RICCAR

Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-economic Vulnerability in the Arab Region

WATER
Efficiency, Productivity, and Sustainability
in the Near East and North Africa countries

Climate-proof watershed management design and resilience package

Nahr el Kalb basin

TECHNICAL REPORT

Sweden Sverige

Food and Agriculture Organization of the United Nations

UNITED NATIONS الاسكوا ESCWA

Shared Prosperity Dignified Life

Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR)

E/ESCWA/CL1.CCS/2022/RICCAR/TECHNICAL REPORT.15

Climate-proof watershed management design and resilience package
Nahr el Kalb basin

Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR)

United Nations Economic and Social Commission for Western Asia (ESCWA)

TECHNICAL REPORT

This technical report was written by contributors from the Food and Agriculture Organization of the United Nations (FAO) and the United Nations Economic and Social Commission for Western Asia (ESCWA).

Reference as:
United Nations Economic and Social Commission for Western Asia (ESCWA), Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD), Ministry of Energy and Water of Lebanon and Food and Agriculture Organization of the United Nations (FAO). 2022. Climate-proof watershed management design and resilience package: Nahr el Kalb basin. RICCAR technical report, Beirut, E/ESCWA/CL1.CCS/2022/RICCAR/Technical report.15

Authors:
United Nations Economic and Social Commission for Western Asia (ESCWA)
Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD)
Food and Agriculture Organization of the United Nations (FAO)
Ministry of Energy and Water, Lebanon

23-00122

ACKNOWLEDGEMENTS

The Economic and Social Commission for Western Asia (ESCWA) is supporting implementation of the Food and Agriculture Organization (FAO) project entitled “Implementing the 2030 Agenda for Water Efficiency/Productivity and Water Sustainability in NENA Countries”. The project is funded by the Swedish International Development Cooperation Agency (Sida).

Contributions and analyses for this technical report were provided by Maya Atie and a team from ESCWA that include Marlene Ann Tomaszkiewicz, Mohamed Abd Salam El Vilaly, Elie Alrahi, Ziad Khayat, Sara Hess, Tracy Zaarour, Sarah Daniel and Carol Chouchani Cherfane. The report was prepared in consultation with national stakeholders in Lebanon, including the Ministry of Energy and Water, the Ministry of Agriculture, the Ministry of Environment, the FAO office in Lebanon and the FAO Regional Office for the Near East and North Africa. Data and map information were provided by local stakeholders, including the Beirut Mount Lebanon Water Establishment (BMLWE), the Lebanese Agricultural Research Institute (LARI), and the National Council for Scientific Research (CNRS), and through consultations with local farmers in the Nahr El Kalb basin area. Technical support and input were also provided by the Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD).

The authors would particularly like to thank the key stakeholders who actively participated in consultations for this study.

PREFACE

The Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR) is a joint initiative of the United Nations and the League of Arab States.

RICCAR was launched under the auspices of the Arab Water Council in 2010. Its mandate is guided by resolutions adopted by the Arab Water Council, the Council of Arab Ministers Responsible for the Environment, the Arab Permanent Committee on Meteorology and the ministerial sessions of the Economic and Social Commission for Western Asia (ESCWA).

RICCAR is a collaborative partnership involving 11 regional and specialized organizations. The RICCAR Regional Knowledge Hub (RKH) is managed by ESCWA and ACSAD while FAO hosts the Arab States/Middle East and North Africa region Domain data portal. ESCWA coordinates the regional initiative under the umbrella of its Arab Center for Climate Change Policies.

This report was prepared through a collaboration between ESCWA and ACSAD in consultation with the Ministry of Energy and Water. The study on which the report is based was conducted under an FAO-ESCWA interagency contribution agreement to support the implementation of the FAO project entitled “Implementing the 2030 Agenda for Water Efficiency/Productivity and Water Sustainability in NENA Countries”. This project was led by FAO with funding from Sida from December 2016 to December 2022.

CONTENTS

FIGURES

TABLES

ABBREVIATIONS AND ACRONYMS

ACSAD	Arab Center for the Studies of Arid Zones and Dry Lands
AR4	Fourth Assessment Report
AUB	American University of Beirut
BMLWE	Beirut Mount Lebanon Water Establishment
ESCWA	Economic and Social Commission for Western Asia
ET	actual evapotranspiration
FAO	Food and Agriculture Organization
GCM	global climate model
GHG	greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
IWRM	Integrated Water Resources Management
LARI	Lebanese Agriculture Research Institute
MOA	Ministry of Agriculture
MOE	Ministry of Environment
MOEW	Ministry of Energy and Water
NCSR	National Council for Scientific Research
NDU	Notre Dame University
RCM	regional climate model
RCP	representative concentration pathway
RICCAR	Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region
SDG	Sustainable Development Goal
SIDA	Swedish International Development Cooperation Agency
SPI	Standardized Precipitation Index
SSP	shared socioeconomic pathway
UNFCCC	United Nations Framework Convention on Climate Change
VA	vulnerability assessment
WEF	water-energy-food

EXECUTIVE SUMMARY

The climate-proof watershed management design and resilience package is a collaborative initiative by the Food and Agriculture Organization (FAO) and the Economic and Social Commission for Western Asia (ESCWA) that falls under the auspices of an FAO framework project entitled "Implementing the 2030 Agenda for Water Efficiency/Productivity and Water Sustainability in NENA Countries" (WEPS-NENA), which is being funded by the Government of Sweden. The objective of the package is to support efforts to improve water resource management given the decreasing availability of freshwater and climate change pressures in the Nahr el Kalb basin.

The Nahr el Kalb basin, with a total area of 291 km^2 (begins at the coast and extends to 2,622 m above sea level, supplying approximately 60 per cent of the freshwater needed by the city of Beirut. The basin is used by a range of stakeholders and affects diverse land and water users and economic sectors, including tourism, agriculture and industry. It is also the location of several historical and religious sites. The basin has been identified by the Government of Lebanon as a basin of particular interest and subsequently a water accounting and water governance analysis exercise was conducted as part of the WEPS-NENA framework project.

The package adopted a 10-step methodology that included consultation meetings, new regional climate modelling projections for the Mashreq Domain using RICCAR data, watershed-specific assessments that examine the water-energy-food security nexus within the context of climate change and an integrated vulnerability assessment of the water sector to identify high vulnerability areas across the basin.

- Climate change projections show an increase in average temperatures of 1°C in the near-term (2021–2040) and 2.2°C in the mid-term (2041–2060), with a minimum to maximum gradient extending from the sea to the mountains. Projected decreases in precipitation are estimated to be 5.1 mm/month in the near-term, a decrease of 4 per cent, and 12.1 mm/month in the mid-term, a decrease of 10 per cent. Drought events are expected to increase in severity by about 5 per cent every ten years.

- An integrated vulnerability assessment of the water sector identified areas with the highest rates of vulnerability to climate change, as assessed using the RICCAR methodology. The vulnerability assessment included the participation of major stakeholders from the basin, including public and private sector actors, research institutions, farmer cooperatives, young people and civil society organizations (CSOs). The impact chain developed used a total of 16 sensitivity indicators based on social, environmental and anthropogenic factors that put water resources in Nahr el Kalb basin under pressure. In addition, eight adaptive capacity indicators were selected based on factors that enhance the ability of the basin to accommodate climate change. An increasing vulnerability trend is expected over time and is closely related to a projected increase in exposure indicators. In the mid-term, 32 per cent of the basin area is projected to experience moderate vulnerability and 48 per cent high vulnerability.

- The impact of climate change on apple production in the basin was identified during consultations as a major crop of concern. The CropSyst model was applied without and with concurrent increases of atmospheric CO_2 concentration, as shown in the shared socioeconomic pathway (SSP) 5–8.5 (very high greenhouse gas emission) (SSP5-8.5) scenario. The results projected that climate change will result in a 24 per cent increase in water consumption. In addition, apple yields were projected to decrease by about 48 per cent by 2070.

- Water-energy-food nexus considerations in the context of climate change were analysed in the basin. Agricultural areas in the basin consume a large percentage of water provided by the Chabrouh Dam, freshwater springs and groundwater. Furthermore, energy is needed to pump and distribute water and thus the rehabilitation of the Hrache hydropower plant should be considered in addition to the use of solar energy for irrigation.

The climate-proof watershed management design and resilience package reflects the results and analyses that resulted from consultations with major stakeholders. The package includes a list of 10 suggested intervention measures to be implemented in the Nahr el Kalb basin with a focus on areas with high vulnerability projections. The recommendations presented gauge different scales and levels of interventions from a water-energy-food nexus perspective, including measures that address the expansion of infrastructure projects, the adoption of new and efficient technologies, building capacities and enhancing research, data collection and partnerships. Those interventions aim to improve the availability of water for domestic use, tourism, industry and agriculture, while reducing the stress on surface and groundwater quality and quantity, and to improve livelihoods and access to information.

Furthermore, four intervention measures were shortlisted with the aim of reducing sensitivity and/or enhancing adaptive capacity within the basin. The shortlisted intervention measures include:

- **Intervention measure 1:** enhancing agriculture sector resilience by increasing water availability and promoting sustainable agriculture, including with hill reservoirs and microcatchment rainwater harvesting systems to provide supplementary irrigation water for apple cultivation during dry periods and extreme drought events. This will help minimize the adverse effects of climate change on apple productivity. In addition, it will promote sustainable agriculture that encourages the efficient use of resources and reduces pressure on surface and groundwater resources. Activities to support this measure include rehabilitating irrigation canals, promoting sustainable agricultural practices and increasing agriculture water use efficiency by promoting the adoption of drip irrigation and renewable energy sources within a nexus approach.

- **Intervention measure 2:** improving industrial water use by enhancing water allocation for the industrial sector while minimizing the impact on water quality and quantity. The major objectives of this intervention are to provide alternative sources of water in the industrial sector, to encourage efficient water use in the sector and to reduce industrial water quality contamination, thereby reducing pressure on surface and groundwater resources. This intervention measure is a way to reduce the sensitivity of industrial zones in the lower basin areas to climate change impacts. The consultations and the vulnerability assessment highlighted municipalities with a high percentage of industries as highly vulnerable areas.

- **Intervention measure 3:** expanding livelihood diversification through sustainable tourism. In the Nahr el Kalb basin, and specifically in the upper basin area, most tourism occurs during the snowy winter months in the Kfar Dibiane and Faraya municipalities. Climate change projections foresee a decrease in snow cover and depth. Since livelihoods in the upper basin area are highly dependent on winter tourism, increasing the resilience of the sector is essential. This intervention is a way to enhance the adaptive capacity of the upper basin area to climate change impacts. Diversification of activities and revenue, including a focus on summer activities and gender and youth inclusion is encouraged. Developing year-round tourism and activities not dependent on snow is likely a better long term intervention strategy. Promoting nature-based tourism, including agritourism, ecotourism and landscape-based tourism in the upper basin area is highly recommended as it is an important driver of socioeconomic growth. Intervention measure 3 has the potential to increase and diversify household incomes, enhance job opportunities, improve livelihood resilience and promote nature conservation.

- **Intervention measure 4:** promoting reforestation and reducing the risk of forest fires. The Nahr el Kalb basin has dense forest cover composed of pine forests and other highly combustible material that increases fire hazard risk. Forested areas in the Nahr el Kalb basin are highly susceptible to fires, a phenomenon exacerbated by increasing temperatures and human activity. The integrated vulnerability assessment indicates high vulnerability levels in areas identified as highly susceptible to forest fires. The major objective of this intervention measure is to provide a set of activities that will protect forests in the Nahr el Kalb basin and increase their resilience to climate change impacts. By adopting a nexus perspective and involving members of local communities, including women and young people, this intervention can reduce risk sensitivity and enhance climate change adaptivity. Several components are essential to ensure success, including political support for the development of a watershed strategy for forest protection, research on types of trees and locations considered ideal for reforestation, community engagement, capacity building and youth inclusion.

The interventions focus on improving adaptive capacities in the basin area as a response to the vulnerabilities resulting from climate change and are therefore in line with the Paris Agreement. Among other things, the Agreement seeks to strengthen resilience to climate change by focusing on sustainable development and meeting prescribed temperature goals.

INTRODUCTION

The Economic and Social Commission for Western Asia (ESCWA) has, in recent years, striven to develop a climate-proof watershed management plan and resilience package. That objective has been pursued in three key watersheds in North Africa and the Middle East: in Algeria (Algerois) and in Lebanon (Nahr el Kalb and Nahr el Kabir). This technical report focuses on the Nahr el Kalb basin, the main source of water for Beirut.

The report is divided into two parts. Part 1 discusses the methodology and analysis conducted and is composed of six sections.

- Section I provides a description of the 10-step methodology adopted in the basin and a summary of the three consultations done.
- Section II provides background information on the basin in terms of its natural and socioeconomic characteristics, including information obtained through mapping exercises by major stakeholders and institutions.
- Section III outlines climate change projections for the near-term (2021–2040) and the mid-term (2041–2060) and compares those projections to data from the reference period of 1995–2014.
- Section IV shows the integrated vulnerability assessment of the water sector and identifies areas that exhibit the highest vulnerability to climate change, according to the RICCAR methodology.
- Section V explores the impact of climate change on apple production in the basin since this was identified as a major crop of concern.
- Section VI summarizes the water-energy-food nexus considerations in the basin.

Part 2 outlines the climate-proof watershed management design and resilience package and sets out intervention measures for the basin based on conclusions from the analysis undertaken in part 1.

PART 1: METHODOLOGY AND ANALYSIS

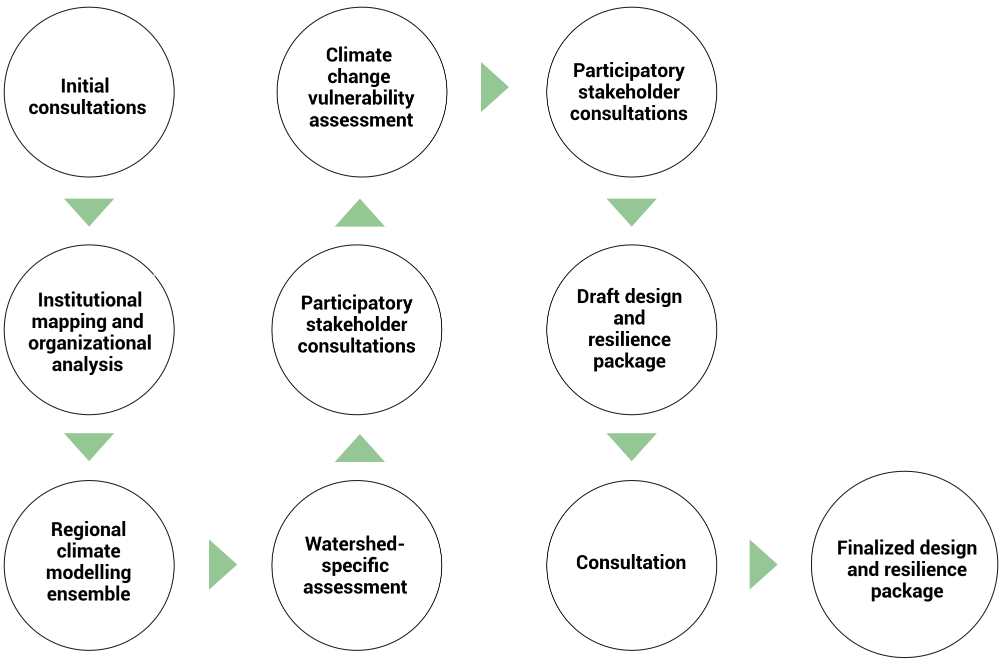
1 METHODOLOGY AND CONSULTATIONS

A. Methodology overview

The Nahr el Kalb basin includes multiple land and water users and economic sectors, including tourism, agriculture and industry, and is also home to historical and religious sites. Urbanization in the basin has encroached on agricultural and forested areas, especially in the lower basin areas.

Research for the Nahr el Kalb basin project was carried out using through a 10-step methodology, illustrated in figure 1, that draws on new regional climate modelling projections for the Mashreq Domain and watershed-specific assessments that examine the water-energy-food nexus and vulnerability factors. The vulnerability assessment is the result of consultations regarding the geospatial indicators identified during the preparation of the "Integrated Vulnerability Assessment Application on the Lebanese Agricultural Sector" (ESCWA, 2019). The assessment took place in parallel with stakeholder consultations.

FIGURE 1: Ten-step project methodology



Source: Authors.

The activities undertaken in the context of the 10-step methodology were:

1. Initial consultations were done with national government counterparts and the Food and Agriculture Organization (FAO) national office to review the scope of work and determine which national institutions and local stakeholder groups should be consulted.
2. Institutional mapping and organizational analysis was carried out to update current information and reflect changes in land use/ land cover in the watershed. It identified areas contributing to pollution and incorporated a human rights-based approach.
3. Regional climate modelling was generated for the Mashreq Domain for SSP5-8.5 at a 10 km grid resolution. The ensemble included six projections that were used to inform the vulnerability assessment and agricultural productivity models.
4. Watershed-specific assessments were conducted to map and examine the water-energy-food security nexus from a climate change perspective. The assessments included measuring the impact of climate change on crop production.

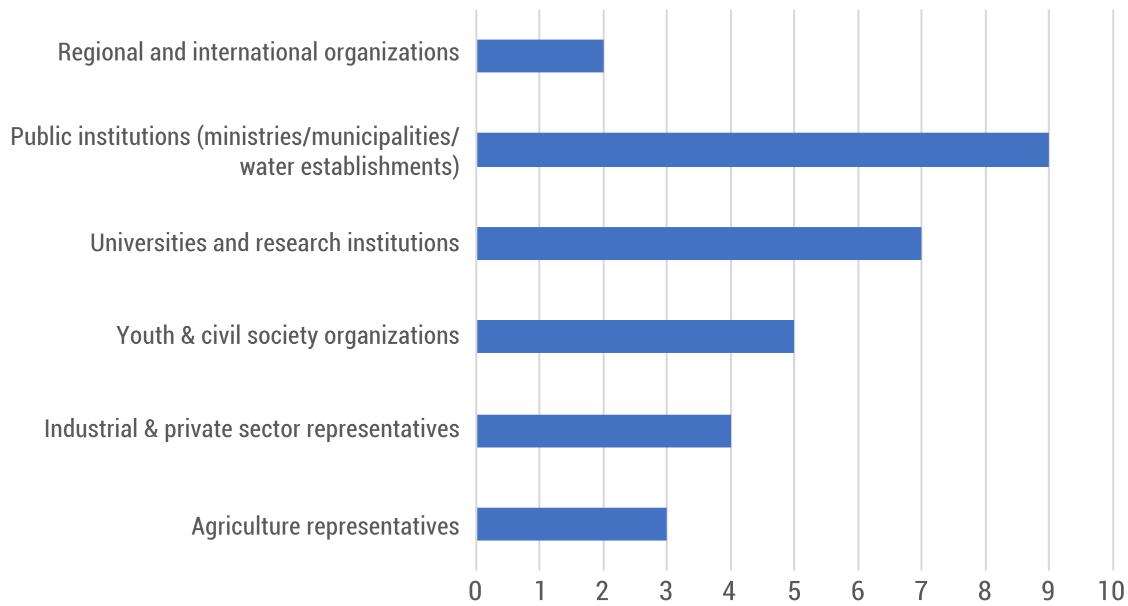
5. Participatory stakeholder consultations were convened to discuss the community's capacity to cope with climate change. Information was collected on vulnerability indicators and was used in the vulnerability assessment.
6. Climate change vulnerability assessments were prepared to project how climate change is likely to affect community livelihoods in the basin using the RICCAR integrated vulnerability assessment methodology, drawing on indicators identified during consultations and the integrated vulnerability assessment of the agricultural sector.
7. Participatory stakeholder consultations were conducted to vet and validate the vulnerability assessment and solicit input on preliminary response measures from an integrated basin management perspective.
8. A climate-proof watershed management design and resilience package was drafted in consultation with FAO local and regional offices, and in close coordination with the Ministry of Energy and Water, the Ministry of Agriculture and the Ministry of Environment.
9. Consultations were undertaken with national counterparts in Beirut and local stakeholders in Mount Lebanon Governorate on the proposed watershed management design and resilience package.
10. Based on feedback received, the climate-proof watershed management design and resilience package was finalized in collaboration with FAO and submitted to national government counterparts.

B. Consultation process

The Nahr el Kalb assessment took place in consultation with major stakeholders in the basin. Three major consultations took place using different formats and with specific objectives.

The first consultation meeting took place on 24 February 2022 at Notre Dame University-Louaize. The meeting brought together 30 stakeholders from the public and private sectors, research institutions, farmer cooperatives, youth and civil society organizations, as well as local citizens (figure 2). The meeting introduced the project to stakeholders and presented preliminary findings. It also included interactive discussion that addressed community-based challenges and capacity deficits affecting climate change adaptability (section VI); identified key crops in the basin that may be impacted by climate change (section V); and prioritized indicators for the vulnerability assessment study (section IV).

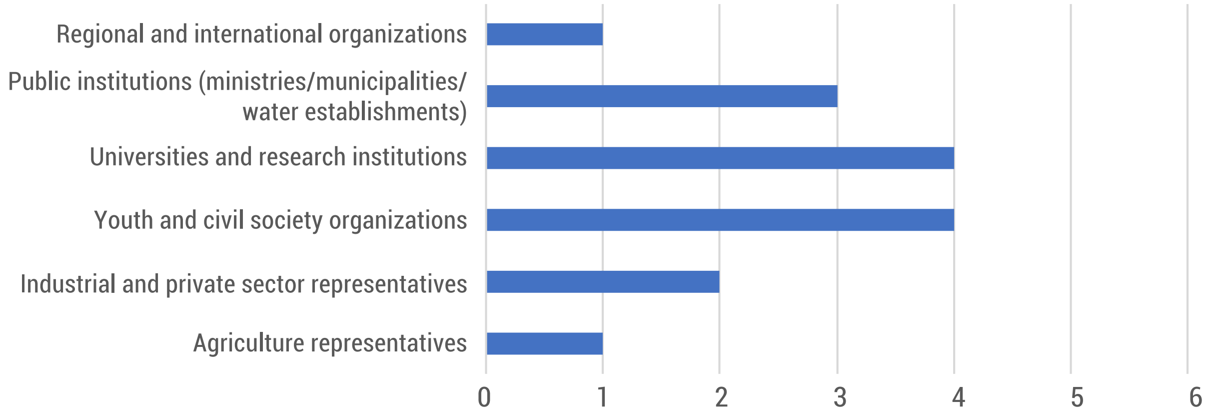
FIGURE 2: Distribution of first consultation participants by stakeholder category



Source: Authors.

The second consultation took place virtually on 28 March 2022. The meeting brought together 15 stakeholders from the public and private sectors, research institutions, youth and civil society organizations, and other entities (figure 3). During the meeting, the results of the vulnerability assessment were presented and discussed, and the preliminary findings of the apple simulation model were shown. The participants discussed response measures needed to increase the resilience of the basin (part 2 of the present report).

FIGURE 3: Distribution of second consultation participants by stakeholder category



Source: Authors.

The third consultation consisted of one-on-one meetings, either in person or by telephone, with selected stakeholders who had attended the first two consultation meetings. The meetings helped draw attention to priority areas for intervention and collect additional input in that regard.

2 WATERSHED DESCRIPTION

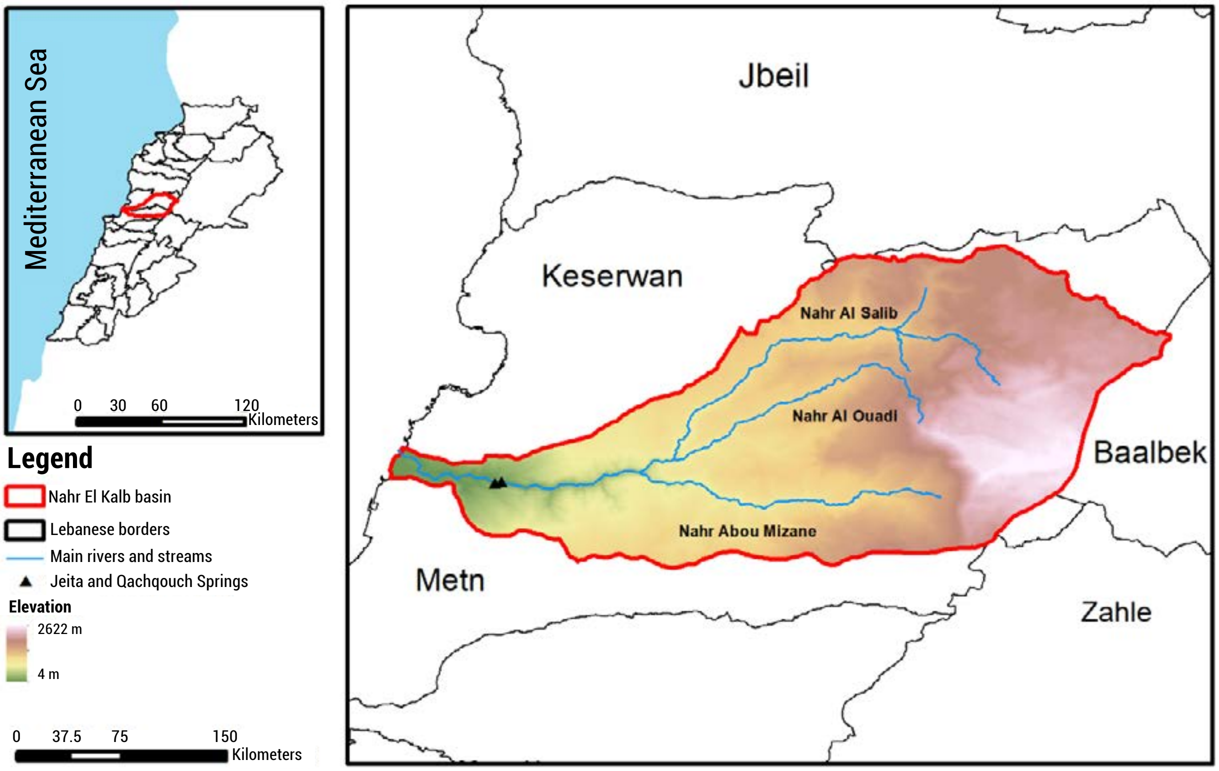
A. Biophysical characteristics

The Nahr el Kalb basin is located, primarily, in the northern part of Mount Lebanon Governorate and covers a total area of 291 km^2. The basin has an elevation variation that extends from the coast to 2,622 m above sea level at Mount Sannine. It encompasses the valley that connects the district of Kesrouane, with 26 municipalities, and the district of Metn, with 55 municipalities, and intersects with 3 municipalities in Baalbek-Hermel Governorate that includes three municipalities.

The basin is characterized by a semi-arid climate with a rainy season that lasts from October to February. The basin is home to Nahr el Kalb, which originates in the highlands of Kesrouane district and reaches the sea at its estuary in Zouk Mousbeh. There are three main tributaries that join to form the main branch of Nahr el Kalb (figure 4).

Kfar Dibiane, photo by Tracy Zaarour

FIGURE 4: Map of the Nahr el Kalb basin

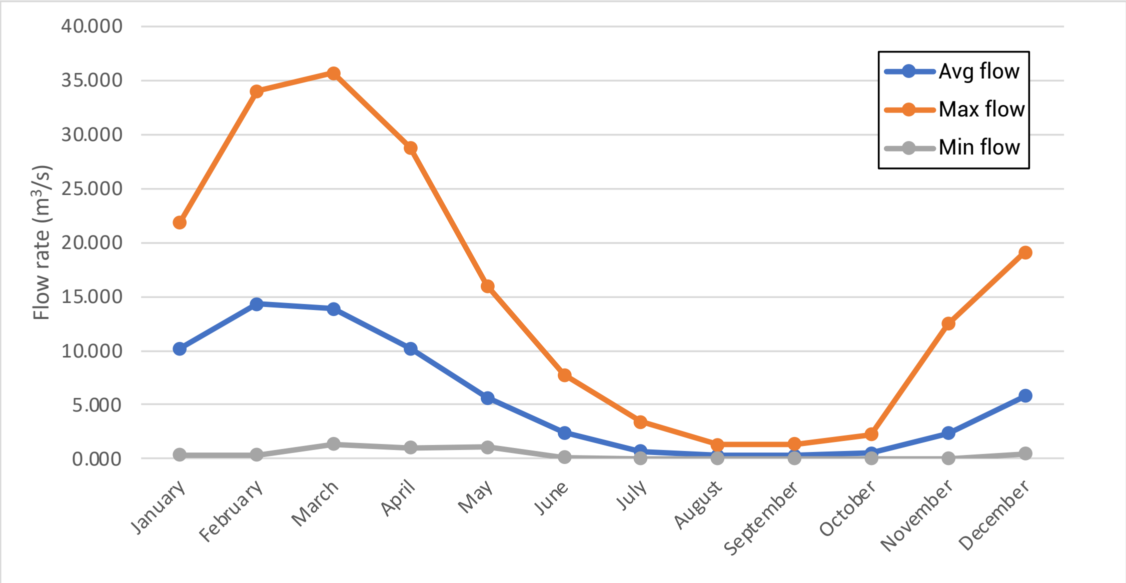


Source: Authors.

Inflow sources to Nahr el Kalb include precipitation and ground water inflow from adjacent basins. The main inflow into the river is runoff from rainfall and snowmelt, which makes water availability highly dependent on seasonal precipitation and spring melting. Outflow is mainly through evapotranspiration, outflow to the sea, groundwater outflow and export of water to Beirut. The flow station at the outlet of the basin indicates that the average monthly river discharge is 5.6 m^3/s with the highest mean monthly outflow of 14.3 m^3/s occurring in February and the lowest in August totaling 0.3 m^3/s during flow recession periods (figure 5). Water from the Jeita springs supplies approximately 60 per cent of the freshwater needs of Beirut. Qachqouch Spring is located about 64 meters above sea level and is used to compensate for water deficits in Beirut and the surrounding areas during low flow periods (Doummar and Aoun, 2018).

Nahr el Kalb in the spring of 2022, photo by Nabil Haddad.

FIGURE 5: Average monthly flowrate of the Nahr el Kalb basin, as measured at the basin outlet (1996–2017)

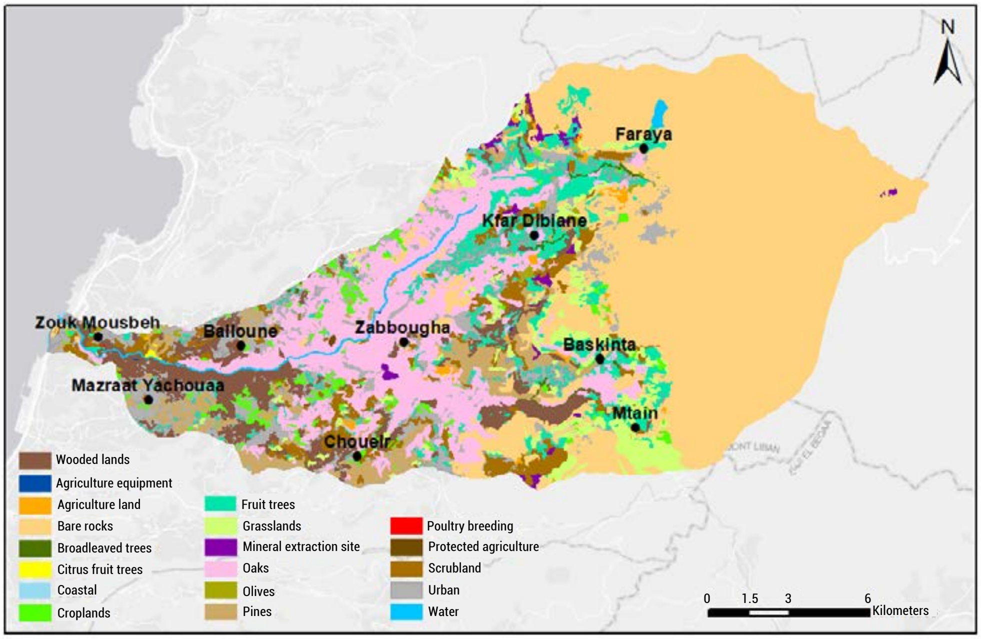


Source: Litani Water Authority, 2018.

Water from the basin is allocated for domestic, agricultural, industrial and touristic purposes with increased demand during the summer months. Figure 6 shows the land use and land cover map of the watershed. Bare rocks are concentrated in the mountainous areas and constitute 44 per cent of the basin area, followed by oak tree cover at 15 per cent, urban areas at 14 per cent and fruit trees accounting for 8 per cent.

In recent years, much arable land has been replaced by impervious urban surfaces, thus reducing agricultural activities and impacting hydrology. Urbanization between 2000 and 2015 has meant an increase in cities, dense and semi-dense urban clusters and suburbs of those areas (Pesaresi and others, 2019; European Commission, n.d.)

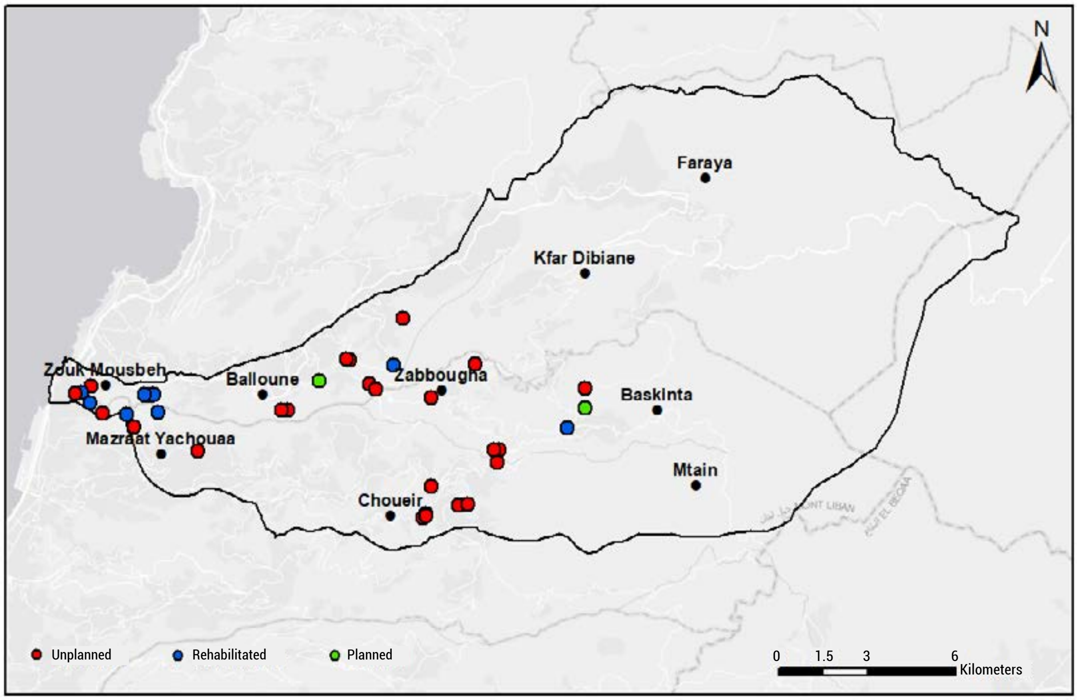
FIGURE 6: Land use and land cover map of the Nahr el Kalb basin



Source: National Council for Scientific Research (NCSR), 2017.

Surface and groundwater quality is also a major concern in the basin because there are no effective wastewater treatment plants in operation at present and thus wastewater is either directly discharged into the river or into cesspools. Contamination is expected to increase with the expansion of industrial, urban and agricultural activities at mid-elevation levels, and will then move downstream and reach lowland areas. In addition, waste dumping areas across the basin constitute a significant threat to groundwater quality (figure 7).

FIGURE 7: Distribution of waste dumps in the basin



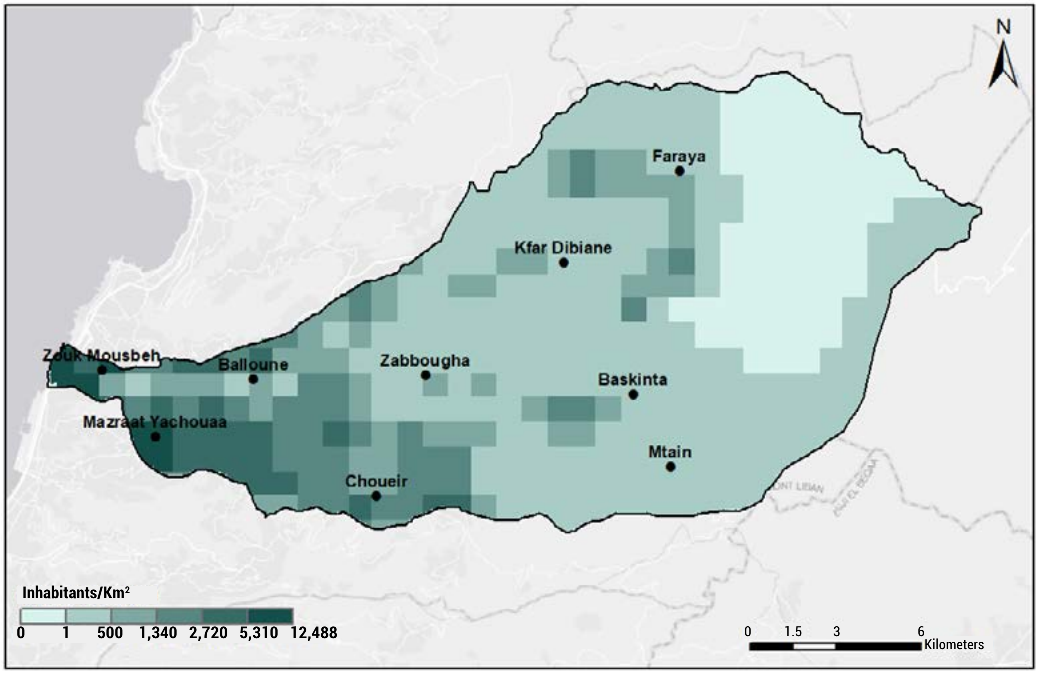
Source: Ministry of Environment, 2016.

B. Socioeconomic considerations

The Nahr el Kalb basin is a popular tourist and recreational area and includes ski resorts, coastal resorts, natural attractions such as the Jeita cavern and Wadi al Salib, archeological and religious sites, and shopping districts. A higher population concentration is present in the lower basin, where the density of inhabitants living in 1 km^2 reaches approximately 12,500 inhabitants (figure 8), with a youth to adult ratio of between 0.25 and 0.5. There are a number of associations aimed at young people, but these are limited. Population statistics for the basin are available on the Government of Lebanon Inter-Ministerial and Municipal Platform for Assessment, Coordination and Tracking (IMPACT). Public schools are dispersed around the basin but are mainly located in the lower watershed. As illustrated in figure 9, however, there are many areas with a high population of children, but no public schools located in the surrounding vicinity. Figure 10 illustrates that the lower basin has better access to healthcare than the upper watershed, with the average time needed to reach a healthcare center between 5 and 10 minutes as compared with 60 to 155 minutes for residents in the upper basin.

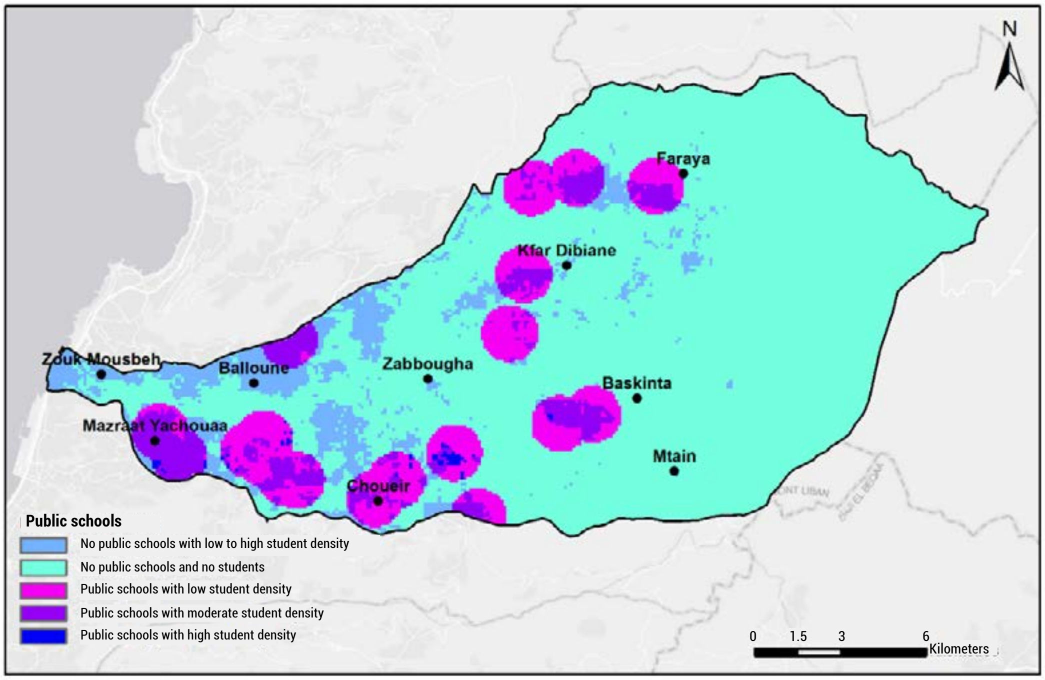
A strong correlation exists between population density, built-up areas, and public/private well distribution (figure 11) due to higher water demand in populated areas. Furthermore, the distribution of the water network also correlates with the distribution of public/private wells, indicating the need for water extraction from wells even in areas where a water distribution network has been established.

FIGURE 8: Population density, 2020



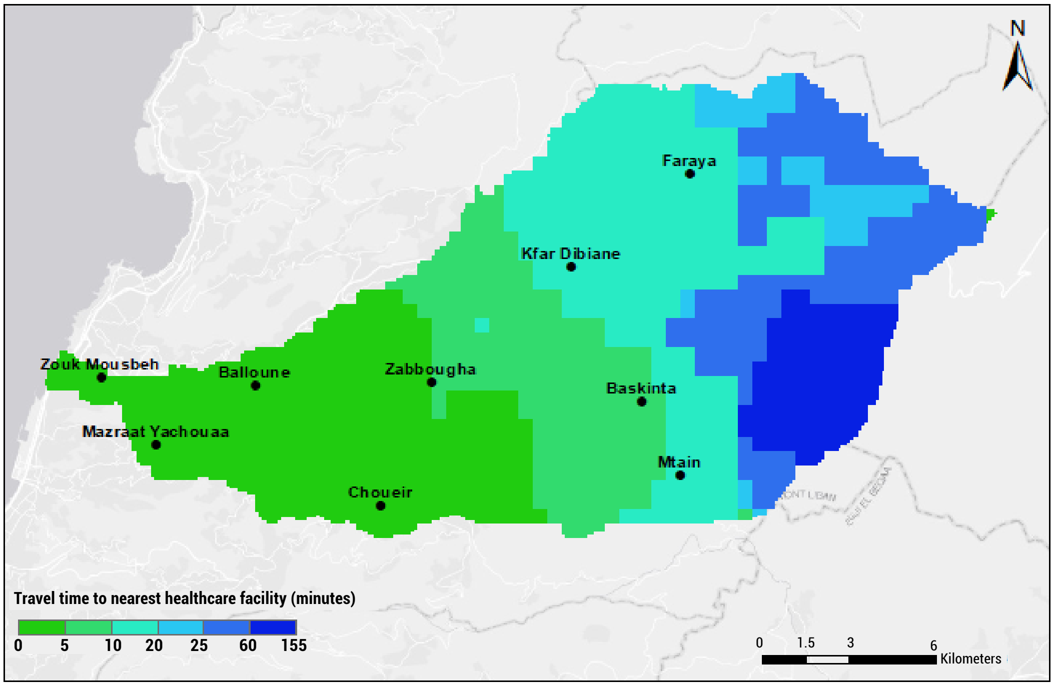
Source: WorldPop, 2020.

FIGURE 9: Availability of public schools and student density



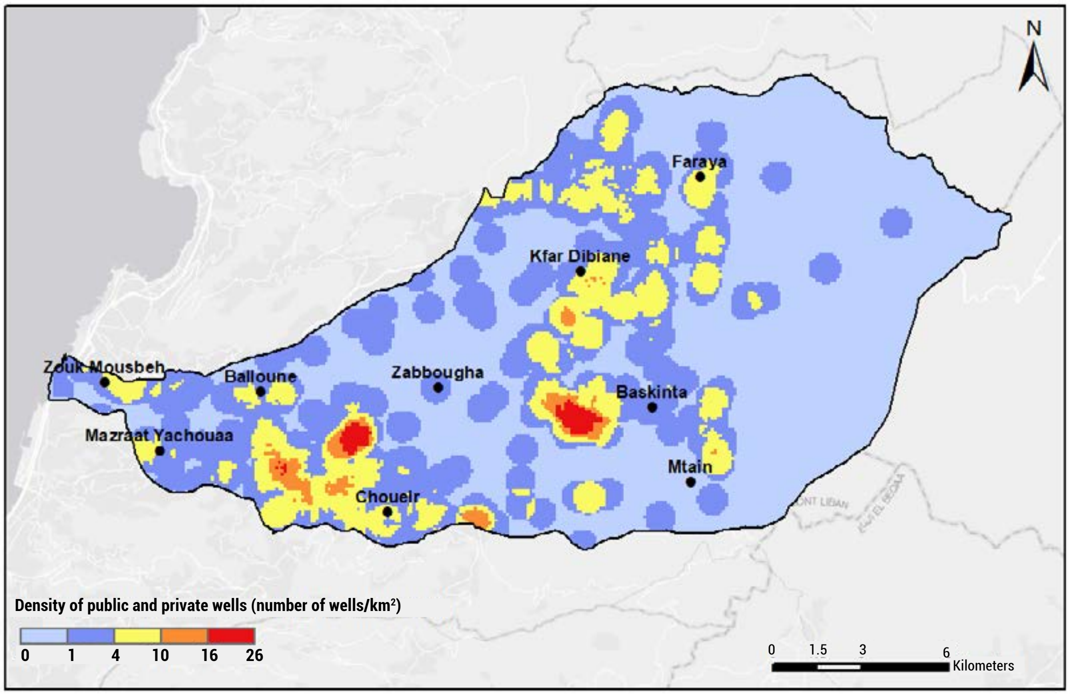
Source: United Nations Office for the Coordination of Humanitarian Affairs, 2021 and WorldPop, 2020.

FIGURE 10: Access to health care facilities



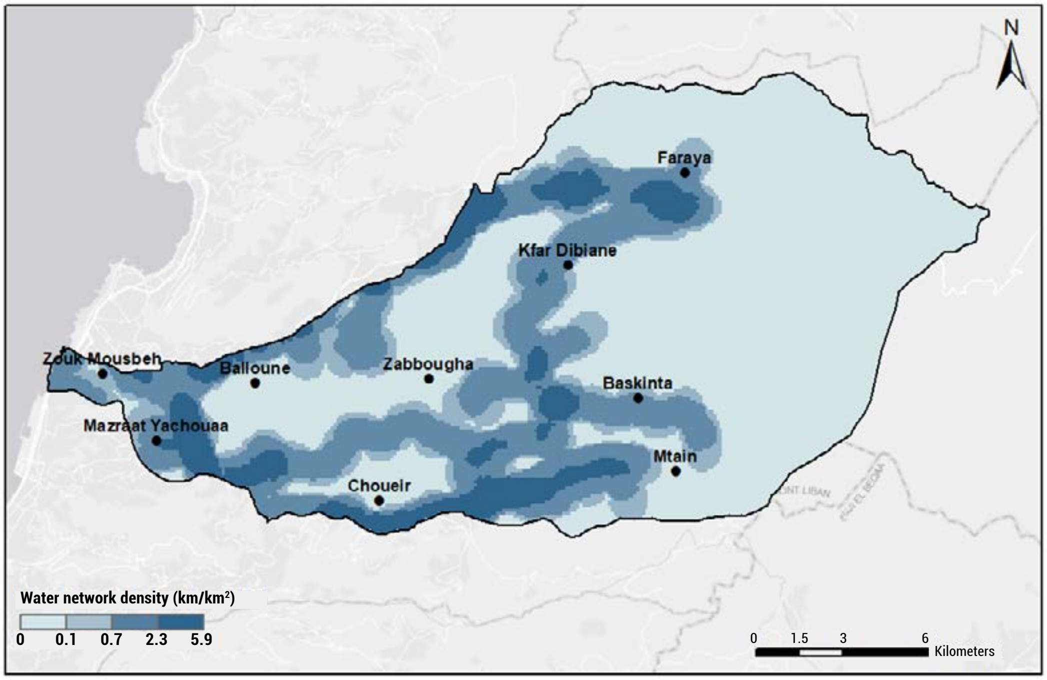
Source: United Nations Biodiversity Lab database, 2020.

FIGURE 11: Density of public and private wells



Source: Beirut Mount Lebanon Water Establishment (BMLWE), n.d.

FIGURE 12: Water network density

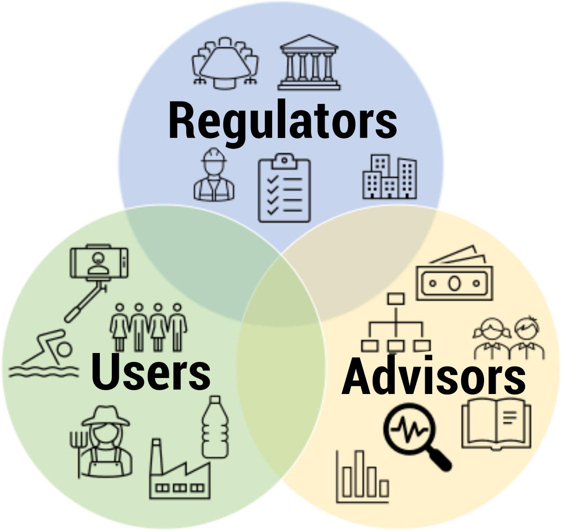


Source: BMLWE, n.d.

C. Stakeholder mapping

Involving stakeholders from the early planning stages is key for the successful implementation of any project since it creates confidence in the project, promotes ownership, addresses the concerns of stakeholders and uses an agreed upon methodology. In the Nahr el Kalb basin project, stakeholders were defined as any individuals or groups with an interest in the management of water resources in the basin. A range of stakeholders with varied interests were identified, and these were divided into three key categories (figure 13) based on their particular stake in the watershed resilience project.

FIGURE 13: Categorizing basin stakeholders



Source: Authors.

Resource users: this category includes stakeholders that depend on the water resource, and/or those that profit from the resource but who also impact its quantity and quality.

Resource regulators: stakeholders in this category have a legal responsibility to monitor, protect, regulate and manage the water resource. Regulator involvement is also needed for the implementation of any related project. Stakeholders in this category participate in decision-making at local and national levels.

Resource advisors: this category includes stakeholders that provide input on the project based on their specialized knowledge/ research in the area and can contribute to the effective implementation of projects by providing in-depth knowledge and/or financial support.

Table 1 provides input on the different stakeholder groups, who have different interests in connection with the watershed resilience project. It also provides information on stakeholder involvement, their capacity to influence policymaking and implementation processes, the impact of the project on those stakeholders and their capacity to participate in the project. It should be noted that certain stakeholders may play more than one role. For example, farmers' associations may also be considered managers. However, the table uses broad categories and, for the purposes of the project, farmers are considered resource users.

TABLE 1: Identifying stakeholder groups and their relevance to the project

Stake in watershed resilience	Stakeholder group	Relevance to project	Examples
Users	Farmers' associations	• Partners in piloting new systems (enhancing agricultural practices for implementation of adaptation/mitigation measures) • Beneficiaries of successful project implementation (improving livelihoods) • Dependent on the resource quantity and quality • Impact the quantity and the quality of the resource • Must demonstrate a level of commitment to the resilience project • Provide their knowledge of agricultural activities in the basin • Play a role in raising awareness and rationalizing the use of resources	• Baskinta cooperatives • Kfaraaqab cooperatives • Syndicate of vegetable and fruit exporters in Kesrouane • Individual farmers and agricultural landowners
	Industries	• Partners in piloting new systems (implementation of adaptation/mitigation measures) • Impact the quality and the quantity of the resource (direct effluent discharge into water sources) • Must demonstrate a level of commitment to the resilience project	• Industrialist assembly in North Metn • Kesrouane assembly of industrialists
	Culture and tourism	• Businesses that depend on the water source • Beneficiaries of successful project implementation (improving livelihoods) • Impact the quality and the quantity of the resource	• Jeita Grotto • Federation of restaurants and hotels • Waterpark management
	Local community	• Beneficiaries of successful project implementation (improving livelihoods) • Provide extensive knowledge of basin activities and perspectives on acceptable implementation • Can influence policy making and implementation and are affected by policies	• Individual experts • Local political figures

Regulators/ managers	Union of municipalities and individual municipalities	• Accelerate change within their own administration and meet national requirements • Support implementation • Resolve water conflicts • Could play a role in resource monitoring • Beneficiaries of successful project implementations • Key negotiators, with the power to approve or prevent projects being implemented in their territories • Important interlocutors between local communities and regional water establishments	• Federation Kesrwan-Ftouh • Ajaltoun/Faraya/Kfar Dibiane/Zouk Mousbeh/ Jeita municipalities • Metn municipalities
	Public water establishments	• Influence within the system • Help improve livelihoods • Mobilize people for policy implementation • Monitor water quantity and quality • Set up mechanisms for allocating water between sectors, as well as for environmental flows • Carry out investment and feasibility studies related to the master plan prepared by the Ministry of Energy and Water. Suggest tariffs for potable and irrigation water and discharging wastewate	• Beirut Mount Lebanon Water Establishment (BMLWE)
	Ministries	• Ensure cooperative governance • Implement government policy • Develop sustainable water policies and planning at the national level • Set goals and general guidelines for sustainable resource management • Create financing programmes and identify sources of finance • Provide overall leadership and political support	• Ministry of Energy and Water • Ministry of Environment • Ministry of Agriculture

Advisors	Youth groups	• Enhance youth involvement and facilitate youth-led initiatives and solutions • Provide advice on all parts of the system • Beneficiaries of project implementation • Raise awareness of the project	• Shabab Kesrouane • Lebanon Youth Parliament for Water • Recycler donation
	Universities and research centers	• Promote research and development, and provide data, technological tools and analyses using academic and technical expertise • Analyse input and provide advice on best practices • Assist regarding science polices and promote scientific research programmes • Deliver water education	• Notre Dame University-Louaize • Lebanese Agriculture Research Institute • American University of Beirut • National Council for Scientific Research
	Non-governmental organizations (NGOs) and civil society organizations (CSOs)	• Ensure cooperation of local communities and address their priorities • Provide advice on all system aspects • Provide knowledge of basin activities • Raise awareness of the project	• Arab Network for Social Accountability • Auberge Beity Association
	International/ regional agencies and donors	• Provide economic support • Support policy implementation and sustainable management, in line with their individual mandates • Funding and feasibility studies	• Arab Center for the Studies of Arid Zones and Dry Lands • United Nations entities • International Committee of the Red Cross • Swedish International Development Cooperation Agency • KfW Development Bank

Source: Authors.

The roles of national and local government institutions, as mandated by various laws and decrees:

The Ministry of Energy and Water: the ministry is comprised of the general directorates of hydraulic resources, exploitation and oil and has a broad mission including, (a) collecting, controlling, metering, establishing statistics and studying water resources, as well as evaluating water needs and areas of use; (b) controlling the quality of surface and ground water; (c) establishing general planning for the allocation and reparation of hydraulic resources; (d) preparing and continuously updating the Water Master Plan; (e) designing, studying, implementing and operating large water installations and works, such as dams, artificial lakes, tunnels, water networks and the rectification of watercourses; (f) issuing licences and permits for water prospecting, public water usage and the temporary occupation of public properties; (g) implementing, when needed, the artificial recharge of groundwater aquifers and controlling groundwater extraction; (h) enhancing and monitoring the performance of water establishments according to business plan indicators; (i) engaging in public relations and providing the population with water-related information and offering adequate education regarding usage.

The Water Code (Law 192/2020): this law represents a substantial effort towards modernizing the legal, institutional and financial aspects of the water sector and is considered an added value role of the Ministry of Energy and Water. The most important provisions of Law 192/2020 provide for implementing the water register, establishing the National Water Council, implementing the national Water Master Plan, adopting an integrated approach for the development of basin management plans, and proposing new tools and mechanisms for managing the water sector, such as public private partnerships (including with municipalities). The law provides for the creation of roles for line ministries as members of the National Water Council and stipulates that the master plan should be developed in coordination with those ministries.

BMLWE: this entity was established by article 3 of Law 221/2000, as amended by article 1 of Law 241/2000. It has a mandate to: conduct studies, implement, exploit, maintain and renew water projects to distribute drinking and irrigation water; collect, treat and drain wastewater in accordance with water and wastewater master plans; propose tariffs for water services (drinking, irrigation and wastewater) in line with social and economic conditions; monitor the quality of drinking and irrigation waters and the quality of wastewater at treatment stations, in coordination with the Ministry of Energy and Water; and carry out investment and feasibility studies related to the master plan prepared by the ministry. Paragraph 2 of article 4 of Law 221/2000 stipulates that public establishments must act according to their own specific regulations. In general, the Water Code assigns specific roles and responsibilities to water establishments.

Litani River Authority: this entity is a public institution with administrative and financial autonomy. In addition to its main functions, the authority was given a mandate to ensure water monitoring in all Lebanese rivers, study and implement mountain lakes and study and survey dam locations in northern Lebanese rivers.

Ministry of Agriculture: this ministry conducts technical studies on irrigation and drainage projects and oversees the distribution and use of irrigation water. The management of forested areas in Lebanon is the responsibility of the department of forest and natural resources, under the directorate of rural development and natural resources at the ministry. In addition, the ministry oversees the General Directorate of Cooperatives and implementation of a green plan, which both play an important role in supporting regional strategies for land and water, including the creation of hill lakes and water ponds.

Ministry of Environment: this ministry has a mandate to prepare a general policy on short, medium and long-term projects and plans that relate to the safeguarding and sustainability of natural environmental resources; develop the strategy, work plans, programmes, projects, activities and studies needed to safeguard the environment, ensure the sustainability of natural resources, and control pollution; expand legislation, standards and measures and identify the standards and indicators necessary to guarantee the protection of the environment and the sustainability of natural resources; and determine ideal environmental conditions for the protection of rivers, springs, marshes and ponds.

Ministry of Industry: this ministry has launched an integrated vision, entitled "Lebanon Industry 2025" for the industrial sector, which includes 11 strategic objectives to be achieved by 2025. Objectives include encouraging local industries to move towards green industry, expanding their use of renewable and alternative energy and encouraging energy and water efficiency and water treatment. In addition, the zoning development guidelines previously developed by the ministry were expected to include environmental protection measures such as wastewater treatment.

Ministry of Public Health: this ministry is responsible for conducting studies and proposing programmes in accordance with the laws in force to ensure the health of the environment; and proposing the technical specifications and conditions required for the construction of public and private sewers and drinking water network construction projects. The ministry also conducts sampling surveys and bacteriological analyses of water sources and water supplies in coordination with water authorities to ensure compliance with local and international standards, in addition to monitoring the incidence of waterborne diseases, and publishes related epidemiological studies.

Ministry of Interior and Municipalities: this ministry oversees the activities and coordinates with governorates, districts, municipalities (and federations and union of municipalities) and monitors local matters.

Council for Development and Reconstruction: the council has a wide array of objectives including planning, advising and project implementation. Project implementation includes the undertaking of any works related to water and water networks in any urban area, as per direction by the Council of Ministers. Furthermore, the Council for Development has the authority to implement work, including in the water sector, by engaging public authorities, private companies or a combination thereof. In 2002, the Council of Ministers asked that the National Physical Master Plan of the Lebanese Territory (NPMPLT) be prepared by the Council for Development and Reconstruction.

Ministry of Public Works and Transport: this ministry oversees the main governmental bodies responsible for urban policy planning, including the Higher Council for Urban Planning (HCUP) and the Directorate General of Urban Planning (DGUP). Ministerial departments of urban planning have been established in every district to review construction permits and ensure compliance with all urban planning regulations.

LARI: this institute conducts basic and advanced scientific research for the development and advancement of the agricultural sector in Lebanon. Additionally, the institute works closely with farmers in developing research activities aimed at addressing their concerns. LARI makes use of a number of meteorological stations and eight experimental stations. These stations offer farmers routine soil analysis upon request. The Institute also provides farmers with chemical and microbiological analysis of water used for irrigation and as potable water.

CNRS: this council serves the scientific community in Lebanon by conducting research in all scientific disciplines, including with regard to the country's water resources. Its main objective is to encourage scientific research and support human resources as per the scientific policies of the Government.

Municipalities and unions of municipalities: the municipal council of each city supports implementation of local water sector projects. These projects are usually in accordance with local needs within the boundaries of the municipality in charge of implementing water networks and waste disposal. Unions of municipalities have various roles and responsibilities when it comes to land use and water resource planning and management at the local level.

The consultations that took place between February and June 2022 aimed to improve active stakeholder participation in efforts to increase the resilience of the basin to climate change. In line with the objectives of each of the consultation meetings, stakeholder involvement was identified. Three major consultations took place, in accordance with the 10-step methodology. Here are the objectives of each consultation:

Objectives of first consultation (24 February 2022, Notre Dame University-Louaize):

- Objective 1: introduce the project, report information already collected and discuss community-based challenges and capacities that affect the ability of communities to cope with climate change.
- Objective 2: identify key crops in the basin that may be impacted by climate change.
- Objective 3: identify high-priority livelihood vulnerability indicators for use in the vulnerability assessment.

Objectives of second consultation (28 April 2022, held virtually):

- Objective 1: examine and validate the vulnerability assessment.
- Objective 2: gather input on preliminary response measures.

Objectives of third consultation (one-on-one meetings, held in May 2022):

- Objective 1: discuss the proposed watershed management design and resilience package.
- Objective 2: gather input on the proposed design.

3 CLIMATE CHANGE PROJECTIONS

A. Methodology overview

Global assessments of projected climate change are conducted using global climate models (GCMs), which are numerical models developed by research institutions that represent physical processes in the land surface, ocean, atmosphere and cryosphere to simulate the response of the global climate to increasing greenhouse gas emissions. Regional climate models (RCM) are nested within global climate models and use the most advanced tools to estimate projected climate change for specific domains since they are based on finer spatial and temporal resolutions. Climate data presented herein are primarily based on RCM outputs obtained from the Mashreq Domain (SIDA and ESCWA, 2021), which are based on the sixth phase of the Coupled Model Intercomparison Project (CMIP6), described in the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6) (IPCC, 2021) for the SSP5-8.5 scenario (Riahi and others, 2017).

Since the Mashreq Domain RCM outputs do not measure snowfall, and this is an important climate variable for the Nahr el Kalb basin, snow data was obtained from the Coordinated Regional Climate Downscaling Experiment (Euro-CORDEX) (Jacob and others, 2014). Data are not yet available for this domain based on the CMIP Sixth Assessment Report; thus, modelling outputs for snow variables are based on CMIP5 from the IPCC Fifth Assessment Report (AR5) (IPCC, 2018) using the representative concentration pathway (RCP) 8.5 scenario (Vuuren, 2011).

RCP 8.5 and the newly updated SSP5-8.5 scenario reflect aggressive predictions in terms of assumed fossil fuel use. They are a useful tool for quantifying climate vulnerability and informing policy. The scenarios have revealed emissions consistent with historical total cumulative CO_2 emissions (Schwalm, Glenden and Duffy, 2020). Although RCP 8.5 was originally conceived as extreme, many policymakers have characterized the scenario as "business as usual", suggesting a likely outcome in the absence of effective climate change mitigation measures (Hausfather and Peters, 2020). Despite scientific debate regarding whether RCP 8.5 is plausible due to current climate action, temperature trajectories closely mirror RCP 8.5 projections.[1]

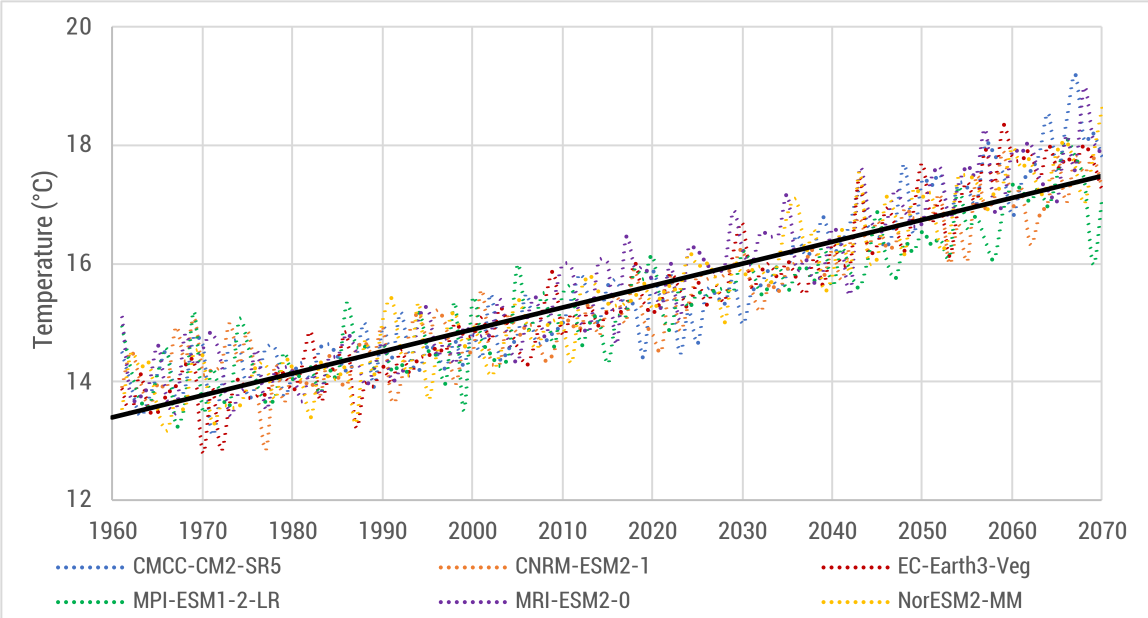
Climate projections are typically compared to a historical reference period to demonstrate how well the RCM outputs compare to the present climate. To gain the best perspective on the climate overall, outputs are presented as an ensemble. Each ensemble includes six modelling outputs (a minimum of three is recommended) averaged over a 20-year period. Consistent with the IPCC AR6, the reference period presented herein is from 1995 to 2014. The near- and mid-term periods are set at 2021–2040 and 2041–2060, respectively.

The RCM outputs include annual temperatures, precipitation and selected extreme event indices displayed as maps and the two future periods are compared to the reference period. Most extreme events indices are derived from the Expert Team on Climate Change Detection and Indices (ETCCDI).[2] Drought frequency is derived from the six-month Standardized Precipitation Index (SPI-6) using a peer-reviewed methodology (Spinoni and others, 2020; Tomaszkiewicz, 2021) and the Mashreq Domain RCM outputs. Results for core climate variables are presented for both Lebanon and the basin so that results from the basin can be seen in context. Results for the extreme events indices are only presented for the basin.

B. Change in temperature and related extreme events index

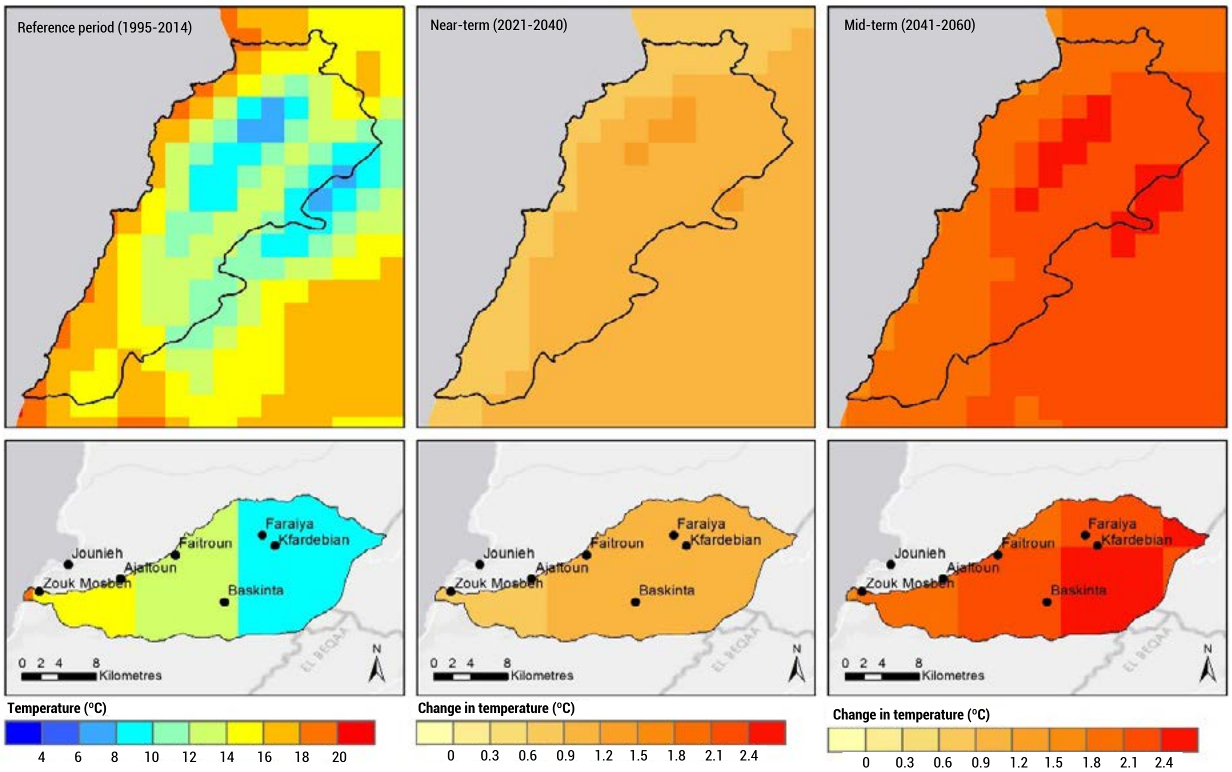
Although there is some interannual variability, the evaluated climate models all predict generally increasing temperatures across the watershed, as shown in figure 14. The mean annual temperature during the reference period of 1995 to 2014 ranged from 19°C near the coast to 11°C in the mountains, where the basin is located. Those temperature figures are comparable to an observed average temperature of 15.9°C between 2003 and 2015 obtained from the Qartaba station, located at 34° 5′ 44″, 35° 0′ 55″ with an elevation of 1,222 m (Saade and others, 2021). Projected increases in temperature average 1°C for the near-term (2021–2040) and 2.2°C for the mid-term (2041–2060), with a minimum to maximum rising gradient from the coast to the mountains, as shown in figure 15. Several studies have concluded that mountainous areas are warming at a more rapid rate due to snow/ice albedo feedbacks, cloud cover and differences in water vapour content (Rangwala and Miller, 2012).

FIGURE 14: Time series analysis for mean annual temperatures for the Nahr el Kalb basin from six climate models in the Mashreq Domain, SSP5-8.5



Source: Authors.

FIGURE 15: Mean change in annual temperature for the near-term (2021–2040) and the mid-term (2041–2060) as compared to the reference period (1995–2014) based on six models from the Mashreq Domain, SSP5-8.5

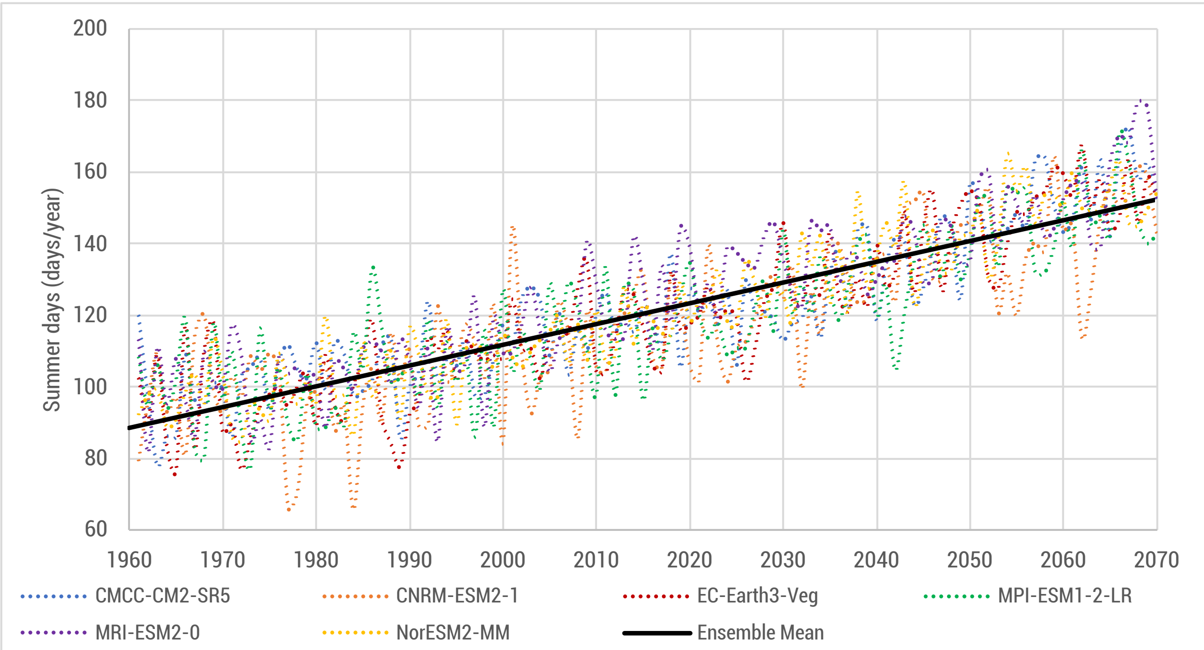


Source: Authors.

Key crops in the basin, including apples, are sensitive to temperature extremes. Rising temperatures could mean fewer freezing temperatures, which are needed for fruit tree dormancy and subsequent bud break and flowering (Funes and others, 2016). Centenarian maximum temperature increases of 5°C in models have predicted an apple tree cultivation area loss of nearly 50 per cent from current levels (Ahmadi, Ghalhari and Baaghideh, 2019). For these reasons, it is critical to evaluate temperature extremes, including the total number of very hot days, in tandem with average annual temperatures.

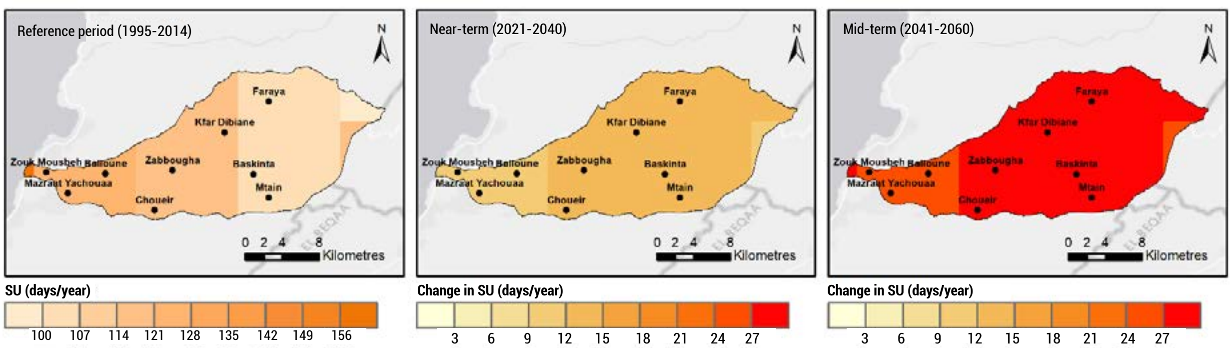
The Expert Team on Climate Change Detection and Indices has defined the number of summer days (SU) as the count of days when daily maximum temperatures exceed 25°C. Using this criterion, summer days will increase by nearly six days per decade and, by 2070, over 40 per cent of the year will have maximum temperatures exceeding the 25°C threshold, as shown in figure 16. During the reference period, the number of summer days is highest nearest to the coast and decreases as the elevation increases. However, the change in the number of total summer days is projected to be higher in mountainous areas (figure 17).

FIGURE 16: Time series analysis for mean annual number of summer days or days when Tmax exceeds 25°C for the Nahr el Kalb basin



Source: Authors.
Note: Data are from six climate models from the Mashreq Domain, SSP5-8.5.

FIGURE 17: Mean change in the annual number of summer days when Tmax exceeds 25°C for the near-term (2021–2040) and the mid-term (2041–2060) compared to the reference period (1995–2014) based on six bias-corrected models from the Mashreq Domain, SSP5-8.5



Source: Authors.

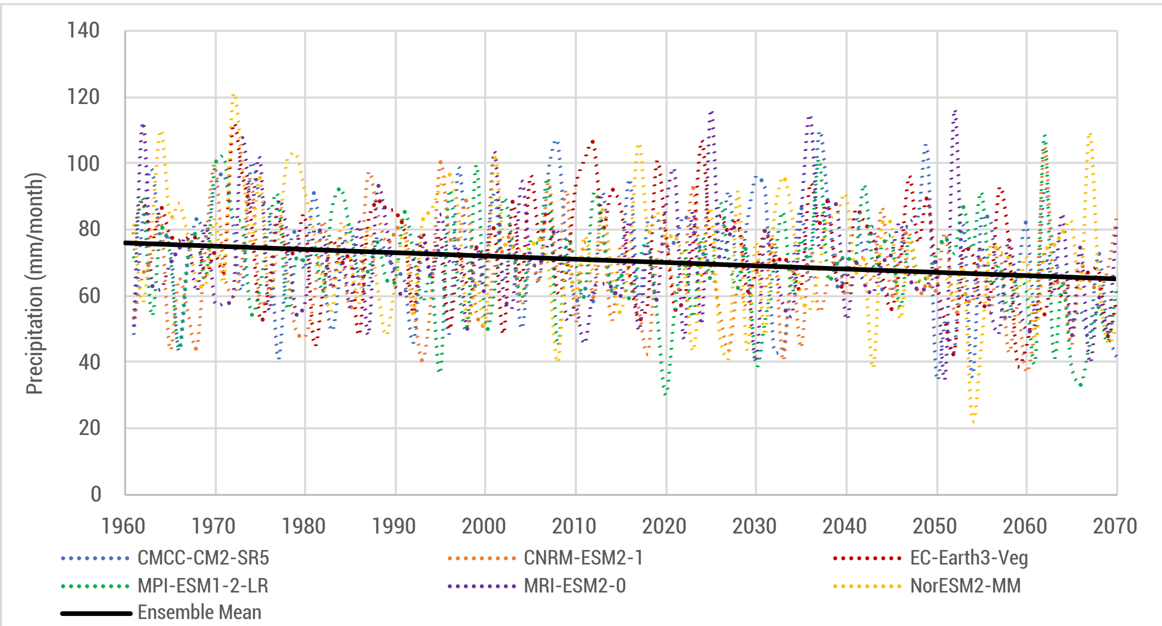
C. Change in precipitation and related extreme events index

Precipitation exhibits wide interannual variability, but in general is projected to decline (figure 18). Temperature extremes, such as those described above, have been linked to precipitation deficits (Mueller and Seneviratne, 2012). Observed annual precipitation in the basin has been estimated at 91 mm/month at the Qartaba station (Saade and others, 2021). This is slightly less than the 119 mm/month reported for the reference period as obtained from the modelling outputs for the basin. Higher volumes occur between December and February and rainfall is minimal between June and August. Projected decreases in precipitation in Nahr el Kalb are estimated to be 5.1 mm/month, a 4 per cent decrease, for the near-term and 12.1 mm/month, a 10 per cent decrease, for the mid-term (figure 19). These decreases are higher than the overall reduction in precipitation of 3 and 9 per cent for Lebanon in the near- and mid-term timeframes, respectively.

Although flood risk remains a concern in Lebanon given its potential for damaging infrastructure and causing fruit tree cultivation losses (Abdallah and Hdeib, 2016), this study focuses on increased drought risk due to generally decreasing precipitation. Drought frequency was calculated using the Standard Precipitation Index (SPI) for six-month intervals (SPI-6), considered suitable for small watershed analysis. A drought event is recorded once the SPI-6 is continuously negative and at levels less than or equal to 1 and concludes when the SPI-6 is greater or equal to 0 (McKee, Nolan and Kleist, 1993). Drought severity is calculated by the sum of SPI values (as absolute values) during a given event.

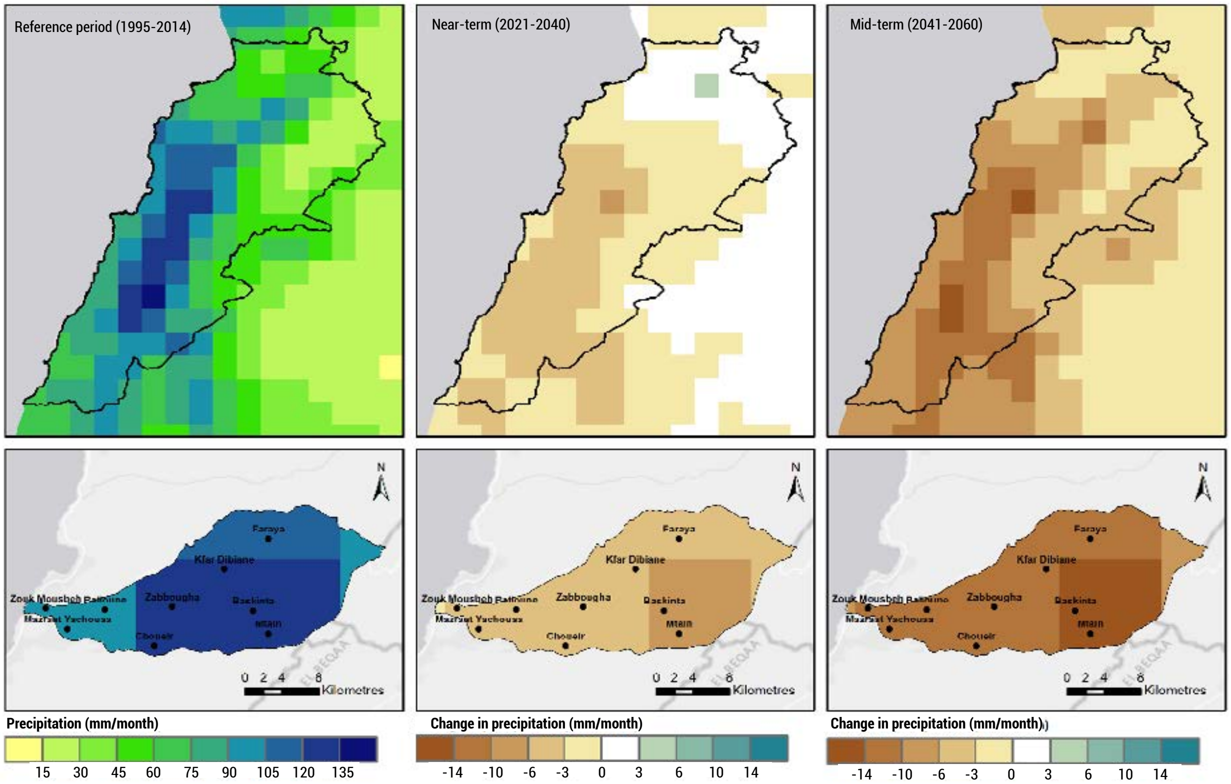
Both drought frequency and severity are highly variable on an interannual basis. In general, drought frequency is projected to remain the same, indicating one event every two years (figure 20). However, severity, which reflects both drought intensity and duration, is expected to increase. Droughts are expected to be about 5 per cent more severe every ten years. These trends are consistent with reported changes in the maximum lengths of dry periods in the basin (SMHI and ESCWA, 2021). In terms of land area, the greatest increase in drought is expected in the mountains near Qanat Bakish (figure 21).

FIGURE 18: Time series analysis for mean annual precipitation for the Nahr el Kalb basin from six climate models from the Mashreq Domain, SSP5-8.5



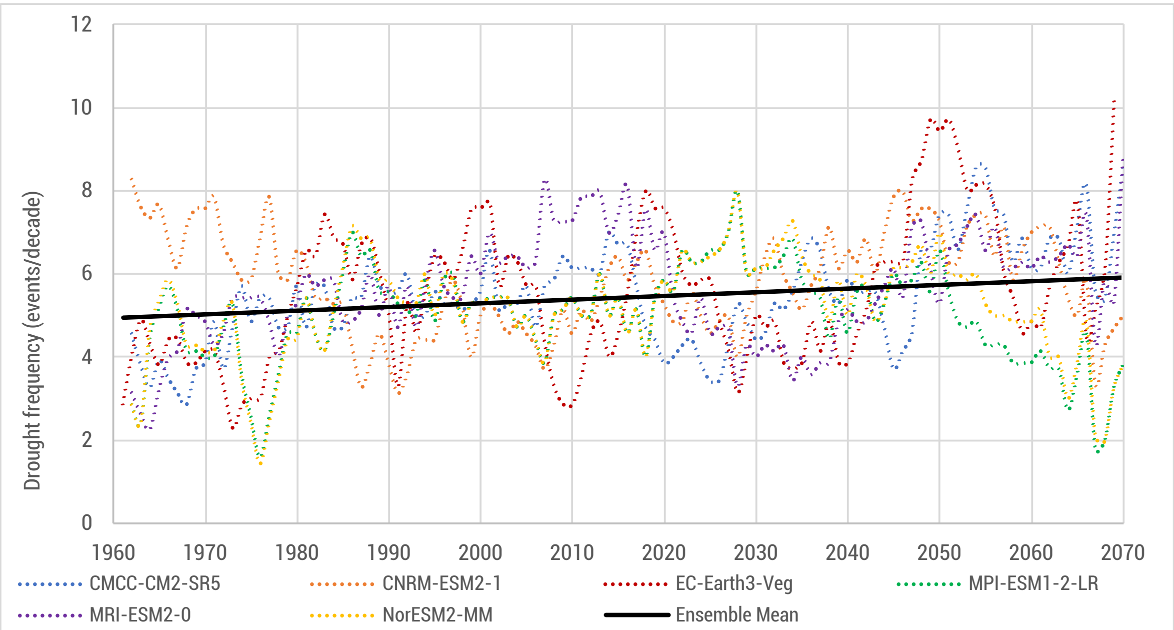
Source: Authors.

FIGURE 19: Mean change in annual precipitation for the near-term (2021–2040) and the mid-term (2041–2060) compared to the reference period (1995–2014) based on six models from the Mashreq Domain, SSP5-8.5



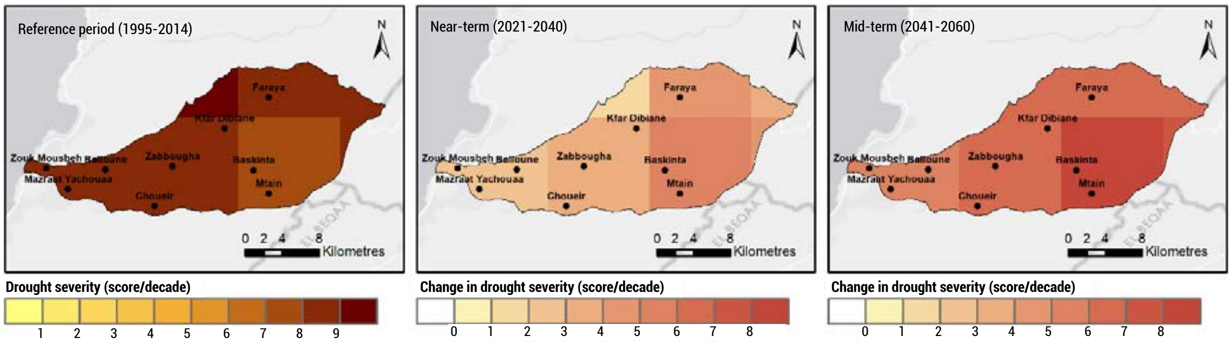
Source: Authors.

FIGURE 20: Time series analysis for mean drought frequency and drought severity based on SPI-6 for the Nahr el Kalb basin using a 10-year rolling average and data from six climate models from the Mashreq Domain, SSP5-8.5



Source: Authors.

FIGURE 21: Mean change in drought severity (based on SPI-6) for the near-term (2021–2040) and the mid-term (2041–2060) compared to the reference period (1995–2014) based on six models from the Mashreq Domain, SSP5-8.5



Source: Authors.

D. Change in snow variables

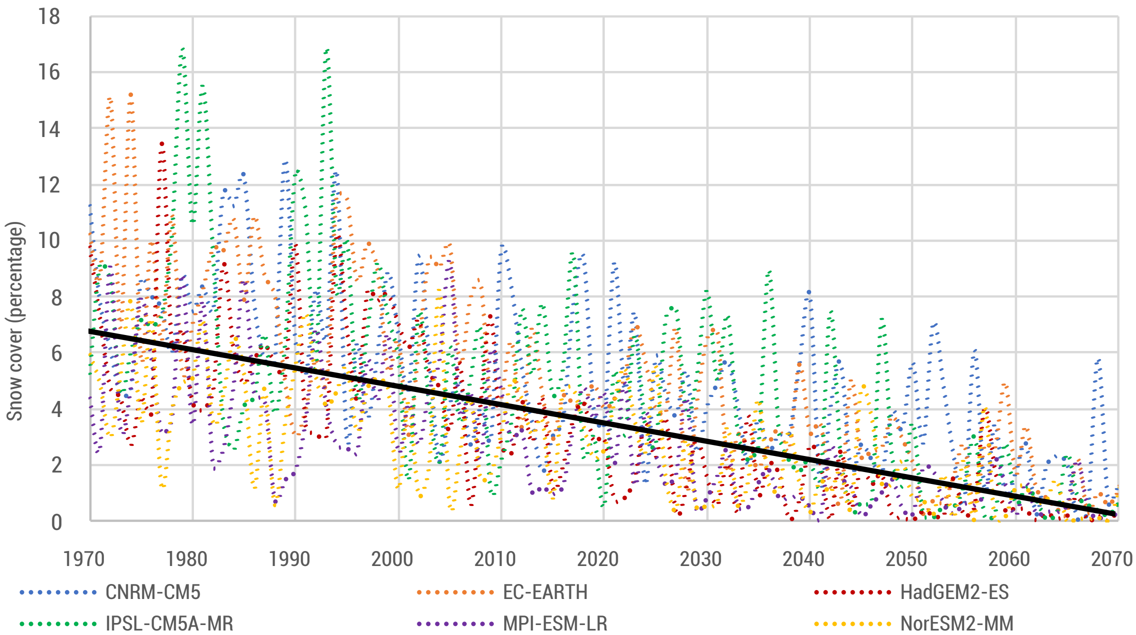
Snowmelt is an essential water resource in Lebanon that affects several basins including Nahr el Kalb. Approximately 26 per cent of surface and groundwater hydrologic sourcing in Lebanon is attributed to snowmelt (Mharwej and others, 2014). In addition to its impact on water resources, snow is important for the growth patterns of certain crops. For example, years with low and/or late seasonal snowfall have resulted in unfavourable apple production (Jangra and Sharma, 2013).

Climate change impacts on snowmelt are challenging to assess, particularly in karstic environments, and require detailed hydrological analysis (Gampe, Nikulin and Ludwig, 2016). However, changes can be evaluated using proxy climate variables, namely snow cover and snow depth. Measurements during the last decade obtained at the Mzaar ski station in the upper basin at an elevation of 2,296 m have revealed average snow depth, snow water equivalent and snow density to be 80 cm, 30 cm and 490 kg/m^3 respectively (Fayad and others, 2017).

Snow cover is expected to exhibit variability due to orography and other phenomena. However, models indicate a general decline, with the potential for disappearing by the end of the century (figure 22). Across Lebanon, measured snow coverage averaged approximately 7 per cent annually, peaking in February at around 29 per cent between 2000 and 2011 (Mhawej and others, 2014). Those results are comparable to RCM results obtained during the reference period of 1995 to 2014, which estimated 6.4 per cent snow cover averaged over the basin (figure 23). In the near-term (2021–2040), snow cover will be reduced by one-third in the basin and will further reduce by nearly two-thirds by mid-term (2041–2060), as compared to the reference period.

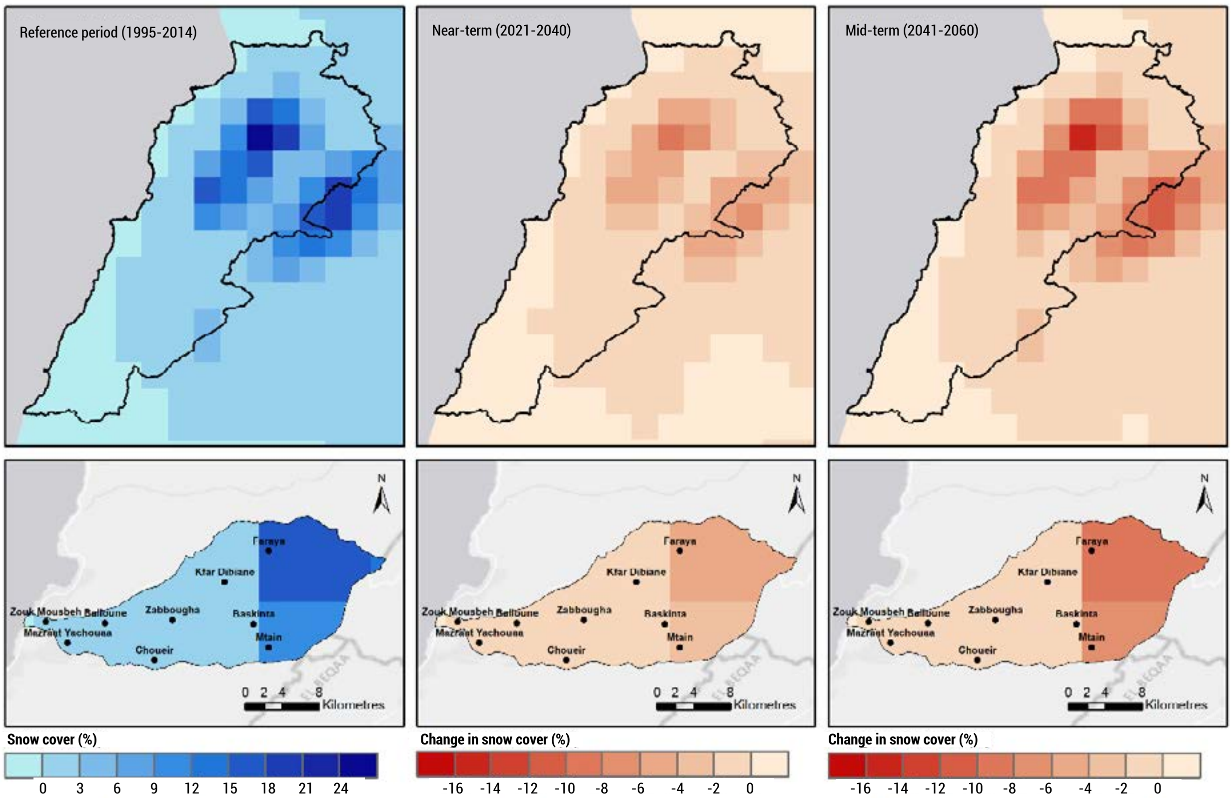
Figure 24 and figure 25 illustrate how snow depth will fluctuate but decrease overall. Based on RCM outputs, average annual snow depth during the reference period was 78 cm, with a maximum of 222 cm. These results are higher than observed data (Fayad and others, 2017), and those differences are partly attributed to the climate data spatial resolution. Snow depth is expected to decline 41 cm on average in the near-term and 60 cm in the mid-term.

FIGURE 22: Time series analysis for mean annual snow cover for the Nahr el Kalb basin from six climate models obtained from Euro-CORDEX, RCP 8.5



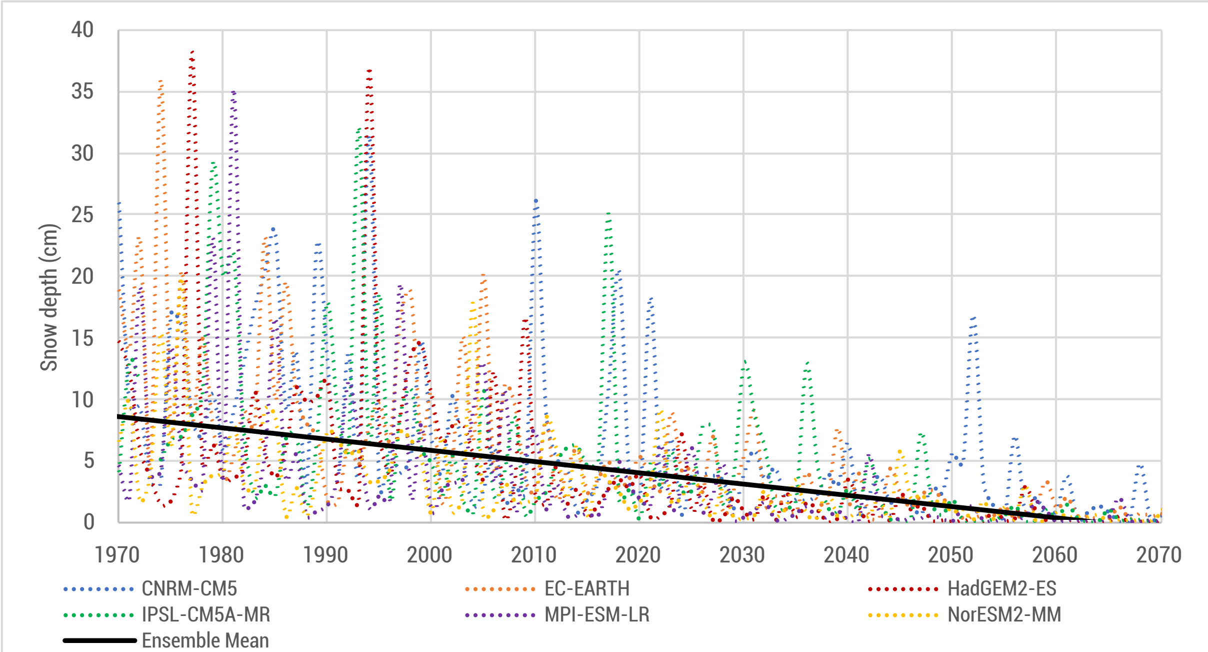
Source: Authors.

FIGURE 23: Mean change in annual snow cover for the near-term (2021–2040) and the mid-term (2041–2060) as compared to the reference period (1995–2014) and based on six models from Euro-CORDEX, RCP 8.5



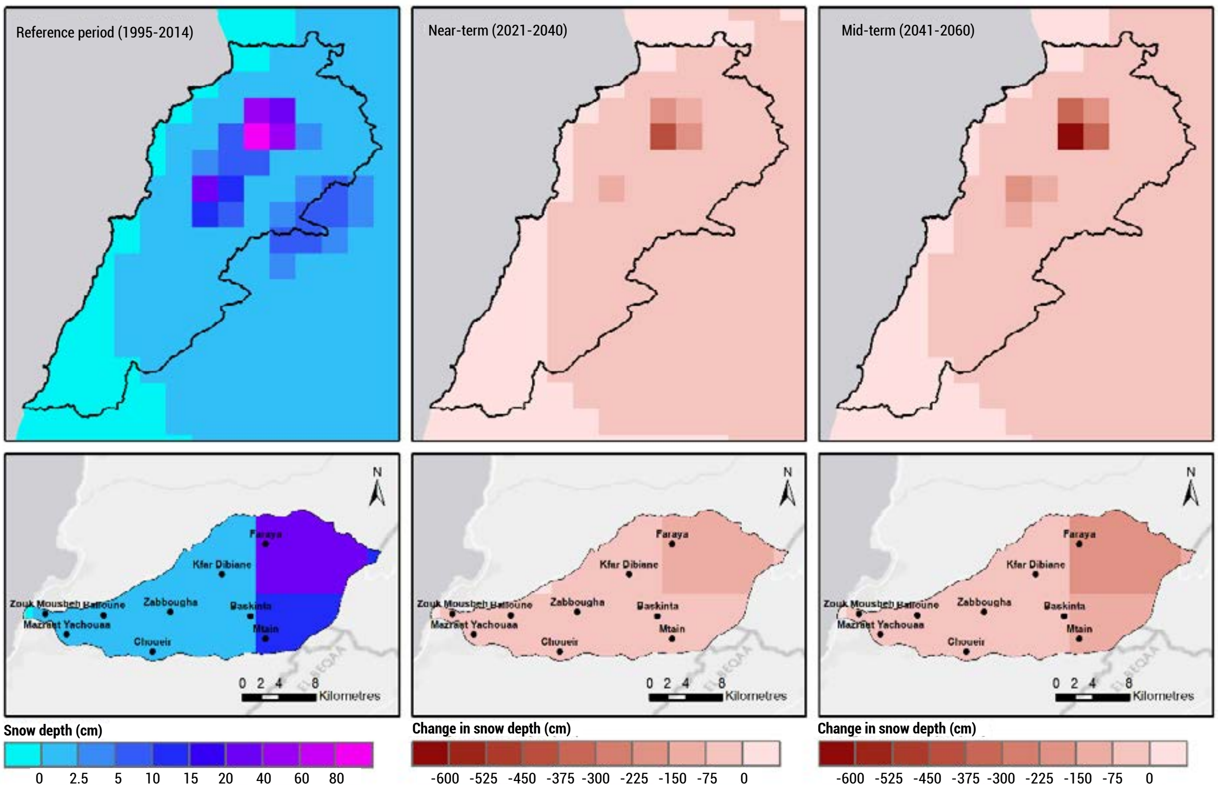
Source: Authors.

FIGURE 24: Time series analysis for mean annual snow depth for the Nahr el Kalb basin, based on six climate models from Euro-CORDEX, RCP 8.5



Source: Authors.

FIGURE 25: Mean change in annual snow depth in the near-term (2021–2040) and the mid-term (2041–2060) as compared to the reference period (1995–2014) based on six models from Euro-CORDEX, RCP 8.5



Source: Authors.

E. Other climate data

The datasets included here were selected due to their relevance to this technical report. The presented data were used for the agricultural and vulnerability assessments. However, evaporation, run-off and other climate variables also impact the Nahr el Kalb basin and are summarized subsequently.

Typically, evaporation is correlated with temperature. As temperature increases, evaporation increases. However, evaporation is a key component of the hydrological cycle and in the Arab region, evaporation may decrease due to limited hydrological water availability, despite increasing temperatures (ESCWA and others, 2017). Thus, the data indicate that evaporation is projected to increase during the wet season between October and March and decrease during the dry season between April and September.

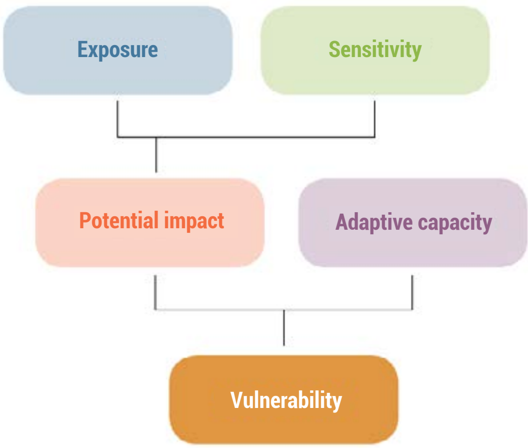
Many climate variables are affected by overall declines in precipitation. The number of very high precipitation days (R20), defined as days with more than 20 mm precipitation and run-off, are projected to decrease. By 2060, R20 is estimated to be 2 days/year less than the long-term average. Run-off will decrease by about 10 mm/month during the dry season and about 30 mm/month during the wet season. However, precipitation intensity is predicted to increase between 2030 and 2050 before returning to a long-term normal by 2060 (SMHI and ESCWA, 2021). Increasing precipitation intensity despite decreasing volumes means higher risk of flash floods, a circumstance that is exacerbated by increased drought risk. A detailed hydrological study would be needed to assess the situation further.

4 INTEGRATED VULNERABILITY ASSESSMENT OF THE WATER SECTOR TO CLIMATE CHANGE

A. Methodology overview

Vulnerability is a complex concept which can be used to describe the relationship between climate change and its impact on a specific system. As proposed by the IPCC in its Fourth Assessment Report (AR4) (IPCC, 2007) and endorsed by RICCAR, vulnerability is comprised of three primary components: exposure, sensitivity and adaptive capacity. Exposure refers to quantifiable climate change parameters such as changes in temperature and precipitation. Sensitivity helps to describe the natural and physical environment as well as the population groups that are most susceptible to climate change. Combining exposure and sensitivity elements results in a better understanding of the total potential impact. Adaptive capacity, or the ability to cope, mitigate and adapt to climate change is a means for countering total potential impact and the net difference between potential impact and adaptive capacity defines vulnerability (figure 26). Vulnerability is the degree to which a system, in this case the water resources in the Nahr el Kalb basin, is susceptible to the adverse impacts of climate change.

FIGURE 26: Components of vulnerability, as outlined in the IPCC AR4 approach



Source: Economic and Social Commission for Western Asia (ESCWA), Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD) and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Integrated Vulnerability Assessment: Arab Regional Application, E/ESCWA/SDPD/2017/RICCAR/TechnicalNote.2.

The integrated vulnerability assessment methodology, as endorsed by RICCAR draws upon appropriate geospatial indicators to evaluate watershed resilience in the Nahr el Kalb basin. The methodology is based on an iterative process and makes use of ArcGIS software to define vulnerability levels and zones at high risk of vulnerability.[3]

B. Impact chain

Impact chains help convey the cause-and-effect relationship between various indicators and their respective components and vulnerabilities. Indicators are selected according to the three components of exposure, sensitivity and adaptive capacity, and are then aggregated together to evaluate vulnerability. To ensure a balance among the components, sensitivity and adaptive capacity indicators are divided into groups called dimensions. For example, the sensitivity component includes population, natural and man-made dimensions, whereas the adaptive capacity includes infrastructure, economic resources, awareness, institutions and equity. Other dimensions may also be included depending on the analysis being done and data availability.[4]

BOX 1: Prioritizing impact chain indicators and identifying challenges and opportunities through a participatory process

On 24 February 2022, a first consultation meeting of key stakeholders in the Nahr el Kalb basin took place at Notre Dame University-Louaize. This initial consultation was divided into two parts. The first part aimed to introduce the stakeholders to the project and the 10-step methodology. The second part aimed at identifying and prioritizing indicators to be used in the impact chain, on the basis of stakeholder expertise and priorities in the water sector. During this session, participants were given a list with various indicators including exposure, sensitivity and adaptive capacity and were asked to prioritize indicators, adding any they felt were relevant. Afterwards, participants were divided into four groups to discuss how they prioritized the indicators and come to an agreement regarding top priority indicators and those that should be added. Each group included private sector, public sector, research and university, youth, farmer and civil society representatives. Based on the results of the discussions, the impact chain was updated to include the contributions of the major stakeholders. For example, it was proposed that waste dumps and the percentage of industry distribution be added.

Furthermore, during the first stakeholder meeting, participants discussed community-based challenges and capacities affecting their ability to cope with climate change. Each stakeholder group had the opportunity to discuss perceived challenges and opportunities regarding climate change and the basin as indicated in table 2.

Source: Authors.

Initially, a large list of indicators was prepared. Those indicators were then filtered and prioritized with weightings based on expert knowledge including relevance, homogeneity, validity, reliability, as well as data availability and stakeholder consultations (box 1). For the Nahr el Kalb basin, figure 27 shows the finalized impact chain developed for this study. A total of 16 sensitivity indicators were selected based on social, environmental and anthropogenic factors that exert pressure on water resources in Nahr el Kalb. In addition, eight adaptive capacity indicators were selected based on factors that enhance climate change adaptability within the basin.

TABLE 2: Perceived challenges and opportunities in Nahr el Kalb

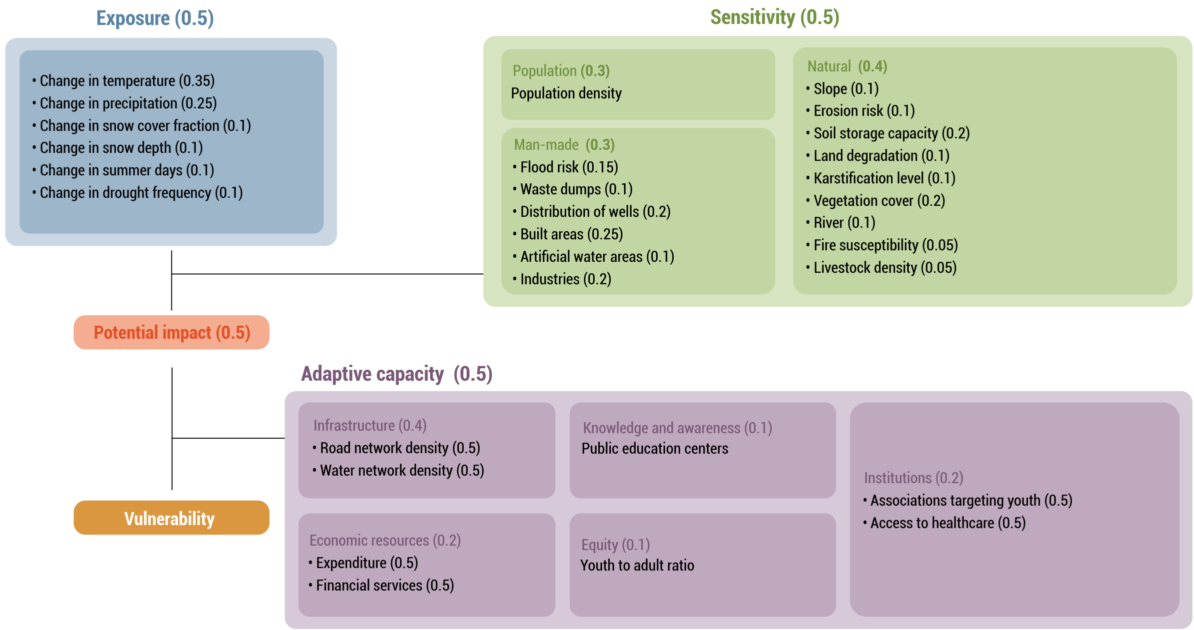
Group	Challenges	Opportunities
Ministries and international organizations	• Decreased water storage and water supply for all sectors (domestic use, tourism, industry, agriculture). • Pollution due to wastewater effluents and agricultural production. • Lack of coordination between sectors involved in water management.	• Develop awareness campaigns to promote sustainable water consumption. • Update the national Water Master Plan and river basin schemes and plans. • Set up mechanisms for proper water allocation within each sector and rationalize consumption. • Construct hill lakes. • Increase collaboration between ministries and municipalities to implement integrated water management plans, especially in the field of protecting aquatic ecosystems, including tourism, industry, energy, forest management and agricultural activities, livestock, fishing and urban planning. • Establish surface and groundwater protection zones. • Implement sanctions and penalties. • Set up tariffs and fees for water use, including for potable water, irrigation, industrial use, wastewater and pollution management. • Manage well permits, licensing and settlements of drilled wells. • Implement a wastewater strategy. • Establish a non-profit water users association.
Private sector and industries	• Reduced precipitation will decrease available water for potable, industrial and agricultural uses.	• Promote capacity-building and awareness campaigns on water consumption. • Encourage industries to construct wastewater treatment plants with reuse capabilities. • Strengthen collaborations between related ministries, municipalities and the Ministry of Energy and Water for proper water management. • Allocate more water quality monitoring responsibility to municipalities
Agriculture	• High groundwater extraction rates for irrigation in rural areas. • High reliance on rainfall, especially in municipalities with no rivers, thus increasing climate change vulnerability.	• Implement a wastewater treatment project to reuse treated wastewater in irrigation and reduce stress on groundwater reserves. • Enhance conservation and protection of groundwater sources.
Research institutions	• Limited data availability and accessibility. • High stress on water quality and quantity and deterioration in air quality. • Increased soil erosion and land degradation.	• Allocate research funding. • Increase stakeholder involvement in identifying research needs.
Youth and civil society organizations	• Significant water quality degradation from point and non-point sources. • Insufficient funds allocated for enhancing the environment. • Lack of governmental management and follow up.	• Develop wastewater treatment plants. • Create campaigns to increase awareness.
Municipalities	• High population growth. • Increase in fire events. • Lack of wastewater treatment facilities. • Significant pollution of water sources from agricultural activities (pesticides and herbicides). • Change of topography due to quarry activities.	• Increase awareness regarding water consumption best practices. • Develop water and wastewater networks. • Improve the tourism sector. • Promote employment and increase job opportunities.

Source: Authors.

Data were collected from multiple sources to assess relevance, and exposure indicators were obtained from the regional climate modelling outputs described in section III. Tables 3 and 4 show the sources of the 16 sensitivity and 8 adaptive capacity indicators, respectively.

Since selected indicators varied in magnitude and units of measurement, they were first reclassified using a common unitless scale prior to aggregation analysis using ArcMap GIS methodology. Specifically, grid pixels within each geospatial indicator were assigned values from 1 to 10. For the exposure and sensitivity indicators, a value of 1 represents favourable conditions (low exposure, low sensitivity) and a value of 10 designates unfavourable conditions (high exposure, high sensitivity). The inverse pertains to adaptive capacity with 1 indicating low, unfavourable adaptive capacity and 10 indicating high, favourable adaptive capacity.

FIGURE 27: Impact chain for the Nahr el Kalb basin



Source: Authors based on the Economic and Social Commission for Western Asia (ESCWA), Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD) and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), 2017.

TABLE 3: Sensitivity indicators selected for the vulnerability assessment

Indicator name	Data type	Source	Year
Population density	Raster	WorldPop	2020
Slope	Raster	United States Geological Survey	2014
Erosion risk	Raster	NCSR	2002
Soil storage capacity	Raster	CNRS: Soil map of Lebanon	2006
Land degradation	Vector	Mitri and others	2019
Karstification level	Raster	United Nations Development Programme (UNDP)	2014
Vegetation cover	Vector	CNRS land use and land cover map	2017
River	Raster	UNDP	2014
Fire susceptibility	Raster	NCSR	2020
Livestock density	Raster	United Nations Biodiversity Lab	2020
Flood risk	Raster	NCSR	2017
Waste dumps	Point data	Ministry of Energy	2016
Distribution of wells	Point data	BMLWE	[a]
Built areas	Vector	CNRS land use and land cover map	2017
Artificial water areas	Vector	CNRS land use and land cover map	2017
Industries	Tabular data	Industrial associations	2022

Source: Authors.
[a] Distribution of well data was provided by BMLWE in 2022 but actual date of data collection has not been provided.

TABLE 4: Adaptive capacity indicators selected for the vulnerability assessment

Indicator name	Data type	Source	Year
Road network density	Raster	United Nations Office for the Coordination of Humanitarian Affairs (OCHA)	2020
Water network density	Vector data	BMLWE	[b]
Public education centers	Point data	OCHA	2019
Expenditure	Raster	Ministry of Telecommunications	2005
Financial services	Point data	OCHA	2021
Youth to adult ratio	Raster	WorldPop	2020
Associations targeting youth	Tabular form	IMPACT	2022
Access to health care	Raster	United Nations Biodiversity Lab	2020

Source: Authors.

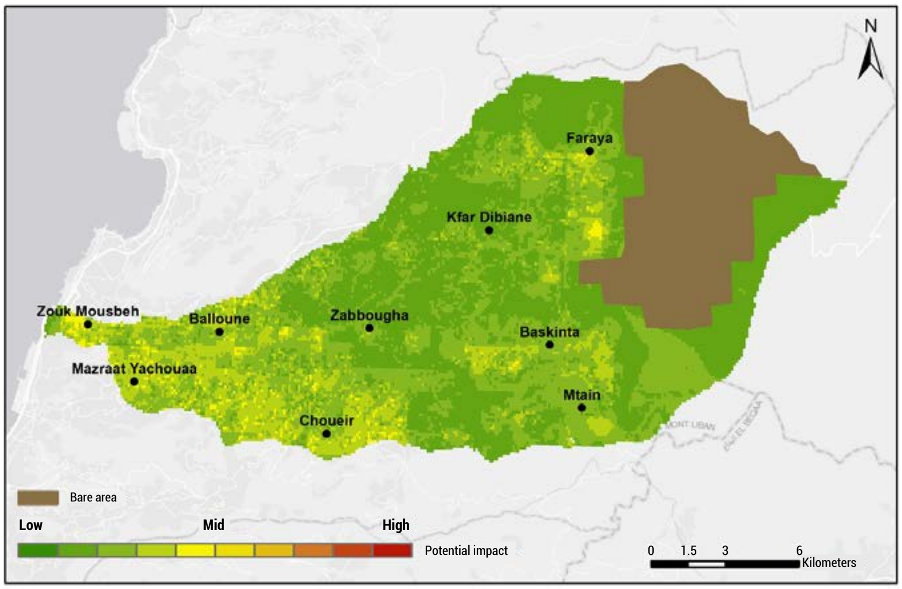
[b] Water network density data was provided by BMLWE in 2022, but actual date of data collection has not been provided.

C. Potential impact

The potential impact reflects the aggregation of exposure and sensitivity. Those factors are weighted equally and three annual potential impact maps are shown for different periods. During the reference period (1995–2014), shown in figure 28, low potential impact is observed across the basin. Figure 29 shows the potential impact map in the near-term period of 2021 to 2040 while figure 30 shows mid-term projections. During the mid-term period, 53 per cent of the basin area exhibited a moderate potential impact. This increase in potential impact between periods is relative to the change in exposure indicators and is demonstrated with increases in temperature and declines in precipitation which deteriorate with respect to the reference period. In the absence of adaptation measures, high potential impact is also observed in areas with high sensitivities dependent on population density, well distribution, built-up areas, industries, vegetation cover and others.

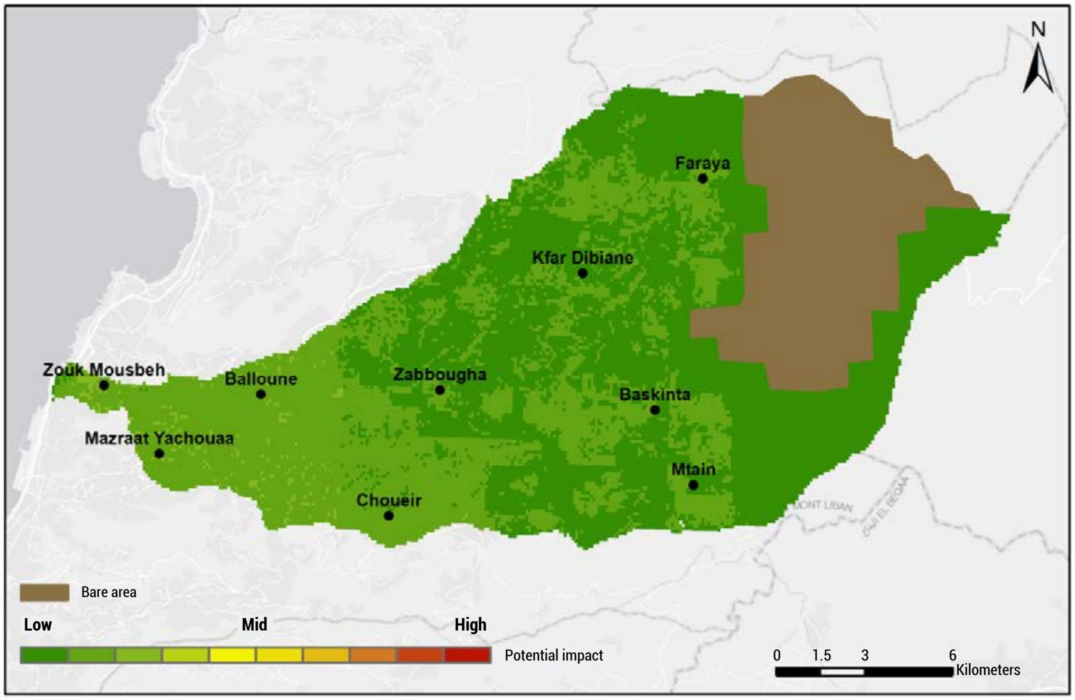
In the mid-term, the municipalities that exhibited the highest potential impacts in the lower basin area include Zouk Mousbeh, Zouk El-Kharab, Chouaya El-Matn, Mazraat Yachouaa, Choueir, Qornet El-Hamra, Kfar Dibiane, Bikfaya and Khinchara. In the upper basin area, the municipalities of Baskinta, Faraya and Kfar Dibiane had the highest rates of potential impact.

FIGURE 28: Annual potential impact map for the reference period (1995–2014)



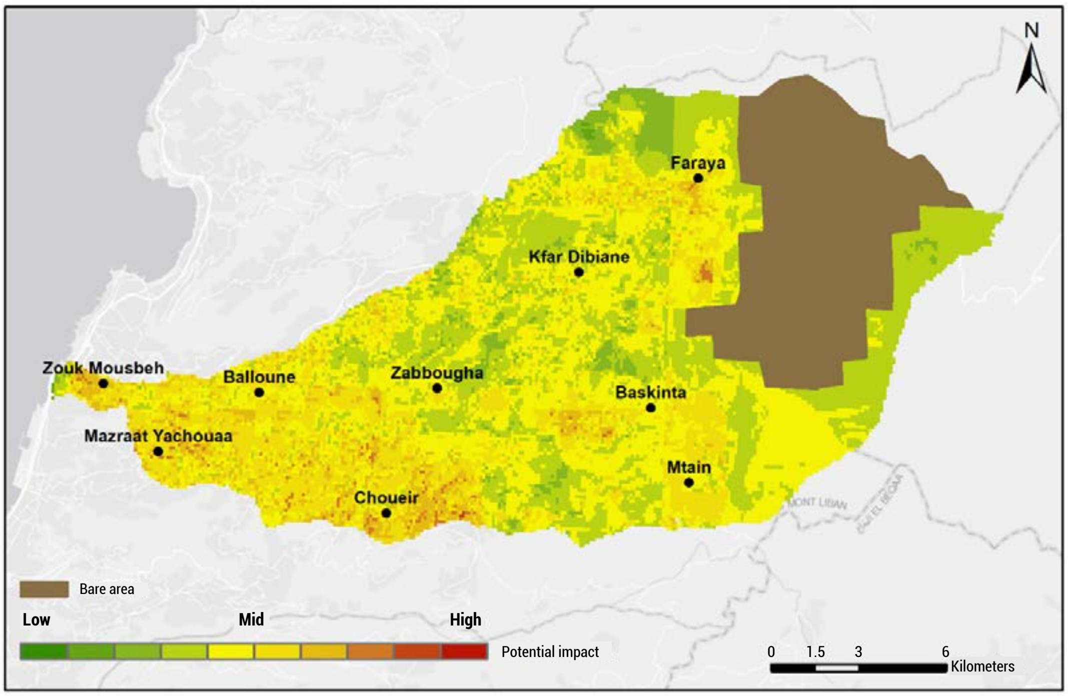
Source: Authors.

FIGURE 29: Annual potential impact map for the near-term period (2021–2040)



Source: Authors.

FIGURE 30: Annual potential impact map for the mid-term (2041–2060)

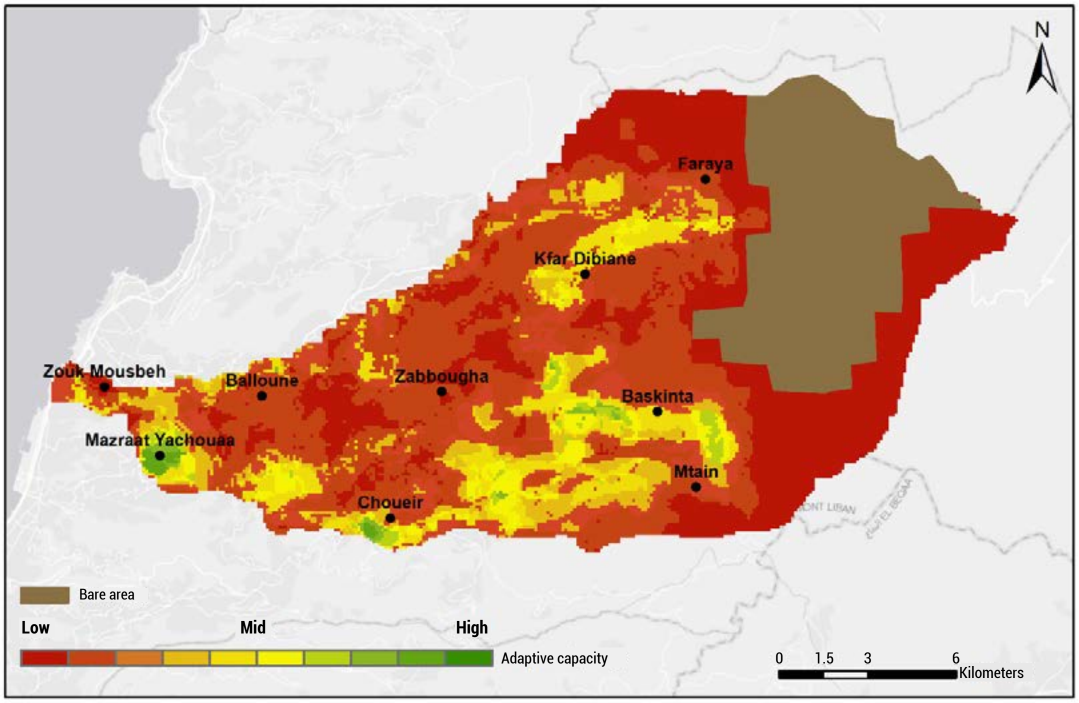


Source: Authors.

D. Adaptive capacity

Adaptive capacity reflects the ability of a system to cope with the impact of climate change. Research for this technical report indicates that the basin's adaptive capacity is low to moderate, although small areas, especially in the lower basin and near the coast, exhibit higher adaptive capacities. Figure 31 shows the adaptive capacity map and reveals that areas with higher adaptive capacity are generally those with access to public schools, financial services and water networks. Some of these areas are located within the municipalities of Mazraat Yachouaa, Choueir, Bteghrine, Baskinta and Marjaba. Despite some limited improvements, within the basin overall only 13 per cent of municipalities have moderate to high adaptive capacity. Although contributing indicators are based on current conditions, adaptive capacity may change in the future as coping mechanisms are developed.

FIGURE 31: Annual adaptive capacity map



Source: Authors.

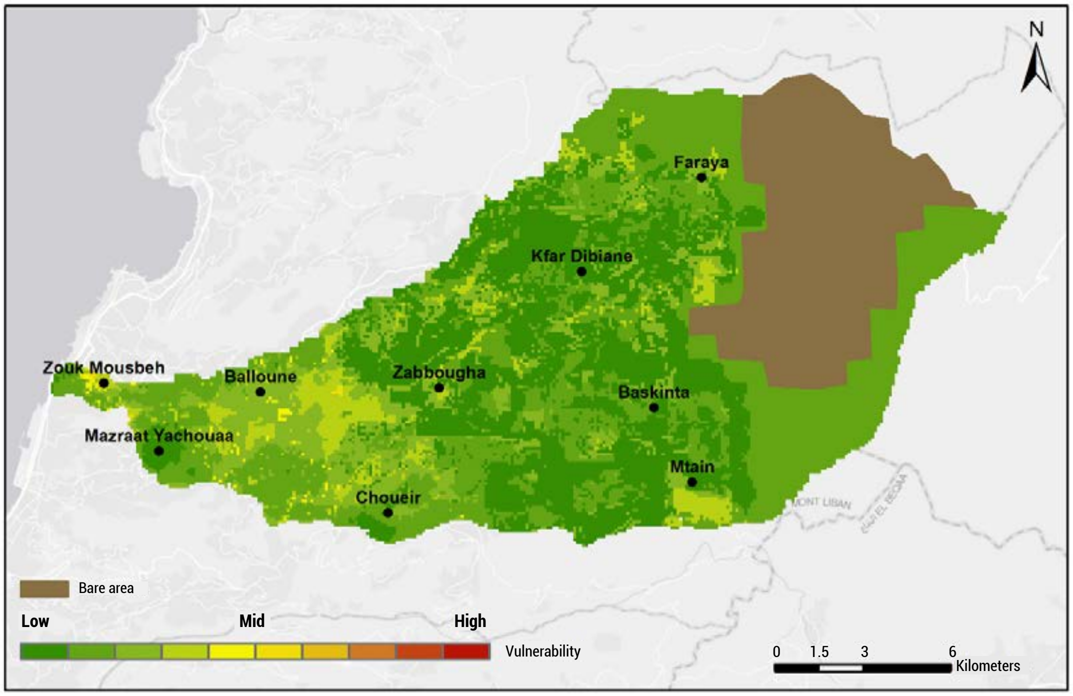
E. Vulnerability assessment findings

Figure 32, figure 33 and figure 34 show the results of the vulnerability assessment for the reference (1995–2014), the near-term (2021–2040) and the mid-term (2041–2060) periods. The reference period is dominated by areas exhibiting low vulnerability, while the near-term period exhibits higher vulnerability than the reference period but is still within the low to moderate vulnerability range. The mid-term period is dominated by areas exhibiting high vulnerability. Indeed, there is an increasing vulnerability trend across the three time periods that is highly correlated to projected increases in exposure. Figure 35 shows the percentage of areas impacted (low, moderate, high) in the reference, near-term and mid-term periods. In the mid-term period, 32 per cent of the basin is projected to exhibit moderate vulnerability, whereas 48 per cent will likely exhibit high vulnerability. Figure 36 shows that in the mid-term period, out of the total area with cultivated crops, 40 per cent exhibits moderate vulnerability and 54 per cent exhibits high vulnerability. Regarding the percentage of the population impacted, figure 37 shows that by the mid-term, 37 per cent of the population will be living in areas that exhibit moderate vulnerability and 55 per cent in areas that exhibit high vulnerability.

Areas exhibiting the highest rates of vulnerability are those with the greatest potential for being impacted and the lowest amount of adaptive capacity. During the near-term period, the municipalities with highest vulnerability in the lower basin include Zighrine El-Matn, Mar Boutros Karm Et-Tine, Mayasseh, Chouaya El-Matn, Balloune, Aain El-Kharroubeh Himlaya, Ain el Qash, Jeita, Khinchara, Zabbougha, Abou Mizane, Ajaltoun, Jouar El-Matn, Chaouiyeh, Daraya Kesrouane, Mhaidset El Matn, Deir Chamra, Bikfaya, Sfeilet

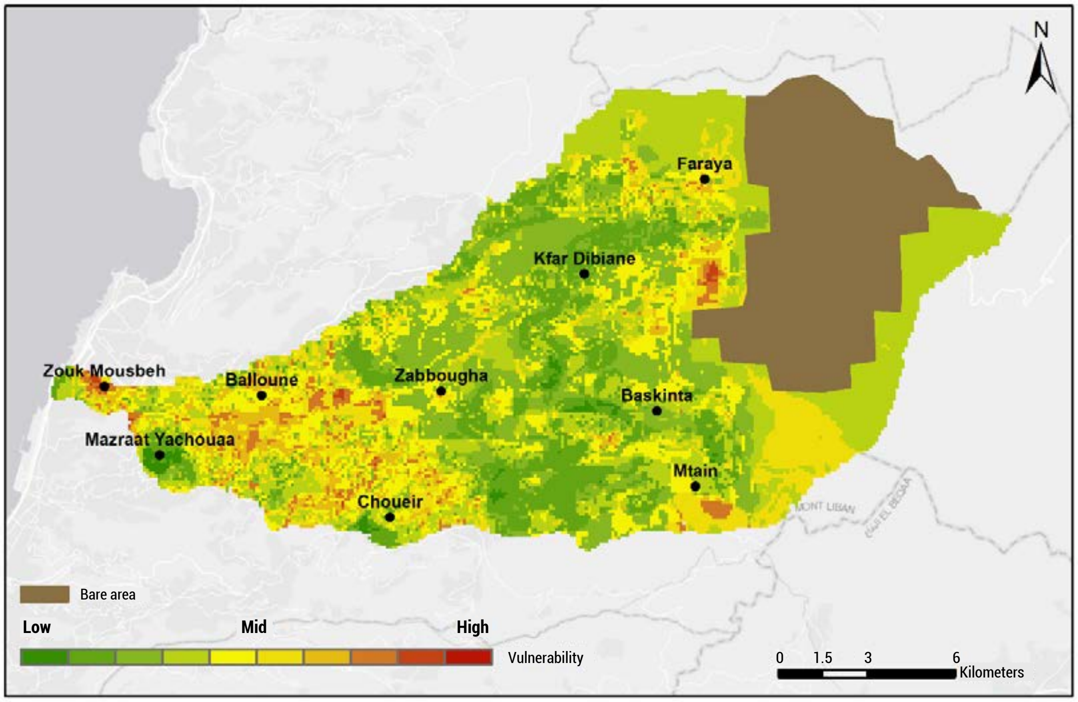
Bikfaya, Beit Chabab, Fraikeh, Qleiaat Kesrouane and Zakrit. In the upper basin, the most vulnerable municipalities include Faraya, Mayrouba, Bqaatouta, Mtain, Baskinta and Kfar Dibiane.

FIGURE 32: Vulnerability assessment for the reference period (1995–2014)



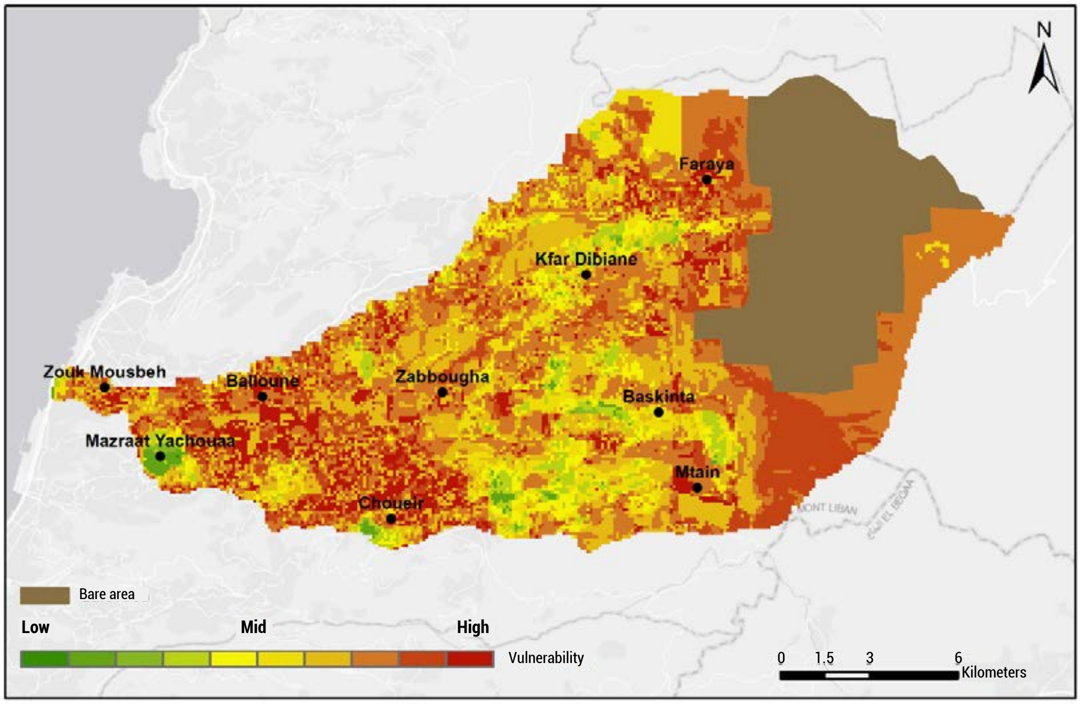
Source: Authors.

FIGURE 33: Vulnerability assessment for the near-term period (2021–2040)



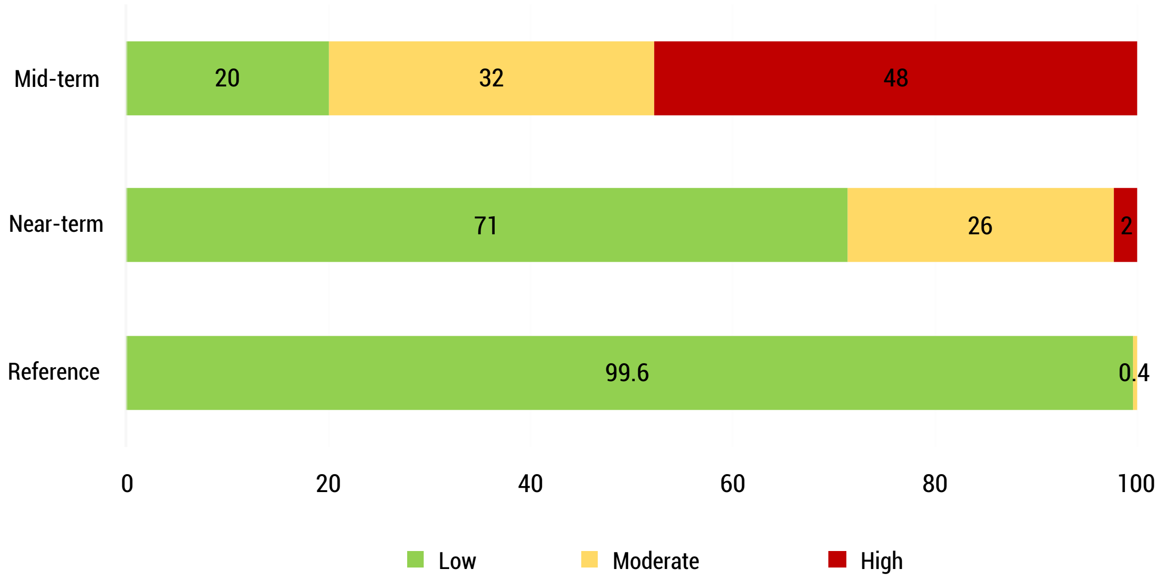
Source: Authors.

FIGURE 34: Vulnerability assessment for the mid-term period (2042–2060)



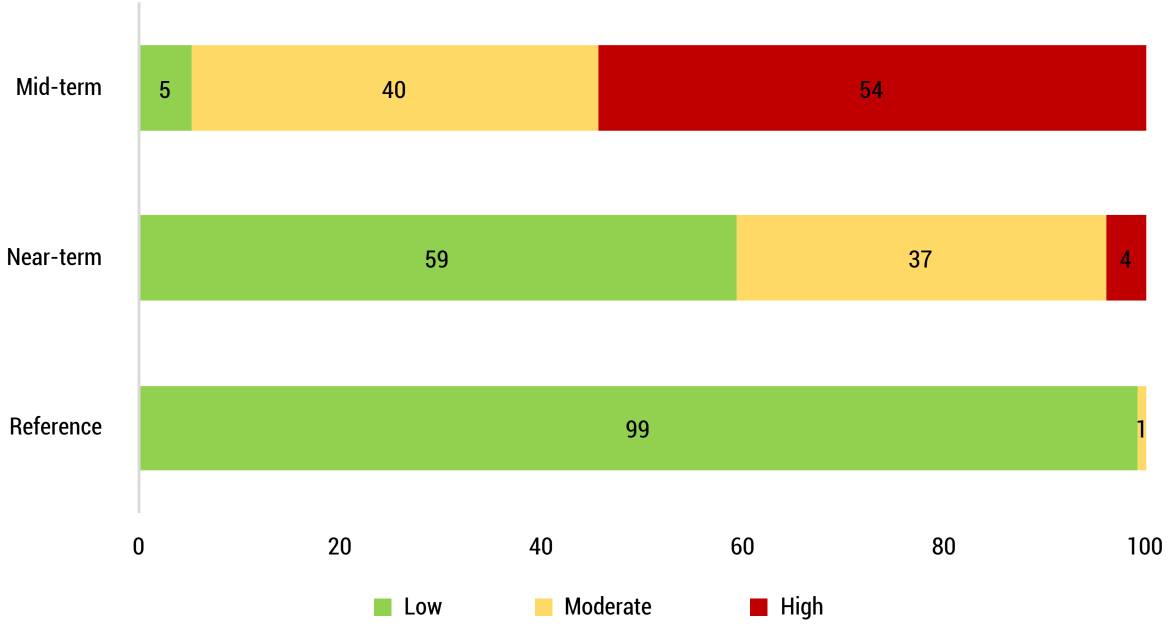
Source: Authors.

FIGURE 35: Percentage area that exhibits low (1–4), moderate (5–7) and high (8–10) vulnerability in the reference, near-term and mid-term periods



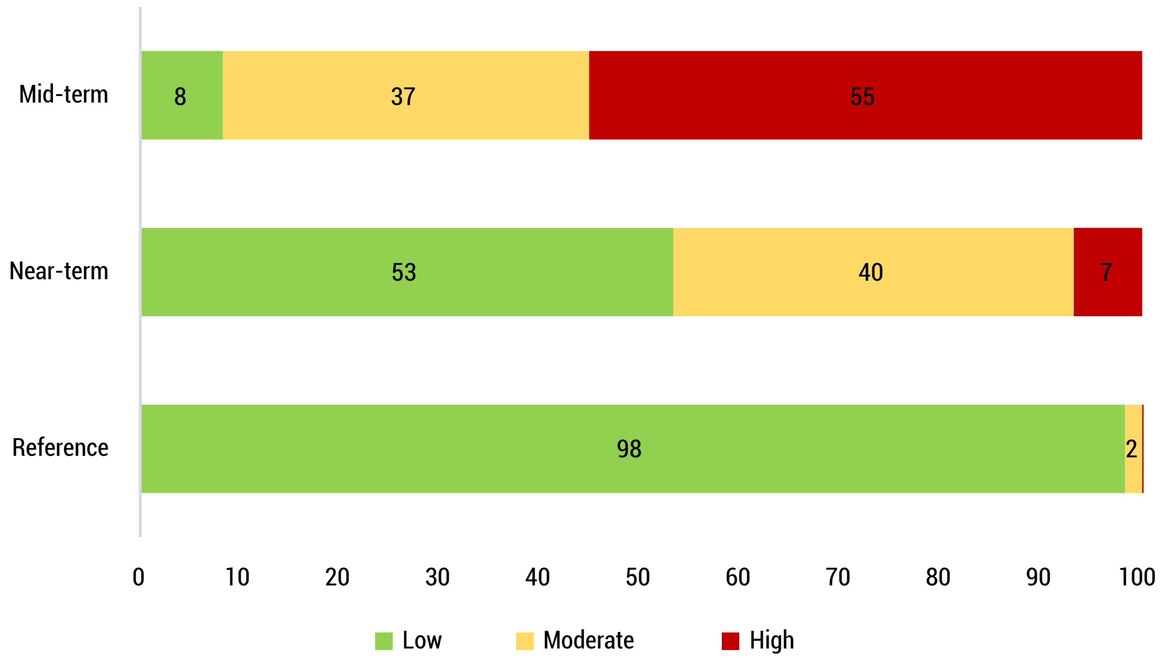
Source: Authors.

FIGURE 36: Percentage of total crop cultivated area that exhibits low (1–4), moderate (5–7) and high (8–10) vulnerability in the reference, near-term and mid-term periods



Source: Authors.

FIGURE 37: Percentage of population that exhibits low (1–4), moderate (5–7) and high (8–10) vulnerability in the reference, near-term and mid-term periods



Source: Authors.

5 CLIMATE CHANGE IMPACT ON THE AGRICULTURAL PRODUCTION OF APPLES

Following consultations with farmers and local stakeholders in the basin, it was reported that apples, produced mainly in the upper part of the basin, are a key crop in Nahr el Kalb. Given that the bud break and flowering of apples are sensitive to the impact of climate change-related temperature extremes (Funes and others, 2016), climate change impacts on apple production are discussed in the following section of this report.

A. Methodology

The CropSyst model was selected to assess climate change impacts on apple tree production in the basin. CropSyst is a user-friendly, conceptually simple but sound multi-year multi-crop simulation model with daily time steps. The model simulates the soil water budget, soil plant nitrogen budget, crop canopy and root growth, dry matter production, yield, residue production and decomposition, and erosion. Management options include cultivar selection, crop rotation (including fallow years), irrigation, nitrogen fertilization, more than 80 options for tillage operations and residue management.

CropSyst is made available free of charge by Washington State University and takes into account the effect of changes in temperature, precipitation and CO_2 concentration. It has been used in many studies to assess the impact of climate change on the productivity of agricultural crops. Its main advantage is that it can be used to assess the effect of climate change on certain trees.

Data needed for calibration of the model, including crop, soil, field management and irrigation schedules were collected from field questionnaires and phone interviews with farmers in the area. Climatic data was provided by LARI.

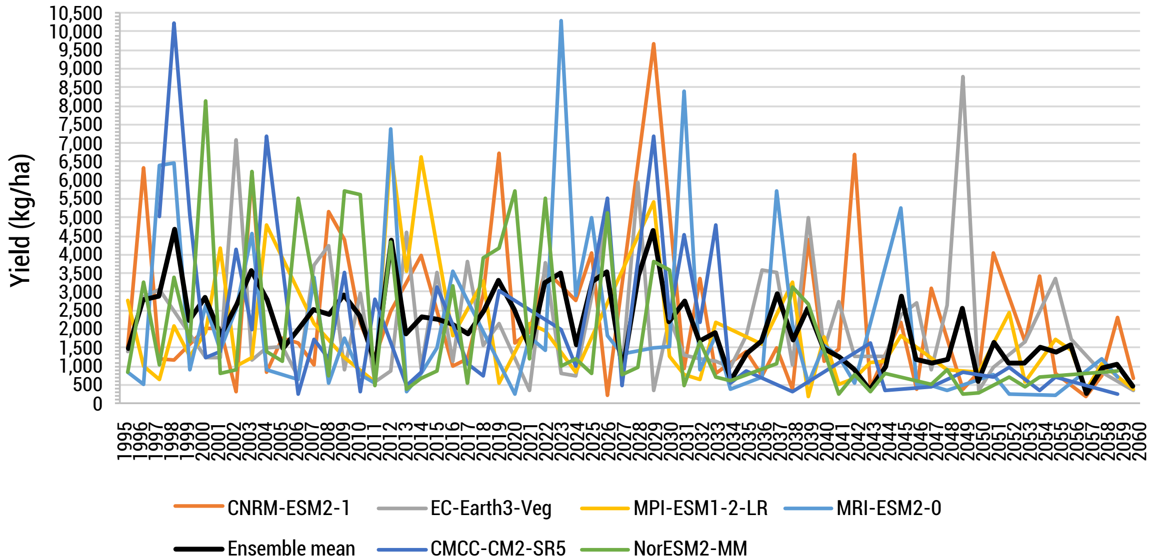
B. Findings

1. Changes in apple crop yields

To evaluate the impact of climate change on apple yields, the CropSyst model was applied both with and without elevated atmospheric CO_2 concentrations as per the SSP5-8.5 scenario.

Figure 38 and figure 39 show the results of the simulation with fixed atmospheric CO_2 concentrations of 400 ppm and table 5 provides a summary of the results. The yield is projected to decrease by 10 and 47.6 per cent during the periods (2021–2040) and (2041–2060) respectively, as compared with the reference period (1995–2014).

FIGURE 38: Projected apple crop yields for the period (1995–2060) according to six regional climate models, assuming a fixed CO_2 concentration of 400 ppm



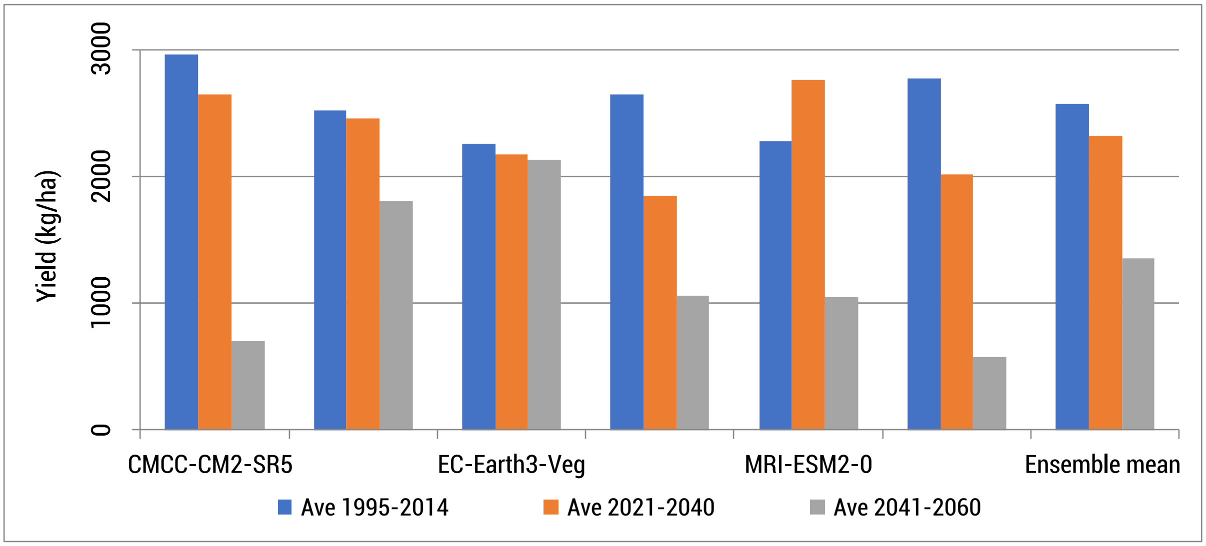
Source: Authors.

TABLE 5: Projected apple crop yield (kg/ha) for the periods (2021–2040) and (2041–2060) as compared to the reference period (1995–2014) in the Nahr el Kalb basin according to six regional climate models, assuming a fixed CO_2 concentration of 400 ppm

Time period	Apple crop yields (kg/ha)						
	CMCC-CM2-SR5	CNRM-ESM2-1	EC-Earth3-Veg	MPI-ESM1-2-LR	MRI-ESM2-0	NorESM2-MM	Ensemble mean
1995–2014	2 961	2 523	2 258	2 639	2 281	2 775	2 573
2021–2040	2 643	2 454	2 169	1 843	2 764	2 017	2 315
2041–2060	698	1 800	2 130	1 063	1 051	572	1 348
Relative change (mid-term/ reference period)	-76.4%	-28.6%	-5.7%	-59.7%	-53.9%	-79.4%	-47.6%

Source: Authors.

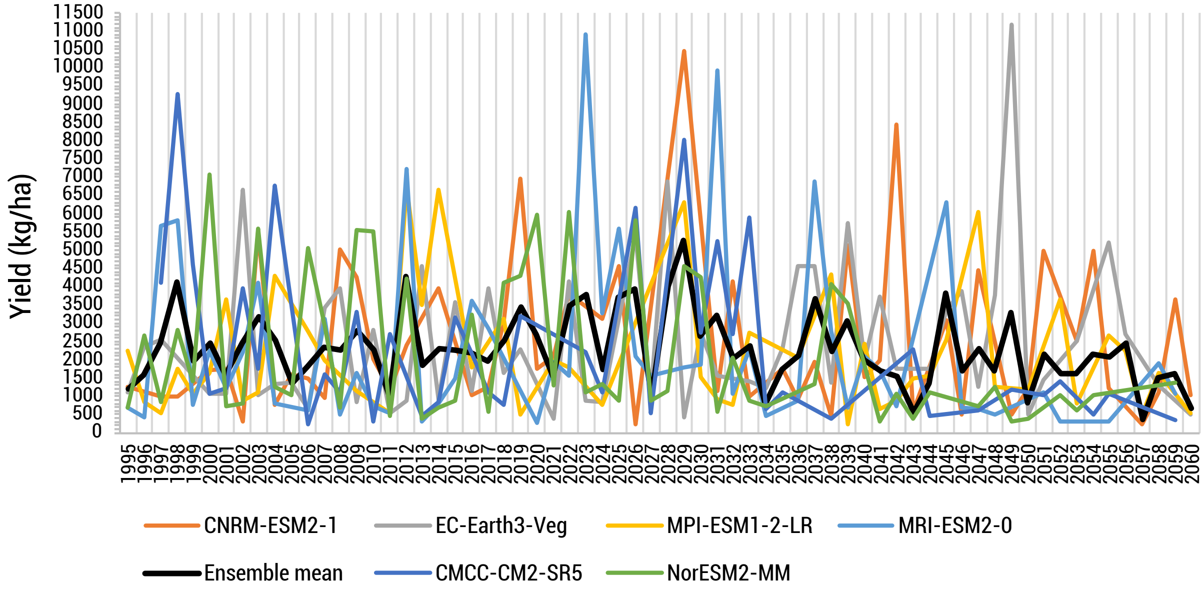
FIGURE 39: Projected apple crop yields for the periods (2021–2040) and (2041–2060) as compared with the reference period (1995–2014), assuming a fixed CO_2 concentration of 400 ppm



Source: Authors.

When the effect of elevated atmospheric CO_2 concentration is considered, apple crop yields are projected to decrease by only 16.4 per cent during the period (2041–2060) as compared with the reference period (1995–2014), as shown in figure 40, table 6 and figure 41.

FIGURE 40: Projected apple crop yield for the period (1995–2070) according to six regional climate models, assuming elevated atmospheric CO_2 levels



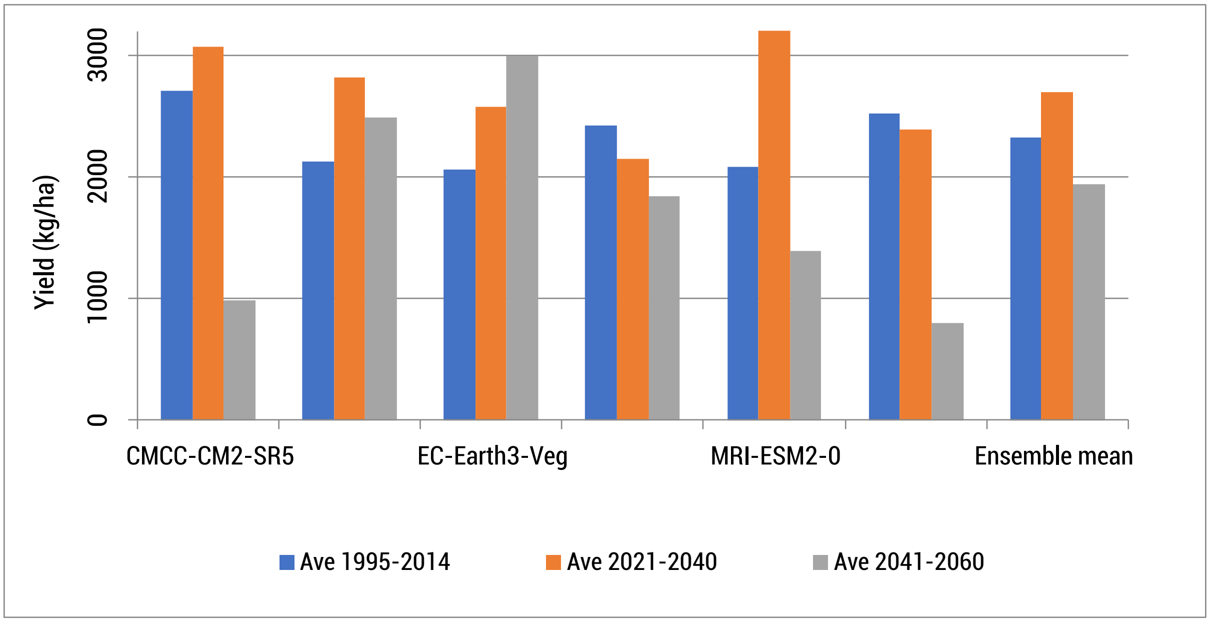
Source: Authors.

TABLE 6: Projected apple crop yields (kg/ha) for the periods (2021–2040) and (2041–2060) as compared with the reference period (1995–2014) in the Nahr el Kalb basin according to six regional climate models, assuming elevated atmospheric CO_2 levels

Time period	Apple crop yields (kg/ha)						
	CMCC-CM2-SR5	CNRM-ESM2-1	EC-Earth3-Veg	MPI-ESM1-2-LR	MRI-ESM2-0	NorESM2-MM	Ensemble mean
1995–2014	2 707	2 125	2 065	2 427	2 080	2 521	2 321
2021–2040	3 067	2 821	2 576	2 153	3 204	2 386	2 701
2041–2060	989	2 490	2 990	1 846	1 388	803	1 941
Relative change (mid-term/ reference period)	-63.5%	17.2%	44.8%	-23.9%	-33.3%	-68.2%	-16.4%

Source: Authors.

FIGURE 41: Projected apple crop yields for the periods (2021–2040) and (2041–2060) as compared with the reference period (1995–2014), assuming elevated atmospheric CO_2 levels

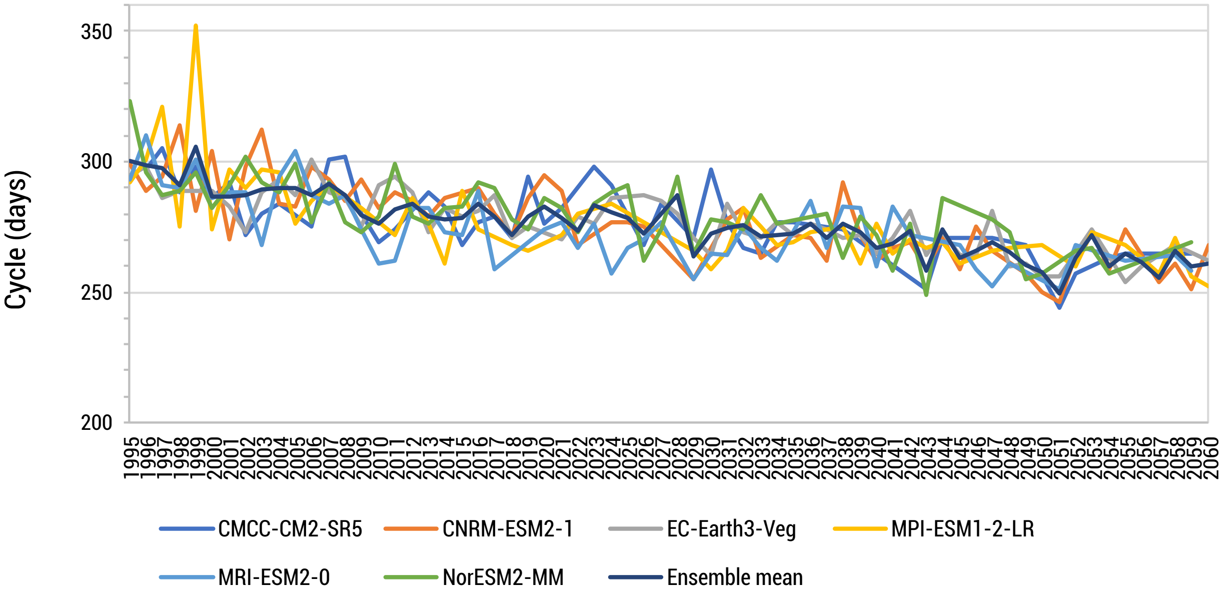


Source: Authors.

2. Changes in the apple growth cycle

The expected increase in temperatures in the basin will cause faster development and a shortened growing period for cultivated crops. The growth cycle for apple fruit is projected to be reduced by 14 and 24 days during the periods (2021–2040) and (2041–2060) respectively, as compared with the reference period (1995–2014). This is illustrated in figure 42, figure 43 and table 7.

FIGURE 42: Projected changes to the apple growth cycle according to six regional climate models (1995–2060)



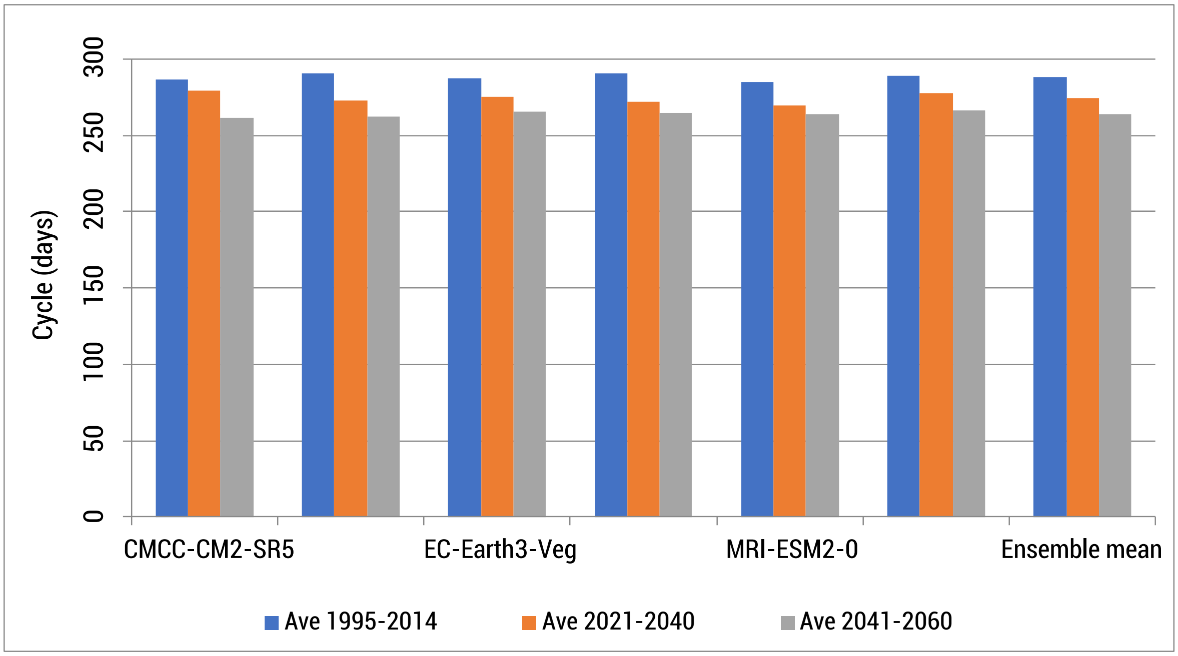
Source: Authors.

TABLE 7: Projected growth cycle (days) of apple fruit for the periods (2021–2040) and (2041–2060) as compared with the reference period (1995–2014), according to six regional climate models

Time period	Apple fruit growth cycle						
	CMCC-CM2-SR5	CNRM-ESM2-1	EC-Earth3-Veg	MPI-ESM1-2-LR	MRI-ESM2-0	NorESM2-MM	Ensemble mean
1995–2014	287	291	287	290	285	289	288
2021–2040	279	273	275	272	270	278	274
2041–2060	262	262	266	265	263	266	264
Relative change (mid-term/ reference period)	-8.7%	-9.8%	-7.6%	-8.8%	-7.6%	-8.0%	-8.6%

Source: Authors.

FIGURE 43: Projected growth cycle of apple fruit for the periods (2021–2040) and (2041–2060) as compared with the reference period (1995–2014), according to six regional climate models

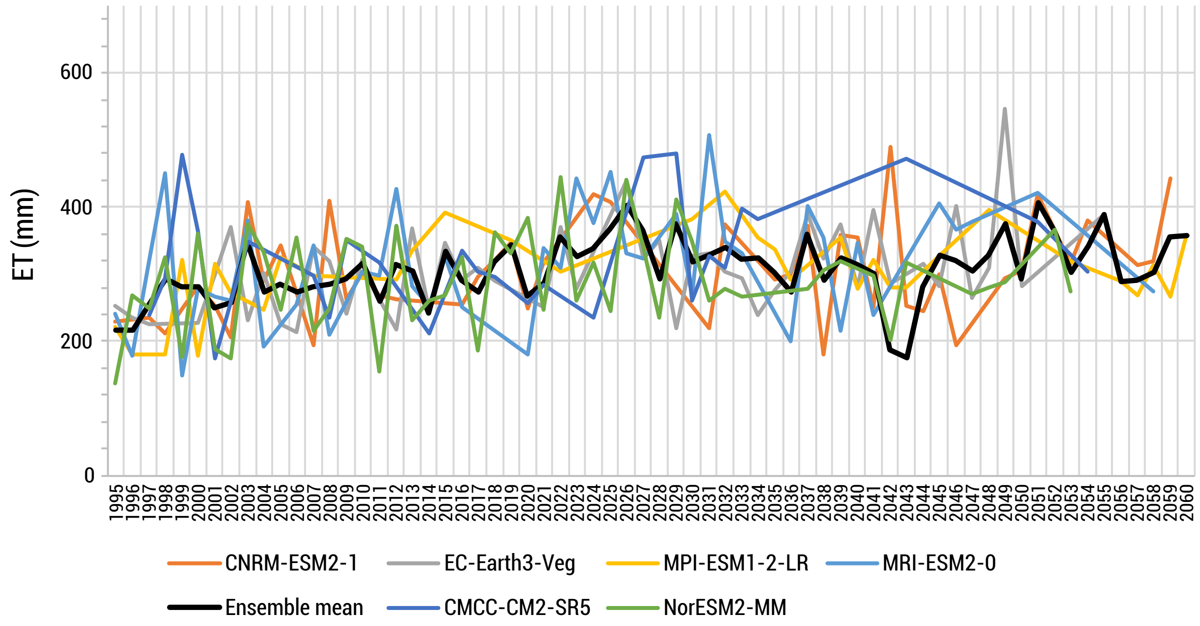


Source: Authors.

3. Changes in apple tree water requirements

Seasonal evapotranspiration (ET) of apple trees is projected to increase due to rising temperatures. The projected increase in crop evapotranspiration for apple trees is 55 mm, a 20 per cent rise, and 66 mm, a 24 per cent rise, during the periods between 2021 and 2040 and between 2041 and 2060, respectively, as compared to the reference period (1995–2014). This is illustrated in figure 44, figure 45 and table 8.

FIGURE 44: Projected average seasonal evapotranspiration (ET) according to six regional climate models (1995–2060)



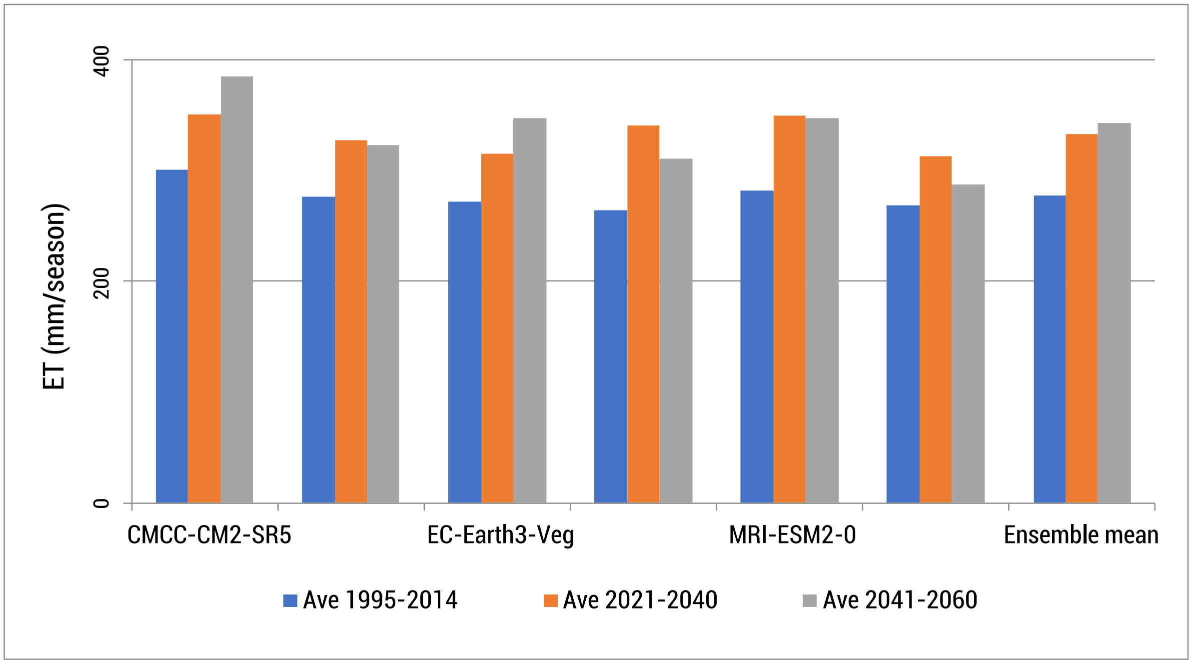
Source: Authors.

TABLE 8: Projected seasonal evapotranspiration (ET) of apple trees for the periods (2021–2040) and (2041–2060) as compared with the reference period (1995–2014) for the six regional climate models (mm)

Time period	Seasonal actual ET (mm)						
	CMCC-CM2-SR5	CNRM-ESM2-1	EC-Earth3-Veg	MPI-ESM1-2-LR	MRI-ESM2-0	NorESM2-MM	Ensemble mean
1995–2014	301	277	272	264	281	268	277
2021–2040	350	327	315	341	349	312	332
2041–2060	384	323	347	311	347	287	343
Relative change (mid-term/ reference period)	27.8%	16.7%	27.7%	17.8%	23.5%	6.9%	23.6%

Source: Authors.

FIGURE 45: Projected seasonal evapotranspiration (ET) of apple trees for the periods (2021–2040) and (2041–2060) as compared with the reference period (1995–2014) for the six regional climate models



Source: Authors.

D. Conclusions

- Increased temperatures are likely to lead to shortened growing periods for apples of about 9 per cent.
- Climate change is projected to result in an increase in apple tree water consumption of about 24 per cent.
- Apple yields are projected to decrease by about 48 per cent as a result of climate change by 2070, but when the positive impact of increasing atmospheric CO_2 levels is taken into consideration, the decrease in yield is estimated at just 16 per cent.
- It is necessary to take measures for climate change adaption to reduce the impact on apple trees in the basin.

6 WATER-ENERGY-FOOD NEXUS IN THE NAHR EL KALB BASIN

To achieve water, energy and food security, a nexus approach of building synergies across sectors and a move away from silos is required. The concept of the water-energy-food nexus was developed at the Bonn 2011 Nexus Conference - The Water, Energy and Food Security Nexus - Solutions for a Green Economy, which took place from 16 to 18 November 2011, and takes into consideration the interconnectedness of the three nexus elements (Hoff, 2011).

Water and energy are essential for producing food: water management, including pumping, treating and distribution, requires energy, and energy generation requires water. The water-energy-food nexus influences and is influenced by social, economic, environmental and political conditions. Recent work on ensuring water, energy and food security (ESCWA, 2015) has incorporated climate change and a human rights-based approach so as to meet key objectives set out in the Sustainable Development Goals (SDGs), as highlighted in box 2. As shown in figure 46, a more holistic framework of the nexus: considers the capacity to apply and build on lessons learned from integrated water resources management; provides principles and tools for improved water security; supports sustainable energy for all to promote improved energy security; and promotes sustainable agriculture and reliable trade as a means of achieving food security.

BOX 2: The water-energy-food nexus and achieving the Sustainable Development Goals

The water-energy-food nexus is critical to consider when assessing progress towards the achievement of the SDGs, particularly SDGs 2, 6, 7 and 13, which are elaborated below.

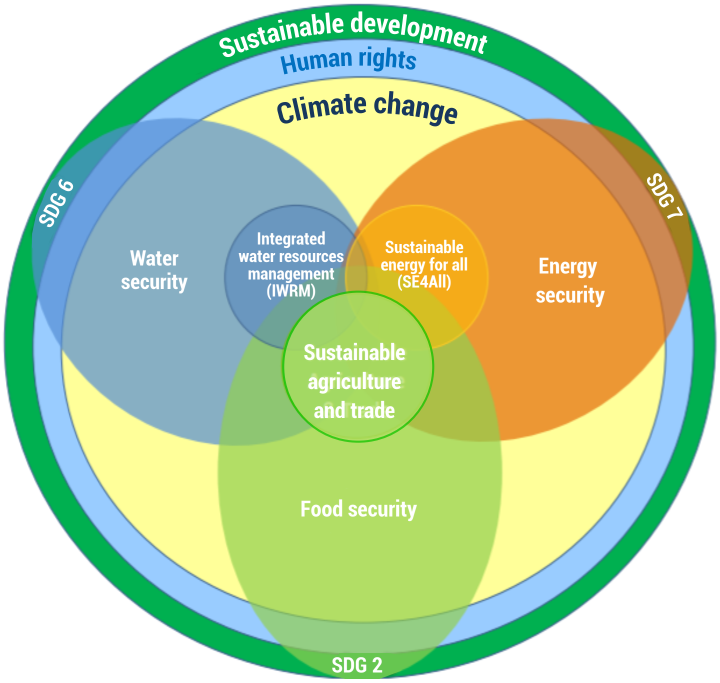
Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture.

Goal 6. Ensure availability and sustainable management of water and sanitation for all.

Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all.

Goal 13. Take urgent action to combat climate change and its impacts.

FIGURE 46: The water-energy-food security nexus in the Arab region



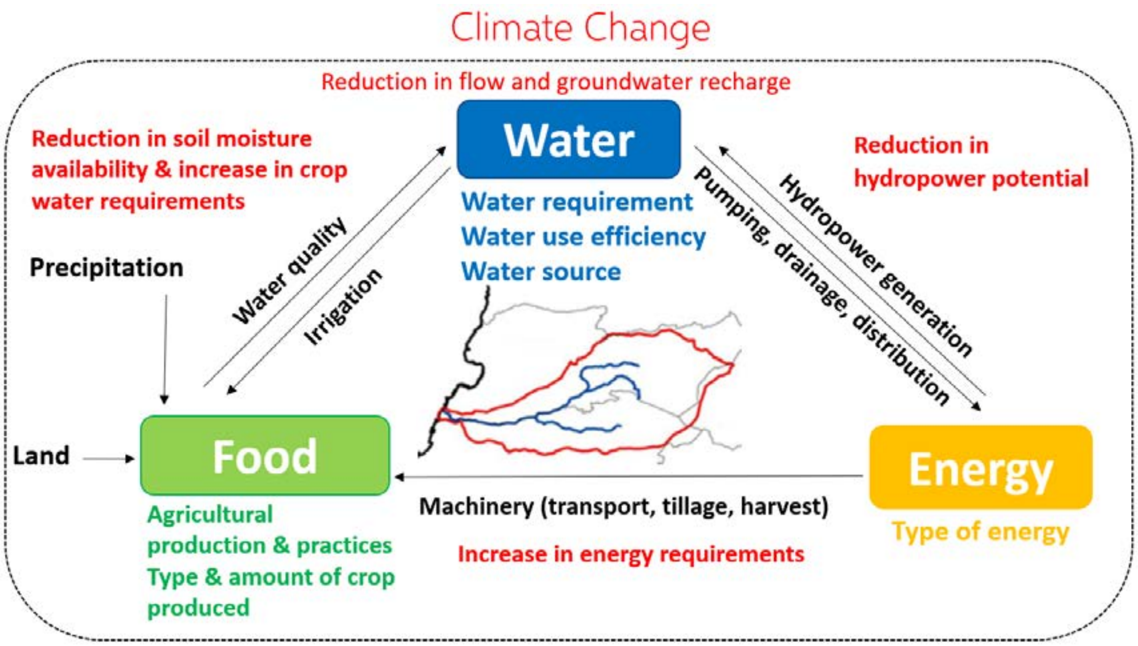
Source: ESCWA, 2015. The Water, Energy and Food Security Nexus in the Arab Region.

The water-energy-food nexus may be used as an analytical tool, a conceptual framework and/or a discourse tool. As an analytical tool it can be used to assess water-energy-food resource interactions quantitatively and qualitatively, but has been criticized for being complex and hard to replicate. As a conceptual framework, it can be used to map the nexus linkages to enable clarity and promote policy coherence, while as a discourse tool, it addresses problems and promotes cross-sector collaboration (Nhamo, 2020). The present watershed-specific assessment maps and examines water-energy-food security nexus considerations in Nahr el Kalb from a climate perspective, using a conceptual framework to enhance understanding of correlations and develop a guiding scheme for the adoption of a nexus approach at the basin level.

The application of a water-energy-food nexus approach is impacted by population growth, increased urbanization, unsustainable production and consumption patterns, soil and land degradation, declining water quality and water scarcity, all of which are exacerbated by climate change. It can be used as an adaptive management approach to various challenges, including climate change.

Figure 47 provides a conceptual framework for examining the water-energy-food nexus in the Nahr el Kalb basin, taking into consideration its unique specificities and the fact that diverse forces can exacerbate or mitigate stresses.

FIGURE 47: Water-energy-food nexus framework showing the impact of climate change on the Nahr el Kalb basin



Source: Authors.

A. Water-food (agriculture) nexus

In Lebanon, 62 per cent of total water resources are allocated to the agriculture sector, with net irrigation demand expected to reach 1,050 million cubic metres (MCM) per year by 2030. In 2020, irrigated areas reached 105,000 ha with an average irrigation consumption of 8,400 m^3/ha. Prioritizing agriculture ensures food security and maintains livelihoods for agricultural workers to support their families (UNDP, 2020).

Although the Nahr el Kalb basin is becoming more urbanized at the expense of agricultural areas, a large percentage of water is still needed for irrigated agriculture. The Chabrouh dam on the Laban spring has a capacity of 9 MCM and is used as a potable water supply and for irrigation (UNDP, 2020). Other springs, such as the Assal spring, and a few constructed hill lakes are also used for irrigation. Groundwater also constitutes a key source for irrigation for multiple farmers. No sources of unconventional water have been used for irrigation in the basin because as yet there are no wastewater treatment plants. Section V provided an example of how changes in water availability impact the productivity of the apple crop in the basin. Furthermore, agricultural practices can impact the quantity and quality of water resources. Wasteful agricultural practices and inefficient irrigation technologies can seriously undermine the sustainability of water resources. In fact, inefficient flood irrigation accounts for between 50 and 70 per cent of irrigation activities (ESCWA, 2016). In addition, agricultural run-off and the discharge of fertilizers and pesticides has led to significant pollution of water bodies (UNDP, 2020).

B. Water-energy nexus

Energy is needed to treat, pump and distribute water for agriculture, domestic and industrial uses. Alternatively, water can be used to generate energy through hydropower and to cool power plants. Lebanon imports all of its fossil fuel needs, including for power generation. In 2010, only 3.2 per cent of energy in Lebanon was generated by hydropower plants (International Renewable Energy Agency (IRENA, 2020). In 2018, Lebanon updated its renewable energy targets by aiming to increase renewable energy contributions to 30 per cent of the total energy mix. Lebanon has the potential to supply 30 per cent of its electricity from renewables by 2030, with 601 MW of that total coming from hydropower (IRENA, 2020). However, new hydropower sites are yet to be utilized and climate change implications for water availability must be taken into consideration.

In 2012, the Ministry of Energy and Water, in collaboration with the Artelia Group prepared a hydroelectric potential study for Lebanon that identified 32 new sites along main rivers with potential hydroelectric capacity. The hydroelectric capacity of the Chabrouh dam was studied in the Nahr el Kalb basin. The dam location was given a level two categorization, with a low environmental impact and moderate levelized costs. The ministry, in collaboration with UNDP and Country Entrepreneurship for Distributed Renewables Opportunities (CEDRO) also assessed microhydropower potential within various non-river water systems. Installation of microhydropower generators on small streams may also have potential in the development of renewable energy sources in the basin (box 3). More recently, a feasibility study was conducted on the Hrache Jeita hydroplant that suggested the potential benefits stemming from the rehabilitation of pre-existing locations (box 4).

BOX 3: Micro hydropower potential

Microhydropower plants are an important prospect for future hydroelectric developments in locations where large-scale dams have already been exploited or are now considered environmentally unacceptable. Streams that flow continuously all year are suitable for microhydropower generation, but the proper identification and design of microhydropower generators is highly dependent on flow variability. Reliable flow duration curves are key for optimal design of generators and are used for flow prediction as they contain information regarding the characteristics of hydrological regimes and flow variability. The construction of flow duration curves at gauged stations is a simple task when using the method described by Vogel and Fennessey (1994). However, for ungauged sites with limited to no flow data available, as is the case in the Nahr el Kalb basin, this becomes more challenging.

Atieh and others (2017) developed a methodology for elaborating flow duration curves at ungauged sites using artificial neural networks to capture the complex nonlinear effects of watershed characteristic parameters and climatic factors. This method incorporates topographic, land cover and climatic data as well as groundwater contributions to streamflow. Given the limited number of flow monitoring stations across the Nahr el Kalb basin, that methodology may be adopted to identify optimal designs for microhydropower plants.

Source: M. Atieh, G. Taylor, A. Sattar, B. Gharabaghi (2017). Prediction of flow duration curves at ungauged basins. Journal of Hydrology.

BOX 4: The Hrache-Jeita hydroplant

The Hrache-Jeita hydroplant is run by BMLWE. It is a small plant that constitutes less than 0.5 per cent of the installed hydrocapacity in the country. It began operations in the 1960s but stopped in 1995 when the selling tariff of the hydroenergy produced did not cover the operating costs of the plant (UNDP and CEDRO, 2013). Scenario analysis for the rehabilitation of the Hrache-Jeita hydroplant followed by discussions with BMLWE resulted in the installation of three turbines, two with 500 KW capacities and one 200 kW turbine. There was no need for additional conveyance works because part of the total available flow of the spring was already diverted to generate 4.65 kWh per year and run the pumping station. The UNDP-CEDRO project also studied the state of the Hrache-Jeita hydroplant and indicated that existing equipment needed replacement. In 2021, a feasibility study for rehabilitating the hydropower plant was conducted by the Lebanon Water Project. Results showed that BMLWE could save up to $200,000 annually in energy costs when operating the Jeita pumping station to provide Metn with water and when operating well pumps to deliver water to Beirut (Lebanon Water Project, 2021).

Source: Lebanon Water Project, 2021.

Hrache-Jeita during the spring of 2022, photo by Nabil Haddad.

C. Energy-food nexus

The agriculture sector requires energy for indirect and direct uses. Indirect uses include energy used in energy-intensive inputs such as the production of fertilizers and pesticides. However, Lebanon does not produce pesticides and relies on imports to meet its needs. Direct energy uses in the agriculture sector include the energy consumed through agricultural operations such as tilling, planting, irrigating and harvesting. Energy is also consumed during food production, transportation, storage, processing and retail. Pumping water for irrigation is also a major energy consumer. Wasteful agricultural practices can lead to significant energy losses.

In the Nahr el Kalb basin, and specifically in the upper part of the basin where the main agricultural activities are concentrated, many farmers use privately-owned generators to pump water from a water source to their fields.

Apples and pears are the primary crops cultivated in the Nahr el Kalb upper basin. Those crops do not require large energy consumption except in the case of cold storage and thus electricity needs can be supported through solar power generation. Given the energy-related challenges in Lebanon and the high cost and often limited availability of fuel, solar pumps have become an appealing solution, especially during the summer season when irrigation is required for agriculture. Solar powered pumps use photovoltaic panels as opposed to grid electricity diesel fuel. Studies comparing the costs of using solar photovoltaic and diesel fuel pumping systems at site scale have concluded that solar pumps are profitable and a less risky investment when compared to diesel engine-operated pumps. However, solar pumps must be monitored and abstraction limits strictly enforced so that over pumping does not occur due to the perception that the energy used to power solar pumps is "free".

Energy consumption in livestock farms differs according to the type of farm and its requirements. For example, cows require less energy than poultry. Electricity is needed for milk extraction through electrical equipment, mostly in medium and large farms, and for cold storage, but poultry production requires heating and cooling, and the energy/electricity load is higher. For dairy production, cold storage is responsible for the bulk of electricity consumed (ESCWA, 2020), although solar energy has the potential to make energy available at a lower cost than electricity generated by other means.

D. Climate change and the water-energy-food nexus

The impacts of climate change on the water-energy-food nexus undermine the achievement of water, energy and food security, hamper economic development and increases environmental damage. For example, climate change exacerbates stress on water availability and quality, causing more frequent extreme events that can result in severe socioeconomic and environmental consequences. As such, understanding the relationship between climate change and the water-energy-food nexus is essential if stakeholders are to predict the repercussions for different economic sectors and develop efficient coping strategies.

Section III of this technical report sets out the predicted climate changes in the Nahr el Kalb basin for the near-and mid-term. The projected increase in temperatures and reduction in precipitation are expected to reduce ground water recharge and impact streamflow. In turn, this will put a strain on the water supply for domestic use, tourism and industrial and agricultural needs. Climate change may also impact the potential to use hydropower due to increasing water scarcity. Furthermore, higher temperatures negatively impact the performance of solar photovoltaic generation and tend to lower wind speed, thus also negatively affecting solar and wind power generation. Increases in temperature are also likely to increase energy demand and undermine energy efficiency.

Climate change is also expected to cause an increase in demand for water and energy. For instance, the rise in temperature and reduction of precipitation are expected to increase crop water requirements and decrease soil moisture levels. Supplemental irrigation may be required, thus impacting water allocation and energy security due to pumping and irrigation needs.

E. Recommendations

There is a need to foster policy coherence among the water-energy-food sectors within the Nahr el Kalb basin to improve livelihoods, enhance resource security, identify priority areas for intervention and provide watershed level management pathways towards sustainable development. In the long term, the expected outcome is to apply lessons learned from the Nahr El Kalb basin to other basins in the country. As such, two recommendations are made:

1. Identify coordinated and parallel strategies for the water-energy-food sectors

Currently, institutions function in silos in which the management of each sector is the responsibility of one institution with its own specific mandate (Farajalla, Haydamous and El Hajj, 2016). In Lebanon, the Ministry of Energy and Water oversees both the water and energy sectors. Nonetheless, national strategies for water, energy and food must consider the interdependence among systems and should be developed in collaboration with relevant ministries through the use of a national nexus assessment and a participatory inclusive process leading to the development of a national nexus strategy. This will limit inefficiencies, duplicated efforts, conflicting strategies and resource competition. For example, the Lebanese National Agricultural Strategy 2020–2025 references the need to expand the supply of water resources for irrigation and growth in agricultural production and productivity. These expansions must be done in line with the Lebanese National Water Strategy, which allocates water for different sectors and identifies prospects for water projects. In fact, inconsistencies and a lack of cohesiveness will eventually lead to conflicts in resource allocation.

The gradual institutionalization of the Nahr el Kalb river nexus, led by the Ministry of Energy and Water in collaboration with local authorities in the basin and using a participatory and multidisciplinary approach, should be considered. Addressing the water-energy-food nexus at the watershed level involves addressing "thematic models" within the nexus, in which themes and links within the nexus may be identified in line with basin priorities.

2. Develop a knowledge platform for decision and policy makers that integrates strategies at different spatial and temporal scales

A knowledge platform would facilitate the integration of data from different sectors and could make use of interactive visualization tools that provide easy access to, and deepen understanding of, policy implementation at various scales. That would facilitate the conversion of scientific data into actionable plans and would promote awareness of the nexus. For example, a decision on expanding a specific type of crop production could be evaluated on the basis of trade-offs such as energy requirements, irrigation needs and land exploitation. Additionally, the platform could be used to assess changes in energy usage and types of energy production, establish and enforce minimum energy efficiency requirements and identify technologies that could enhance water distribution and pumping systems. The platform could facilitate an assessment of trade-offs between water consumption and energy use, given that energy-intensive methods save water while water-intensive methods use less energy.

PART 2: CLIMATE PROOF WATERSHED MANAGEMENT DESIGN AND RESILIENCE PACKAGE

This section discusses a climate-proof watershed management design and resilience package for the Nahr el Kalb basin based on the results and analysis presented in part 1 together with the outcome of consultations with key stakeholders.

The 10-step methodology adopted by ESCWA for increasing climate resilience in the Nahr el Kalb basin as described in part 1 was useful in the analysis and design of a climate-proof watershed management and resilience package. The integrated vulnerability assessment identified high vulnerability areas in the basin and active participation in consultations allowed reflection of major stakeholder concerns and priorities within the analysis and recommendations. As such, replication of this study in other watersheds is highly recommended as it could inform updates to Lebanon's Fourth National Communication under the United Nations Framework Convention on Climate Change.

The package includes a list of 10 intervention measures to be implemented in the Nahr el Kalb basin with a focus on areas that are projected to exhibit high vulnerability levels. The recommendations presented include the implementation of measures related to the expansion of infrastructure projects related to the water sector, the adoption of innovative and efficient technologies, the promotion of the water-energy-food nexus, building capacities, research enhancement, data collection and the forging of partnerships with relevant stakeholders. The proposed interventions aim to improve water availability for domestic use, tourism, industry and agriculture while reducing pressures on surface and groundwater quality and quantity, and to improved livelihoods and access to information. Furthermore, four intervention measures have been shortlisted and detailed descriptions of each are provided. Shortlisting of intervention measures was based on the discussions held during the consultation meetings. The shortlisted interventions are in line with Lebanon's Economic Vision,[5] adopted with a view to reviving the economy, which recommended that investments should be made in promising sectors, including agriculture, industry, tourism, financial services and the knowledge economy. To elaborate on each shortlisted intervention measure, one-on-one consultations took place, both in person and virtually, with relevant stakeholders.

The ten intervention measures recommended for the Nahr el Kalb basin include:

1. Constructing planned wastewater treatment plants and networks in the basin, which will significantly reduce stress on surface and groundwater quality and will allow for the allocation of treated water resources for agricultural purposes. The German Federal Ministry for Economic Cooperation and Development (Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung) has conducted an assessment of potential sites for wastewater facilities in the Nahr el Kalb catchment and recommended three schemes: scheme one, which would cover Jeita, Shaile, Balloune, Daraya, Ajaltoun, Qleyyat, Raifoun, Ashkout and Faitroun municipalities, scheme two, covering Kfar Dibiane, and scheme three covering Mayrouba, Hrajel and Faraya (Margane, 2011).
2. Rehabilitating and expanding public water networks to enhance community access to public water sources, reduce losses in water and non-revenue water and reduce stress on groundwater resources. The rehabilitation of the Nahr el Kalb – Dbayeh water conveyor is also essential because the canal is an old, partially open 5.5 km cement channel with leakage and blockage problems.

Promoting sustainable agricultural practices that facilitate the efficient use of land and water resources in apple cultivation, a key crop in the basin. Activities to support this measure include rehabilitating irrigation canals, promoting sustainable agricultural practices and increasing agriculture water use efficiency by promoting the adoption of drip irrigation and the exploitation of renewable energy resources. In addition, the construction of reservoirs that capture snowmelt for irrigation in high altitude areas and the implementation of small rainwater harvesting systems could provide additional irrigation water for apples and help minimize the impact of climate change on farm productivity. This was selected as a shortlisted intervention.

3. Improving industrial water and energy use efficiency through the implementation of water and energy saving technologies and the construction of small wastewater treatment plants to facilitate the reuse of treated effluent water. The intervention is particularly relevant to industries that require large volumes of water as it could help to reduce pressures on water quality and quantity. This was selected as a shortlisted intervention.
4. Rehabilitating the Hrache Jeita hydropower plant to offset BMLWE operating costs related to power generation, which have been exacerbated by rising fuel costs and the devaluation of the Lebanese pound. A feasibility study for the plant has already been

carried out and provides the BMLWE with a proposal for donor or private sector investors to partner in launching this sustainable and cost-efficient project (Lebanon Water Project, 2021).

5. Adopting solar pumps to create a supply of constant, reliable and affordable energy for irrigation is of paramount importance because it will reduce energy costs for farmers who currently pump water using petro and gas-powered generators – generators that have become increasingly expensive to run (Kiprono and Llario, 2020). It is recommended that field scale projects should be implemented in collaboration with the Ministry of Energy and Water and private sector stakeholders, and care should be taken to ensure that the low energy costs of solar energy do not lead to increased groundwater extraction.

6. Increasing livelihood resilience by promoting sustainable tourism in mountainous areas that depend, primarily, on winter tourism. This could be done by promoting summer tourism and other activities, including the establishment of women-led businesses, thus reducing migration to lower areas of the basin where increasing urbanization is already problematic. This was selected as a shortlisted intervention.

7. Promoting reforestation and reducing the risk of forest fires through the development of an integrated strategy for forest protection, with targeted research on the types of trees and locations appropriate for reforestation. It is also important to promote community engagement, capacity-building and the inclusion of young people in that process. This was selected as a shortlisted intervention.

8. Determining the storage potential of existing infrastructure and identifying storage alternatives in or outside the Nahr el Kalb catchment area in order to combat water scarcity during winter months. Promoting sustainable water consumption and prioritizing water use efficiency for households and in restaurants and hotels. This could be through the introduction of water-efficient technologies for saving water, including low-flow alternatives, water-efficient showerheads and faucets, and through awareness campaigns that engage civil society and youth activists in the area. It is also important to increasing collaboration between the Ministry of Energy and Water and unions of municipalities to promote appropriate water management, and to make municipalities responsible for monitoring water quality. It is, moreover, important to ensure that municipalities have the tools and specialist knowledge necessary to undertake monitoring activities.

9. Developing an interactive platform/website dedicated to the Nahr el Kalb basin that allows stakeholders to interact and share information through discussion groups. The website could also be used to identify tourist areas, restaurants, hotels, schools and banking services. An advisory scientific team in collaboration with the municipalities could manage the information and facilitate data coordination. An interactive online map could promote data collection and allow for downloading data, for example, on weather, water quality and quantity, socioeconomic indicators and agriculture, and provide links to published research on those topics. Stronger collaboration among BMLWE, municipalities, research institutes and universities, such as cited in this technical report, is needed. In addition, consolidation of the existing network of flow monitoring stations on rivers, streams and springs should also include the maintenance of equipment, the potential purchase of probes for in situ measurements, site visits for data collection, capacity-building for technicians on data acquisition and processing, and the establishment of a water monitoring protocol. Those measures will encourage watershed-based research, including on managed aquifer recharge (Itani and others, 2021), proper water allocation methodologies and water accounting. In that regard, FAO is developing a water accounting system for the basin[6]

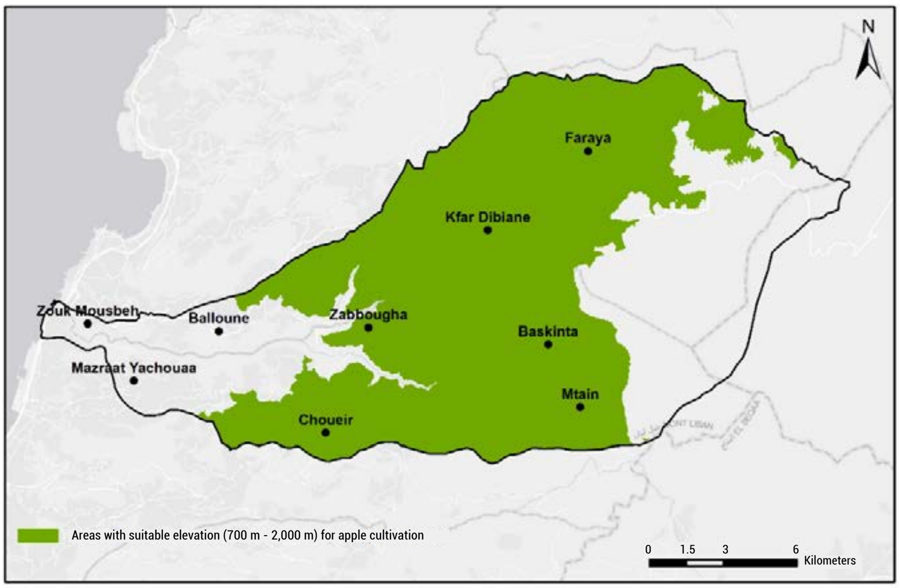
10. Projects currently at the pilot scale could, moreover, be expanded to include other sites to help in the quantification of water quality and quantity.

Jeita Dbayeh Conveyer, photo by Tom Zoghby.

1 INTERVENTION MEASURE 1: ENHANCING AGRICULTURE SECTOR RESILIENCE IN THE NAHR EL KALB BASIN

While the agricultural sector contributes only 3.56 per cent of national greenhouse gas emissions in Lebanon, the sector is highly impacted by climate change (Ministry of Environment, n.d.). Apples, a key crop in the Nahr el Kalb basin, are sensitive to climate change and temperature extremes. Figure I.1 highlights the areas at suitable altitude for apple cultivation in the basin, which ranges between 700 and 2,000 m (Ministry of Agriculture, n.d.). Rising temperatures could place apple chilling temperatures at risk, which are needed for fruit production tree dormancy and subsequent bud break and flowering (Funes and others, 2016). Centenarian maximum temperature increases of 5°C in models have predicted an apple tree cultivation area loss of nearly 50 per cent from current levels (Ahmadi, Ghalhari and Baaghideh, 2019). However, enhancing sustainable agricultural practices in apple cultivation has the potential to improve the management of resources (water, soil, energy), increase rural income, sustain livelihoods and increase resilience and adaptation to the impacts of climate change.

FIGURE 48: Areas with suitable elevation for apple cultivation in the basin



Source: Authors.

This section provides details on intervention measure 1 and notes the importance of the apple sector, especially in the upper basin area. This intervention is a way to enhance the adaptive capacity of the upper basin area to climate change impacts.

A. Objectives

The main objective of this intervention is to promote sustainable agricultural practices that facilitate the efficient use of land and water resources in apple cultivation. Activities to support this measure include rehabilitating irrigation canals, and the use of drip irrigation to reduce pressure on surface and groundwater resources, while considering renewable energy to generate power for irrigation. In addition, a source of irrigation water can be provided through the implementation of microcatchment rainwater harvesting systems at the individual farm level and through the construction of hill reservoirs. Hill lakes provide water for supplementary irrigation to help minimize the adverse effects of climate change on apple productivity. This intervention is in line with the strategy of the Ministry of Energy and Water, which advocates for the efficient use of water in irrigation, additional surface water storage and improved productivity. It should be noted that while this intervention is primarily focused on water management, soil management should also be taken into consideration.

B. General description of the main activities

Drip irrigation is a widely accepted and efficient irrigation technique because it facilitates the uniform dispersion of water and nutrients. Drip irrigation uses technology for irrigating plants at the root level making use of emitters that are fitted on a network of water pipes, including mains, sub mains and laterals. Emitting devices may include drippers, microsprinklers, minisprinklers, microjets or pipes designed to discharge water at pre-programmed rates. The efficiency of drip irrigation is about 90 per cent.

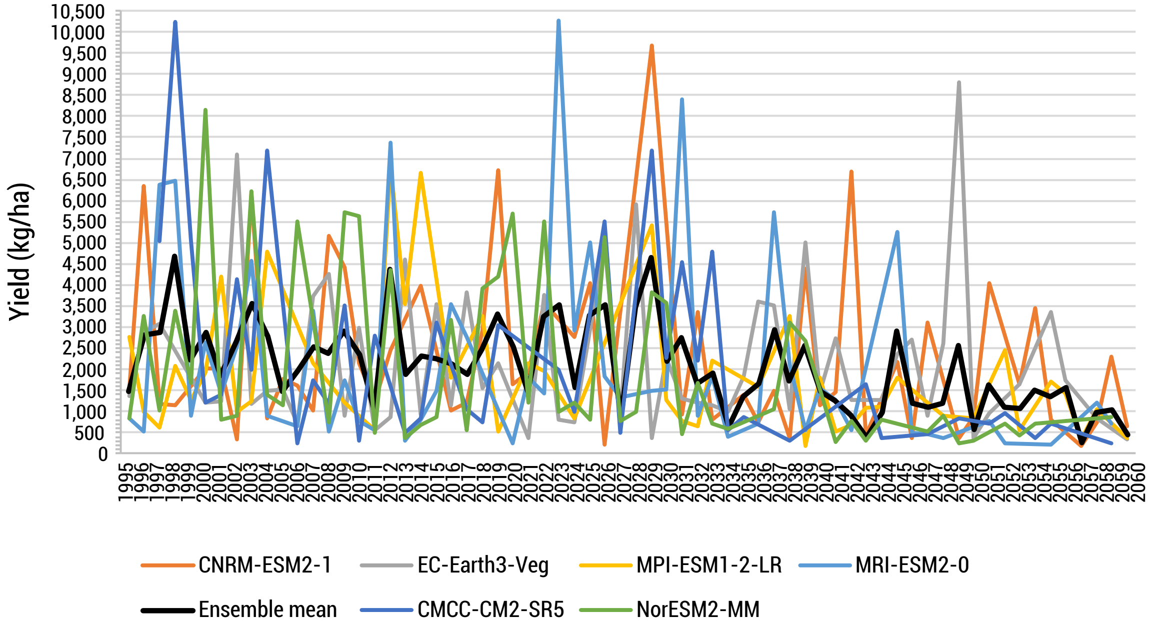
Eyebrow bounds are microcatchment rainwater harvesting systems that supply single trees or bushes with run-off water on hillsides. They are semicircular structures that use stone to support the part facing downhill. Eyebrow bounds are built in a staggered sequence over a plot to allow the second line to catch water run-off flowing between the structures in the line above and further lines of bounds continue to catch water from the structure above. Catchment size is between 5 and 50 m^2 and the cultivated area is between 1 and 5 m^2. This technology can be applied on slopes with a gradients of up to 15 per cent; the steeper the gradient, the greater the reinforcement required, with stone being the preferred material. Eyebrow bounds can be applied in areas with annual rainfall rates of between 200 and 600 mm.

A hill lake is a natural or artificial reservoir created using a dam to store rain or spring water. Reservoirs can be created in a number of ways, including by controlling a watercourse that drains an existing body of water, interrupting a watercourse to form an embayment within it, through excavation or the building of retaining walls or levees. Hill lakes can be of varying sizes to suit local needs and available water. A hill lake is acknowledged to be a technology with resilience against climate change. It enables smallholder farmers to adapt to climate change and reduce the risk of extreme events as it allows water to be kept in reserve for supplementary irrigation during dry periods.

C. Rationale

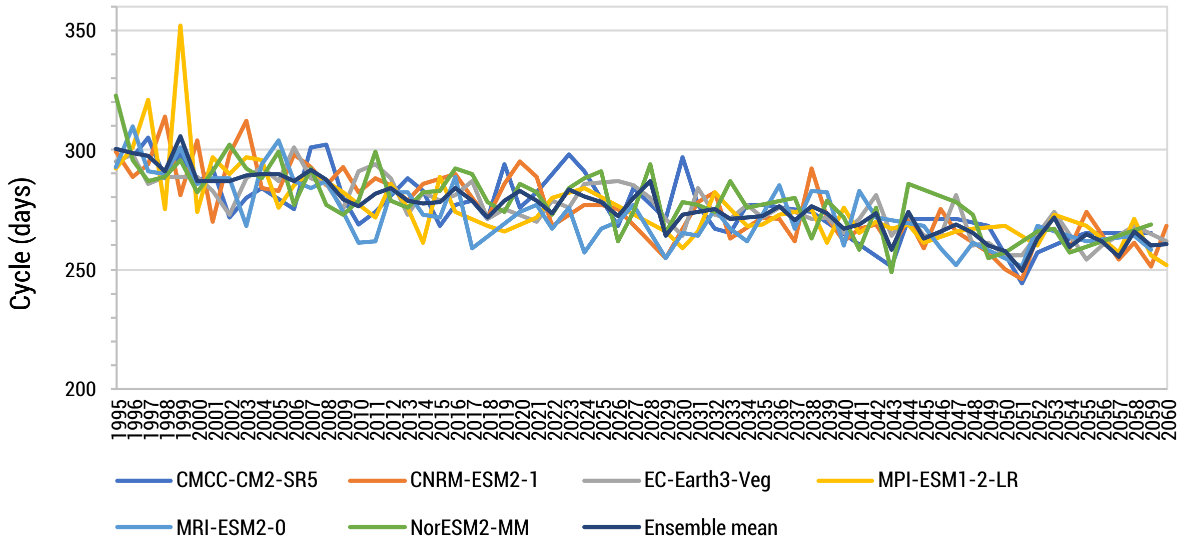
The assessment of climate change impact in the Nahr el Kalb basin using the CropSyst model shows that apple tree yield could be reduced by up to 48 per cent by the mid-term period (2041–2060) as compared with the reference period (1995–2014), as shown in figure 49. The growing cycle of apple fruit is also projected to be reduced by 24 days annually and the seasonal evapotranspiration of apple trees is projected to increase by 66 mm, or 24 per cent (figures 50 and 51). Results also showed that changes in the climate will result in an increase in apple tree water consumption of approximately 24 per cent. To minimize the adverse impact of climate change on apple tree yield it is necessary to adopt sustainable agricultural practices and access additional water resources to meet the increased water needs of apple trees.

FIGURE 49: Changes in apple tree yields between 1995 and 2060 in the Nahr el-Kalb basin according to six regional climate models



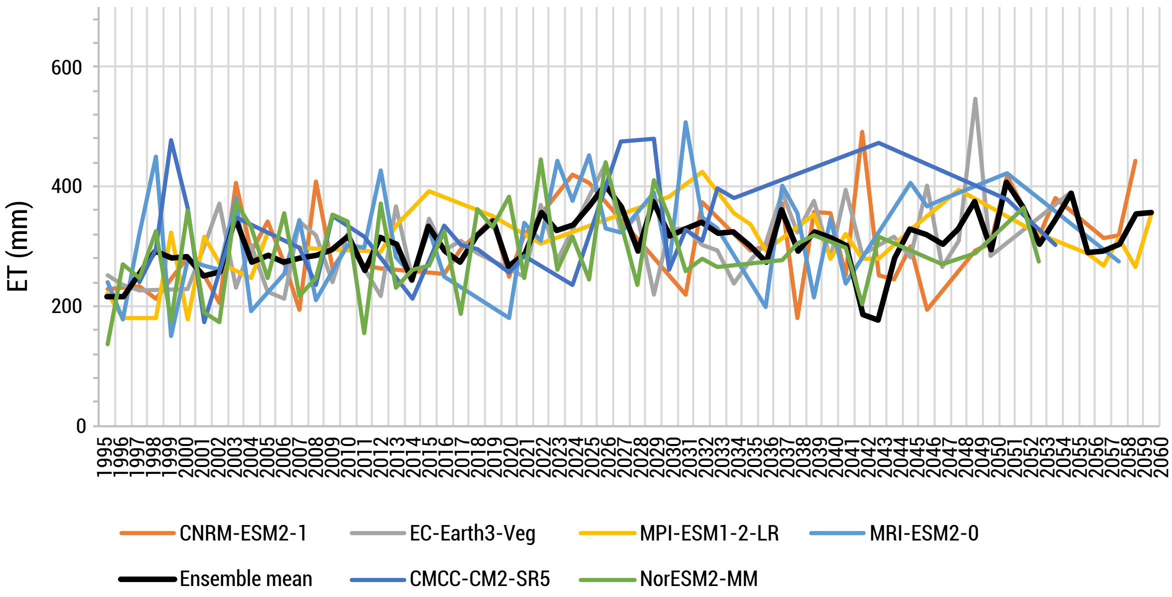
Source: Authors.

FIGURE 50: Changes in the apple fruit growing cycle between 1995 and 2060 in the Nahr el-Kalb basin according to six regional climate models



Source: Authors.

FIGURE 51: Changes in average seasonal evapotranspiration (ET) for the period 1995 to 2060 in the Nahr el-Kalb basin according to six regional climate models



Source: Authors.

D. Link to sustainable development and climate change policies and plans

An adequate and reliable supply of water is a prerequisite for food production and sustainable farming, as is outlined in the SDGs. The Ministry of Agriculture is responsible for creating an agricultural strategic framework, formulating and implementing policies and programmes for the agriculture sector, developing a suitable legal and regulatory framework and enhancing infrastructure development. The Ministry's strategy for 2015 to 2019 addressed climate change in a separate target area with specific activities, indicators and a timeline for climate change responses to support the agricultural sector. A key adaptation measure of the updated nationally-determined contributions is to strengthen the agricultural sector's resilience and enhance Lebanon's agricultural output through climate-friendly interventions. Promoting and supporting the application of modern methods and technologies, improving local and regional food markets and supporting the transition to high value crops are suggested.

In addition to the construction of hill lakes, this intervention is in line with the water-energy-food nexus approach. It promotes the efficient use of water and the implementation of good agricultural practices, while encouraging the use of renewable energy for improved agricultural productivity and more sustainable food production. It also supports the achievement of SDG 7. The Ministry of Agriculture, the Ministry of Energy and Water, the Lebanese Agricultural Research Institute, individual municipalities and farmers should all play a role in the implementation of this intervention.

E. Activities

The following activities are suggested:

Activity 1: formulating and proposing a restoration plan for irrigation canals in the Nahr el Kalb basin including considering the possibility of installing solar panels on open canals, where applicable. Panels could help reduce evaporation and be used to generate power for water pumping and irrigation.

Activity 2: promoting sustainable agricultural practices through the implementation of capacity development for farmers including on subjects such as crop rotation, climate impacts on planting and harvesting seasons, integrated pest management, agroforestry, the introduction of crop varieties resistant to climate change, regenerative agriculture, conservation agriculture, organic farming and green agricultural technologies.

Activity 3: increasing the water-use efficiency of irrigation systems through the implementation of three drip irrigation pilot projects for smallholder farmers in three major apple producing municipalities in the Nahr el Kalb basin, including in Faraya, Kfar Dibiane and Baskinta municipalities, and assessing the use of renewable energy for irrigation systems in those locations.

Activity 4: implementing three pilot projects of eyebrow bound microcatchment rainwater harvesting systems in major apple producing municipalities in the Nahr el Kalb basin, including Faraya, Kfar Dibiane and Baskinta. Those pilot projects should be implemented in tandem with soil fertility and moisture management activities.

Activity 5: constructing hill lakes, including the construction of planned hill lakes as per the updated National Water Strategy. Additionally, this activity will include implementing three pilot small hill lakes or water ponds in three major apple producing municipalities in the Nahr el Kalb basin in order to provide additional water access points.

Activity 6: using water accountability to establish a baseline before interventions and to monitor changes in water resources and consumption with a view to setting sustainable water use limits.

F. Constraints

Constraints include financial challenges, the limited land available for the construction of hill reservoirs, the limited availability of skilled labour and the reluctance of local communities to adopt of innovative agricultural practices.

G. Estimated duration

TABLE 9: Estimated duration of intervention measure 1

Number	Activity	Time period											
		Year 1				Year 2				Year 3			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Assessing and proposing a restoration plan for irrigation canals in the Nahr el Kalb basin including the possibility of installing solar panels on open canals.	■	■	■									
2	Promoting sustainable agricultural practices through the provision of capacity-development support for farmers.	■				■				■			
3	Increasing the efficiency of irrigation systems through the implementation of three drip irrigation pilot projects for smallholder farmers in three major apple producing municipalities (Faraya, Kfar Dibiane, Baskinta) and assessing the suitability of using renewable energy to power irrigation systems.				■	■	■	■	■	■			
4	Implementing three eyebrow bound microcatchment rainwater harvesting system pilot projects				■				■				■
5.1	Constructing the hill lakes planned for Kfar Dibiane as per the updated National Water Strategy	■	■	■	■	■	■	■	■	■	■	■	■
5.2	Implementing pilot projects for three small hill lakes or water ponds in three major apple producing municipalities (Faraya, Kfar Dibiane, Baskinta)				■	■	■	■	■	■	■	■	
6	Using water accountability and setting baselines with Rapid Water Accounting and monitoring performance annually with advanced water accounting				■	■	■	■	■	■	■	■	

Source: Authors.

H. Estimated costs

Activity	Approximate cost ($)
Assessing and proposing a restoration plan for irrigation canals in the Nahr el Kalb basin	100 000
Promoting sustainable agricultural practices through the implementation of annual capacity development for farmers	50 000
Increasing the efficiency of irrigation systems through the implementation of three drip irrigation pilot projects for smallholder farmers in three major apple producing municipalities (Faraya, Kfar Dibiane, Baskinta)	130 000
Implementing three pilot projects for eyebrow bound microcatchment rainwater harvesting systems	600 000
Constructing the hill lakes planned for Kfar Dibiane as per the updated National Water Strategy	14 700 000[a]
Implementing three pilot small hill lakes or water ponds in three major apple producing municipalities (Faraya, Kfar Dibiane, Baskinta)	170 000
Total	**15 750 000**

Source: Authors.

Note: These figures are rough estimates of individual activity costs. An extensive assessment with field and data collection would be needed to more accurately measure potential costs.

[a] Estimated costs of the construction of hill lakes in Wadi El Boud, Wadi Nabaa Es Saquieh and Kfar Dibiane as per the updated National Water Strategy were estimated at $6,600,000, $6,200,000 and $1,900,000, respectively.

Apple trees, photos by Naim Khalil.

2 INTERVENTION MEASURE 2: IMPROVING INDUSTRIAL WATER USE

In parts of the basin where there are no wastewater treatment plants and industrial wastewater effluents are directly discharged into the natural environment, surface and groundwater quality is a serious concern. According to the National Water Strategy 2010–2020, although the industrial sector in Lebanon consumes only 11 per cent of water resources, there are some industries that require large volumes of water, which are often wasted and not reused. In the absence of non-conventional water sources and efficient water saving technologies, groundwater resources are overexploited. Therefore, enhancing appropriate water allocation for the industrial sector, while minimizing its impact on water quality and quantity is essential in Nahr el Kalb basin.

The industrial sector is targeted in this intervention because consultations and the vulnerability assessment identified municipalities with a high percentage of industries as being highly vulnerable. It is therefore critical to establish a water conservation and reuse plan and to enhance collaboration among major stakeholders and institutions to ensure full implementation of that plan.

A. Objectives

The key objectives of intervention measure 2 are to provide alternative sources for water use by the industrial sector, to encourage efficient water consumption and energy use in the sector and to reduce industrial water contamination and relieve pressure on surface and groundwater resources. This intervention is a way to reduce the sensitivity of industrial zones in the lower basin to climate change impacts. It is also an opportunity to consider renewable energy for industrial power generation, and particularly for operating wastewater treatment systems.

B. General description

The major industrial sectors in Lebanon are food and beverages, non-metallic mineral products such as cement and stones and fabricated metal products. Other smaller sectors include the chemical sector, furniture manufacturing and electrical machinery manufacturing (Ministry of Energy, UNDP and Global Environment Facility, 2015). Most industries are located in the lower basin of Nahr el Kalb and include marble factories, food establishments, repair workshops, woodcraft workshops, paint factories, construction materials and equipment factories, and fabric producers.

Although industries have a responsibility to clean effluents before their disposal into rivers, the basin does not have a treatment plant and most industries still discharge untreated effluent directly into the Nahr el Kalb river. This raises concerns about pollution from toxic metals and organic compounds. Unfortunately, the industrial sector in Lebanon has faced many challenges, including an ongoing economic crisis, and thus the ability to sustain operations is a daily struggle for many industries. Although most industries support the idea of treating and reusing water, they have low technical and financial capacities to undertake those activities.

In 2019, the Association of Lebanese Industrialists signed a partnership agreement with the United States Agency for International Development (USAID)-funded Lebanon Water Project entitled Water Efficiency in Lebanese Industry. The aim of the initiative was to improve water conservation in the marble and granite industry in Lebanon (Flint, 2019). The marble and granite industry was identified as a priority sector because approximately 50 per cent of water consumed could be recycled in the manufacturing process. An analysis showed that initial capital investments in water saving technologies could be recovered in two to three years. The USAID Community Support Program, in partnership with the Association of Lebanese Industrialists, provided technical and financial support to improve industrial wastewater treatment and supported seven agrifood firms in adopting low cost and low-tech solutions to reduce wastewater generated (USAID, 2021).

During site visits and one-on-one consultations with industry owners in industrial zones in the Nahr el Kalb basin, the below information was provided by stakeholders:

a. Industries are challenged by the country's economic crisis and any plan to fund new technologies, although welcome, may be difficult for some industries to support, given the need to temporarily stop work, especially in the case of construction companies. Nonetheless, the food production industry was willing to contribute financially.

b. Food industries require large volumes of water for their deep cleaning processes. Seasonal demands for water can be high, especially before and during Ramadan when exports to Arab countries increase.

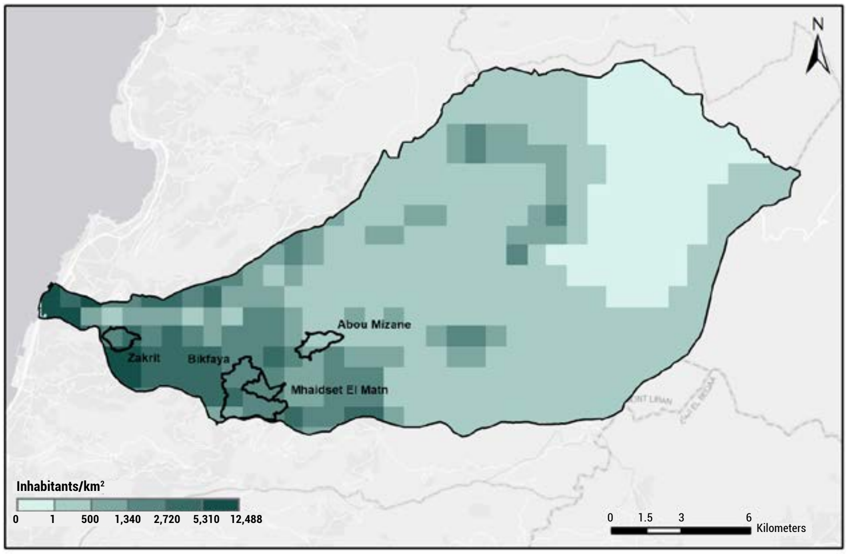
c. Some industries are using the public network for their water needs, supplemented by water cisterns, whereas other industries have their own private wells.

d. The industrial materials and paint production industry currently uses private wells to extract water between March and September, when they have high water volume requirements. The industry showed great interest in reusing treated effluents.

C. Rationale

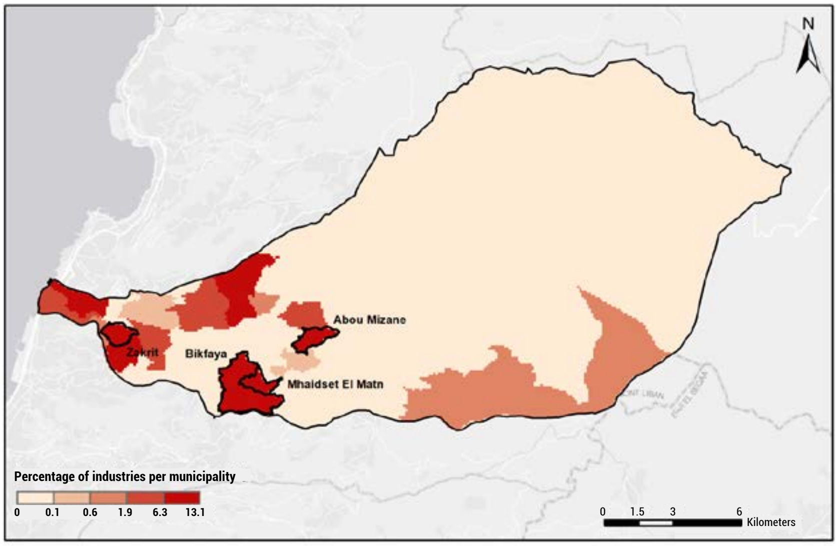
The integrated vulnerability assessment conducted in the Nahr el Kalb basin showed high vulnerability in the near- and mid-term in areas characterized by high population density. In the lower basin, the density of those living in 1 km^2 is about 12,500 inhabitants with a youth to adult ratio of between 0.25 and 0.5 (figure 52). It was also observed that municipalities with a higher percentage of industries have the highest vulnerability rates. Those municipalities include Mhaidset El Matn, Bikfaya, Abou Mizane and Zakrit (figures 53–54).

FIGURE 52: Population density map



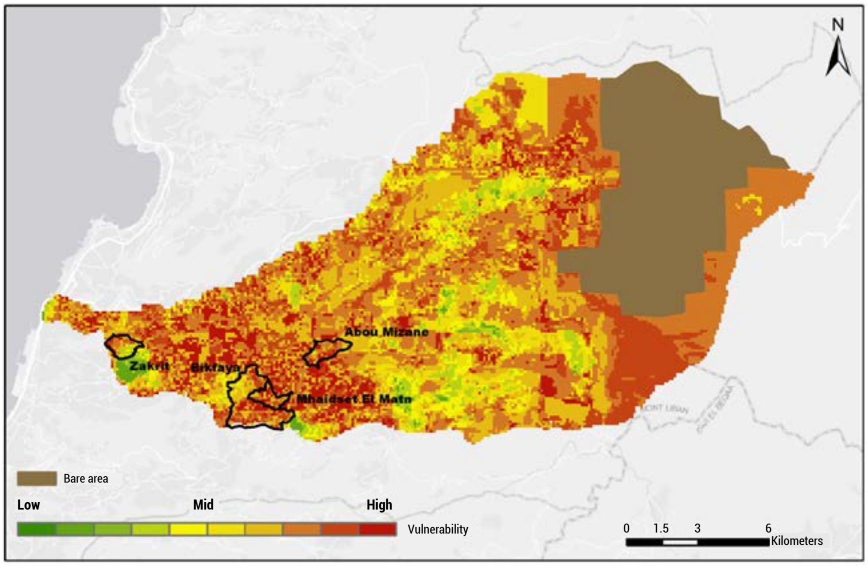
Source: WorldPop, 2020.

FIGURE 53: Percentage of industries per municipality in the Nahr el Kalb basin



Source: Association of Lebanese Industrialists, 2022.

FIGURE 54: Vulnerability assessment for the mid-term (2042–2060)



Source: Authors.

D. Link to sustainable development and climate change policies and plans

The proposed intervention is in direct alignment with SDG Goal 6, target 3 namely, "By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally". In fact, collecting, treating and reusing wastewater from industries reduces pollution and improves water quality. In addition, the proposed intervention is in alignment with SDG 6, target 4 namely, "By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity". Promoting efficient technologies and reusing treated effluents will in fact increase water use efficiency and ensure sustainable withdrawals. Sustainable infrastructure for industries, and safe reuse of wastewater, if well managed, may in fact significantly reduce water demand and contribute to sustainable water usage.

The intervention measure also falls within the scope of the Industrial Sector Development Strategic Plan and Implementation Mechanisms Plan (2020–2025), prepared by the Ministry of Industry. The plan identifies the need to "enforce strict environmental laws, including fighting pollution and taking the necessary measures regarding industrial permits". Furthermore, it identifies the need to provide investment opportunities in industrial zones and to improve services for infrastructure measures, such as water supplies.

This intervention is also applicable to the water-energy-food nexus as it considers the adoption of energy efficient technologies at the industry level, including by food industries in the basin, and the use of renewable energy, in this case for operating wastewater treatment facilities, and meeting SDG 7, target 2.

E. Stakeholders – institutions, partners, implementing agencies

To successfully implement intervention measure 2, it is essential to strengthen collaboration among all stakeholders, including the Association of Lebanese Industrialists, the Ministry of Environment, the Ministry of Energy and Water, individual municipalities and industries themselves. The Association of Lebanese Industrialists promotes collaboration among companies, donors and industrial sectors and encourages water conservation and the use and reuse of treated wastewater. The Ministry of Environment is responsible for the environmental compliance of industrial establishments through implementation of the Environmental Compliance Decree and related decisions, in which municipalities are held responsible for the daily management of public works within their boundaries (Legislative-Decree 118) and can also be asked to frequently monitor implementation. Water and wastewater projects are the responsibility of water establishments as per Law 221 of 2000 on Water Sector Organization.

F. Activities

The following activities are suggested:

Activity 1: mapping industries in four targeted municipalities, namely Mhaidset El Matn, Bikfaya, Abou Mizane and Zakrit, and grouping them into category one (high impact), category two (moderate impact) and category three (low impact).

Activity 2: selecting four industries and making contact to assess prospects for the pilot project. Initiating discussions with industry owners/board members to gauge their interest and commitment to be part of the pilot project.

Activity 3: performing audits on water consumption and quality and on energy consumption and efficiency for the selected industries. The water audits will allow for the assessment of water consumption within industry facilities and identify opportunities for improving water use efficiency. In addition, a study should be carried out to assess whether to establish an appropriate treatment plant in each industry and the possibility of reusing treated effluents.

Activity 4: formulating an optimal implementation strategy that provides for appropriate water and energy efficient technologies and wastewater treatment plant options, with consideration given to renewable energy use in line with the outcomes of a technical and financial feasibility assessment.

Activity 5: developing technical capacities by implementing a capacity development programme for operators at targeted industries on the operation and maintenance of new infrastructure/equipment and on reporting mechanisms.

Activity 6: providing required technologies and undertaking the construction of required facilities.

Activity 7: engaging local authorities in the monitoring and evaluation process: establishing a framework for monitoring and evaluation that adopts a nexus approach that addresses water, energy and environmental concerns (and food concerns if the industry being monitored and evaluated is an agroindustry).

G. Constraints

The intervention measure proposed requires the collaboration and support of industry bodies. As the economic situation in the country worsens, the major constraint on this intervention measure is likely to be the ability of industries to secure funds to cover their share of the project. While industries are open to such projects, their capacity to provide financial support is often limited.

H. Estimated duration

TABLE 10: Estimated duration of intervention measure 2

Number	Activity	Month																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Mapping and grouping of industries																		
2	Selecting industries																		
3	Performing water and energy audits																		
4	Identifying and designing optimal implementation strategies																		
5	Developing technical capacities																		
6	Providing construction and equipment																		
7	Monitoring and evaluation																		

Source: Authors.

I. Estimated costs

A variety of factors must be considered when estimating the costs of industrial wastewater treatment plants including the required level of treatment, the composition/characterization of the raw wastewater, the volume of wastewater and the construction materials needed for operation. For instance, the more stringent the standards, the higher the treatment costs. Estimates of capital expenditure for large industrial wastewater treatment plants range between $20,000 and $40,000 per cubic meter per hour (m^3/h) (Almasi, 2020).

A grant from USAID of $150,000 was allocated to improve industrial wastewater treatment and mitigate pollution (Flint, 2019). The financial support was allocated to seven agrifood firms to facilitate their adoption of low cost and low-tech solutions to reduce wastewater generated from pickle, tahini and olive production facilities (USAID, 2021). The Association of Lebanese Industrialists also contributed approximately $20,000 in support of the initiative (USAID, 2021).

Activity	Approximate cost ($)
Mapping and grouping of industries	20 000
Selecting industries	10 000
Performing audits	40 000
Identifying and designing optimum implementation strategies	350 000
Developing technical capacities	40 000
Construction and provision of equipment	1 000 000
Monitoring and evaluation	10 000
Total	1 470 000

Source: Authors.

Note: The below figures are rough estimates of individual activity costs. An extensive assessment with field and data collection would be needed to generate more accurate cost projections.

3 INTERVENTION MEASURE 3: LIVELIHOOD DIVERSIFICATION THROUGH SUSTAINABLE TOURISM

The tourism and hospitality industry has long been an economic powerhouse in Lebanon. In the Nahr el Kalb basin, and specifically in the upper area, the majority of tourism is during the winter months and focuses on snow-related activities in the Kfar Dibiane and Faraya municipalities. The climate change projections discussed in this technical report foresee a decrease in snow cover/depth resulting in lower quality/quantity and the reduced diversity of winter tourism, including the possible closure of ski areas due to limited snow cover. Since livelihoods and businesses in the upper basin area are highly dependent on winter tourism, increasing the resilience of the tourism sector and livelihood diversification are essential interventions.

We provide details on intervention measure 3 and highlight the importance of maintaining livelihoods so as to enhance resilience to climate change impacts and reduce migration to lower areas in the basin, where increasing urbanization is already problematic.

A. Objectives

The key objectives of this intervention measure are to provide alternatives to snow dependent tourism and enhance sustainable tourism in the upper basin area, thereby diversifying sources of income. This intervention is a way to enhance the adaptive capacity of the upper basin area to climate change impacts.

B. General description

Tourism and climate change are inextricably linked. The snow required for winter sports is key to many winter tourism destinations' economic sustainability and the winter tourism sector is highly sensitive to with increases in greenhouse gas emissions. Decreasing snow cover and depth means lowered tourism revenues in areas dependent on winter tourism. As such, adaptations may include technical measures such as snowmaking or snow farming, or strategies that encourage diversification such as expanding summer-related tourism. Snowmaking, or compensating for diminished natural snow with man-made snow, has been used all over the world to alleviate the impact of climate change on the tourism sector. Snow farming, whether natural or man-made, in which snow is piled and covered with insulation material, has also been adopted in various locations (Steigera and others, 2020). Although this may be of interest to the Kfar Dibiane and Faraya municipalities to maintain winter tourism, such solutions may not be economically or environmentally viable.

On the other hand, other adaptation strategies such as activity and revenue diversification, with more orientation towards summer activities may be viable in the upper basin areas. Developing year-round tourism and tourism that is not dependent on snow may be a better long-term intervention strategy for the area in the light of ongoing climate change. Promoting nature-based tourism, including agritourism, ecotourism and other forms of landscape-based tourism in the upper basin area is highly recommended as it could serve as an important driver of socioeconomic growth. Such forms of tourism could increase and diversify household incomes, enhance job opportunities, bolster the resilience of livelihoods and strengthen the conservation of natural areas. With vast spaces and beautiful scenery to offer, the area could promote nature tour guides, nature photography and camping. Nature-based tourism is directly related to nature protection, tourism promotion and job creation, especially for women, as they are often involved in owning and operating guest houses and promoting locally-produced and homemade products (Romeo and others, 2021).

Examples of activities that may be encouraged within the context of intervention measure three include:

a. Walking tourism: hiking trails that provide access to local features.

b. Adventure and sports activities: mountain biking, zip-lining, horseback riding and rock climbing.

c. Rural tourism: agriculture, handicrafts, food sampling, harvesting and traditional ceremonies and festivals.

d. Other: natural and cultural heritage exploration, spiritual tourism and wellness tourism.

In addition, diversification of incomes through the support of youth- and women-led businesses and small entrepreneurship projects is recommended in order to increase the resilience of livelihoods in the upper basin area. This may enable snow dependent businesses to insulate themselves from climate change and related economic shocks by reducing their reliance on winter activities. It also provides new skills and experiences to those who are keen to diversify their income streams.


Wadi Himlaya, photo by Elie Saade.

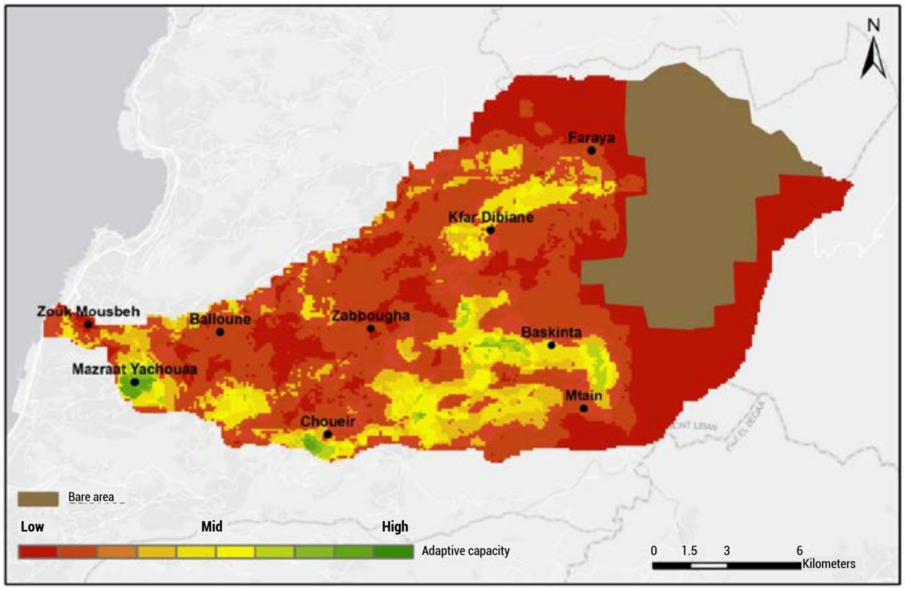
Kfar Dibiane-Faraya, photo by Tracy Zaarour.

It is essential to enhance the role of women in the tourism sector and to tackle the gender gap. This requires intervention at the employment, entrepreneurship, leadership and education and training levels. Positive actions could include addressing unpaid work for women in tourism, diversifying women's market access and fair-trade opportunities for their tourism-related products and services and expanding their access to digital technologies, as well as developing training programmes for women in tourism (World Tourism Organization, 2019).

C. Rationale

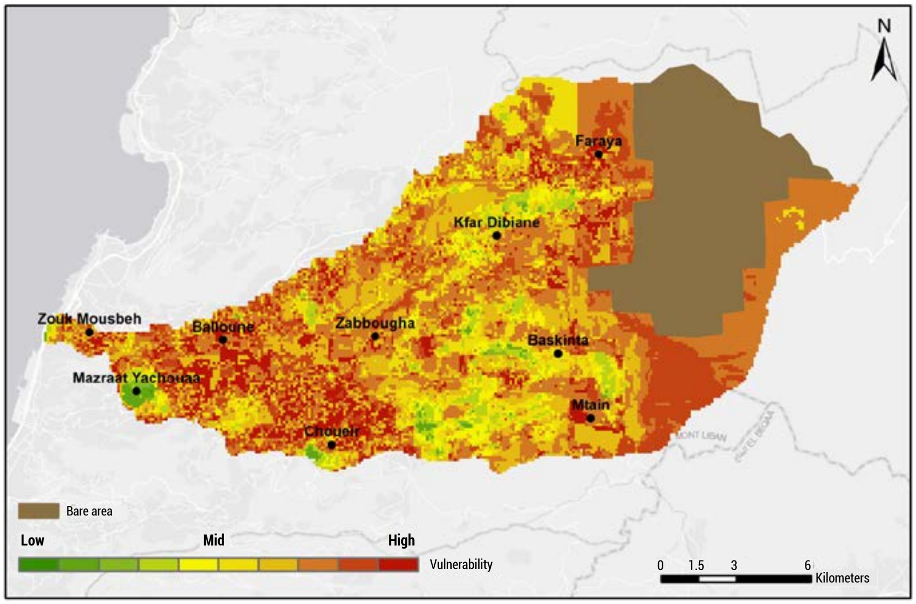
The upper basin areas are less densely populated and thus are subject to less severe anthropogenic impacts, which can, in themselves, exacerbate causing climate. The integrated vulnerability analysis showed that adaptive capacity is very low in the upper basin, where public networks, roads, schools and financial services are all limited in comparison to the lower basin area (figure 55). Those discrepancies mean that the upper basin area suffers from climate injustice: people who contribute relatively little to climate change are more affected and less resilient to its impact than those who contribute relatively more. In the upper basin area, high vulnerability is especially pronounced in the Kfar Dibiane and Faraya municipalities (figure 56).

FIGURE 55: Annual adaptive capacity map



Source: Authors.

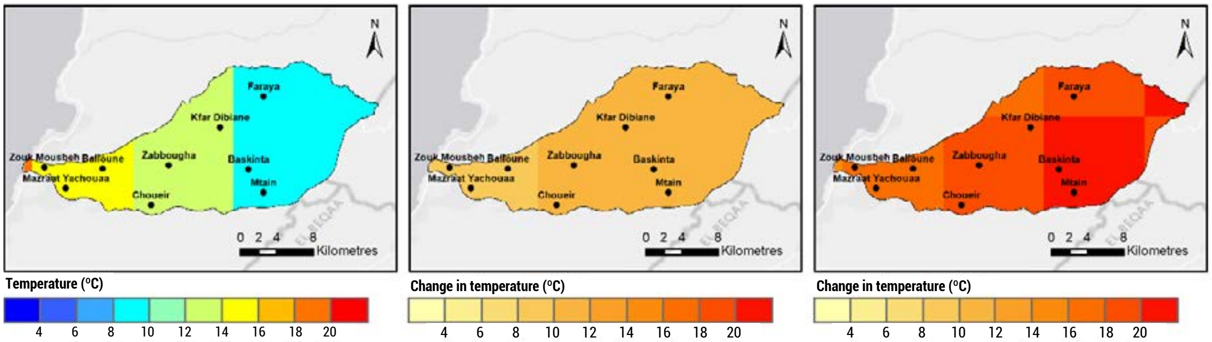
FIGURE 56: Vulnerability assessment for the mid-term period (2042–2060)



Source: Authors.

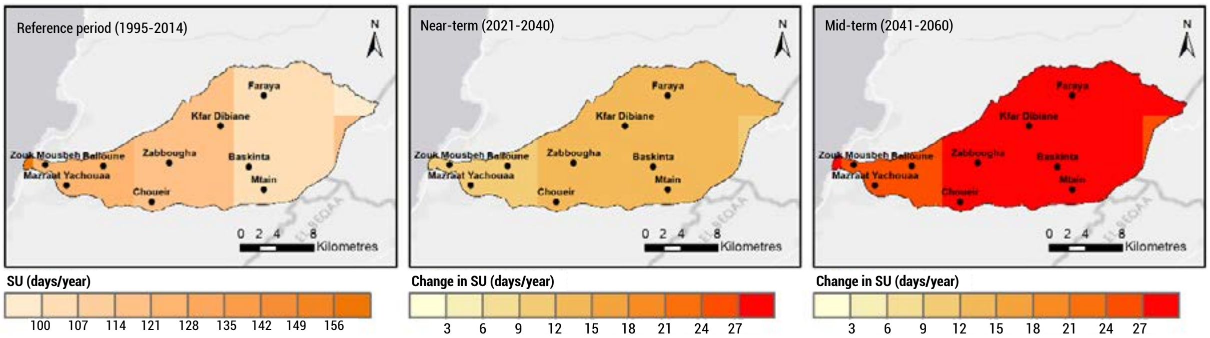
Additionally, climate change projections show that climate change exposure is more pronounced in the upper basin. Projected increases in temperature average 2.2°C for the mid-term period of 2041–2060, with a minimum to maximum rising gradient from the coast to the mountains and with an increased number of summer days projected, particularly in mountainous areas, as shown in figures 57 and 58. Furthermore, climate change projections show that snow cover is likely to decline. By the near-term period of 2021–2040, snow cover is projected to decrease by more than one third in the basin. This will reduce further to be nearly two thirds less by the mid-term period (2041–2060), compared to the reference period. Snow depth is also projected to decline by 41 cm on average by the near-term and by 60 cm on average by the mid-term period (figures 59 and 60). As such, enhancing the livelihoods of the communities in the upper basin and insulating them from climate change impacts is essential in order to minimizing migration to lower areas of the basin where increasing urbanization is already problematic.

FIGURE 57: Mean change in annual temperature for near-term (2021-2040) and mid-term (2041-2060) compared to the reference period (1995-2014) based on an ensemble of 6 models from the Mashreq Domain, SSP5-8.5



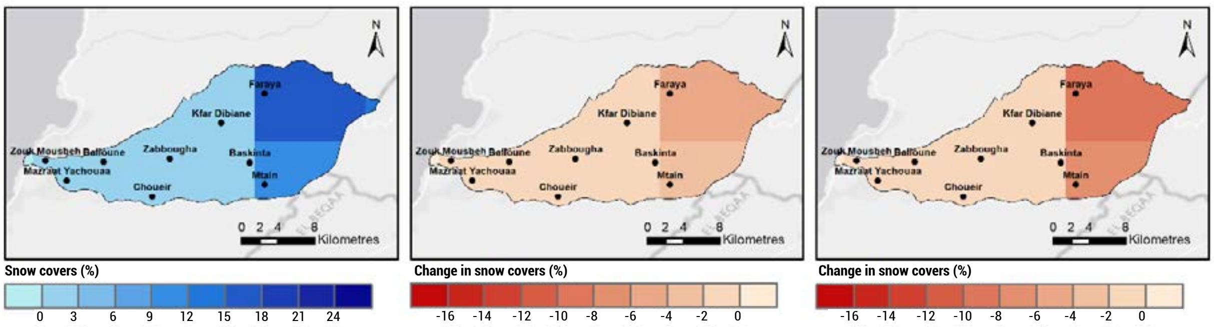
Source: Authors.

FIGURE 58: Mean change in the annual number of summer days (SU; days when Tmax >25°C) for near-term (2021–2040) and mid-term (2041–2060) compared to the reference period (1995–2014) based on an ensemble of 6 bias-corrected models from the Mashreq Domain, SSP5-8.5



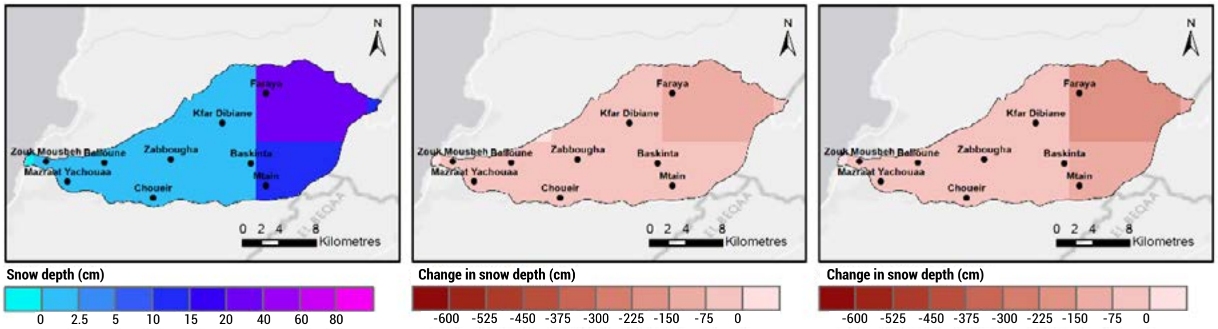
Source: Authors.

FIGURE 59: Mean change in annual snow cover for near-term (2021–2040) and mid-term (2041–2060) compared to the reference period (1995–2014) based on an ensemble of 6 models from the Euro-CORDEX Domain, RCP 8.5



Source: Authors.

FIGURE 60: Mean change in annual snow depth near-term (2021–2040) and mid-term (2041–2060) compared to the reference period (1995–2014) based on an ensemble of 6 models from the Euro-CORDEX Domain, RCP 8.5



Source: Authors.

D. Link to sustainable development and climate change policies and plans

Tourism is specifically mentioned in SDG 8.9, which states, "By 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products". Additionally, SDG 12 addresses sustainable development: target 12.b of that SDG provides, "Develop and implement tools to monitor sustainable development impacts for sustainable tourism that creates jobs and promotes local culture and products". Tourism contributes to the achievement of many SDGs, including those related to poverty, gender equality and resilient cities. For example, SDG 13 provides, "Take urgent action to combat climate change and its impacts". Accelerating climate action in the tourism sector is critical both for the resilience of the tourism sector and in order to reduce the greenhouse gas emissions created by the tourism industry.

A recent report by FAO and the World Tourism Organization, published with input from the Mountain Partnership Secretariat, addressed the role of tourism in supporting the sustainable development of mountainous regions and ensuring that tourism contributes to the achievement of the SDGs, including through job creation, sustainable consumption and production and the conservation of natural resources (Romeo and others, 2021). The Lebanon Rural Tourism Strategy, developed by the Ministry of Tourism with the goal of enhancing economic opportunities in rural areas, outlines strategic intervention areas for improving the rural tourism sector, and tourism in mountainous areas was highlighted in its action plan (Ministry of Tourism, n.d.).

E. Stakeholders – institutions, partners, implementing agencies

A wide range of stakeholders should participate in the implementation of this intervention measure, including the Kfar Dibiane and Faraya municipalities, business owners of hotels, restaurants, rental shops and other businesses, the Ministry of Tourism, the Ministry of Environment, young people and non-governmental organizations. For example, the development of the Lebanon Mountain Trail has helped strengthen protections for the country's natural heritage and promoted responsible tourism and ecotourism.

F. Activities

To encourage snow-independent tourism in the upper basin and to diversify the livelihoods of local communities, especially during the summer season, the following activities are suggested:

Activity 1: consulting with major stakeholders, including business owners, women, young people, municipalities and local non-governmental organizations, to establish relationships, gauge interest in the project and identify needs and priorities.

Activity 2: establishing an intervention plan that outlines target areas and priority actions as well as means for implementation. The plan should:

a. Identify and map local attractions, such as the Faqra bridge, the Faqra ruins, natural scenery such as forests, fauna/flora and guest houses and restaurants.

b. Assess the potential of outdoor activities and identify suitable areas for activities such as mountain biking, zip-lining, horseback riding and rock climbing.

c. Identify trails across the mountain landscape that connect natural areas, including well-established and new trails.

d. Identify small businesses, initiatives and cooperatives working in agrifood, handicrafts and traditional products.

e. Locate farms offering locally produced and homemade products, determine their water/energy requirements and highlight sustainable agriculture champions.

Activity 3: implementing interventions and developing required infrastructure, in collaboration with relevant stakeholders. This will involve:

a. Developing and publishing a tourist map highlighting key attractions.

b. Equipping sites for outdoor activities with needed infrastructure and equipment, such as sporting equipment and bicycles.

c. Rehabilitating and opening biking and hiking trails.

d. Organizing regular exhibitions/markets with local products.

e. Facilitating a circular economy for the production of energy and nutrients.

Activity 4: implementing capacity-development in the areas of ecotourism and the environment (biodiversity, land use and ecosystem management) for local authorities, focusing on police and forestry officers from the Ministry of Agriculture and raising awareness of ecotourism and the environment in local schools.

Activity 5: developing communication materials, including a dedicated website and a social media presence that can provide users with news about the area as well as information on services provided and upcoming events.

Activity 6: establishing a committee that brings together stakeholder representatives and is chaired by a representative of the local authorities to monitor and assess activities and needs on an ongoing basis.

G. Constraints

Livelihood diversification is a complex process. Vocational and business training is essential and funding is required for the provision of inputs and assets as well as mentoring. The major constraint on this intervention measure is a lack of appropriate vocational training programmes and the limited infrastructure in place in the upper basin area. Additionally, security concerns and political and economic challenges may discourage tourists from travelling to the upper basin.

H. Estimated duration

TABLE 11: Estimated duration of intervention measure 3

Number	Activity	Month																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Consulting	■	■	■															
2	Establishing an intervention plan			■	■	■	■	■	■										
3	Implementing interventions							■	■	■	■	■	■	■	■	■	■	■	■
4	Implementing capacity development					■	■	■	■	■	■	■	■	■	■	■	■	■	■
6	Developing communication materials							■	■	■	■	■	■						
7	Monitoring								■	■	■	■	■	■	■	■	■	■	■

Source: Authors.

I. Estimated costs

Activity	Approximate cost ($)
Undertaking consultations	20 000
Establishing an intervention plan	60 000
Implementing interventions	500 000
Promoting capacity development	60 000
Developing communication materials	150 000
Monitoring	20 000
Total	**810 000**

Source: Authors.

Note: These figures are rough estimates of individual activity costs. An extensive assessment with field and data collection would be needed to more accurately measure potential costs.

4. INTERVENTION MEASURE 4: REFORESTATION AND RISK REDUCTION OF FOREST FIRES

The forestry sector supports livelihoods, especially in rural areas, by providing charcoal, fuelwood and even medicinal and aromatic plants, and is also important for the tourism sector. Planting trees promotes resilience to climate change and protects rural livelihoods and ecosystem services. Unfortunately, forests in Lebanon suffer from fragmentation, fires and unsustainable practices that challenge their resilience. In the Nahr el Kalb basin, the protection of forest areas should be made a priority, particularly in terms of reducing fire exposure risks. The below section provides details on intervention measure 4, and draws attention to the importance of forest protection measures to enhance the area's resilience to projected climate change impacts.

A. Objective

The key objective of this intervention measure is to provide a set of recommendations that enhance the protection of forested areas in the Nahr el Kalb basin and increase their resilience to climate change impacts. The intervention is a way to reduce sensitivity and enhance the adaptive capacity of the basin to those impacts.

B. General description

July is the peak month for forest fires in Lebanon with the most common causes of forest fires being anthropogenic practices (Ministry of Environment and University of Balamand, 2020). Those practices include using fires to eliminate crop stubble by farmers, the dumping of cigarettes, campfires, burning solid waste, arson and the installation of high voltage power lines in forested areas. In addition, communities are not fully aware of best practices for forest management and fire prevention. Other main causes of fire include the proximity of forested areas to agricultural lands and severe climatic conditions, including high temperatures and droughts.

The key recommended intervention measure for the Nahr el Kalb basin is reforestation, coupled with efforts to reduce the risks of forest fires. However, that measure can only be implemented properly with the adoption of a holistic and integrated strategy that enjoys political support for forest protection, targeted research on topics such as land degradation, the best types of trees and locations for reforestation efforts, community engagement, capacity-building and youth inclusion.

Using a community-based fire prevention approach enhances community engagement, promotes behavioural changes and creates ownership of the project, thus increasing successful project implementation. The approach includes involving the local community and local experts in combination with local authorities at the municipality level to identify measures and practices that reduce fire hazards such as the launching of forest clean up campaigns and identifying best practices for proper waste collection and management. Collaboration among research institutions and ministries is also needed to identify protected areas and formulate emergency response/evacuation plans, including the implementation of measures such as the installation of fire risk warning signs, collecting fire data and information, mapping and displaying accessibility across forest and trail networks for use by firefighters in case of a fire, promoting traditional farming practices, discouraging the burning of crop residues, and allowing controlled grazing and sustainable fuel wood gathering.

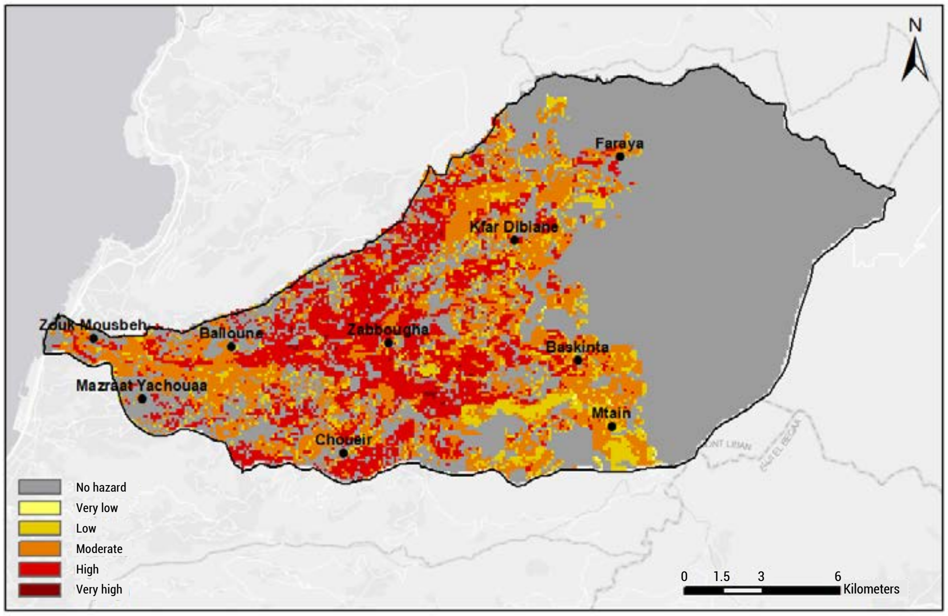
Various past initiatives have promoted reforestation and sought to combat land degradation in Lebanon: these have mainly involved tree planting and capacity-building efforts. In 2016, the Forest and Landscape Restoration Mechanism supported a national transition towards restoring and sustainably managing natural landscapes across Lebanon (FAO, 2016). However, only minimal efforts were directed toward the Nahr el Kalb basin as the only areas targeted in the basin included Faraya Chabrouh and Mchaa Kfar Dibiane municipalities, within the context of the Ministry of Environment-FAO Smart Adaptation of Forest Landscapes in Mountain Areas project.

C. Rationale

Much of the Nahr el Kalb basin is characterized by dense forest cover composed of highly combustible fuel such as pine forests. Of the total wooded land area in the country, more than 80 per cent is highly susceptible to forest fires (figure 62) and forested areas in the Nahr el Kalb basin are highly susceptible due to higher temperatures, with human activity exacerbating that risk. Several fires have impacted the area over the last few years but targeted initiatives to address fire risk have been limited (Ministry of Environment and University of Balamand, 2020). Furthermore, an increase in demographic vulnerability to wildfires is directly related to the increase in urban sprawl close to forested areas. The Lebanon Reforestation Initiative has identified the zone over Jeita cave as highly vulnerable to degradation and fire risk.

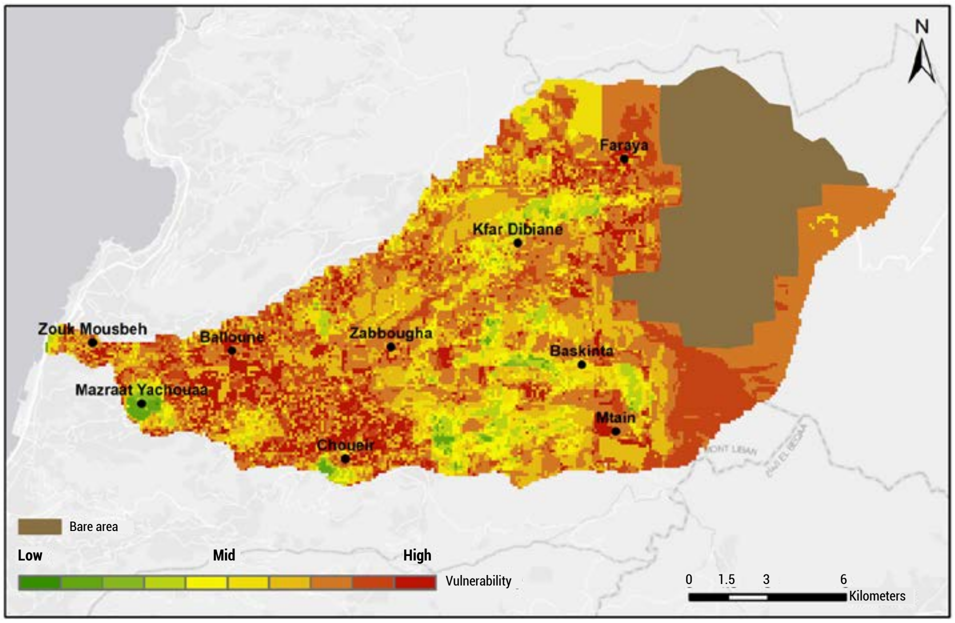
The integrated vulnerability assessment has shown high vulnerability levels in areas identified as highly susceptible to forest fires. During the mid-term period, it is projected that around 50 per cent of areas highly susceptible to fire will exhibit high vulnerability. In addition, another 40 per cent of areas that are highly susceptible to fires will exhibit moderate vulnerability (figures 62–63). With regard to land degradation, during the mid-term period, around 55 per cent of highly degraded land is likely to exhibit high vulnerability and 25 per cent of the highly degraded land to exhibit moderate vulnerability (figures 63–64).

FIGURE 62: Fire susceptibility map of the Nahr el Kalb basin



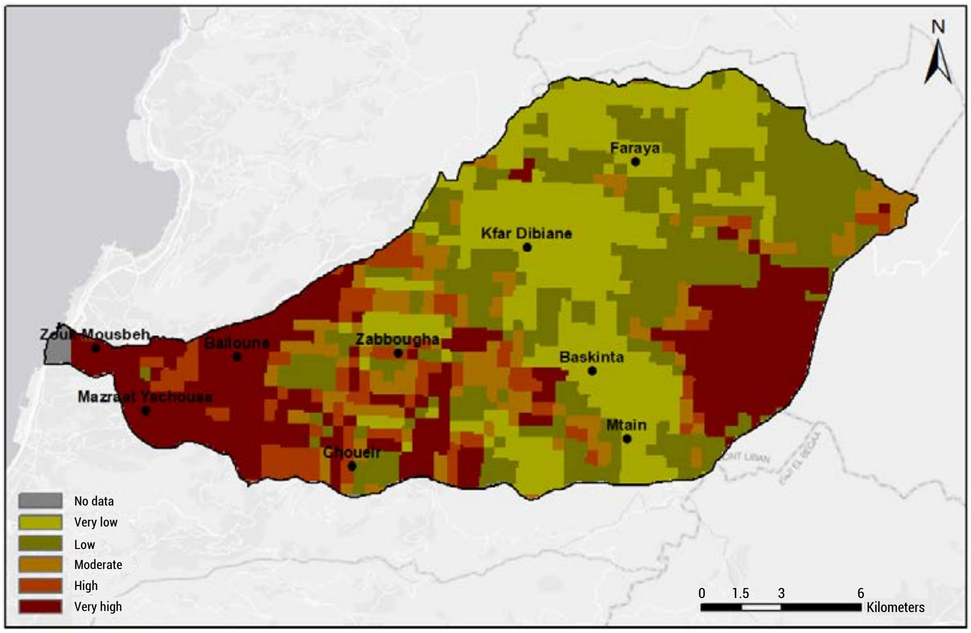
Source: CNRS, 2020.

FIGURE 63: Vulnerability assessment for the mid-term period (2042–2060)



Source: Authors.

FIGURE 64: Land degradation in the Nahr el Kalb basin



Source: Mitri and others, 2019.

D. Link to sustainable development and climate change policies and plans

The development of a forest fire management and reforestation plan is closely related to the attainment of internationally accepted goals and obligations set out in United Nations instruments on the protection of forests and combating land degradation. For example, the Convention on Biological Diversity includes key obligations in connection with the development of national strategies and plans for the conservation and sustainable use of biological resources, including forests. The Convention to Combat Desertification requires parties to have national plans and strategies to combat land degradation and desertification, which can have a direct impact on fire management. The United Nations Framework Convention on Climate Change commits parties to the sustainable management of forests. Furthermore, forest protection is addressed in SDG 6, target 6, which states, "By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes". SDGs 11, 12, 13 and 15 also establish targets on the conservation, restoration and sustainable use of freshwater ecosystems, on the promotion of sustainable management of all types of forests, and on afforestation, reforestation and restoring degraded land.

Lebanon has adopted two key forest laws, namely the Forest Code of 1949, which provides the basis for the management of forests by the Ministry of Agriculture, and Law No. 85, amended in 1996 by Law No. 558. Ministry of Agriculture forestry officer, in addition to police officers and municipality personnel from the Ministry of Interior and Municipalities are responsible for the enforcement of those laws. The Lebanon National Forest Program (2015–2025) was adopted to promote the sustainable management of forest resources, safeguard ecological integrity and promote economic and social development. In 2009, the National Forest Fire Management Strategy was formulated. The strategy addressed the need to provide information about fire seasonality and the relationship between weather variability and the occurrence of fires in Lebanon. The joint Ministry of Agriculture-FAO-Global Environment Facility project entitled "Smart Adaptation of Forest Landscapes in Mountain Areas" was launched in 2016 to enhance the climate resilience of vulnerable forest ecosystems through sustainable forest management and reforestation. In addition, the National Biodiversity Strategy and Action Plan 2016—2030 was developed to provide adaptation plans for ecosystems vulnerable to climate change. Lebanon also assessed burned areas and emissions from fires in its third National Communication under UNFCCC (Ministry of Environment, 2016).

E. Stakeholders – institutions, partners, implementing agencies

National agencies directly involved in fire risk management in Lebanon should be major stakeholders in this intervention measure. Those agencies include the General Directorate of Civil Defense, particularly in connection with firefighting and rescue operations; the Disaster Risk Management Unit, in connection with disaster risk reduction, monitoring and community support; the Ministry of Agriculture Forestry Department, in connection with follow up on forestry laws and regulations; and the Ministry of Environment, in connection with the management of nature reserves and ecosystems. Other critical stakeholders in this intervention measure include the Ministry of Tourism, municipalities, the Lebanon Mountain Trail Association, the Lebanon Reforestation Initiative and key members of the community, including engineers, forest guards, volunteers, researchers and youth groups.

F. Activities

To increase the resilience of the basin, it is recommended that fire protection be enhanced by developing and implementing a forest fire protection and fighting strategy that engages community actors and restores deforested lands. Reforestation helps enhance basin resilience, reduces erosion, improves water quality, increases infiltration and reduces flooding.

The suggested activities are:

Activity 1: developing a forest management plan for the basin by identifying fire prevention measures based on basin fire risk analysis, in collaboration with central authorities and ministries, local authorities, forest owners, herders and other local stakeholders. This would require the planning of several meetings and conducting site visits.

Activity 2: assessing the possibility of establishing additional hill lakes or water ponds for use in fire-fighting activities and constructing three pilot hill lakes, the location of which should be determined on the basis of the outcomes of the integrated vulnerability assessment.

Activity 3: implementing prevention measures in collaboration with the Ministry of Agriculture, local authorities and other concerned entities. Those measures could include:

a. Undertaking preventive silviculture practices, including fuel management actions such as grubbing, tree thinning and pruning, brushwood crushing, prescribed burning and controlled grazing.

b. Reducing tree density to minimize tree competition for soil water, dieback processes and the accumulation of dry biomass. This will have the advantage of speeding up tree growth and ensuring continuity among forest layers.

c. Identifying locations for firebreaks in collaboration with local communities in order to break landscape homogeneity in fire-prone landscapes, such as in large scrubland territories that arise after agriculture land abandonment and facilitating ecological succession processes.

d. Applying best practices of silvopastoral systems to reduce fire risks on private and public forest lands.

Activity 4: undertaking active post-fire restoration actions, including soil stabilization, reforestation and other recovery activities.

Activity 5: planning and implementing public awareness campaigns regarding the value of forest lands beyond direct timber production, such as their value as the source of non-wood forest products and providers of ecosystem services, which are vital for the well being and livelihoods of local communities. Awareness campaigns should target schools and young people and be implemented in collaboration with youth groups and civil society organizations.

Activity 6: strengthening the capacity of local authorities, especially through technical training on fire prevention actions.

Activity 7: developing wood value chain circular business models that focus on making briquettes from agricultural waste residues and from tree pruning activities in order to support forest management best practices. This activity covers the following: a feasibility study, farmer outreach, the formulation of business models, location selection and implementation at four pilot sites.

Activity 8: undertaking ongoing monitoring and needs assessments. This should be done by a committee consisting of diverse stakeholders and chaired by the local authority.

G. Constraints

Major limitations to the application of this intervention measure include dispersed responsibility and a lack of a coordination among stakeholders, including public and private sector actors. Furthermore, many communities do not feel a sense of ownership and therefore have little sense of responsibility for managing their forests. There is, moreover, little data on recent forest fires in the Nahr el Kalb basin.

H. Estimated duration

TABLE 12: Estimated duration of intervention measure 4

Number	Activity	Month																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Developing a forest fire management plan for the basin and identifying fire prevention measures	■	■	■															
2	Assessing additional strategic hill lakes or water ponds for fire-fighting activities; establishing three pilot hill lakes based on the vulnerability assessment			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
3	Implementing prevention measures			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
4	Undertaking active post-fire restoration actions			■	■	■	■	■	■					■	■	■	■	■	■
5	Planning/ implementing public awareness campaigns			■	■	■							■	■	■				
6	Strengthening the capacity of local authorities				■	■				■	■				■	■			
7	Developing wood value chain circular business models that focus on making briquettes from agricultural wastes residues and from tree pruning activities							■	■	■	■	■	■	■	■	■	■	■	■
8	Monitoring and governance							■	■	■	■	■	■	■	■	■	■	■	■

Source: Authors.

I. Estimated costs

Activity	Approximate cost ($)
Developing a forest fire management plan for the basin and identifying fire prevention measures	70 000
Assessing the benefits of establishing additional strategic hill lakes or water ponds to be used in fire-fighting operations. Establishing three pilot hill lakes on the basis of the assessment	300 000
Implementing prevention measures	220 000
Undertaking active post-fire restoration activities	400 000
Creating public awareness campaigns	30 000
Strengthening the capacity of local authorities on fire prevention	30 000
Developing a wood value chain and circular business model that focuses on making briquettes from agricultural waste residues and from tree pruning activities	150 000
Total	**1 200 000**

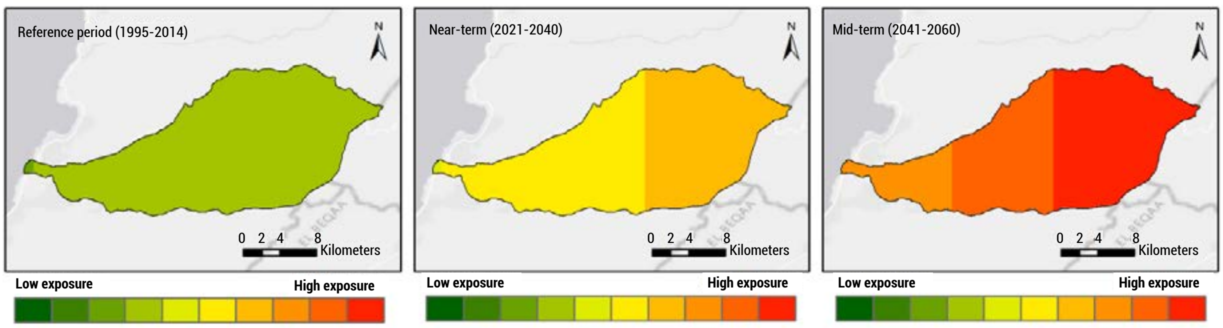
Source: Authors.

Note: These figures are rough estimates of individual activity costs. An extensive assessment with field and data collection would be needed to more accurately measure potential costs.

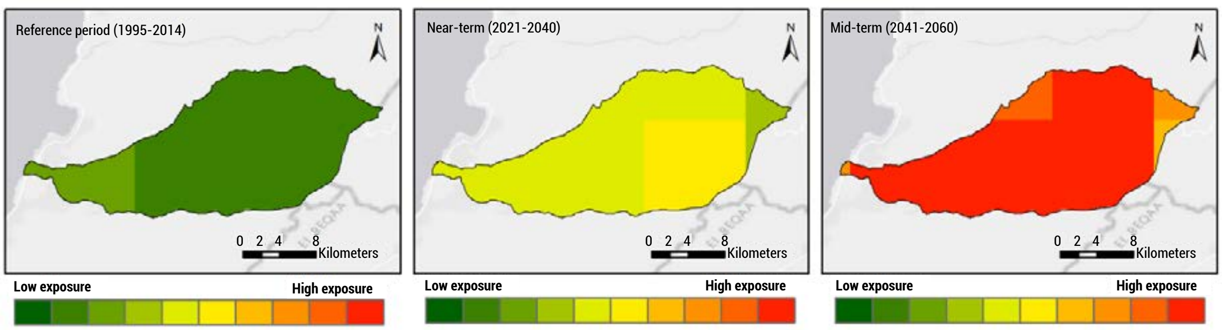
ANNEX

Indicator factsheets and maps

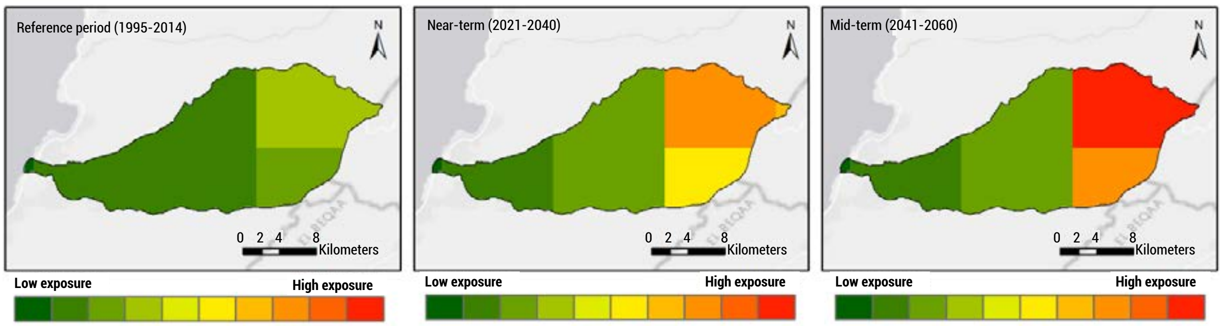
1.Change in temperature		
Vulnerability component	Exposure	
Description	Change in annual temperature compared with the reference period (1995–2014) in the near-term (2021–2040) and the mid-term (2041–2060), calculated on the basis of an ensemble of 6 bias-corrected regional climate modelling outputs under the shared socioeconomic pathway (SSP) 5-8.5 (very high greenhouse gas emission) scenario (SSP5-8.5)	
Classes and ranges for the vulnerability assessment	1 (low exposure):	≤0°C
	2:	0–0.4
	3:	0.4–0.8
	4:	0.8–1.2
	5:	1.2–1.6
	6:	1.6–2
	7:	2–2.4
	8:	2.4–2.8
	9:	2.8–3.2
	10 (high exposure):	>3.2
Influence on vulnerability	Increases in temperature is the primary means to quantify climate change	
Data information		
Type of data	Raster	
Resolution	10 km x 10 km projections	
Unit of measurement	°C	
Methodology for classification and transformation of values	Manual classification based on equal intervals	
Indicator maps		



2. Change in precipitation		
Vulnerability component	Exposure	
Description	Change in annual precipitation compared with the reference period (1995–2014) in the near-term (2021–2040) and the mid-term (2041–2060), calculated on the basis of an ensemble of 6 bias-corrected regional climate modelling outputs under the SSP5-8.5 scenario	
Classes and ranges for the vulnerability assessment	1 (low exposure):	0 mm/month
	2:	|0.0–1.5|
	3:	|1.5–3.0|
	4:	|3.0–4.5|
	5:	|4.5–6.0|
	6:	|6.0–7.5|
	7:	|7.5–9.0|
	8:	|9.0–10.5|
	9:	|10.5–12.0|
	10 (high exposure):	|>12|
Influence on vulnerability	Increases in precipitation can induce floods, whereas decreases in precipitation can result in droughts	
Data information		
Type of data	Raster	
Resolution	10 km x 10 km projections	
Unit of measurement	mm/month	
Methodology for classification and transformation of values	Manual classification based on equal intervals	
Indicator maps		

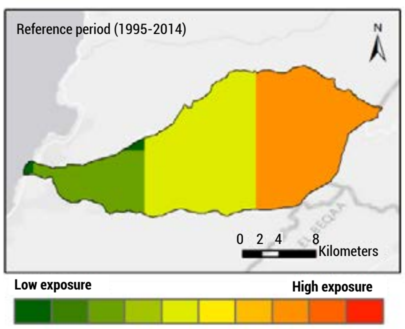


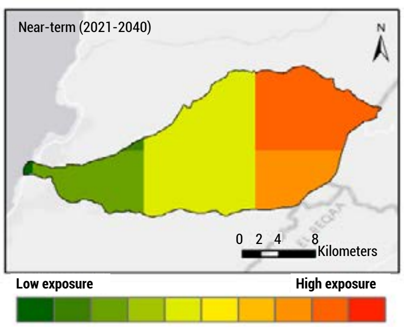
3. Change in snow cover fraction		
Vulnerability component	Exposure	
Description	Change in annual precipitation compared with the reference period (1995–2014) in the near-term (2021–2040) and the mid-term (2041–2060), calculated on the basis of an ensemble of 6 bias-corrected regional climate modelling outputs under the representative concentration pathway (RCP) 8.5 (high-emissions worse-case no-mitigation) scenario (RCP 8.5)	
Classes and ranges for the vulnerability assessment	1 (low exposure):	0%
	2:	|0–1.5|
	3:	|1.5–3|
	4:	|3–4.5|
	5:	|4.5–6|
	6:	|6–7.5|
	7:	|7.5–9|
	8:	|9–10.5|
	9:	|10.5–12|
	10 (high exposure):	|>12|
Influence on vulnerability	Decreasing percentage of snow cover is a proxy for decreasing snow melt with adverse impacts upon water availability	
Data source	Coordinated Regional Climate Downscaling Experiment for the Europe Domain (Euro-CORDEX) regional climate modelling outputs	
Data information		
Type of data	Raster	
Resolution	12.5 km x 12.5 km projections	
Unit of measurement	Snow cover fraction	
Methodology for classification and transformation of values	Manual classification based on equal intervals	
Indicator maps		

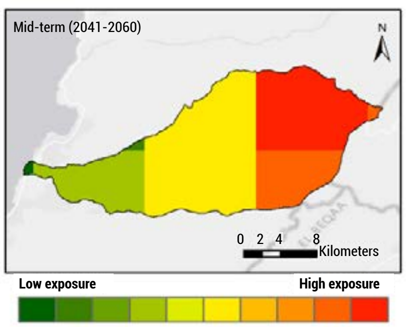


4. Change in snow depth		
Vulnerability component	Exposure	
Description	Change in annual snow depth compared with the reference period (1995–2014) in the near-term (2021–2040) and the mid-term (2041–2060), calculated on the basis of an ensemble of 6 bias-corrected regional climate modelling outputs under the RCP 8.5 scenario	
Classes and ranges for the vulnerability assessment	1 (low exposure):	|<0.4| cm
	2:	|0.4–0.9|
	3:	|0.9–2.1|
	4:	|2.1–4.7|
	5:	|4.7–10.6|
	6:	|10.6–24.1|
	7:	|24.1–54.8|
	8:	|54.8–124.4|
	9:	|124.4–282.5|
	10 (high exposure):	|>282.5|
Influence on vulnerability	Decreasing snow depth is a proxy for decreasing snow melt with adverse impacts upon water availability	
Data source	Euro-CORDEX regional climate modelling outputs	
Data information		
Type of data	Raster	
Resolution	12.5 km x 12.5 km projections	
Unit of measurement	ln (depth in cm)	
Methodology for classification and transformation of values	Manual classification based on equal intervals of ln values	

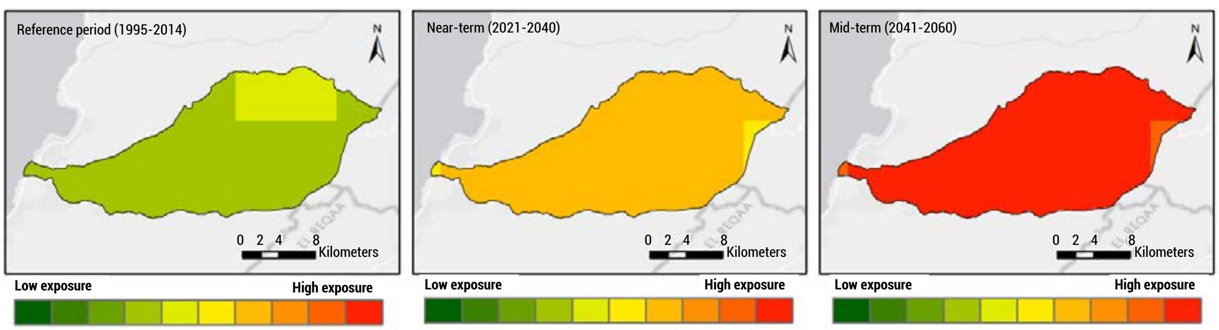
Indicator maps





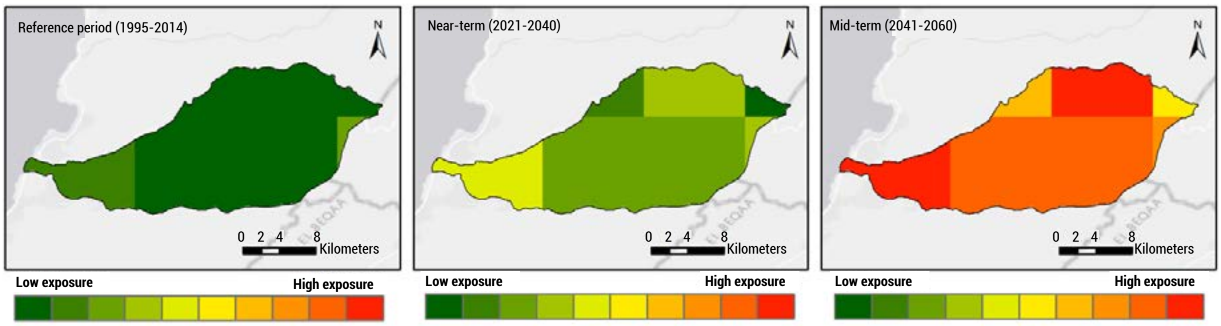


5. Change in summer days (SU)		
Vulnerability component	Exposure	
Description	Change in summer days (days on which maximum temperature is >25°C) compared with the reference period (1995–2014) in the near-term (2021–2040) and the mid-term (2041–2060), calculated on the basis of an ensemble of 6 bias-corrected regional climate modelling outputs under the SSP5-8.5 scenario	
Classes and ranges for the vulnerability assessment	1 (low exposure):	≤0 days/year
	2:	0–5
	3:	5–10
	4:	10–15
	5:	15–20
	6:	20–25
	7:	25–30
	8:	30–35
	9:	35–40
	10 (high exposure):	>40
Influence on vulnerability	Extreme climate index to assess the risk of heat waves and increased water usage	
Data source	Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR) Mashreq Domain regional climate modelling outputs	
Data information		
Type of data	Raster	
Resolution	10 km x 10 km projections	
Unit of measurement	Days/season	
Methodology for classification and transformation of values	Manual classification based on equal intervals	
Indicator maps		

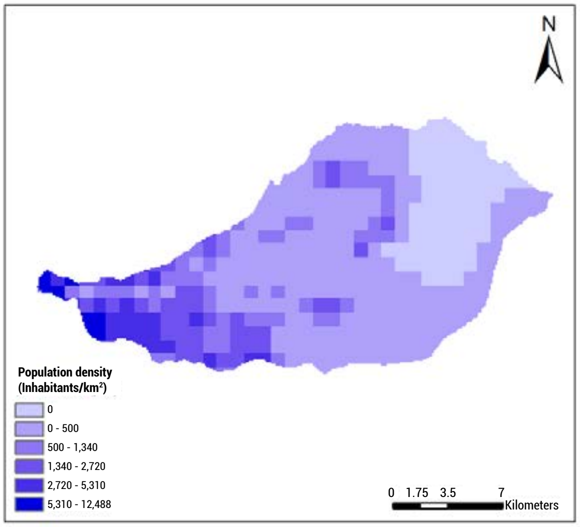


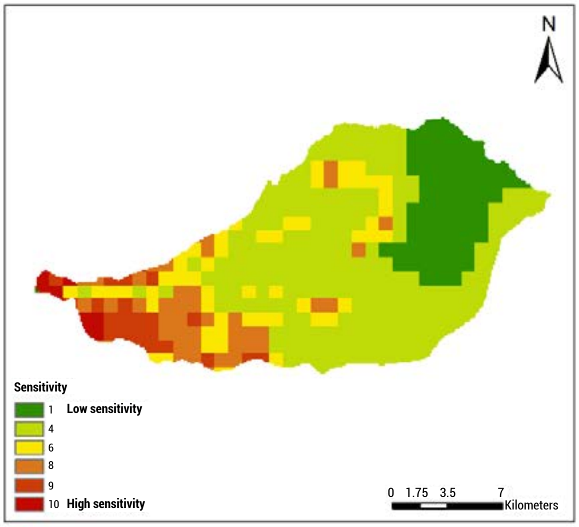
6. Change in drought frequency (SPI-6)		
Vulnerability component	Exposure	
Description	Change in drought frequency (SPI-6) compared with the reference period (1995–2014) in the near-term (2021–2040) and the mid-term (2041–2060), calculated on the basis of an ensemble of 6 bias-corrected regional climate modelling outputs under the SSP5-8.5 scenario	
Classes and ranges for the vulnerability assessment	1 (low exposure):	≤0 events/decade
	2:	0–1
	3:	1–2
	4:	2–3
	5:	3–4
	6:	4–5
	7:	5–6
	8:	6–7
	9:	7–8
	10 (high exposure):	>8
Influence on vulnerability	More frequent and more severe droughts reduce water availability	
Data source	Monthly bias-corrected precipitation data from the Mashreq Domain	
Data information		
Type of data	Raster	
Resolution	10 km x 10 km projections	
Unit of measurement	Events per decade	
Methodology for general data calculation	SPI determined using the SPI raster, as calculated by Jo (2020). Drought frequency estimated by the number of occurrences when SPI <-1.25	

Indicator maps

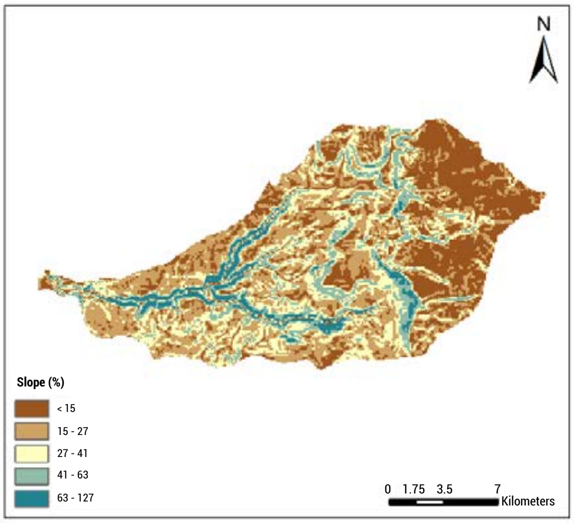


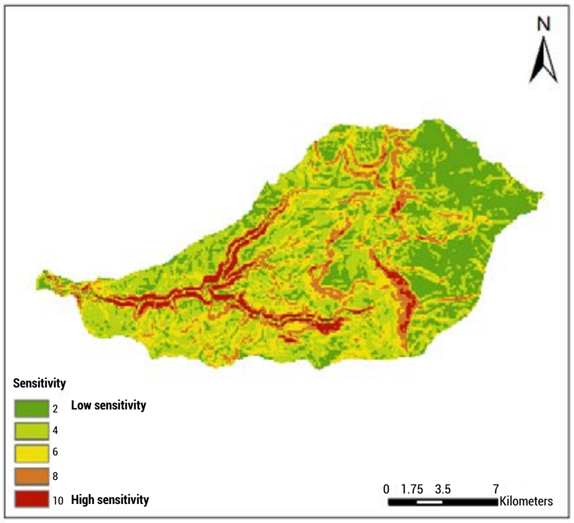
7. Population density		
Vulnerability component	Sensitivity	
Description	Map derived from the global dataset developed by WorldPop (2020)	
Classes and ranges for the vulnerability assessment	1 (low sensitivity):	0
	2:	
	3:	
	4:	0–500
	5:	
	6:	500–1 340
	7:	
	8:	1 340–2 720
	9:	2 720–5 310
	10 (high sensitivity):	5 310–12 488
Influence on vulnerability	Dense population centers are more affected by the availability of water than less densely populated area due to food and water security, access and cost considerations	
Data source	Monthly bias-corrected precipitation data from the Mashreq Domain	
Data information		
Type of data	Raster	
Resolution	100 m x 100 m	
Unit of measurement	Inhabitant/km²	
Methodology for classification and transformation of values	Manual classification	
Indicator maps		



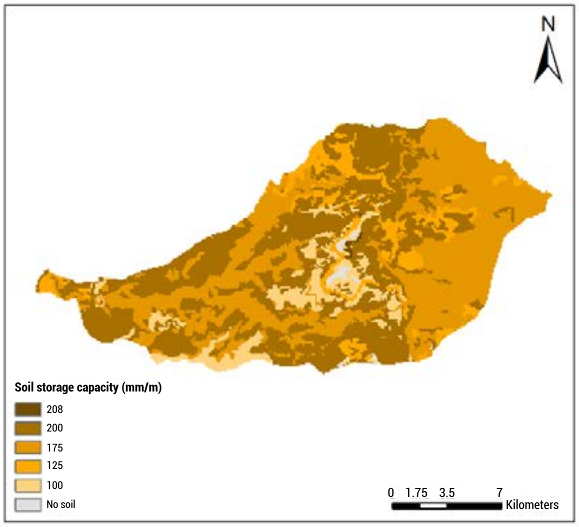


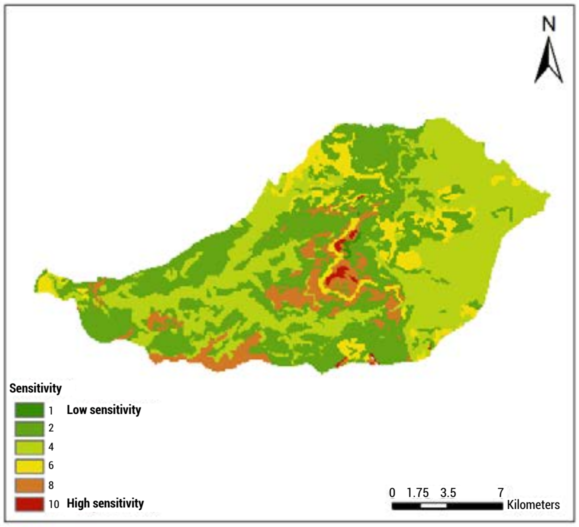
8. Slope gradient		
Vulnerability component	Sensitivity	
Description	Source: United States Geological Survey Digital Elevation Model of Lebanon. Slope derived from the Digital Elevation Model, expressed as a percentage	
Classes and ranges for the vulnerability assessment	1 (low sensitivity):	
	2:	<15
	3:	
	4:	15–27
	5:	
	6:	27–41
	7:	
	8:	41–63
	9:	
	10 (high sensitivity):	>63
Influence on vulnerability	Steeper slopes are more sensitive due to fast-draining soils.	
Data source	Monthly bias-corrected precipitation data from the Mashreq Domain	
Data information		
Type of data	Raster	
Resolution	30 m x 30 m	
Unit of measurement	Percentage	
Methodology for classification and transformation of values	Manual classification	
Indicator maps		



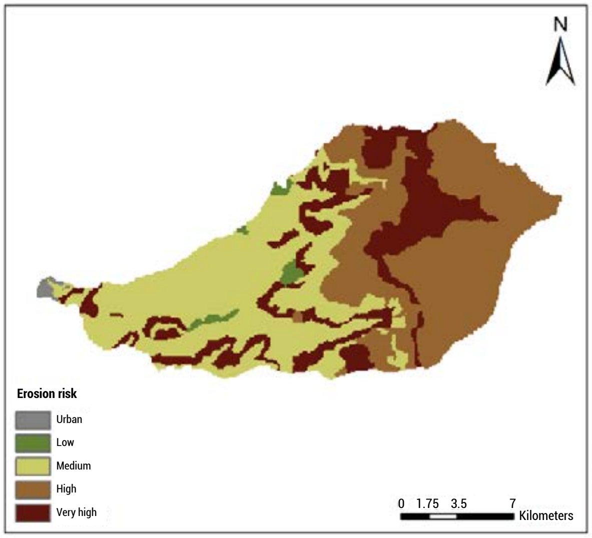


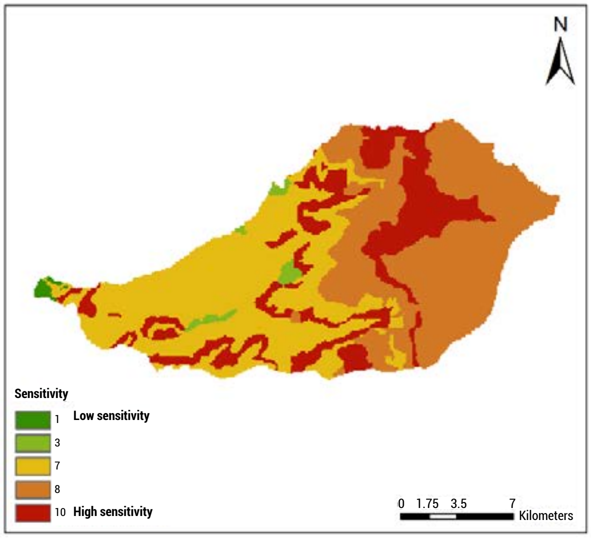
9. Soil storage capacity		
Vulnerability component	Sensitivity	
Description	Source: Soil map of Lebanon, National Council for Scientific Research (CNRS), 2006. In general, soil storage capacity is defined as the total amount of water that is stored in the soil within the plant's root zone.	
Classes and ranges for the vulnerability assessment	1 (low sensitivity):	208
	2:	200
	3:	
	4:	175
	5:	
	6:	125
	7:	
	8:	100
	9:	
	10 (high sensitivity):	No soil
Influence on vulnerability	Areas with less capacity to store water have adverse impacts on crops and water drainage.	
Data source	Monthly bias-corrected precipitation data from the Mashreq Domain	
Data information		
Type of data	Vector	
Resolution	1: 50 000	
Unit of measurement	mm/m depth	
Methodology for classification and transformation of values	Manual classification	
Indicator maps		



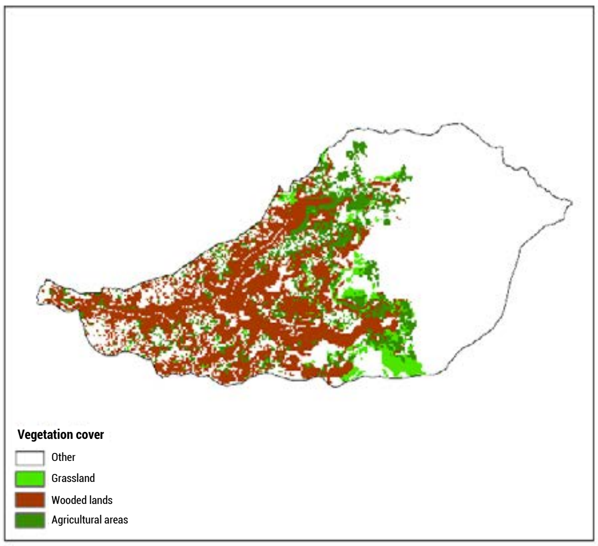


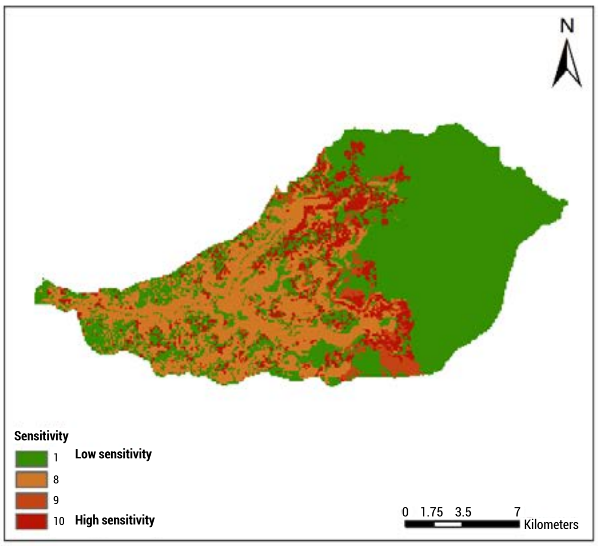
10. Potential soil erosion hazard		
Vulnerability component	Sensitivity	
Description	Source: CNRS land cover/land use map of Lebanon 2017.	
Classes and ranges for the vulnerability assessment	1 (low sensitivity):	Urban
	2:	
	3:	Low
	4:	
	5:	
	6:	
	7:	Medium
	8:	High
	9:	
	10 (high sensitivity):	Very high
Influence on vulnerability	Areas at high risk of erosion are more affected by surface water run-off. Erosion risk is also driven by climatic conditions. Areas that are prone to soil erosion can result in loss of crops.	
Data information		
Type of data	Vector	
Resolution	1: 100 000	
Unit of measurement	Descriptive	
Methodology for classification and transformation of values	Manual classification	
Indicator maps		





11. Vegetation cover		
Vulnerability component	Sensitivity	
Description	Source: CNRS land cover/land use map of Lebanon, 2017.	
Classes and ranges for the vulnerability assessment	1 (low sensitivity):	Other
	2:	
	3:	
	4:	
	5:	
	6:	
	7:	
	8:	Grassland
	9:	Wooded lands
	10 (high sensitivity):	Agricultural areas
Influence on vulnerability	Areas with vegetation cover require water and are therefore highly sensitive.	
Data information		
Type of data	Vector	
Resolution	1: 20 000	
Unit of measurement	Descriptive	
Methodology for classification and transformation of values	Manual classification	
Indicator maps		

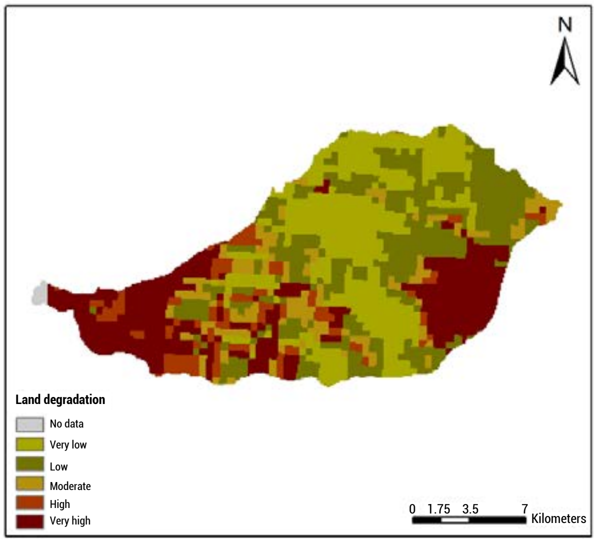


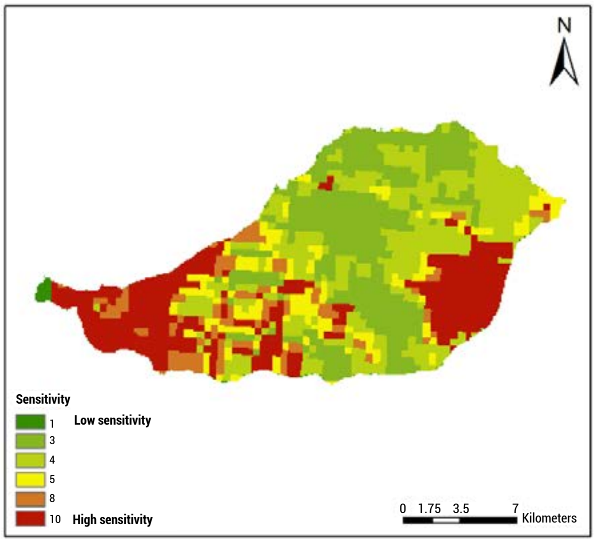


11. Vegetation cover		
Vulnerability component	Sensitivity	
Description	Source: Land Degradation Neutrality Project, implemented by the Association for Forests, Development and Cooperation, in collaboration with the Ministry of Agriculture.	
Classes and ranges for the vulnerability assessment	1 (low sensitivity):	No data
	2:	
	3:	Very low
	4:	Low
	5:	Moderate
	6:	
	7:	
	8:	High
	9:	
	10 (high sensitivity):	Very high
Influence on vulnerability	Areas that are prone to degradation are linked to a decline in water infiltration and an agricultural landscape. Land degradation is also driven by climatic conditions.	

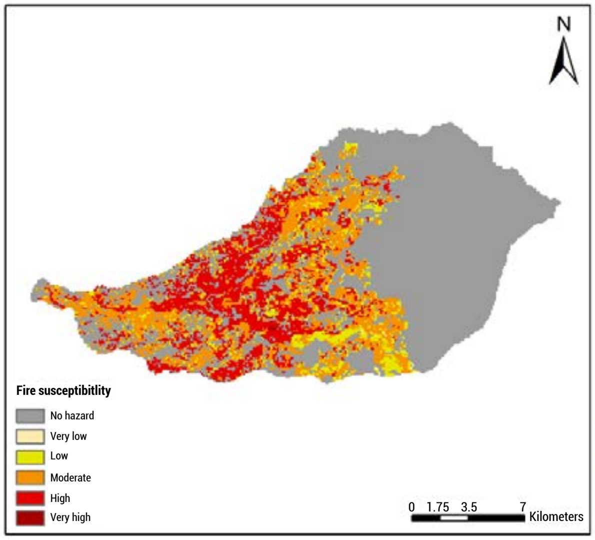
Data information	
Type of data	Vector
Resolution	100 m x 100 m
Unit of measurement	Descriptive
Methodology for classification and transformation of values	Manual classification

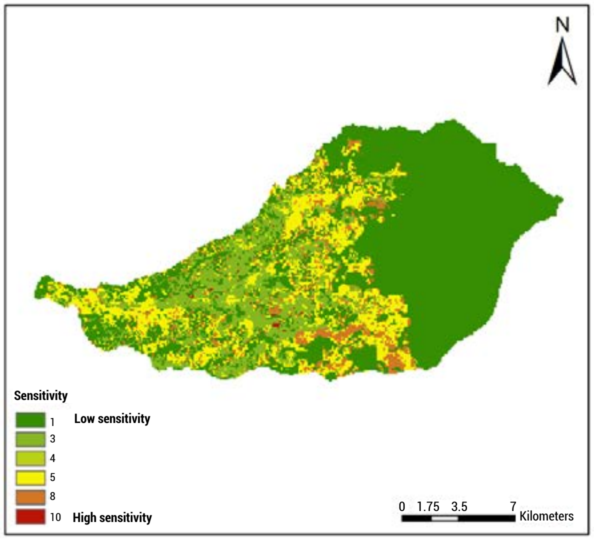
Indicator maps



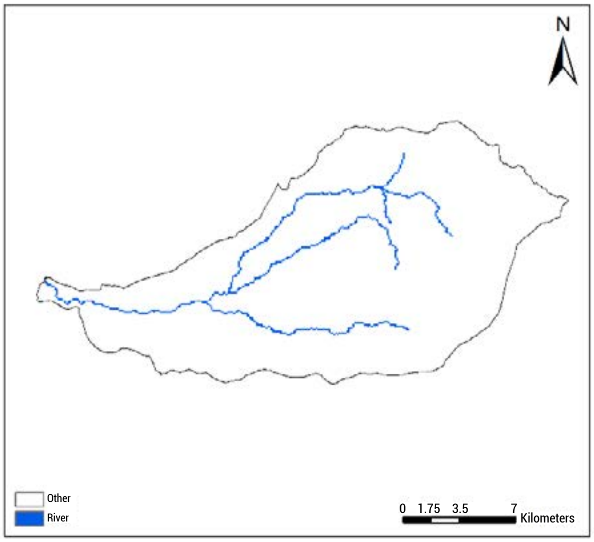


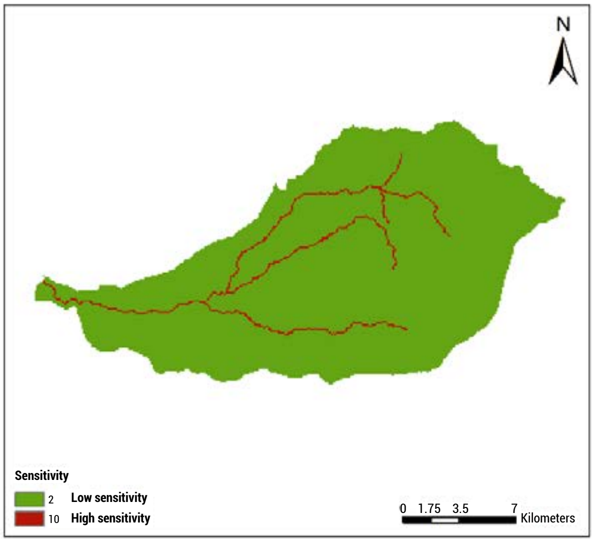
13. Fire susceptibility		
Vulnerability component	Sensitivity/natural	
Description	Source: CNRS, report on the potential risk of fires, 2020.	
Classes and ranges for the vulnerability assessment	1 (low sensitivity):	No hazard
	2:	
	3:	Very low
	4:	Low
	5:	Moderate
	6:	
	7:	
	8:	High
	9:	
	10 (high sensitivity):	Very high
Influence on vulnerability	The quantity and quality of water is affected by post-fire conditions on the site. Fire suppression operations require significant amount of water resources; and water infrastructure in the Wild-land-Urban Interface is increasingly exposed to fire.	
Data information		
Type of data	Raster	
Resolution	100 m x 100 m	
Unit of measurement	Descriptive	
Methodology for classification and transformation of values	Manual classification	
Indicator maps		



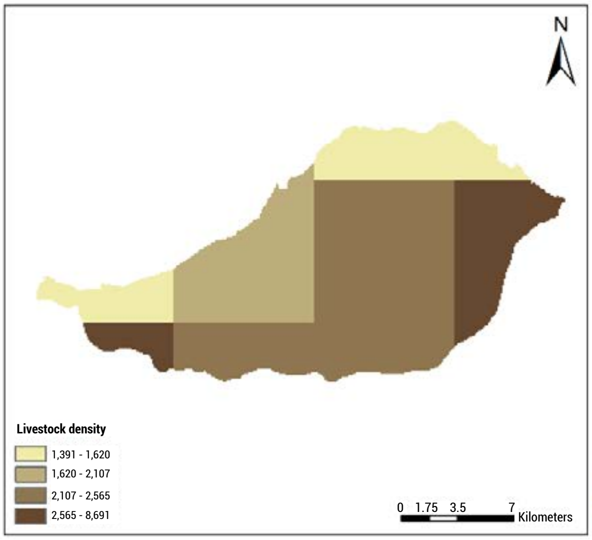


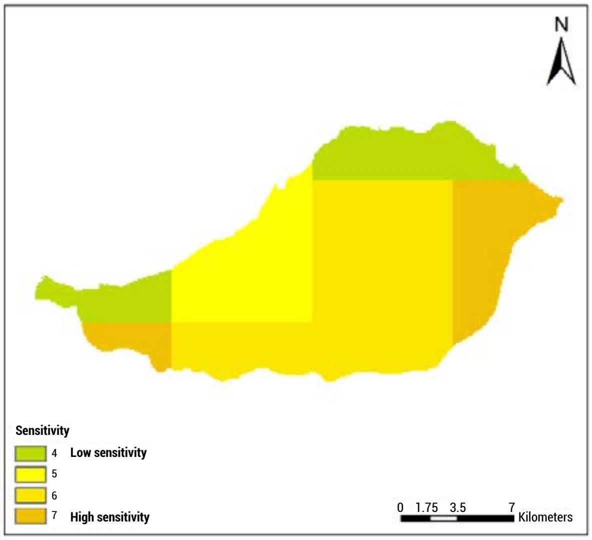
14. Presence of rivers		
Vulnerability component	Sensitivity	
Description	Source: United Nations Development Programme (UNDP), 2014.	
Classes and ranges for the vulnerability assessment	1 (low sensitivity):	
	2:	No river
	3:	
	4:	
	5:	
	6:	
	7:	
	8:	
	9:	
	10 (high sensitivity):	River
Influence on vulnerability	Water flow of river(s) is affected by changes in climatic conditions particularly at climate extreme indices, therefore making river and river tributaries highly sensitive.	
Data information		
Type of data	Vector	
Resolution	1: 20 000	
Unit of measurement	Descriptive	
Methodology for classification and transformation of values	Manual classification	
Indicator maps		





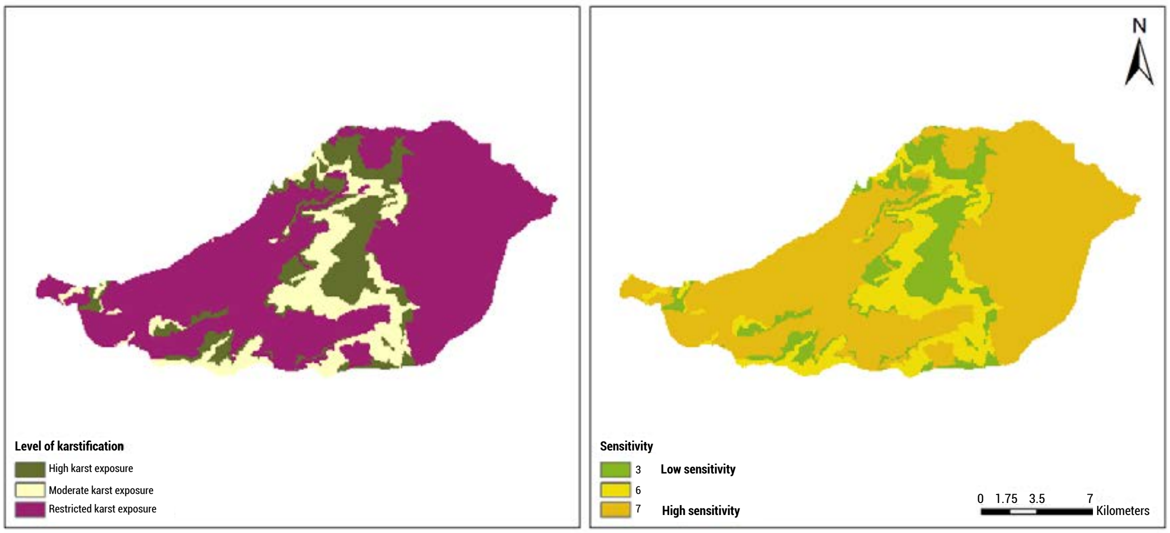
15. Livestock density		
Vulnerability component	Sensitivity/natural	
Description	Source: United Nations Biodiversity Lab, 2010. Density of cattle, goats and sheep per pixel	
Classes and ranges for the vulnerability assessment	1 (low sensitivity):	
	2:	
	3:	
	4:	1391–1620
	5:	1620–2107
	6:	2107–2565
	7:	2565–8591
	8:	
	9:	
	10 (high sensitivity):	
Influence on vulnerability	Grazing animals put pressure on environmental systems	
Data information		
Type of data	Raster	
Resolution	8 700 m x 8 700 m	
Unit of measurement	Density of livestock per pixel	
Methodology for classification and transformation of values	Manual classification	
Indicator maps		



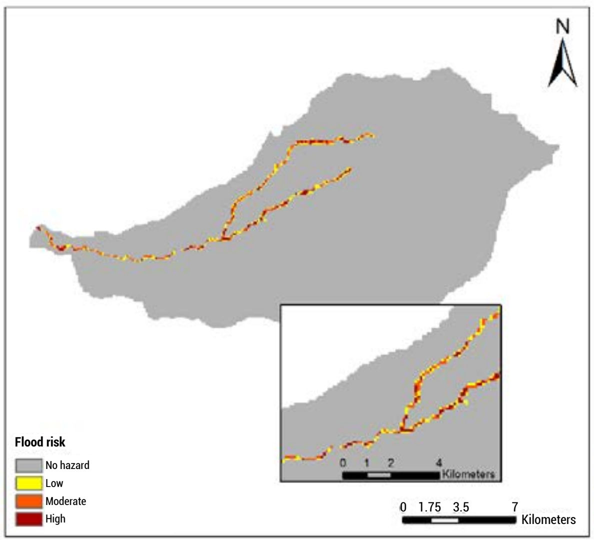


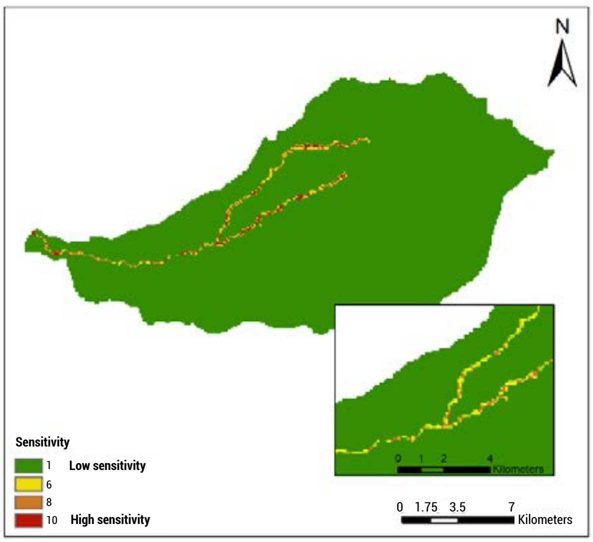
16. Karstification		
Vulnerability component	Sensitivity/natural	
Description	Source: UNDP, 2014. Degree of Karst exposure	
Classes and ranges for the vulnerability assessment	1 (low sensitivity):	
	2:	
	3:	High karst exposure
	4:	
	5:	
	6:	Moderate karst exposure
	7:	Restricted karst exposure
	8:	
	9:	
	10 (high sensitivity):	
Influence on vulnerability	The erosion of limestone in karst landscapes creates fissures and fractures that promote the percolation and infiltration of water	
Data information		
Type of data	Raster	
Resolution	100 m x 100 m	
Unit of measurement	Descriptive	
Methodology for classification and transformation of values	Manual classification	

Indicator maps

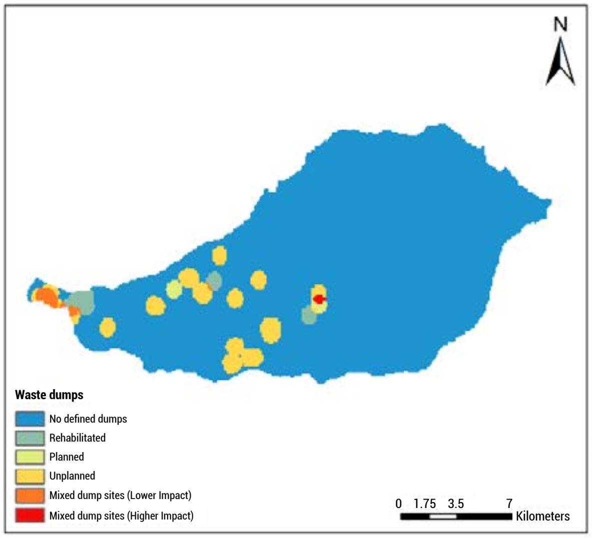


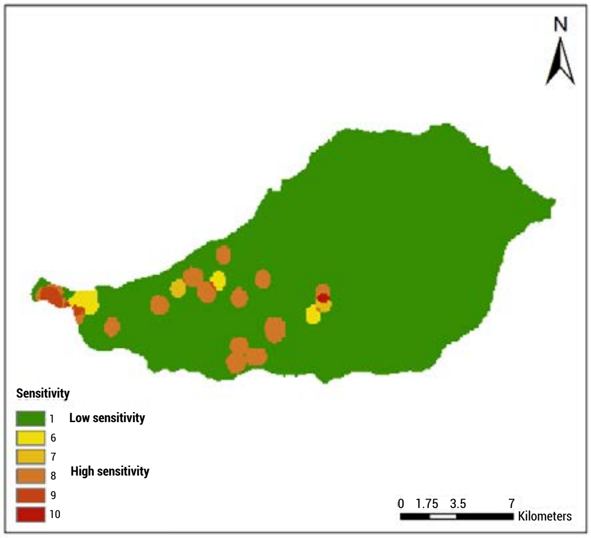
17. Flood risk		
Vulnerability component	Sensitivity	
Description	Source: CNRS, 2017.	
Classes and ranges for the vulnerability assessment	1 (low sensitivity):	No hazard
	2:	
	3:	
	4:	
	5:	
	6:	Low hazard
	7:	
	8:	Moderate hazard
	9:	
	10 (high sensitivity):	High hazard
Influence on vulnerability	Areas at relatively high flood risk are prone to increased damage, both in built-up areas and on agricultural land. Flood events are also affected by climatic conditions.	
Data information		
Type of data	Raster	
Resolution	100 m x100 m	
Unit of measurement	Descriptive	
Methodology for classification and transformation of values	Manual classification	
Indicator maps		



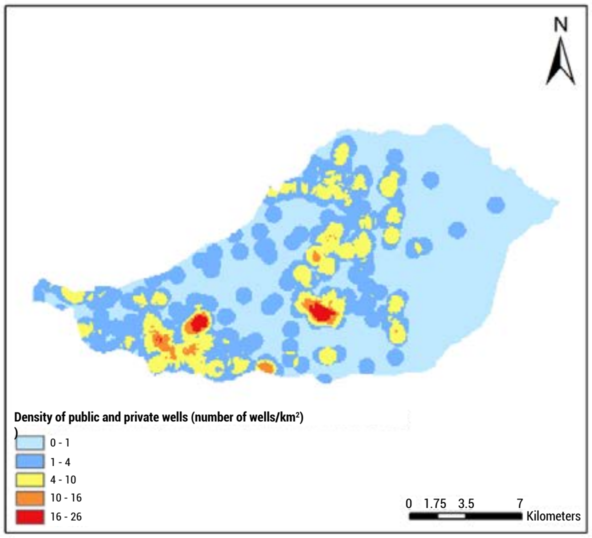


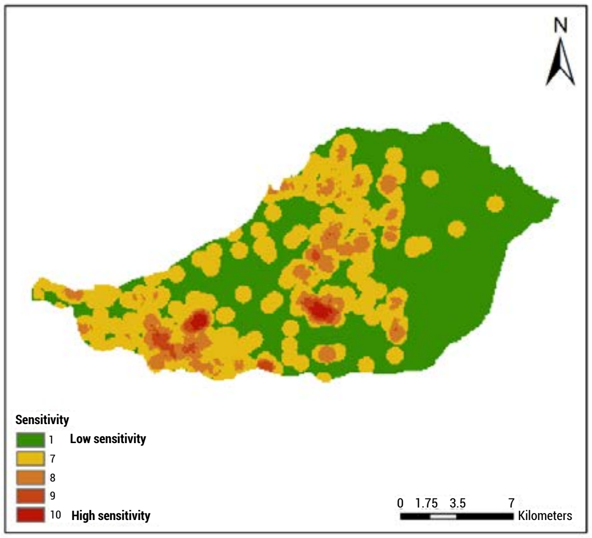
18. Waste dumps		
Vulnerability component	Sensitivity	
Description	Source: Ministry of Environment, 2016.	
Classes and ranges for the vulnerability assessment	1 (low sensitivity):	No defined dumps
	2:	
	3:	
	4:	
	5:	
	6:	Rehabilitated
	7:	Planned
	8:	Unplanned
	9:	Mixed dump sites (low impact)
	10 (high sensitivity):	Mixed dump sites (high impact)
Influence on vulnerability	Areas with dump sites are prone to more pollution of water sources than areas without dump sites due to pollution infiltration.	
Data information		
Type of data	Tabular	
Resolution		
Unit of measurement	Point location	
Methodology for classification and transformation of values	Manual classification	
Indicator maps		



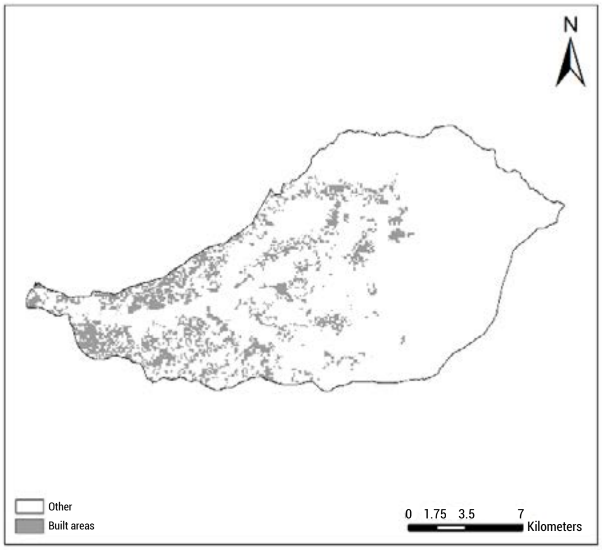


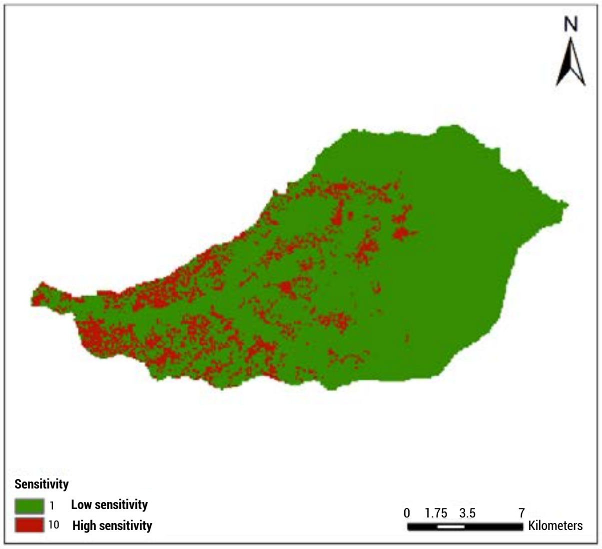
19. Distribution of wells		
Vulnerability component	Sensitivity	
Description	Source: Beirut Mount Lebanon Water Establishment (BMLWE).	
Classes and ranges for the vulnerability assessment	1 (low sensitivity):	0–1
	2:	
	3:	
	4:	
	5:	
	6:	
	7:	1–4
	8:	4–10
	9:	10–16
	10 (high sensitivity):	16–26
Influence on vulnerability	Areas with high well density are characterized by higher sensitivity than areas with low well density due to greater water extraction	
Data information		
Type of data		
Resolution		
Unit of measurement		
Methodology for classification and transformation of values	Manual classification	
Indicator maps		



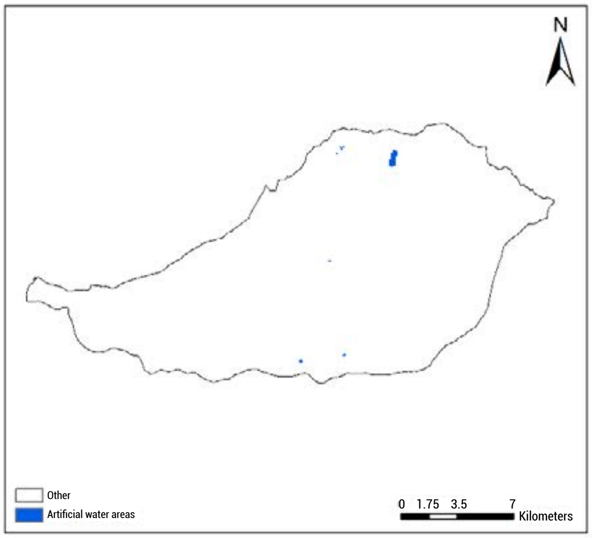


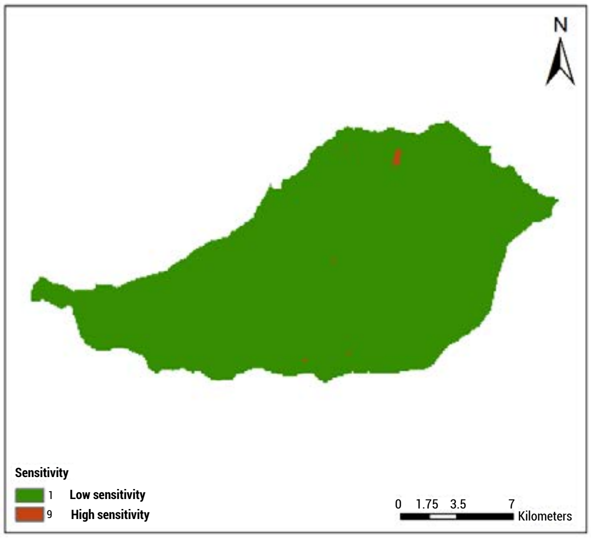
20. Built-up areas		
Vulnerability component	Sensitivity	
Description	Source: CNRS land cover/land use map of Lebanon, 2017.	
Classes and ranges for the vulnerability assessment	1 (low sensitivity):	Other
	2:	
	3:	
	4:	
	5:	
	6:	
	7:	
	8:	
	9:	
	10 (high sensitivity):	Built-up
Influence on vulnerability	Built-up areas are highly sensitive due to lower level of infiltration, higher water requirements and greater likelihood of pollution	
Data information		
Type of data	Vector	
Resolution	1: 20 000	
Unit of measurement	Descriptive	
Methodology for classification and transformation of values	Manual classification	
Indicator maps		





21. Artificial water areas		
Vulnerability component	Sensitivity	
Description	Source: CNRS land cover/land use map of Lebanon, 2017.	
Classes and ranges for the vulnerability assessment	1 (low sensitivity):	Other
	2:	
	3:	
	4:	
	5:	
	6:	
	7:	
	8:	
	9:	Artificial water areas
	10 (high sensitivity):	
Influence on vulnerability	Artificial water areas are highly sensitive due to high evaporation rates from open bodies of water.	
Data information		
Type of data	Vector	
Resolution	1: 20 000	
Unit of measurement	Descriptive	
Methodology for classification and transformation of values	Manual classification	
Indicator maps		

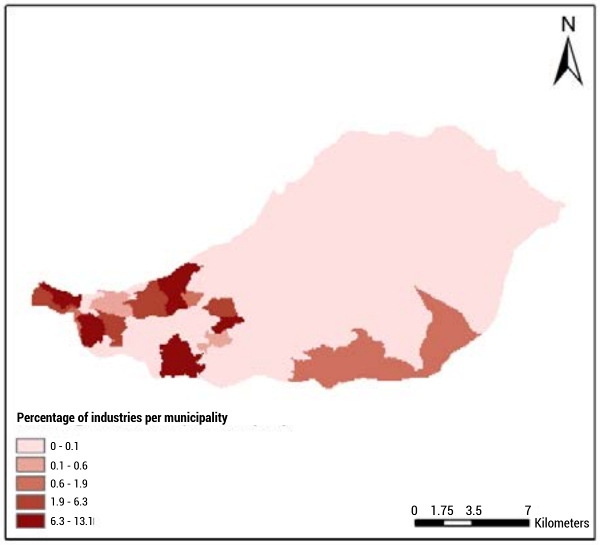


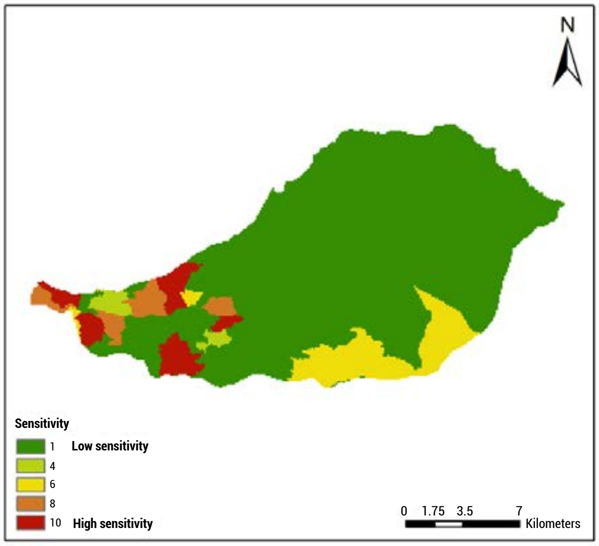


22. Industries		
Vulnerability component	Sensitivity	
Description	Source: Association of Lebanese Industrialists, 2022. Percentage of industries in each municipality out of the total number of industries	
Classes and ranges for the vulnerability assessment	1 (low sensitivity):	0–0.1
	2:	
	3:	
	4:	0–0.6
	5:	
	6:	0.6–1.9
	7	
	8:	1.9–6.3
	9:	
	10 (high sensitivity):	6.3–13.1
Influence on vulnerability	Areas that have higher number of industries are highly sensitive due to higher water demand and the greater likelihood of pollution.	

Data information	
Type of data	Tabular
Resolution	Municipality
Unit of measurement	Percentage
Methodology for classification and transformation of values	Manual classification

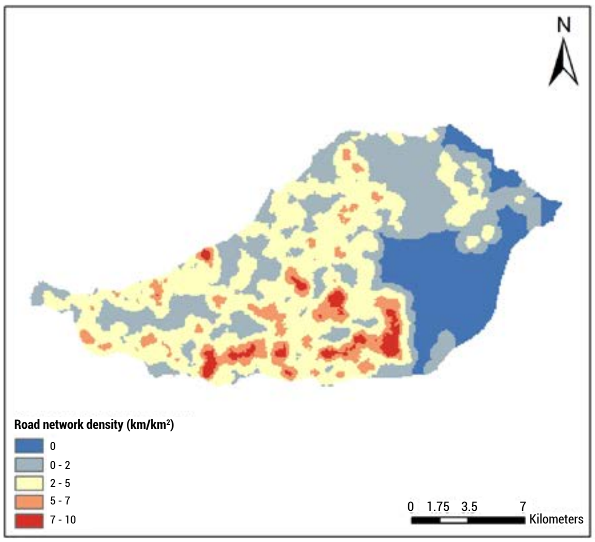
Indicator maps

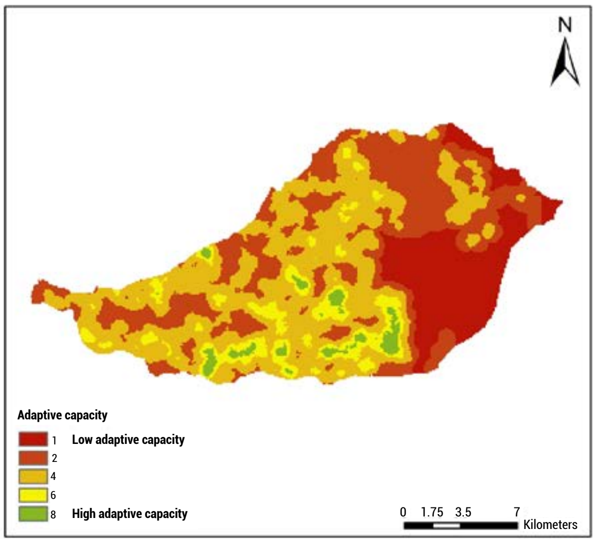




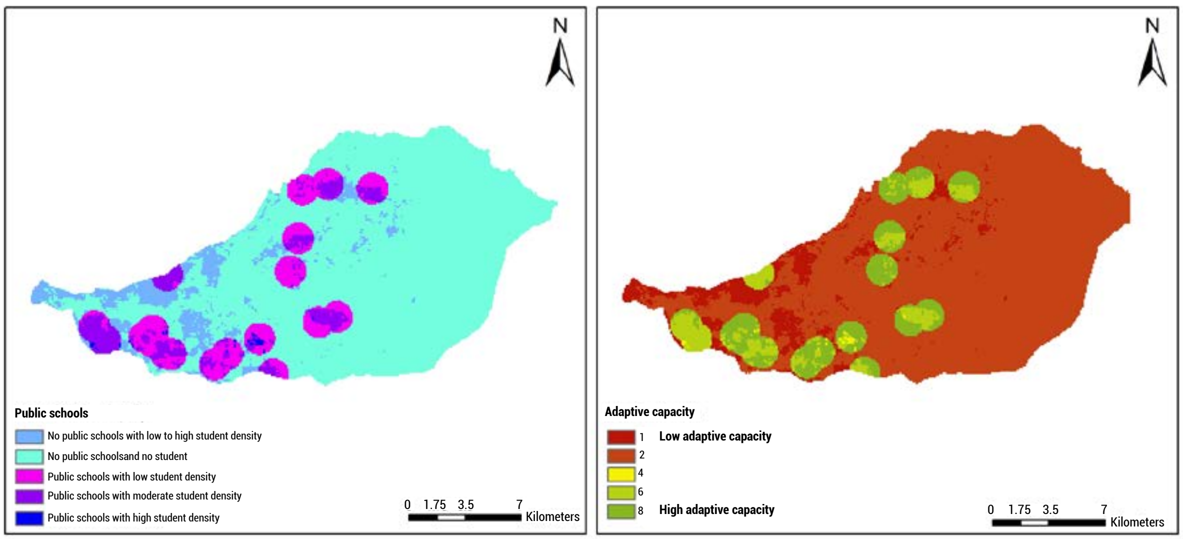
23. Road network density		
Vulnerability component	Adaptive capacity/infrastructure	
Description	Source: United Nations Office for the Coordination of Humanitarian Affairs (OCHA). Length of road per unit area	
Classes and ranges for the vulnerability assessment	1 (low adaptive capacity):	0
	2:	0–2
	3:	
	4:	2–5
	5:	
	6:	5–7
	7:	
	8:	7–10
	9:	
	10 (high adaptive capacity):	
Influence on vulnerability	Higher road density mitigates road segments affected by flood risk, fire risk, erosion risk, etc. and improves accessibility to alternative water sources.	
Data information		
Type of data	Raster	
Resolution	100 m x 100 m	
Unit of measurement	km/km^2	
Methodology for classification and transformation of values	Manual classification	

Indicator maps





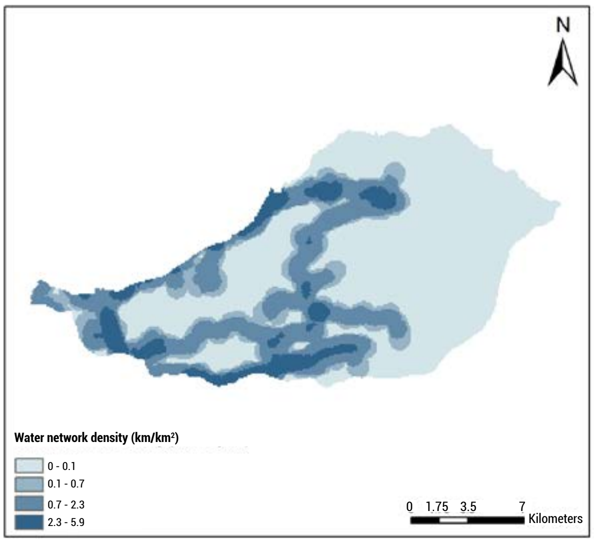
24. Public education centers	
Vulnerability component	Adaptive capacity
Description	Sources: OCHA and WorldPop 2020 Student population per school zone
Classes and ranges for the vulnerability assessment	1 (low adaptive capacity): No public schools with low, moderate or high student density
	2: No public schools and no students
	3:
	4:
	5:
	6: Public schools with low student density
	7: public schools ublic schoopublic schools with moderate student density
	8: Public schools with high student density
	9:
	10 (high adaptive capacity):
Influence on vulnerability	A high number of schools is linked to increased knowledge and learning and thus to greater adaptive capacity. Accordingly, a high population number for a particular school reflects lower adaptive capacity.
Data information	
Type of data	
Resolution	
Unit of measurement	
Methodology for classification and transformation of values	Manual classification

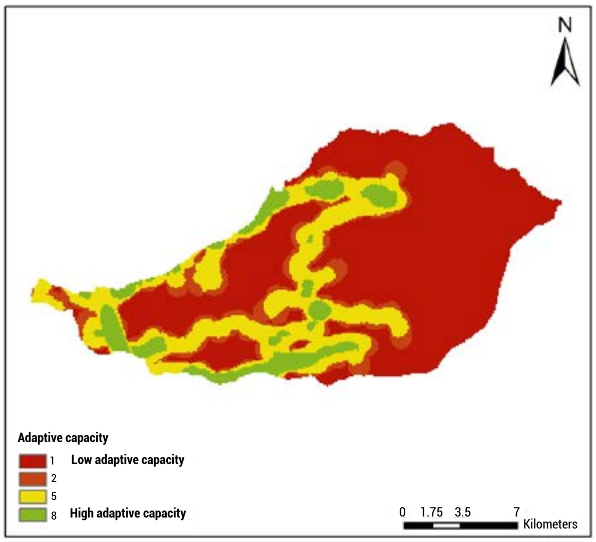


25. Water network		
Vulnerability component	Adaptive capacity	
Description	Source: BMLWE. Length of network per unit area	
Classes and ranges for the vulnerability assessment	1 (low adaptive capacity):	
	2:	0–0.1
	3:	0.1–0.7
	4:	
	5:	0.7–2.3
	6:	
	7:	
	8:	2.3–5.9
	9:	
	10 (high adaptive capacity):	
Influence on vulnerability	High network density indicates areas that are serviced by public water infrastructure. This decreases pressure on water resources.	

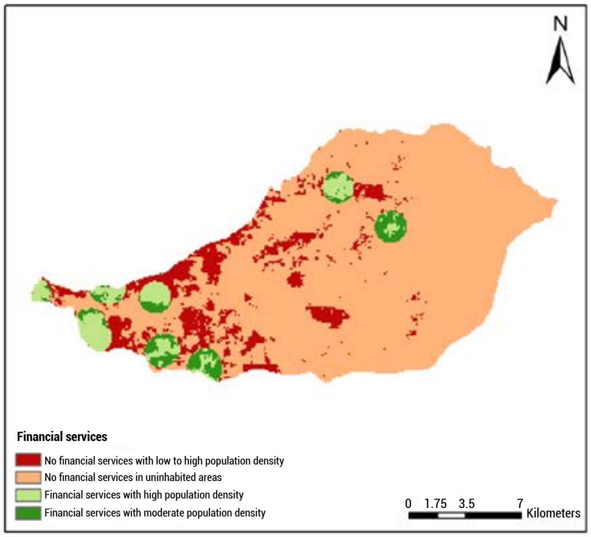
Data information	
Type of data	Raster
Resolution	100 m x 100 m
Unit of measurement	km/km^2
Methodology for classification and transformation of values	Manual classification

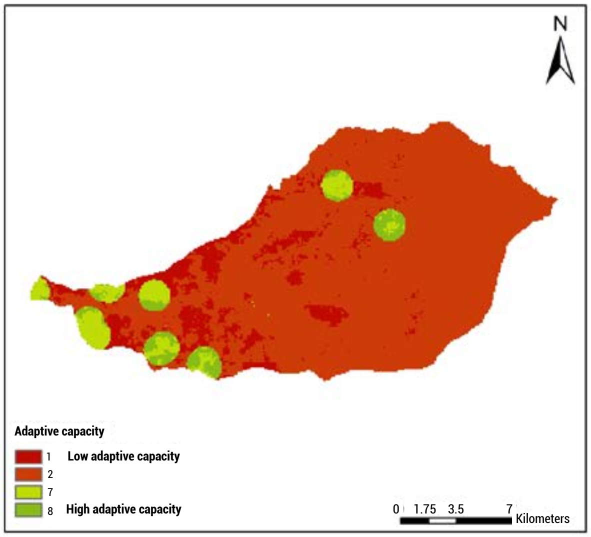
Indicator maps



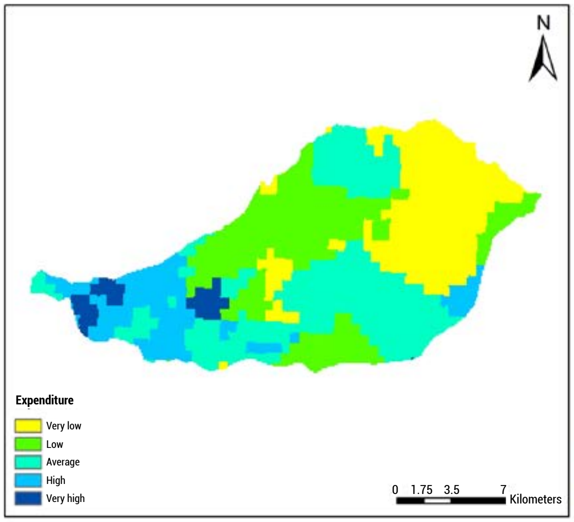


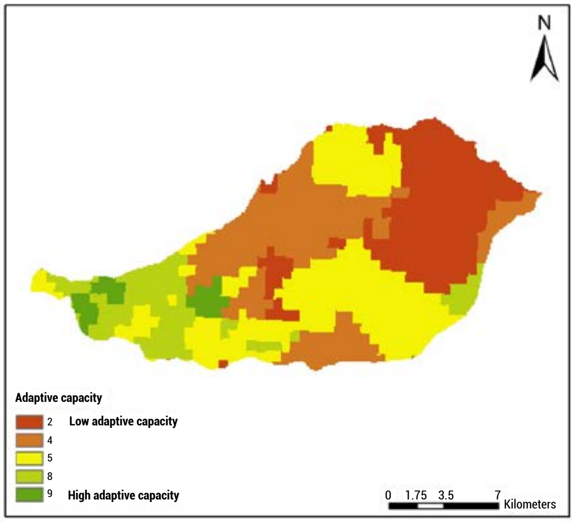
26. Financial services	
Vulnerability component	Adaptive capacity
Description	Sources: OCHA and WorldPop 2020 Number of financial services with respect to the population
Classes and ranges for the vulnerability assessment	1 (low adaptive capacity): No financial services with low to high population density
	2: No financial services in uninhabited areas
	3:
	4:
	5:
	6:
	7: Financial services with high population density
	8: Financial services with moderate population density
	9:
	10 (high adaptive capacity):
Influence on vulnerability	High number of financial services are linked to increased adaptive capacity.
Data information	
Type of data	
Resolution	
Unit of measurement	
Methodology for classification and transformation of values	Manual classification
Indicator maps	





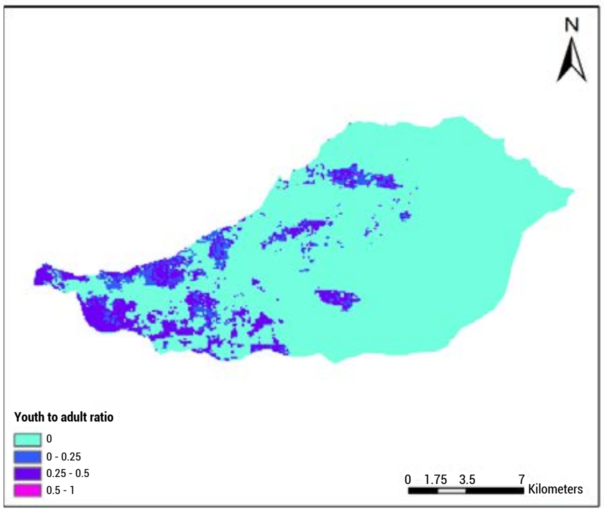
27. Expenditure		
Vulnerability component	Adaptive capacity/economic resources	
Description	Source: Schema directeur d'amenagement du territoire libanais: (SDATL) and Ministry of Telecommunications, 2005. Composite index of residential telephone expenditure, commercial activity in terms of ratio of residences to shops, and construction rate.	
Classes and ranges for the vulnerability assessment	1 (low adaptive capacity):	
	2:	Very low
	3:	
	4:	Low
	5:	Average
	6:	
	7:	
	8:	High
	9:	Very high
	10 (high adaptive capacity):	
Influence on vulnerability	Expenditure is indicative of the economic resources of the population. Economic resources positively correlate with adaptive capacity.	
Data information		
Type of data	Raster	
Resolution	Village level; 1: 375 000	
Unit of measurement	Unitless index	
Methodology for classification and transformation of values	Manual classification	
Indicator maps		

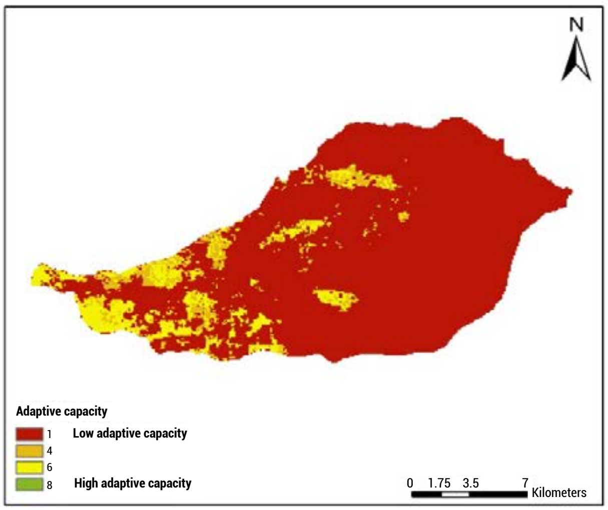




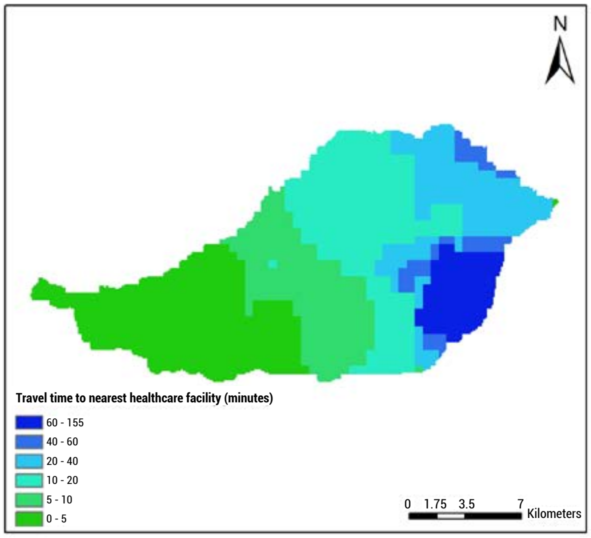
28. Youth to adult ratio		
Vulnerability component	Adaptive capacity	
Description	Source: Population map derived from a global dataset (WorldPop 2020).	
Classes and ranges for the vulnerability assessment	1 (low adaptive capacity):	0
	2:	
	3:	
	4:	0–0.25
	5:	
	6:	0.25–0.5
	7:	
	8:	0.5–1
	9:	
	10 (high adaptive capacity):	
Influence on vulnerability	Young people have an impact upon livelihoods, especially in rural areas and thus increase adaptive capacity. More specifically, young people are recognized as an age group with significant potential in addressing the challenges posed by climate change.	
Data information		
Type of data	Raster	
Resolution	100 m x 100 m	
Unit of measurement	Ratio (unitless)	
Methodology for classification and transformation of values	Manual classification	

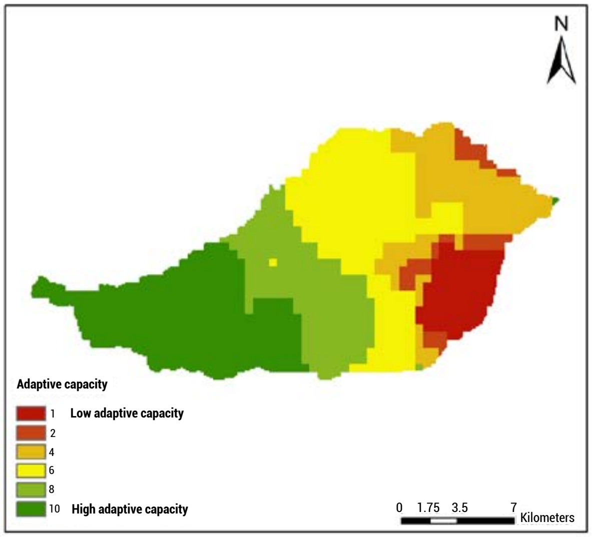
Indicator maps



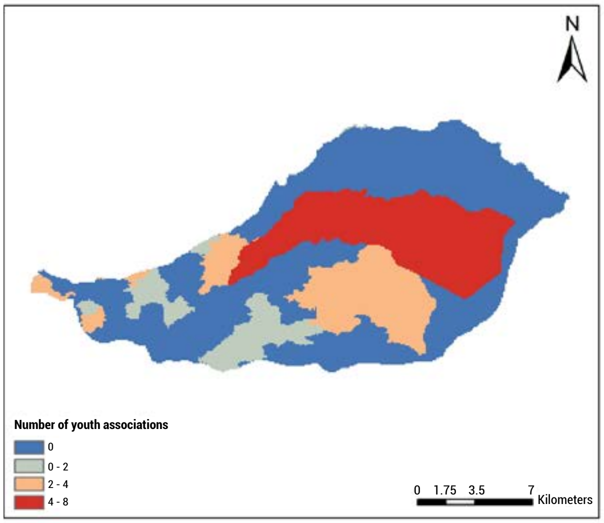


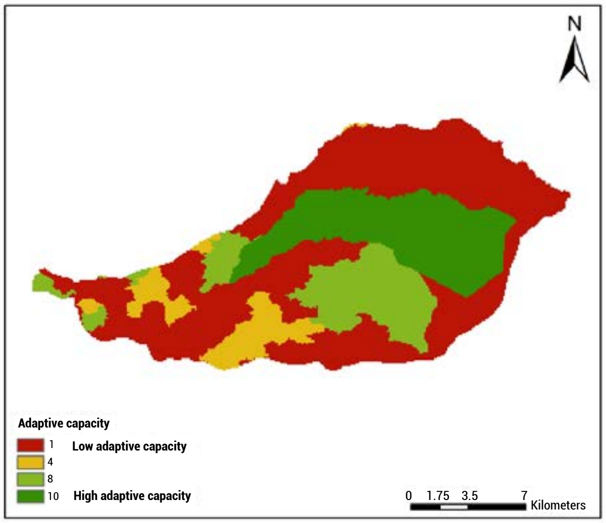
29. Access to health care		
Vulnerability component	Adaptive capacity/institutions	
Description	Source: United Nations Biodiversity Lab. Motorized travel time to the nearest health-care facility	
Classes and ranges for the vulnerability assessment	1 (low adaptive capacity):	60–155
	2:	40–60
	3:	
	4:	20–40
	5:	
	6:	10–20
	7:	
	8:	5–10
	9:	
	10 (high adaptive capacity):	0–5
Influence on vulnerability	Reaching a health-care center within a reasonable period of time means that people can effectively address the threats to their health posed by climate change and water-related challenges.	
Data information		
Type of data	Raster	
Resolution	875 m x 875 m	
Unit of measurement	Travel time (minutes)	
Methodology for classification and transformation of values	Manual classification	
Indicator maps		





30. Number of associations promoting the interests of young people		
Vulnerability component	Adaptive capacity	
Description	Source: Government of Lebanon Inter-Ministerial and Municipal Platform for Assessment, Coordination and Tracking (IMPACT). Number of associations promoting the interests of young people	
Classes and ranges for the vulnerability assessment	1 (low adaptive capacity):	0
	2:	
	3:	0–2
	4:	
	5:	
	6:	
	7:	
	8:	2–4
	9:	
	10 (high adaptive capacity):	4–8
Influence on vulnerability	A larger number of associations promoting the interests of young people can contribute to a higher level of knowledge and awareness among the youth segment of the population and thus encourages a high adaptive capacity. Young people can meaningfully contribute towards climate-resilient development, provided that an enabling environment is created by those associations.	
Data information		
Type of data	Vector	
Resolution	Municipality level	
Unit of measurement	Number of associations promoting the interests of young people	
Methodology for classification and transformation of values	Manual classification	
Indicator maps		





References

Abdallah, Chadi, and Rouya Hdeib (2016). Flood risk assessment and mapping for the Lebanese watersheds. Conference paper, EGU General Assembly Conference Abstracts, vol. 18, EGU2016-9588.
Available at www.researchgate.net/publication/301747729_Flood_risk_assessment_and_mapping_for_the_Lebanese_watersheds.

Ahmadi, Hamzeh, Gholamabbas Ghalhari and Mohammad Baaghideh (2019). Impacts of climate change on apple tree cultivation areas in Iran. Climatic Change, 153(1), 91–103. Available at https://link.springer.com/article/10.1007/s10584-018-2316-x#:~:text=In%20fact%2C%2046.7%25%20of%20apple,the%20cold%20regions%20of%20Iran. Almasi, Amin (2020). Industrial Wastewater Treatment Plants. Water Technology. 16 October. Available at https://www.watertechonline.com/wastewater/article/14183810/industrial-wastewater-treatment-print.

Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD), Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and Economic and Social Commission for Western Asia (ESCWA). 2017. Training Manual on the Integrated Vulnerability Assessment Methodology. In Adaptation to Climate Change in the Water Sector in the MENA Region (ACCWaM) Programme. RICCAR training manual, Beirut, E/ESCWA/SDPD/2017/RICCAR/Manual.

Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD) of the League of Arab States, Ministry of Agriculture in Lebanon (MoAg), National Council for Scientific Research (CNRS) and United Nations Economic and Social Commission for Western Asia (ESCWA) (2019). Integrated Vulnerability Assessment Application on the Lebanese Agricultural Sector. Available at riccar.org/publications/integrated-vulnerability-assessment-application-lebanese-agricultural-sector.

Doummar, Joanna, and Michel Aoun (2018). Occurrence of selected domestic and hospital emerging micropollutants on a rural surface water basin linked to a groundwater karst catchment. Environmental Earth Sciences, vol. 771, No. 9. Available at: https://link.springer.com/journal/12665/volumes-and-issues/77-9.

Economic and Social Commission for Western Asia (2015). Water Development Report 6. The Water, Energy and Food Security Nexus in the Arab Region. Available at www.unescwa.org/sites/default/files/pubs/pdf/e_escwa_sdpd_15_2_e_0.pdf.

__________ (2016). Strategic Review of Food and Nutrition Security in Lebanon. Available at https://archive.unescwa.org/sites/www.unescwa.org/files/page_attachments/escwa_food_and_nutrition_security_in_lebanon_final_version_high_res_en.pdf.

__________ (2020). Regional Initiative for Promoting Small-scale Renewable Energy Applications in Rural Areas of the Arab Region (REGEND): Report on the Baseline Study for Lebanon. Available at https://archive.unescwa.org/sites/www.unescwa.org/files/publications/files/report-baseline-study-lebanon-english.pdf.

Economic and Social Commission for Western Asia and others (2017). Arab Climate Change Assessment Report – Main Report. Beirut, E/ESCWA/SDPD/2017/RICCAR/Report. Available at https://digitallibrary.un.org/record/1324240.

European Commission (n.d.). Global Human Settlement Layer. Available at https://ghsl.jrc.ec.europa.eu/visualisation.php#.

Farajalla, Nadim, Patricia Haydamous and Rana El Hajj (2016). Water, Energy, Food Nexus: An Outlook on Public Institutions in Lebanon. Issam Fares Institute for Public Policy and International Affairs. Available at https://www.aub.edu.lb/ifi/Documents/publications/working_papers/2015-2016/20160828_nexus_lebanon.pdf.

Fayad, Abbas and others (2017). Snow observations in Mount Lebanon (2011–2016). Earth System Science Data 9.2 (2017): 573–587. Available at essd.copernicus.org/articles/9/573/2017/essd-9-573-2017.pdf.

Flint, G. (2019). Improving water conservation in the marble and granite industry in Lebanon. Available at https://pdf.usaid.gov/pdf_docs/PA00WH71.pdf.

Food and Agriculture Organization of the United Nations (2016). Forest and landscape restoration in Lebanon. Available at https://www.fao.org/in-action/forest-landscape-restoration-mechanism/resources/detail/en/c/412643/.

Funes, Inmaculada, and others (2016). Future climate change impacts on apple flowering date in a Mediterranean subbasin. Agricultural Water Management, vol. 164, pp. 19–27. Available at medacc-life.eu/sites/medacc-life.eu/files/docuemnts/funes_et_al_2016_awm.pdf.

Gampe, David, Gregory Nikulin and Ralf Ludwig (2016). Using an ensemble of regional climate models to assess climate change impacts on water scarcity in European river basins. Science of the Total Environment, 573, pp. 1503–1518. Available at https://pubmed.ncbi.nlm.nih.gov/27539825/.

Government of Lebanon, Inter-Ministerial and Municipal Platform for Assessment, Coordination and Tracking (IMPACT). Available at https://impact.cib.gov.lb/home.

Hausfather, Zeke, and Glen Peters (2020). Emissions–the 'business as usual' story is misleading. Nature 577, pp. 618–620. Available at www.nature.com/articles/d41586-020-00177-3.

Hoff, Holger (2011). Understanding the Nexus. Background Paper for the Bonn2011 Conference: The Water, Energy and Food Security Nexus. Stockholm Environment Institute, Stockholm. Available at https://mediamanager.sei.org/documents/Publications/SEI-Paper-Hoff-UnderstandingTheNexus-2011.pdf.

Intergovernmental Panel on Climate Change (2007). Fourth Assessment Report. Available at www.ipcc.ch/assessment-report/ar4/.

__________ (2018). Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Available at: www.ipcc.ch/report/ar5/wg1/.

__________ (2021). Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Available at: www.ipcc.ch/report/ar6/wg1/.

International Renewable Energy Agency (2020). Renewable Energy Outlook: Lebanon. Available at: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jun/IRENA_Outlook_Lebanon_2020.pdf.

Itani, Nour, and others (2021). Potential of Managed Aquifer Recharge in Lebanon: A Case Study of the Damour River Basin. Available at https://pdf.usaid.gov/pdf_docs/PA00XJG2.pdf.

Jacob, Daniela, and others (2014). EURO-CORDEX: new high-resolution climate change projections for European impact research. Regional environmental change, 14(2), pp. 563–578.

Jangra, Mohan, and J.P. Sharma (2013). Climate resilient and apple production in Kullu valley of Himachal Pradesh. International Journal of Farm Sciences, vol. 3(1), pp. 90–97. Available at citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.1009.1343.

Jo, H.W. Calculate Standardized Precipitation Index (SPI) in ArcGIS Version 3.0 (Computer Model). 2020. Available online: https://github.com/Hyun-Woo-Jo/CalculateSPI/releases (accessed on 22 March 2021).

Kiprono, Asenath, and Alberto Llario (2020). Solar Pumping for Water Supply: Harnessing solar power in humanitarian and development. Rugby, United Kingdom: Practical Action Publishing.

Lebanon Water Project (2021). Assessment of Hrache Hydropower Plant Rehabilitation to Serve as a Sustainable Green Source of Energy for the Operation of Nearby Pump Stations.

Margane, Armine (2011). Site Selection for Wastewater Facilities in the Nahr el Kalb Catchment. Technical Report 1. German Federal Ministry for Economic Cooperation and Development (Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung, BMZ). Available at: https://www.bgr.bund.de/EN/Themen/Wasser/Projekte/abgeschlossen/TZ/Libanon/techn_rep_1.pdf?__blob=publicationFile&v=2.

McKee, Tom, Nolan Doesken and John Kleist (1993). The relationship of drought frequency and duration of time scales. In Eighth Conference on Applied Climatology; American Meteorological Society: Boston, MA, USA, pp. 179–186.

Mhawej, Mario and others (2014). Towards an enhanced method to map snow cover areas and derive snow-water equivalent in Lebanon. Journal of Hydrology, 513, pp. 274–282. Available at www.sciencedirect.com/science/article/abs/pii/S0022169414002431.

Ministry of Agriculture, Lebanon (n.d.). Lebanese fresh fruits and vegetables. Available at http://www.agriculture.gov.lb/getattachment/6f47f218-c269-4317-ba4b-6e4130e51138/Lebanese-Fresh-Fruits-and-Vegetables.

Ministry of Energy, Lebanon, United Nations Development Programme and Global Environment Facility (2015). National Greenhouse Gas Inventory Report for Industrial Processes in Lebanon. Beirut.

Ministry of Environment, Lebanon (2016). Lebanon's Third National Communication to the UNFCCC. Available at https://unfccc.int/documents/81373.

Ministry of Environment, Lebanon (n.d.). Agriculture. Webpage. Available at https://climatechange.moe.gov.lb/agriculture.

Ministry of Environment, Lebanon, and Institute of the Environment, University of Balamand (2020). State of Lebanon's wildfires in 2019. Available at http://ioe-firelab.balamand.edu.lb/ForestFires/ForestFires2019.pdf.

Ministry of Industry, Lebanon (2020). Industrial Sector Development Strategic Plan and Implementation Mechanisms (2020–2025). Available at http://www.industry.gov.lb/getattachment/PublicationsAndStudies/Industry-Strategy-Implementation-Plan-2020-2025-v4-7-EN.pdf?lang=en-US.

Ministry of Tourism, Lebanon (n.d.). Lebanon Rural Tourism Strategy. Available at http://www.mot.gov.lb/Content/uploads/Publication/150225013030192~Rural%20Tourism%20Strategy_English.pdf.

Mitri, G., Chnais, E., Asmar, F., Amidi, J. 2019. Integration of Lebanon's Land Degradation Neutrality (LDN) Targets within the National Action Program (NAP) to Combat Desertification. Ministry of Agriculture/Association for Forests, Development and Conservation, Beirut, pp. 137.

Mueller, Bridget, and Sonia Seneviratne (2012). Hot days induced by precipitation deficits at the global scale. Proceedings of the National Academy of Sciences, 109(31), 12398–12403. Available at pubmed.ncbi.nlm.nih.gov/22802672/.

Nhamo, Luxon and others (2020). An integrative analytical model for the water-energy-food nexus: South Africa case study. Environmental Science and Policy, vol. 109, pp. 15–24. Available at www.sciencedirect.com/science/article/pii/S1462901119315618.

Pesaresi, Martino, and others (2019). GHS-SMOD R2019A - GHS settlement layers, updated and refined REGIO model 2014 in application to GHS-BUILT R2018A and GHS-POP R2019A, multitemporal (1975-1990-2000-2015) - OBSOLETE RELEASE. European Commission, Joint Research Center. Available at http://data.europa.eu/89h/42e8be89- 54ff-464e-be7b-bf9e64da5218.

Rangwala, Imtiaz, and James Miller (2012). Climate change in mountains: a review of elevation-dependent warming and its possible causes. Climatic Change, 114(3-4), pp. 527–547.

Riahi, Keywan, and others (2017). The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: an overview, Global Environmental Change, vol. 42, pp. 153–168.

Romeo, Rosalaura, and others (2021). Mountain tourism – Towards a more sustainable path. FAO and World Tourism Organization. Available at: https://www.fao.org/mountain-partnership/publications/publication-detail/en/c/1459778/.

Saade, Jad, and others (2021). Modeling Impact of Climate Change on Surface Water Availability Using SWAT Model in a Semi-Arid Basin: Case of El Kalb River, Lebanon. Hydrology, vol. 8(3): 134. Available at www.researchgate.net/publication/354445709_Modeling_Impact_of_Climate_Change_on_Surface_Water_Availability_Using_SWAT_Model_in_a_Semi-Arid_Basin_Case_of_El_Kalb_River_Lebanon.

Schwalm, Christopher, Spencer Glendon and Philip Duffy (2020). RCP8. 5 tracks cumulative CO2 emissions. Proceedings of the National Academy of Sciences, 117(33), 19656–19657. Available at https://pubmed.ncbi.nlm.nih.gov/32747549/.

Spinoni, Jonathan and others (2020). Future global meteorological drought hot spots: a study based on CORDEX data. Journal of Climate, vol. 33(9), 3635–3661. Available at journals.ametsoc.org/view/journals/clim/33/9/jcli-d-19-0084.1.xml.

Steigera, Robert and others (2020). Climate change and winter outdoor activities in Austria. Journal of Outdoor Recreation and Tourism, vol. 34. Available at: https://doi.org/10.1016/j.jort.2020.100330.

Swedish Meteorological and Hydrological Institute and Economic and Social Commission for Western Asia (2021). Future climate projections for the Mashreq region: Summary outcomes. RICCAR technical report, Beirut. E/ESCWA/CL1.CCS/2021/RICCAR/TECHNICAL REPORT.7. Available at riccar.org/publications/future-climate-projections-mashreq-region-summary-outcomes.

Tomaszkiewicz, Marlene (2021). Future seasonal drought conditions over the CORDEX-MENA/Arab Domain. Atmosphere, vol. 12(7), p. 856. Available at www.mdpi.com/2073-4433/12/7/856.

United Nations Biodiversity Lab database. Available at https://map.unbiodiversitylab.org/.

United Nations Development Programme and Country Entrepreneurship for Distributed Renewables Opportunities (CEDRO) (2013). Hydropower in Lebanon: History and Prospects.

United Nations Development Programme and others (2020). Lebanon – State of the Environment and Future Outlook: Turning the Crises into Opportunities (SOER 2020). Available at www.unicef.org/lebanon/media/7161/file/SOER_Report_EN.pdf.

United Nations Economic and Social Commission for Western Asia (ESCWA). 2015. The Water, Energy and Food Security Nexus in the Arab Region. https://www.unescwa.org/sites/default/files/pubs/pdf/water-energy-food-security-nexus-arab-region-english.pdf.

United Nations Economic and Social Commission for Western Asia (ESCWA), Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD) and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). 2017. Integrated Vulnerability Assessment: Arab Regional Application. RICCAR technical note, Beirut, E/ESCWA/SDPD/2017/RICCAR/TechnicalNote.

United States Agency for International Development (2021). USAID's Community Support Program Launches its "Industrial Wastewater Treatment" Project in Partnership with the Association of Lebanese Industrialists. Press release, 9 April. Available at https://csplebanon.org/pressreleases/usaids-community-support-program-launches-its-industrial-wastewater-treatment-project-in-partnership-with-the-association-of-lebanese-industrialists/.

Vuuren, Detlef, and others (2011). The representative concentration pathways: an overview. Climatic Change, vol. 109(1), pp. 5–31, November. Available at: link.springer.com/content/pdf/10.1007/s10584-011-0148-z.pdf.

WorldPop, 2020. Available at: www.worldpop.org.

World Tourism Organization (2019). Global Report on Women in Tourism, second edition. Available at http://www.unwto.org/publication/global-report-women-tourism-2-edition.

Endnotes

1. For further information, see www.climatenexus.org/climate-change-news/rcp-8-5-business-as-usual-or-a-worst-case-scenario/.
2. For further information, see http://etccdi.pacificclimate.org/list_27_indices.shtml.
3. For methodology information, see www.riccar.org/sites/default/files/2018-07/RICCAR-VA%20Manual-online_0.pdf.
4. Details for all indicators can be found in the annex.
5. For further information, see https://lebanon.fes.de/e/mckinseys-lebanon-economic-vision-summarized-evaluated-and-revised/.
6. For further information, see www.fao.org/in-action/water-efficiency-nena/countries/lebanon/results/en/.

This technical report serves as a climate-proof watershed management plan and resilience package for the Nahr el Kalb basin. Its objective is to improve water resources management in light of increasing freshwater scarcity and climate change pressures. The report results from a project implemented by the Food and Agriculture Organization (FAO) with support from the Economic and Social Commission for Western Asia (ESCWA) entitled "Implementing the 2030 Agenda for water efficiency, productivity and sustainability in the Near East and North Africa (NENA) region (NENA-WepS)."

The study process involved conducting an integrated vulnerability assessment (VA) using a methodology developed by the Regional Initiative for the Assessment of Climate Change Impacts on Socio-Economic Vulnerability in the Arab Region (RICCAR), institutional mapping and participatory consultations with relevant stakeholders. Regional climate projections and analyses of the water-energy-food nexus and projected climate change impacts on apple tree harvests in the Nahr el Kalb basin were also used to inform consultations and to generate the management plan and resilience package. Climate change projections showed an increase in average temperature and decrease in precipitation for the study area for the near (2040-2021) and mid-term (2060-2041). An increasing vulnerability trend was also found. To address these challenges, a number of detailed interventions are suggested to promote climate change adaptation in the study area.

23-00122