity should be invested in concentrated solar panels, photovoltaics, and wind energy systems. Trainings also need to target car technicians to improve their skills and knowledge of hybrid cars.

On the level of research and systematic observation, the modernization and reorganization of climate monitoring services is needed, with a view of increasing data availability and quality. Training of individuals and research institutions on data base establishment and on anthropogenic emission assessment, as well as on climate modelling, are also recommended. Modern technologies as well as skilled and qualified human resources are necessary.

Also, both public and private sector need to be enabled to benefit from Clean Development Mechanisms. This requires strengthening the capacity of the Designated National Authority (DNA) to develop a clear strategy to promote the implementation of CDM projects in Lebanon.

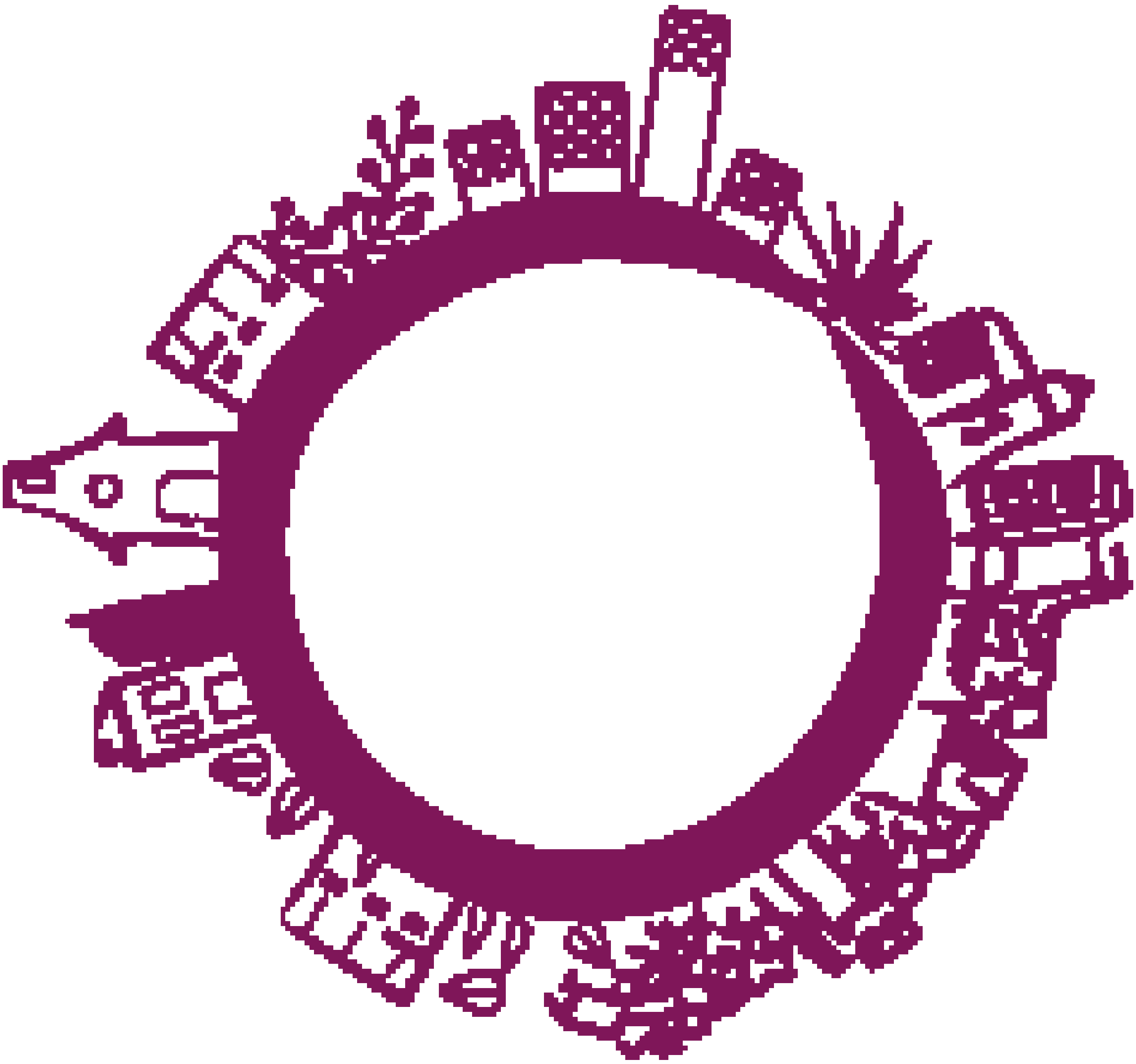
5.6 Information Sharing

Available information published in newsletters, factsheets, and progress reports is generally distributed among several agencies, research bodies and private units. Such information is generally hard to retrieve.

Access to information is therefore quite complicated given the scarcity of data and the absence of a data management mechanism, resulting in redundant and conflicting data.

In order to facilitate access to information and potentially increasing data availability and data sharing, data sharing agreements and protocols between the different ministries and national agencies are necessary. Also, cooperation among research institutions through the preparation of Letters of Agreement is encouraged. The creation of a virtual platform (website, online forums, etc.) where information can be freely shared is necessary.

Constraints, Gaps and Related Financial, Technical and Capacity Needs



6 Constraints, Gaps and Related Financial, Technical and Capacity Needs

Several barriers need to be overcome in order to enable Lebanon to comply with the fundamental principles of the Convention. At present existing main barriers can be categorized into three groups: constraints for the preparation of national communications, difficulties in implementing the proposed mitigation and adaptation measures, and financial constraints.

6.1 Preparation of national communications

In general terms, lack of and access to data are the main barriers that proved to be the most hindering. The lack of statistics particularly affects the assessment of GHG emissions and economic development scenarios.

The absence of scientific assessments and research in terms of assessing e.g., economic impacts of climate change, the ecological impacts of global warming and the degree of resilience of the different systems are hindering the prioritization of adaptation strategies in the decision-making process. The lack of expertise in climate simulation is also considered as a major gap.

6.2 Mitigation and adaptation strategies

Electricity

The weak institutional structure of the EDL and the lack of private sector involvement, the insufficient incentives to promote renewable energies, from one part, and the low efficiency of the power plants, high technical losses, accompanied by a lack of measures to reduce demand, from another part, will hinder the implementation of the proposed measures. There is also a lack of sufficient information on the potential of different renewable energy sources at the policy level, and awareness on their and energy efficiency measures' benefits at the population level.

Transport

Several factors hinder the implementation of mitigation efforts in the transport sector. The absence of legislation governing vehicle emissions and vehicle retirement age, along with the inappropriate infrastructure in accommodating both the ever increasing traffic and the adoption of a well-organized public transport sector, constitute a drastic barrier in the implementation of any proposed plan.

Industry

There is an avert need in improving the efficiency of power generators and production processes in the industrial sector. The major constraints are the inappropriate emissions standards, lack of enforcement of regulations in place, and the high cost of technology and lack of financial support and incentives for the promotion of low emission technologies.

Building and Construction

The improvement of the building envelopes' thermal characteristics is an important measure, which, in the absence of any mandatory application of the already developed national thermal standards and along with incentives for their application, is faced with hindrance. The situation is further exacerbated with the high cost of building insulation techniques and lack of awareness with respect to their long term benefits, and the limited technical know-hoe in the field.

Forestry and Land Use

The sector is deficient and/or lacks adequate legislation and enforcement of regulations pertaining to forest management and planning, in addition to overlapping mandates and poor coordination among governmental bodies. This is partially due to the lack of mainstreaming of biodiversity conservation and ecosystem management in policy making. There is limited budgetary support for managing e.g., many of the country's protected areas, whereas, high financial inputs are required to ensure natural forest regeneration and development, and the sector is highly void of appropriate infrastructure/ equipment for quick interventions in cases of fires and pest outbreaks.

The lack of vocational training, the weakness of the training programs, the scarcity of applied research, and the lack of information on ecosystem services and the forest values are only aggravated by the chronic lack of funding.

Agriculture

Several constraints related to water rights in communal and private springs, the imports of materials used in organic farming and facilitating the adoption of IPM are considered as barriers. There is also a lack of enough staff at the ministry of agriculture as well as private enterprises, which is leading to constraints related to quality control and traceability. The absence of several technologies related to animal husbandry, of insectariums and local providers of traps, pheromones, biological pesticides and natural predators, as well as machineries required for no-till agriculture constitute technological constraints. There is also a pressing need in training farmers and agricultural engineers in sustainable practices and the introduction of new climate resilient cultivars and rootstocks.

Solid Waste

From the legislation perspective, the absence of a grid feed-in tariff and proper regulatory text related to the operation of waste incineration facilities are considered areas where more work is required, especially if waste to energy technologies are planned to be deployed. The country lacks a single, and empowered, regulatory body responsible for the solid waste sector, which lead to several unsuccessful waste management. Local technologies are deficient, and technology transfer is required. Public awareness on the need to start waste segregation at the household level is essential, for a successful waste management.

Water

There is a colossal lack of enforcement in permitting and control of groundwater abstraction. In addition, the inadequate tariff system hinders water conservation. The legal requirement to develop watershed management plans are poorly enforced, while standards pertaining to the reuse of wastewater, greywater and storm water, as well as aquifer recharge are not available. These are accompanied by the limited experience in artificial recharge, watershed management and maintenance of water monitoring systems, with the limited awareness of the population on needs for water conservation makes this sector particularly vulnerable.

Coastal Zone

The major legal constraint identified is the lack of enforcement of regulations related to setting building violation and identifying setback regulations in coastal areas. An institutional mechanism to protect and manage important sites as well as historical/natural assets along the coast is absent, while there is limited coordination between technical agencies and authorities for effective exchange of technical information and proper management.

Human Health

The limited coordination between the health care providers and the MoPH can prove to be detrimental in cases of natural disasters. Specifically, the lack of any surveillance system linking the health care providers to a centralised health databank in MoPH is striking. The limited access to proper sanitation and safe water in underserved areas makes the situation worse. The population also lacks awareness on impacts of climate change on health.

6.3 Financial resources

The Global Environment Facility financially supported Lebanon in preparing the Initial and Second National Communications, Technology Needs Assessment/ Technology Transfer enabling activities, and National Capacity Self Assessment for Global Environmental Management project. All the above mentioned projects have been conducted by the Ministry of Environment, with the support of the UNDP, in addition, in the case of the Second National Communication, to the National Communication Support Programme.

Lebanon, through the Ministry of Environment, contributed in-kind to the climate change related projects, in addition to a USD 20,000 in cash contribution to the SNC process.

Lebanon’s financial needs enabling it to tackle climate change problems required funding in the range of USD 1.5 to 3 billion. These figures are for the short-term and some of the medium-term proposed plans, and the number is much higher when all areas, which have not been able to be properly assessed, are included. The inclusion of long-term plans will further swell the required financial resources.

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Appendix A

Table 1 Sectoral report for energy

(Sheet 1 of 3)

SECTORAL REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)							
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Total Energy	**13,786.20**	**1.61**	**0.11**	**57.95**	**455.38**	**85.68**	**92.59**
A Fuel Combustion Activities (Sectoral Approach)	**13,786.20**	**1.61**	**0.11**	**57.95**	**455.38**	**85.68**	**92.59**
1 Energy Industries	**5,752.89**	**0.23**	**0.05**	**15.22**	**1.14**	**0.38**	**61.19**
a Public Electricity and Heat Production							
b Petroleum Refining							
c Manufacture of Solid Fuels and Other Energy Industries							
2 Manufacturing Industries and Construction	**2,830.60**	**0.06**	**0.02**	**6.43**	**0.32**	**0.16**	**23.46**
a Iron and Steel							
b Non-Ferrous Metals							
c Chemicals							
d Pulp, Paper and Print							
e Food Processing, Beverages and Tobacco							
f Other							

Table 1 Sectoral report for energy

(Sheet 2 of 3)

SECTORAL REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)							
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
3 Transport	**3,929.40**	**1.14**	**0.03**	**34.46**	**453.55**	**85.05**	**2.56**
a Civil Aviation	0.00	0.00	0.00	0.00	0.00	0.00	
b Road Transportation	3,929.40	1.14	0.03	34.46	453.55	85.05	
c Railways	0.00	0.00	0.00	0.00	0.00	0.00	
d Navigation	0.00	0.00	0.00	0.00	0.00	0.00	
e Other	0.00						
Pipeline Transport	0.00						
4 Other Sectors	**1,273.30**	**0.18**	**0.01**	**1.84**	**0.37**	**0.09**	**5.37**
a Commercial/Institutional	336.71	0.05	0.00	0.50	0.10	0.02	
b Residential	443.49	0.07	0.00	0.66	0.13	0.03	
c Agriculture/Forestry/Fishing	493.10	0.07	0.00	0.67	0.13	0.03	
5 Other	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
B Fugitive Emissions from Fuels	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
1 Solid Fuels	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
a Coal Mining		0.00					
b Solid Fuel Transformation							
c Other							
2 Oil and Natural Gas	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
a Oil		0.00		0.00	0.00	0.00	0.00
b Natural Gas		0.00					
c Venting and Flaring		0.00					

Table 1 Sectoral report for energy

(Sheet 3 of 3)

SECTORAL REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)							
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
International Bunkers	**408.12**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Aviation	381.55	0.00	0.00	0.00	0.00	0.00	0.00
Marine	26.56	0.00	0.00	0.00	0.00	0.00	0.00
CO_2 Emissions from Biomass	**0.00**						

Table 2 Sectoral report for industrial processes

(Sheet 1 of 2)

SECTORAL REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)													
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2	HFCs		PFCs		SF_6	
								P	A	P	A	P	A
Total Industrial Processes	**1,780.98**	**0.00**	**0.00**	**0.00**	**0.00**	**38.91**	**0.84**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
A Mineral Products	**1,652.98**	**0.00**	**0.00**	**0.00**	**0.00**	**36.12**	**0.84**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
1 Cement Production	1,630.87						0.84						
2 Lime Production	21.73												
3 Limestone and Dolomite Use	0.00												
4 Soda Ash Production and Use	0.39												
5 Asphalt Roofing					0.00	0.04							
6 Road Paving with Asphalt						35.84							
7 Other	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Glass Production						0.24							
Concrete Pumice Stone							0.00						
B Chemical Industry	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
1 Ammonia Production	0.00				0.00	0.00	0.00						
2 Nitric Acid Production			0.00	0.00									
3 Adipic Acid Production			0.00	0.00	0.00	0.00							
4 Carbide Production	0.00	0.00											
5 Other		0.00		0.00	0.00	0.00	0.00						
C Metal Production	**128.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
1 Iron and Steel Production	128.00			0.00	0.00	0.00	0.00						
2 Ferroalloys Production	0.00												
3 Aluminium Production	0.00			0.00	0.00		0.00				0.00		
4 SF_6 Used in Aluminium and Magnesium Foundries													0.00
5 Other	0.00												

Table 2 Sectoral report for industrial processes

(Sheet 2 of 2)

SECTORAL REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)													
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2	HFCs		PFCs		SF_6	
								P	A	P	A	P	A
D Other Production	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**2.78**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
1 Pulp and Paper				0.00	0.00	0.00	0.00						
2 Food and Drink						2.78							
E Production of Halocarbons and Sulphur Hexafluoride	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
1 By-product Emissions									0.00		0.00		
2 Fugitive Emissions									0.00		0.00		
3 Other													
F Consumption of Halocarbons and Sulphur Hexafluoride	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
1 Refrigeration and Air Conditioning Equipment									0.00		0.00		
2 Foam Blowing									0.00		0.00		
Fire Extinguishers									0.00		0.00		0.00
4 Aerosols									0.00		0.00		
5 Solvents									0.00		0.00		
6 Other									0.00		0.00		0.00
G Other (please specify)													
P = Potential emissions based on Tier 1 Approach. A = Actual emissions based on Tier 2 Approach. This only applies in sectors where methods exist for both tiers.													

Table 3 Sectoral report for solvent and other product use

(Sheet 1 of 1)

SECTORAL REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)			
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	N_2O	NMVOC
Total Solvent and Other Product Use	0.00	0.00	3.97
A Paint Application			0.98
B Degreasing and Dry Cleaning			2.45
C Chemical Products, Manufacture and Processing			
D Other Ink			0.54

Table 4 Sectoral report for agriculture

(Sheet 1 of 2)

SECTORAL REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)					
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CH_4	N_2O	NO_x	CO	NMVOC
Total Agriculture	**0.60**	**2.99**	**0.03**	**0.77**	**0.00**
A Enteric Fermentation	**6.03**				
1 Cattle	2.62				
2 Buffalo	0.00				
3 Sheep	0.87				
4 Goats	2.09				
5 Camels and Llamas	0.02				
6 Horses	0.11				
7 Mules and Asses	0.31				
8 Swine	0.02				
9 Poultry	0.00				
10 Other					
B Manure Management	**0.51**	**0.34**			
1 Cattle	0.12				
2 Buffalo	0.00				
3 Sheep	0.03				
4 Goats	0.07				
5 Camels and Llamas	0.00				
6 Horses	0.01				
7 Mules and Asses	0.03				
8 Swine	0.05				
9 Poultry	0.20				

Table 4 Sectoral report for agriculture

(Sheet 2 of 2)

SECTORAL REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)					
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CH_4	N_2O	NO_x	CO	NMVOC
B Manure Management (cont...)					
10 Anaerobic		0.00			
11 Liquid Systems		0.00			
12 Solid Storage and Dry Lot		0.34			
13 Other		0.00			
C Rice Cultivation	**0.00**				
1 Irrigated	0.00				
2 Rainfed	0.00				
3 Deep Water	0.00				
4 Other					
D Agricultural Soils		**2.65**			
E Prescribed Burning of Savannas	**0.00**	**0.00**	**0.00**	**0.00**	
F Field Burning of Agricultural Residues	**0.06**	**0.00**	**0.03**	**0.77**	
1 Cereals					
2 Pulse					
3 Tuber and Root					
4 Sugar Cane					
5 Other					
G Other					

Table 5 Sectoral report for land-use change and forestry

(Sheet 1 of 1)

SECTORAL REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)						
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	NO_x	CO
Total Land-Use Change and Forestry	**0.00**	**-143.87**	**2.90**	**0.02**	**0.72**	**25.34**
A Changes in Forest and Other Woody Biomass Stocks	**0.00**	**-807.60**				
1 Tropical Forests						
2 Temperate Forests						
3 Boreal Forests						
4 Grasslands/Tundra						
5 Other						
B Forest and Grassland Conversion	**663.73**		**2.90**	**0.02**	**0.72**	**25.34**
1 Tropical Forests	0.00					
2 Temperate Forests	663.73					
3 Boreal Forests	0.00					
4 Grasslands/Tundra	0.00					
5 Other	0.00					
C Abandonment of Managed Lands		**0.00**				
1 Tropical Forests		0.00				
2 Temperate Forests		0.00				
3 Boreal Forests		0.00				
4 Grasslands/Tundra		0.00				
5 Other		0.00				
D CO_2 Emissions and Removals from Soil	**0.00**	**0.00**				
E Other						

Table 6 Sectoral report for waste

(Sheet 1 of 1)

SECTORAL REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)						
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	NO_x	CO	NMVOC
Total Waste	**2.96**	**78.68**	**0.26**			
A Solid Waste Disposal on Land	**0.00**	**78.10**	**0.00**			
1 Managed Waste Disposal on Land						
2 Unmanaged Waste Disposal Sites						
3 Other						
B Wastewater Handling	**0.00**	**0.59**	**0.26**			
1 Industrial Wastewater		0.00				
2 Domestic and Commercial Wastewater		0.59	0.26			
3 Other						
C Waste Incineration	**2.96**					
D Other						

Table 7a Summary report for national greenhouse gas inventories

(Sheet 1 of 3)

SECTORAL REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)														
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	NO_x	C	NMVOC	SO_2	HFCs		PFCs		SF_6	
									P	A	P	A	P	A
Total National Emissions and Removals	**15,570.15**	**-143.87**	**89.76**	**3.38**	**58.69**	**481.49**	**128.56**	**93.43**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
1 Energy	**13,786.20**	**0.00**	**1.61**	**0.11**	**57.95**	**455.38**	**85.68**	**92.59**						
A Fuel Combustion (Sectoral Approach)	13,786.20		1.61	0.11	57.95	455.38	85.68	92.59						
1 Energy Industries	5,752.89		0.23	0.05	15.22	1.14	0.38	61.19						
2 Manufacturing Industries and Construction	2,830.60		0.06	0.02	6.43	0.32	0.16	23.46						
3 Transport	3,929.40		1.14	0.03	34.46	453.55	85.05	2.56						
4 Other Sectors	1,273.30		0.18	0.01	1.84	0.37	0.09	5.37						
5 Other	0.00		0.00	0.00	0.00	0.00	0.00	0.00						
B Fugitive Emissions from Fuels	0.00		0.00		0.00	0.00	0.00	0.00						
1 Solid Fuels			0.00		0.00	0.00	0.00	0.00						
2 Oil and Natural Gas			0.00		0.00	0.00	0.00	0.00						
2 Industrial Processes	**1,780.98**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**38.91**	**0.84**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
A Mineral Products	1,652.98					0.00	36.12	0.84						
B Chemical Industry	0.00		0.00	0.00	0.00	0.00	0.00	0.00						
C Metal Production	128.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D Other Production	0.00				0.00	0.00	2.78	0.00						
E Production of Halocarbons and Sulphur Hexafluoride									0.00	0.00	0.00	0.00	0.00	0.00
F Consumption of Halocarbons and Sulphur Hexafluoride									0.01	0.01	0.01	0.01	0.01	0.01
G Other	0.00		0.00	0.00	0.00	0.00	0.00	0.00				0.00		0.00

P = Potential emissions based on Tier 1 Approach. A = Actual emissions based on Tier 2 Approach.

Table 7a Summary report for national greenhouse gas inventories

(Sheet 2 of 3)

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)														
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	NO_x	CO	NMVOC	SO_2	HFCs		PFCs		SF_6	
									P	A	P	A	P	A
3 Solvent and Other Product Use	**0.00**			**0.00**			**3.97**							
4 Agriculture			**6.60**	**2.99**	**0.03**	**0.77**								
A Enteric Fermentation			6.03											
B Manure Management			0.51	0.34										
C Rice Cultivation			0.00											
D Agricultural Soils				2.65										
E Prescribed Burning of Savannas			0.00	0.00	0.00	0.00								
F Field Burning of Agricultural Residues			0.06	0.00	0.03	0.77								
G Other			0.00	0.00										
5 Land-Use Change & Forestry	**0.00**	**-143.87**	**2.90**	**0.02**	**0.72**	**25.34**								
A Changes in Forest and Other Woody Biomass Stocks	0.00	-807.60												
B Forest and Grassland Conversion	663.73		2.90	0.02	0.72	25.34								
C Abandonment of Managed Lands		0.00												
D CO_2 Emissions and Removals from Soil	0.00	0.00												
E Other	0.00	0.00	0.00	0.00	0.00	0.00								
6 Waste	**2.96**		**78.68**	**0.26**	**0.00**	**0.00**	**0.00**	**0.00**						
A Solid Waste Disposal on Land			78.10											
B Wastewater Handling			0.59	0.26										
C Waste Incineration	2.96													
D Other			0.00	0.00										
7 Other														

Table 7a Summary report for national greenhouse gas inventories

(Sheet 3 of 3)

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)														
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	NO_x	CO	NMVOC	SO_2	HFCs		PFCs		SF_6	
									P	A	P	A	P	A
Memo Items														
International Bunkers	**408.12**		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**						
Aviation	381.55		0.00	0.00	0.00	0.00	0.00	0.00						
Marine	26.56		0.00	0.00	0.00	0.00	0.00	0.00						
CO_2 Emissions from Biomass	**0**													

Table 7b Short summary report for national greenhouse gas inventories

(Sheet 1 of 1)

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)																
GREENHOUSE GAS SOURCE AND SINK CATEGORIES		CO_2 Emissions	CO_2 Removals	CH_4	N_2O	NO_x	CO	NMVOC	SO_2	HFCs		PFCs		SF_6	
										P	A	P	A	P	A
Total National Emissions and Removals		**15,570.15**	**-143.87**	**89.76**	**3.38**	**58.69**	**481.49**	**128.56**	**93.43**	**0**	**0**	**0**	**0**	**0**	**0**
1 Energy	Reference Approach	**13,786.22**													
	Sectoral Approach	**13,786.20**	**1.61**	**0.11**	**57.95**	**455.38**	**85.68**	**92.59**	**93**						
A Fuel Combustion		13,786.20		1.61	0.11	57.95	455.38	85.68							
B Fugitive Emissions from Fuels		0.00		0.00		0.00	0.00	0.00	0.00						
2 Industrial Processes		**1,780.98**		**0.00**	**0.00**	**0.00**	**0.00**	**38.91**	**0.84**	**0**	**0**	**0**	**0**	**0**	**0**
3 Solvent and Other Product Use		**0.00**			**0.00**			**3.97**							
4 Agriculture			**6.60**	**2.99**	**0.03**	**0.77**									
5 Land-Use Change & Forestry		**0.00**	**-143.87**	**2.90**	**0.02**	**0.72**	**25.34**								
6 Waste		**2.96**	**78.68**	**0.26**											
7 Other		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**						
Memo Items:															
International Bunkers		**408.12**		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**						
Aviation		381.55	0.00	0.00	0.00	0.00	0.00	0.00	0						
Marine		26.56	0.00	0.00	0.00	0.00	0.00	0.00	0						
CO_2 Emissions from Biomass		**0**													

P = Potential emissions based on Tier 1 Approach. A = Actual emissions based on Tier 2 Approach.