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 Kabir basin

TECHNICAL REPORT

Sweden
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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)

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وزارة الطاقة والمياه

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

TECHNICAL REPORT

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Authors:
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
Food and Agriculture Organization of the United Nations (FAO)

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Substantive contributions and analysis in this report were provided by George Mitri and Sabine Saba, as well as an ESCWA team composed of Marlene Ann Tomaszkiewicz, Mohamed Abd Salam El Vilaly, Elie Alrahi, Ziad Khayat, Sara Hess, Tracy Zaarour, Sarah Daniel and Carol Chouchani Cherfane.

This technical 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 region.

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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 Ministerial Water Council in 2010 and derives its mandate from resolutions adopted by the said council, as well as by the Council of Arab Ministers Responsible for the Environment, the Arab Permanent Committee for Meteorology and the Ministerial Session of the Economic and Social Commission for Western Asia (ESCWA).

The Initiative is implemented through a collaborative partnership involving 11 regional and specialized organizations. The RICCAR Regional Knowledge Hub (RKH) is managed by ESCWA and the Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD), with the Food and Agriculture Organization of the United Nations (FAO) hosting the Arab/Middle East and North Africa (MENA) Domain data portal and ESCWA hosting the Mashreq Domain data portal. The regional initiative is coordinated by ESCWA under the umbrella of its Arab Center for Climate Change Policies.

The technical report was prepared through a collaborative partnership between ESCWA, ACSAD and FAO in consultation with the Ministry of Energy and Water of Lebanon.

The study was conducted through the FAO-ESCWA Interagency Contribution Agreement entitled: “Increasing watershed resilience to climate change: Implementing the 2030 Agenda for water efficiency/productivity and water sustainability in NENA countries – Work Package Component on achieving SDG 6.4” to support the implementation of the FAO project entitled “Implementing the 2030 Agenda for Water Efficiency, Productivity and Sustainability in the Near East and North Africa Countries (WEPS-NENA)”. This project was led by FAO with funding from the Swedish International Development Cooperation Agency (Sida), from December 2016 to December 2022.

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ABBREVIATIONS AND ACRONYMS

ACSAD	Arab Center for the Studies of Arid Zones and Dry Lands
AFDC	Association for Forests, Development and Conservation
CDD	consecutive dry days
CDR	Council for Development and Reconstruction
CMIP	Coupled Model Intercomparison Project
CNRS	National Council for Scientific Research
CWD	consecutive wet days
DGC	Directorate General of Cooperatives
DGUP	Directorate General of Urban Planning
EIA	Environmental Impact Assessment
ESCWA	Economic and Social Commission for Western Asia
ET	evapotranspiration
ETa	actual evapotranspiration
ETCCDI	Expert Team on Climate Change Detection and Indices
FAO	Food and Agriculture Organization
GCM	global climate model
GIS	Geographic Information System
HCUP	Higher Council of Urban Planning
IPCC	Intergovernmental Panel on Climate Change
LARI	Lebanese Agriculture Research Institute
LRA	Litani River Authority
LDN	land degradation neutrality
NBS	nature-based solutions
NENA	Near East and North Africa
NGO	non-governmental organization
NLWE	North Lebanon Water Establishment
OCHA	Office for the Coordination of Humanitarian Affairs
RCM	regional climate model
RKH	Regional Knowledge Hub
R5	precipitation days >5 mm
SIDA	Swedish International Development Cooperation Agency
SDG	Sustainable Development Goal
SU	summer days

UNDP	United Nations Development Programme
UNHCR	United Nations High Commissioner for Refugees
UOM	Union of Municipalities
VA	vulnerability assessment
WEPS	water efficiency, productivity and sustainability
WES	water establishments
WUI	Wildland-Urban Interface

EXECUTIVE SUMMARY

The Food and Agriculture Organization of the United Nations (FAO) is implementing a water efficiency, productivity and sustainability regional project in the Near East and North Africa region (NENA).[1] The Economic and Social Commission for Western Asia (ESCWA) supported the implementation of the project on a specific package designed to achieve "increased watershed resilience to climate change". The specific objective was to develop a climate-proof watershed management plan and resilience package to improve water resource management in view of increasing freshwater scarcity and climate change pressures. This was pursued in Lebanon in the Nahr el Kabir and the Nahr el Kalb basins, and in Algeria in the Algerois watershed. In this context, the current work consisted of undertaking an integrated vulnerability assessment (VA), institutional mapping and participatory consultations, firmly grounded in a science-based approach to informing policy dialogue and project planning in the water sector. Accordingly, the work comprised developing a watershed design and resilience package for the three river basins analysed. This report focuses on the Nahr el Kabir basin in Lebanon.

More specifically, the study area consisted of the southern part of the Nahr el Kabir basin (Lebanese side) in the Akkar region where a shared river forms the north-south border between Lebanon and the Syrian Arab Republic. It is divided into four geomorphological zones: the mountain region in the upper catchment shared by both Lebanon and the Syrian Arab Republic, the intra-mountainous cross-border Bqaiaa plain, the central plateau/gorge area running along the border and the coastal cross-border Akkar/Hamidiye plain.

An initial consultation targeted local stakeholders to assess feedback and input on the most relevant indicators for use in the water sector vulnerability assessment (VA). In this context, the initial selection of indicators was mostly an iterative process based on numerous considerations, most importantly data availability. Each indicator was weighted based on consultation with the local stakeholders; geometric aggregation was employed to build the composite indicators. In addition, the initial consultation determined the main agricultural crops commonly cultivated in the basin and potentially vulnerable to climate change. A second consultation was conducted to present and validate the VA results. More specifically, the consultation featured presenting the results of the climate change VA study in the water sector and barley productivity in the Lebanese side of the Nahr el Kabir basin. The participants discussed the outcomes and the ideas of possible projects within the basin to respond to the impacts of climate change in order to prepare a package of resilience interventions. A final consultation was conducted to receive feedback on proposed interventions.

Overall, all evaluated climate models projected generally increasing temperatures across the basin. The number of days when the daily maximum temperature is greater than 25°C showed an increasing trend of 4.6 days per decade. The near-term (2021–2040) showed some increasing precipitation, particularly in the uppermost basin, yet shifting to declining precipitation in the mid-term (2041–2060). Although changes in consecutive dry days (CDDs) were small, no spatial-temporal trends were evident; the maximum change by the mid-term was estimated at a 6 per cent increase. Projected changes in consecutive wet days (CWDs) were minimal with a slight decrease in the near- and mid-terms. The number of annual precipitation days (i.e., precipitation days >5 mm) showed a decline, but also signalled wide variability. Projected results for the near- and mid-term periods are consistent with the declining trend. The climate change signal is clearer for the mid-term; all precipitation parameters imply an increased drought risk.

The results showed a relatively low reference period exposure while the near-term period exposure was slightly higher across the basin. For the mid-term period, areas of significantly high exposure were observed across the basin. The sensitivity composite indicator revealed areas of relatively low to moderate sensitivity. Areas with the highest sensitivity were located in the lower part of the basin, mostly covered by cropland exposed to floods from the river. The sensitivity level reflected current conditions but could change greatly over time if values of one or more contributing indicators were to evolve. Potential impact (i.e., reflecting the aggregation of exposure and sensitivity) varied between low to moderate across the basin and slightly increased at mid-term. The adaptive capacity varied from very low to low throughout the basin, reflecting the low ability of the water sector within the basin to cope with the impacts of climate change. This was expected, given the marginalization of rural areas in Akkar in terms of services for a relatively long period of time. Although contributing indicators were based upon current conditions, adaptive capacity could potentially either increase or decrease in the future, based on evolving coping mechanisms.

In the reference period, approximately 52 per cent of the basin exhibited moderate vulnerability. This increased for the near-term period when most of the basin area signalled higher vulnerability (i.e., reduced area of low vulnerability and a slight increase in areas ranging from moderately-high to high vulnerabilities). For the mid-term period, 17.2 per cent of the basin exhibited high vulnerability (i.e., hotspots representing the top 30 per cent of the ten vulnerability classes) mostly in the coastal area (i.e., in association with floods and cropland coverage) and in the upper part of the basin (i.e., mostly in association with fire risk, topography and post-fire impact). The vulnerability revealed was strongly impacted by a low adaptive capacity and influenced by moderate sensitivity. Thus, enhancing adaptive capacity measures has the greatest potential to reduce percentage coverage of the projected high vulnerability classes in both near- and mid-term periods. Relatively large and condensed areas of hotspots were primarily located in three different zones, namely Akroum/Sharbine/Chadra (expanding over mountainous lands with a relatively dense tree cover), Machta Hassan/Aaidamoun/Monjez (covering the middle part of the basin mostly characterized by agricultural land with a relatively high sensitivity in the water sector) and El Aarida/Es-Sammaqiye/El Massaoudiye (covering coastal-cropland areas highly exposed to land degradation and flood hazard with a low adaptive capacity).

The results of the VA in question showed that most of the communities in Nahr el Kabir basin were confronting a range of challenges related to water management, including risks from degraded water quality, water scarcity and drought, flooding from both rivers and stormwater, as well as wildfires. For much of the basin, these challenges were projected to increase due to climate change over the next several decades. Diverse solutions would be needed, implemented from the scale of small communities to wide regions across the basin, with interventions ranging from local investments in specific infrastructure water-related projects to broad policy reforms. In this work, nature-based solutions (NbS) were proposed in the form of resilience packages, given their potential to address both environmental and societal challenges. Accordingly, a long list of NbS was suggested to effectively address water challenges within the Nahr el Kabir basin in response to reduced water availability, reduced water quality, drought, wildfires and freshwater flooding, and also given the need for knowledge and capacity development, as well as management improvement.

Consequently, the following interventions were selected in line with the results of the conducted VA, and to directly link NbS to climate change adaptation outcomes based on consultation with local and national stakeholders:

- Adapting to climate change in the Nahr el Kabir basin by establishing traditional water storage systems.
- Providing multi-purpose green infrastructure (a series of constructed wetlands) for water pollution control.
- Applying a set of mitigation and adaptation strategies to combat land degradation and drought.
- Improving forest management to reduce wildfires and enhance resilience in the Nahr el Kabir.
- Improving knowledge management in the water sector at the regional level.

A summary description of each suggested intervention was provided and target areas within the basin were identified. In addition, an overall objective, general description, justification, link to sustainable development and climate change policies and plans, stakeholders, activities, constraints, estimated duration and estimated costs were provided for each suggested intervention. The suggested interventions solely provide a road map for increasing resilience of the study area to climate change in the water sector; further developing the said interventions would require future field visits and assessment to collect more information about their detailed designs and feasibility. Moreover, an initial environmental examination and/or environmental impact assessment might be needed for selected interventions.

This work focuses on enhancing adaptive capacity in the basin as a response to the vulnerabilities resulting from climate change. It, therefore, aligns with the Paris Agreement global goal on adaptation, which seeks to strengthen resilience to climate change, with a view of sustainable development and the temperature goal set by the agreement.

PART 1. WATERSHED VULNERABILITY ASSESSMENT

1 INTRODUCTION

The Food and Agriculture Organization of the United Nations (FAO) and the Economic and Social Commission for Western Asia (ESCWA) collaborated to support the implementation of the FAO project entitled "Implementing the 2030 Agenda for Water Efficiency, Productivity and Sustainability in the Near East and North Africa Countries (WEPS-NENA)". The project was carried out with funding from the Swedish International Development Cooperation Agency (Sida). Part of this work was focused on fulfilling the objectives of Sustainable Development Goal (SDG) 6.4, related to increasing water-use efficiency, entailing increasing watershed resilience to climate change. Accordingly, the objective of this research was to develop a climate-proof watershed management plan and resilience package to improve water resource management in light of the increasing freshwater scarcity and climate change pressures. The work was pursued in three water basins in the NENA region: one in Algeria and two in Lebanon (namely, Nahr el Kalb and Nahr el Kabir).

This work consisted of undertaking an integrated vulnerability assessment (VA), institutional mapping, and participatory consultations that were firmly grounded in a science-based approach to informing policy dialogue and project planning. More specifically, the work comprised devising a watershed design and resilience package for the Nahr el Kabir basin in Lebanon.

This document is divided into two main parts. Part 1 includes a description of the methodology of the study, a description of the basin, relevant regional climate change projections, an integrated vulnerability assessment of the basin using a methodology developed by the Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR) and a summary of climate change impacts on barley production in the Nahr el Kabir basin. Part 2 presents the watershed resilience package and details recommended interventions.

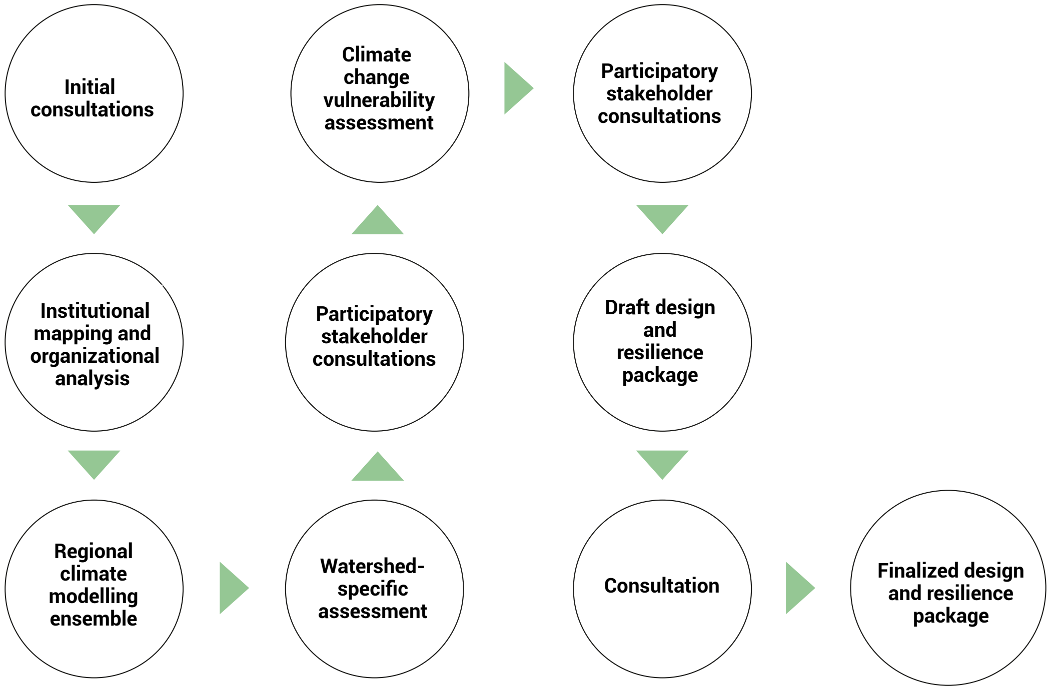
A. Methodology

In brief, this work was undertaken in line with a 10-point methodology:

1. Initial consultations with national government counterparts to review the scope of work and discuss the national institutions and local stakeholder groups to engage in the consultations.
2. Institutional mapping and organizational analysis to reflect changes in land and water governance, incorporating a human-rights-based approach.
3. Regional climate modelling ensemble of projections generated for the watershed, drawing on the RICCAR regional climate modelling ensembles generated for the Mashreq Domain for representative concentration pathway (RCP) 8.5 at a scale of 10 km^2.
4. Watershed-specific assessment to determine changes in agricultural productivity resulting from climate change on a major crop type (other than fruit trees), based on the regional climate models (RCMs) ensemble and using AquaCrop, as well as preliminary recommendations that would be conducted with the Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD).
5. Participatory stakeholder consultations to discuss community-based capacity to cope with climate change in Akkar.
6. Climate change VA to project how climate change is affecting community livelihoods in the basin, drawing on indicators identified during the consultations.
7. Participatory stakeholder consultations to vet and validate the VA and solicit input on preliminary response measures from an integrated watershed management perspective.
8. Preparation of a climate-proof watershed management design and resilience package.
9. Consultation with national counterparts and local stakeholders on the proposed watershed management design and resilience packages.
10. Finalization of the climate-proof watershed management design and resilience package, based on feedback received.

The flow chart demonstrates the various steps undertaken throughout the work process (figure 1).

FIGURE 1: Flow chart of work



Source: 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, 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.

B. Consultations

An initial consultation targeted a number of local stakeholders based on an initial stakeholders' assessment. Those who contributed to the survey were categorized as follows:

- Governmental institutions: Ministry of Agriculture (MoA), Ministry of Environment (MoE), North Lebanon Water Establishment (NLWE), Lebanese Agriculture Research Institute (LARI)
- Non-governmental organizations (NGOs): MADA (Lebanese NGO), Akkar Network Development (AND)
- Municipalities: Akroum, Rmeh, Qobayat, Et Tleil, Heitla, Monjez and Fneideq
- Farmers/agriculture engineers (crops survey)

Moreover, a systematic sampling of villages was conducted to ensure the representation of villages with small, medium and large numbers of population. Two documents were prepared in advance for use in the consultation process (annex 1). One document was used to investigate the main agricultural crops commonly cultivated in the basin and potentially vulnerable to climate change, and the second to score relevant indicators in assessing the vulnerability of the water to climate change. Stakeholders were then contacted, and data were collected either by email, phone or field visits.

A second consultation was conducted to present and validate the VA results. The meeting was held on June 16, 2022, in a hybrid manner, both virtually and in person, at the Municipal Cultural and Social Center in Qobayat, Akkar, Lebanon. The meeting featured the attendance of representatives from FAO, ACSAD, LARI, municipality unions, municipalities, local associations and the private sector.

Moreover, the meeting featured presenting the results of the VA study on climate change in the water sector and barley productivity in the Lebanese side of the Nahr el Kabir basin. The participants discussed the outcomes and ideas of possible projects within the basin to respond to the impacts of climate change so as to prepare a resilience intervention package. Additionally, a final stakeholder consultation was held to discuss proposed interventions.

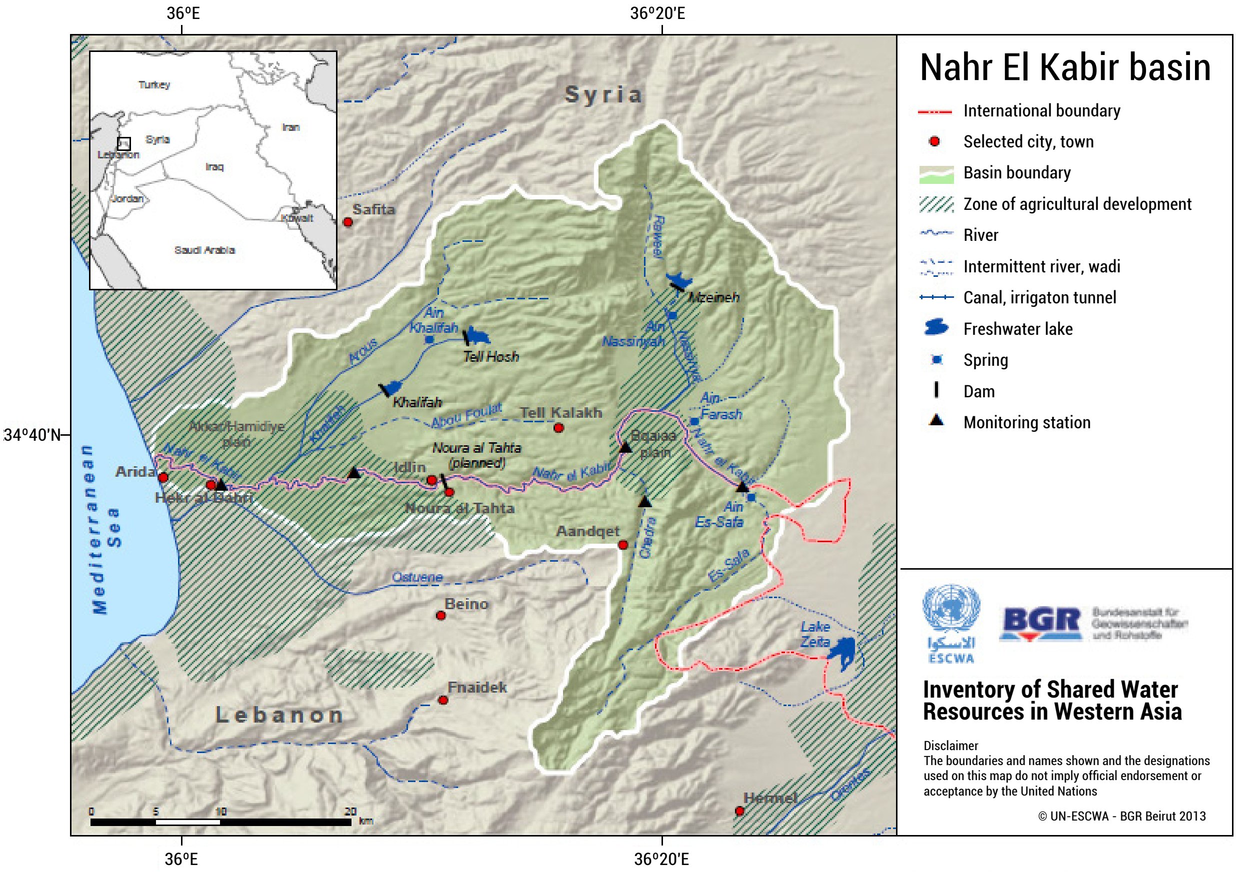
2 BASIN DESCRIPTION

A. Biophysical characteristics

1. Natural characteristics

The study area consisted of the southern part of the Nahr el Kabir basin (Lebanese side) in the Akkar region where a shared river forms the north-south border between Lebanon and the Syrian Arab Republic. The basin covers 954 km^2, of which 26 per cent (i.e., 294 km^2) lie in Lebanon and 74 per cent lie in the Syrian Arab Republic (figure 2). The basin is divided into four geomorphological zones: the mountain region in the upper catchment shared by both Lebanon and the Syrian Arab Republic, the intra-mountainous cross-border Bqaiaa plain, the central plateau/gorge area running along the border and the coastal cross-border Akkar/Hamidiye plain.

FIGURE 2: Location of the Nahr el Kabir basin



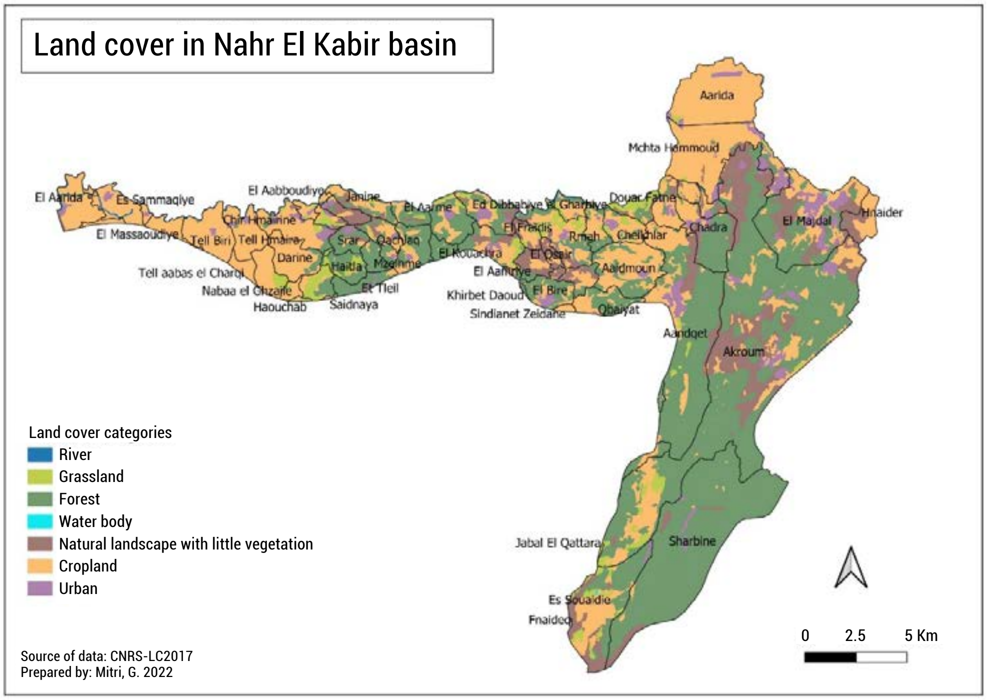
Source: ESCWA-BGR, 2013.

Several tributaries discharge into the Nahr el Kabir on both sides of its course. The main tributaries on the Lebanese side are Wadi Khaled, Es Safa and Chadra. In addition, the Lebanese mountain Qarnat Araba constitutes the highest point of the catchment with an altitude of 2,215 meters above sea level (m.a.s.l.).

The basin is characterized by a relatively widespread forest cover while cropland covers a large area across the basin (figure 3). Urban areas are scattered across the basin territory.

Overview of the Nahr el Kabir and its surroundings on the border between Lebanon and the Syrian Arab Republic from the side of Menjez in Lebanon (photo credit: George Mitri).

FIGURE 3: Main land cover categories of the Nahr el Kabir basin



Source: Authors.

The elevation of the basin ranges from sea level to approximately 2,100 m.a.s.l. The high mountain lands are mainly composed of well-karstified carbonate rocks. The structure of the basin is mostly reflected in the ruggedness level of its terrain, which is sharp and irregular on the elevated lands and slightly-to-extremely even on the plains.

The annual flow volume of Nahr el Kabir has been measured since 1955 (ESCWA and BGR, 2013). At the outlet monitoring station near Hekr al Dahri, the mean annual flow volume was estimated at approximately 377 million cubic meters (MCM) (1969-2011).

2. Socioeconomic aspects

The basin on the Lebanese side has an estimated total population of 100,000 inhabitants (Central Administration of Statistics, [CAS], Lebanon 2011). According to data published by the United Nations Refugee Agency (UNHCR), as of September 2022, there were more than 103,000 registered Syrian refugees in the Akkar region. Settlements are comprised of mixed urban and rural communities. As the Akkar region in the Nahr el Kabir basin remains one of the poorest Lebanese districts, according to the World Bank multidimensional poverty index (MPI) (Seshan, 2022), this has increased pressure on natural resources in the basin. The main source of income is traditional agricultural production, which depends on irrigation in the lowland areas during summer. This explains the dense network of irrigation and drainage canals that has been constructed in the inner plains (ESCWA and BGR, 2013).

The conflict in the Syrian Arab Republic has had a strong spillover effect on northern Lebanon, which has seen a strong influx of Syrian refugees since the beginning of the crisis, owing to its proximity to hotspot cities such as Hama, Homs and Idleb. In 2018, vulnerable localities were mapped and presented by the UNHCR and the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) based on low incomes, lack of access to health, education and water, as well as poor housing conditions. Some localities were considered to be “under high pressure”, with Syrians outnumbering Lebanese nationals by a factor of three to one. The most vulnerable localities were along the border with the Syrian Arab Republic (OCHA, 2018).

B. Stakeholders mapping

A summary of the main governmental and non-governmental organizations involved in water, wastewater and land resource sectors is presented in annex 2. The water-land governance framework was identified:

1. Institutions/governance

The Ministry of Energy and Water (MoEW), comprising the General Directorate of Hydraulic Resources, the General Directorate of Exploitation and the General Directorate of Oil (MoEW, 2020), has a broad mission in the water sector, which includes: (1) collecting, controlling, metering, establishing statistics and studying water resources, as well as evaluating water needs and areas of use throughout the Lebanese territory; (2) controlling the quality of surface and underground water; (3) establishing the general planning project for the allocation and the reparation of hydraulic resources; (4) preparing and continuously updating the National General Water Master Plan; (5) designing, studying, implementing and operating large water installations and works, such as dams, artificial lakes, tunnels, water networks and watercourse rectification; (6) issuing licences and permits for water prospecting, public water usage and temporary occupation of public properties; (7) implementing, when needed, an artificial recharge of groundwater aquifers and controlling groundwater extraction; (8) enhancing and monitoring the performance of water establishments (WEs) according to indicators set in their business plans; and (9) undertaking public relations, providing the population with all necessary water-related information and offering adequate guidance for rational usage.

The Water Code (Law 192/2020)[2] represents a substantial effort towards modernizing the legal, institutional and financial aspects of the water sector, hence adding value to the role of the MoEW. Some of the most important elements of Law 192/2020 (MoE-UNDP, 2021) include the following: (1) implementing the water register; (2) establishing the National Water Council; (3) enforcing a water master plan; (4) devising basin management plans with the use of an integrated approach; and (5) proposing new tools to manage the water sector, including the legal possibilities for a public-private partnership (PPP), as well as public-public partnerships with municipalities. The Water Code also gives a role to the line ministries described in the next sections as members of the National Water Council, and also stipulates that the master plan shall be developed in coordination with those ministries.

The North Lebanon Water Establishment (NLWE) as established by article 3 of Law 221/2000 amended by article 1 of Law 241/2000 is permitted to: (1) conduct studies, implement, exploit, maintain and renew water projects to distribute drinking and irrigation waters, collect, treat and drain wastewater according to the water and wastewater master plans; (2) propose tariffs for water services (drinking, irrigation and wastewater) according to the social and economic conditions; (3) control the quality of drinking and irrigation waters and the quality of wastewater at the exit of the treatment station in coordination with MoEW; and (4) carry out investments and feasibility studies related to the master plan prepared by the MoEW (MoEW, 2020). 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 WEs, which are also members of the National Water Council.

The Litani River Authority (LRA) is considered to be a public institution with administrative and financial autonomy. In addition to its main functions, the LRA is mandated to: (1) ensure water monitoring in all Lebanese rivers; (2) study and construct some mountain lakes like the Kawashira lake in Akkar; and (3) study and survey the locations of dams in the northern Lebanese rivers.

The Ministry of Agriculture (MoA) conducts technical studies for irrigation and drainage projects and organizes the distribution and use of irrigation water. As for land resources, 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 MoA. A center for forest guards is located in the town of Aandqet. In addition, the MoA oversees the Directorate General of Cooperatives (DGC) and the Green Plan, which both play a key role in supporting the implementation of a regional strategy for land and water. More specifically, the Green Plan is involved in the construction of hill lakes and water ponds.

The Ministry of Environment (MoE) is mandated to: (1) prepare the general policy on short, medium and long-term projects and plans in all that relates to the safeguarding and sustainability of natural environmental resources; (2) develop the strategy, work plans, programmes, projects, activities and studies needed to safeguard the environment, ensure the sustainability of natural resources and control pollution from all sources; (3) draft 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 (4) determine the environmental conditions for the protection of rivers, springs, marshes and ponds, among others.

The Ministry of Industry (MoI) launched its integrated vision "Lebanon Industry 2025" for the industrial sector. The vision includes 11 strategic objectives to be achieved by 2025. This involves encouraging local industries to move towards green industry, increasingly use renewable and alternative energy, and encourage increasing energy and water efficiency and water treatment. In addition, the zoning development guidelines previously developed by the MoI are expected to ensure the inclusion of environmental protection measures, such as wastewater treatment.

The Ministry of Public Health (MoPH) is responsible for: (1) conducting studies and proposing programmes in accordance with the laws in force to ensure environmental health; and (2) proposing the technical specifications and conditions to be met in projects including the construction of public and private sewers and drinking water networks. The Ministry 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. It also monitors the incidence of waterborne diseases and publishes related epidemiological studies.

The Ministry of Interior and Municipalities (MoIM) in Lebanon is responsible for Governorates, Cazas, municipalities, federations/unions of municipalities and village matters. The role of municipalities and unions of municipalities in the water sector is further discussed under local stakeholders.

The Council for Development and Reconstruction (CDR) has extensive prerogatives in the field of planning, advice and orientations, and project implementation, including the direct implementation of any project by decision of the Council of Ministers, as well as the execution of any works related to the water and used water networks in any urban area. In addition, the CDR has the authority to implement any works, including in the water sector, through any public authority, private company or mixed company. In 2002, the Council of Ministers requested the CDR to prepare the National Physical Master Plan (NPMP) for Lebanon.

The Ministry of Public Works and Transport (MPWT) houses the main governmental body responsible for urban policy planning, which is the Higher Council of Urban Planning (HCUP), as well as the Directorate General of Urban Planning (DGUP). Regional departments of urban planning at the MPWT were established in every Kadaa, including Akkar, to review construction permits and ensure compliance with urban planning regulations issued by the DGUP and/or HCUP.

The Lebanese Agricultural Research Institute (LARI) conducts applied and basic scientific research for the development and advancement of the agricultural sector in Lebanon. In addition, the Institute maintains close ties with farmers and tries to develop research activities aiming at solving their problems. A number of meteorological stations and eight experimental stations are available to the LARI, including Kfarchakhna and Abdeh stations in North Lebanon, as well as Hermel station. Such stations offer routine soil analysis to farmers at their request, and also chemical and microbiological analysis of water used for irrigation as well as of potable water.

The National Council for Scientific Research (CNRS) serves the scientific community in Lebanon, covering all scientific disciplines including the water theme. Its main objective is to encourage scientific research and support human resource development along the general scientific policies adopted by the Government.

Local stakeholders

Municipalities and unions of municipalities: the municipal council of each city supports the implementation of local projects in the water sector. Such projects usually respond to local needs within the boundaries of the municipality responsible for implementing used water networks and the evacuation of waste. In addition, unions of municipalities have various roles and responsibilities when it comes to land use and water resource planning and management at the local level. Overall, a total of 61 villages/towns were identified in the basin. The main unions of municipalities (UoM) that intersect with the Nahr el Kabir basin include the UoMs of Sahl Akkar, El Dreib el Gharby, El Dreib el Awsat, Akkar el Shamali, Ouadi Khaled, Aarqua el Athariya, Jord el Qaytaa, Mintaqat el Joumeh Akkar and el Hermel.

Academic and research centers in the region are among the main regional stakeholders in the sector. The University of Balamand (UOB) in Beino Akkar, through its Issam Fares Faculty of Technology (IFFT), helps to develop the remote region of Akkar by making high quality education accessible to all. The Beino-Akkar campus offers engineering technology programmes in various fields, including agriculture. The Lebanese University, through its Faculty of Sciences in Halba Akkar, offers undergraduate and master's degrees in various disciplines, including earth and life sciences, environmental management and conservation of natural resources. The Lebanese International University (LIU) in Halba Akkar is based at the Rayak and Halba-Akkar campus. It offers several programmes, including the School of Arts and Sciences and the School of Engineering.

Selected NGOs that are also active in the region include Mada, with an office in North Lebanon. This organization aims to reinforce the relationship between local communities and their natural environment. It works with different groups on various developmental and environmental projects in Lebanon to facilitate the dynamics of change through endogenous and inclusive efforts, as well as policies and regulations appropriate to local realities. The Akkar Network for Development (AND), based in Halba, is designed to be an expression of a unified vision of the region and aims to satisfy the needs of Akkar, as well as establish the foundation of a better community. AND was involved in developing the fire response strategy for the North Akkar Union of municipalities. Arcenciel, with an office in North Lebanon, supports Lebanon's most underprivileged and marginalized communities. Akkarouna is a local non-profit NGO managing three offices in the northern region of Lebanon, namely in Akkar, Tripoli and Baddawi. Its aim is to achieve sustainable socioeconomic growth through empowering youth, women and children by building their capacities, enhancing community networks, implementing development projects and spreading awareness about rights and citizenship. The Association for Forests, Development and Conservation (AFDC), which includes the AFDC Aandqet voluntary unit, aims to achieve sustainable conservation of natural resources, raise awareness and build capacities that contribute to the national efforts for better environmental management. It has established a forest center in the village of Aandqet that can host conferences, meetings and other events.

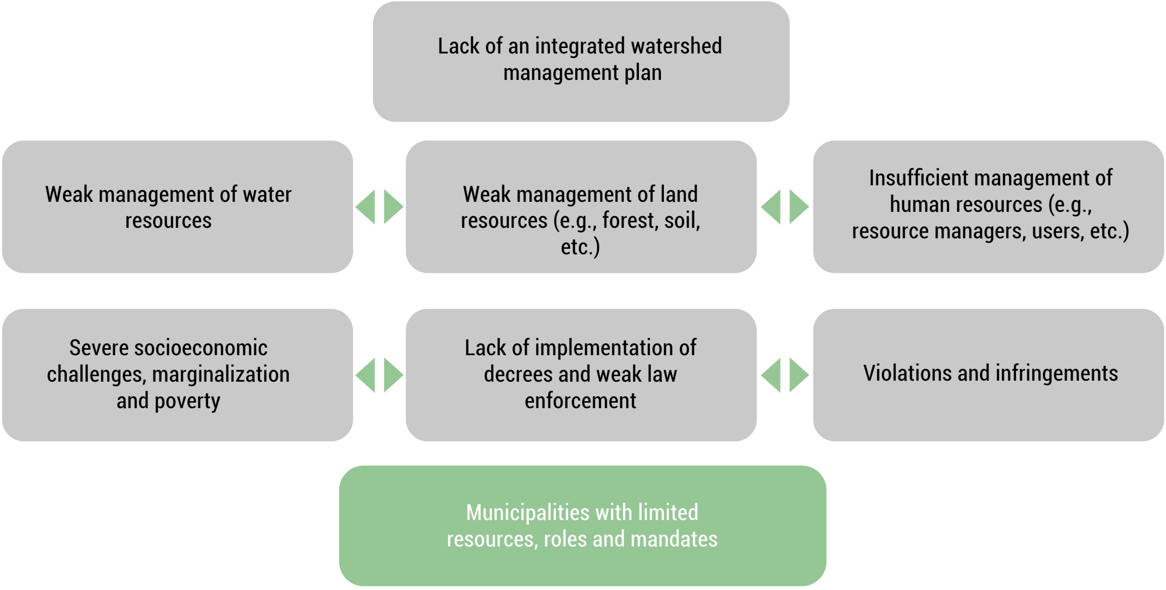
In 2017, there were 1,238 cooperatives in Lebanon, of which 24 per cent were based in Akkar. However, stakeholders estimated that only one third of the registered cooperatives were active. Agricultural cooperatives are usually organized around mechanical means of production and focus on providing value chain upstream supply provision and downstream marketing support to farmers. Selected cooperatives of relevance in the Nahr el Kabir basin include: Chadra agricultural oil press cooperative, Cheikhlar olive oil cooperative, Agricultural Cooperative Association for Rural Development (Al Bireh), Fnaideq Agricultural Cooperative, Monjez Agricultural Cooperative, Association of Cooperatives for Animal Resource Development (Hekr Ed Dahri), Association of Cooperatives for Development and Animal Production (Aandqet), Aaidamoun Agricultural Cooperative, Akroum olive processing cooperative and Qobayat Agricultural Cooperative.

In addition, the basin encompasses a few industries with potential impact on water and/or land resources in the basin area. Such industries include manufacturers (food, ready-mixed concrete, etc.), farms and restaurants, among others.

2. Synthesis

The current dilution of responsibilities and the lack of communication and coordination between institutions aggravate the governance challenges of the water sector within the targeted area. An overall synthesis of the institutional/governance state at the integrated watershed management level is presented in figure 4.

FIGURE 4: Synthesis of institutional/governance framework state



Source: Authors.

3 CLIMATE CHANGE PROJECTIONS (ANNUAL, SEASONAL AND EXTREME EVENTS)

A. Methodology

Global assessments of projected climate change are conducted using global climate models (GCMs), which comprise 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 (RCMs) are nested within GCMs to represent the most advanced tools to estimate projected climate change for specific domains and are based on finer spatial and temporal resolutions. Climate data presented herein is based on RCM outputs obtained from the Mashreq Domain (ESCWA, 2021); the said outputs were 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, 2017; Climate Nexus, 2019; Schwalm and others, 2020; Hausfather and Peters, 2020).

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

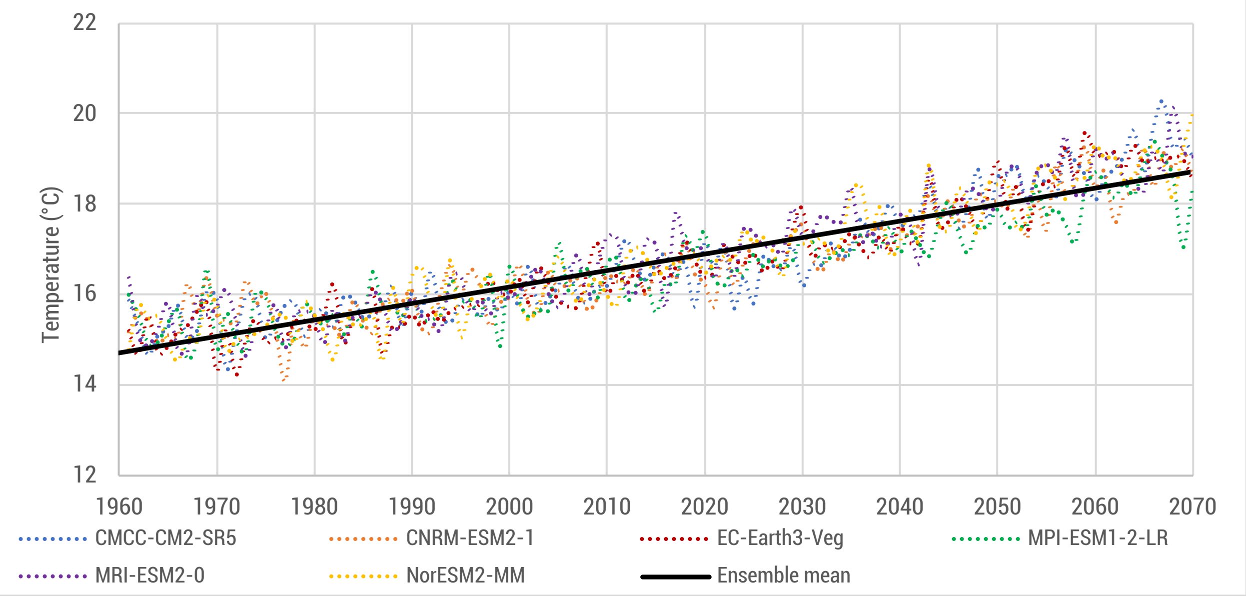
The RCM outputs presented include annual temperature, precipitation and selected extreme event indices displayed as maps comparing the two future periods to the reference period and time series analysis. Extreme event indices were derived from the Expert Team on Climate Change Detection and Indices (ETCCDI, 2009). Seasonal analyses, comparing the wet (October–March) and dry (April–May) seasons, are also presented. Core climate variable results are presented for both Lebanon and the basin, so as to place basin results in context. Results of the extreme event indices are presented for the watershed solely.

B. Climate description of basin

1. Temperature and related extreme climate indices

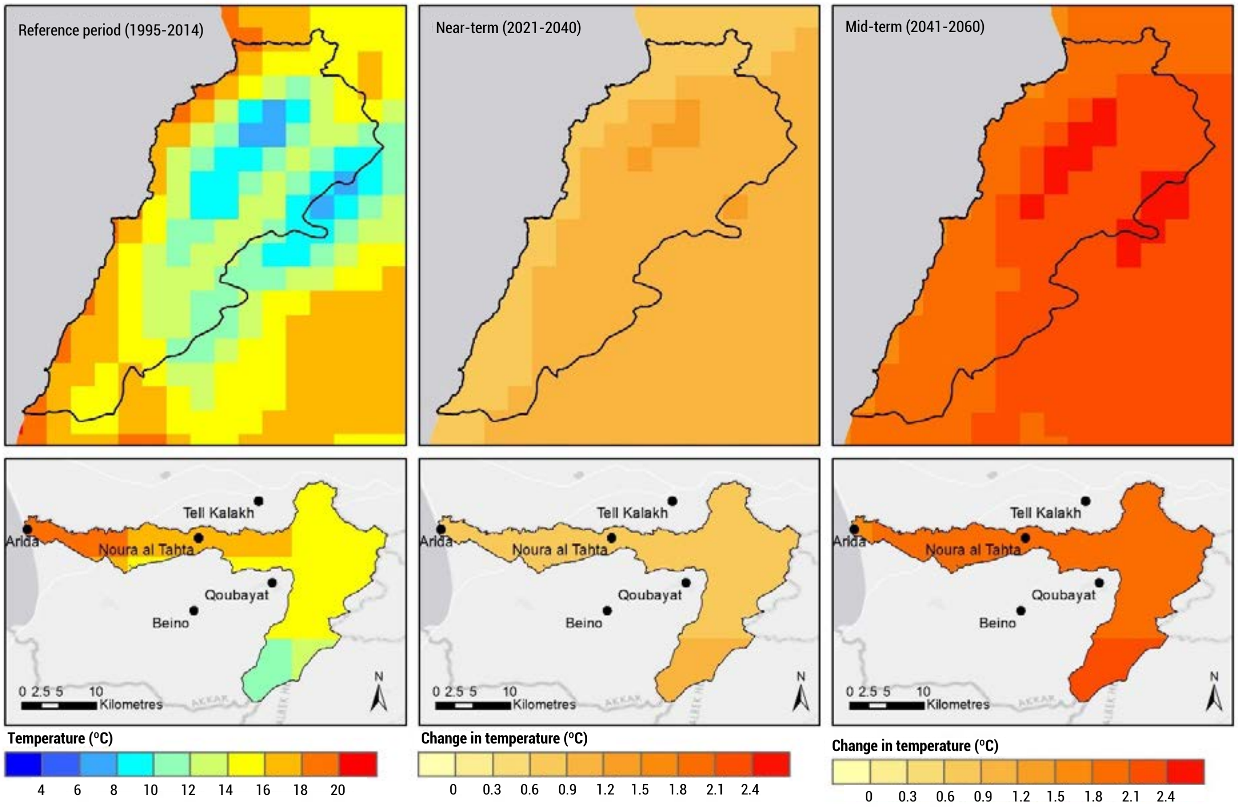
Although some inter-annual variability is observed, all of the evaluated climate models project generally increasing temperature across the basin (figure 5). Accordingly, the time series analysis for mean annual temperature reveals that the basin already has an average temperature of 2.2°C higher than that of 60 years ago, i.e., increasing by about 0.4°C per decade. Mean annual temperature during the reference period (1995–2014) ranged from 19°C adjacent to the Mediterranean coast to 10.7°C in the upper basin. Projected increases in temperature averaged 1°C for the near-term (2021–2040) and 2°C for the mid-term (2041–2060) with a minimum to maximum rising gradient from the sea to the mountains (figure 6). Several studies concluded that mountainous areas were warming at a more rapid rate owing to snow/ice albedo feedbacks, cloud cover and differences in water vapour content (Rangwala and Miller, 2012).

FIGURE 5: Time series analysis for mean annual temperature in the Nahr el Kabir basin for six climate models obtained from the Mashreq Domain, SSP5-8.5



Source: Authors.

FIGURE 6: Mean change in annual temperature compared to the reference period based on an ensemble of six models from the Mashreq Domain, SSP5-8.5

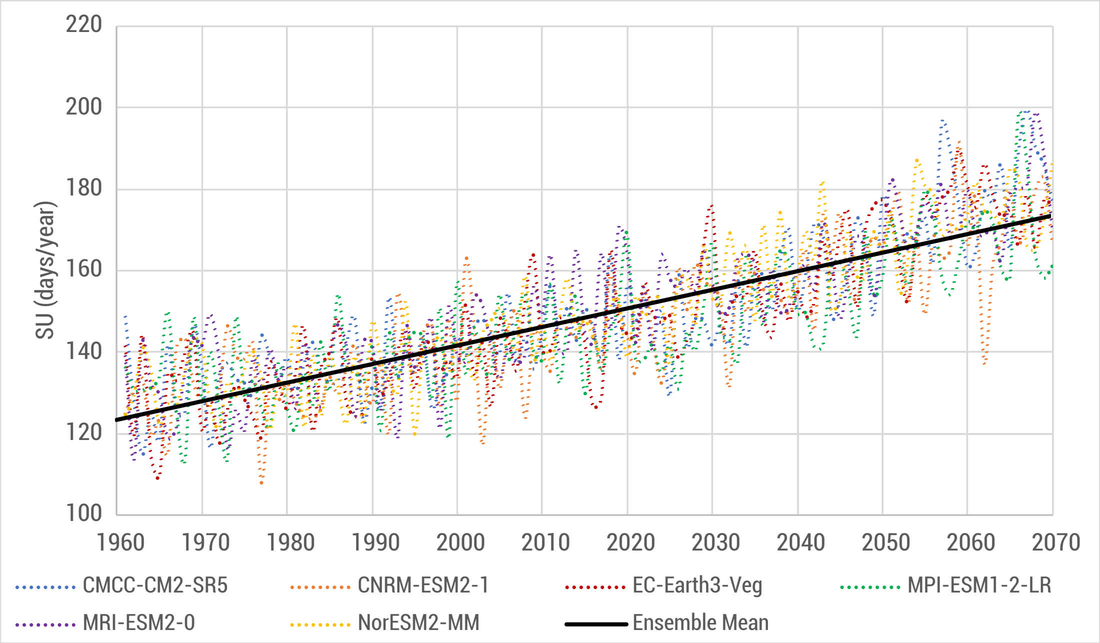


Source: Authors.

Crops are sensitive to temperature extremes inducing adverse results on crop phenology and yield. Temperature thresholds for cereal crops, such as wheat and barley, are well defined; maximum temperatures for wheat for leaf initiation, shoot growth and root growth are 24°C, 20.9°C and 25°C, respectively (Luo, 2011), within the optimal range defined by local farmers (Mitri, 2022). Optimal temperature ranges for barley are similar, reporting a maximum threshold of 27°C (Mitri, 2022). For this reason, it is important to evaluate temperature extremes in tandem with average annual temperature.

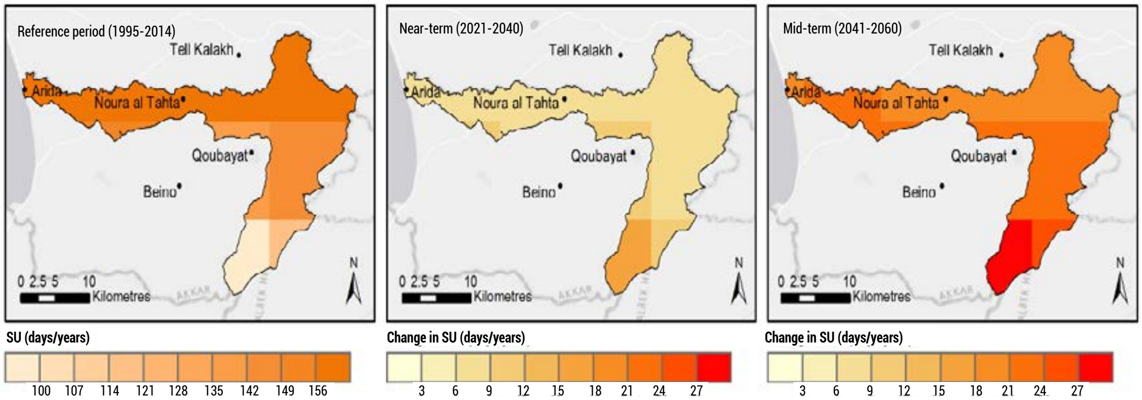
The number of summer days (SU) is defined by ETCCDI as the count of days when the daily maximum temperature is above 25°C. Correlating with temperature, the SU was observed to increase by about 4.6 days per decade; by 2070, for nearly half of the year, the maximum temperature will exceed the 25°C threshold in the basin (figure 7), with spatial patterns following those of temperature. During the reference period, the SU was highest nearest to the coast and followed a decreasing gradient as elevation increased. However, the SU change was projected to be greater in mountainous areas (figure 8).

FIGURE 7: Time series analysis for mean annual number of summer days (SU; days when Tmax >25°C) in the Nahr el Kabir basin for 6 climate models obtained from the Mashreq Domain, SSP5-8.5



Source: Authors.

FIGURE 8: Mean change in the annual number of summer days (SU; days when Tmax >25°C) compared to the reference period based on an ensemble of six bias-corrected models from the Mashreq Domain, SSP5-8.5



Source: Authors.

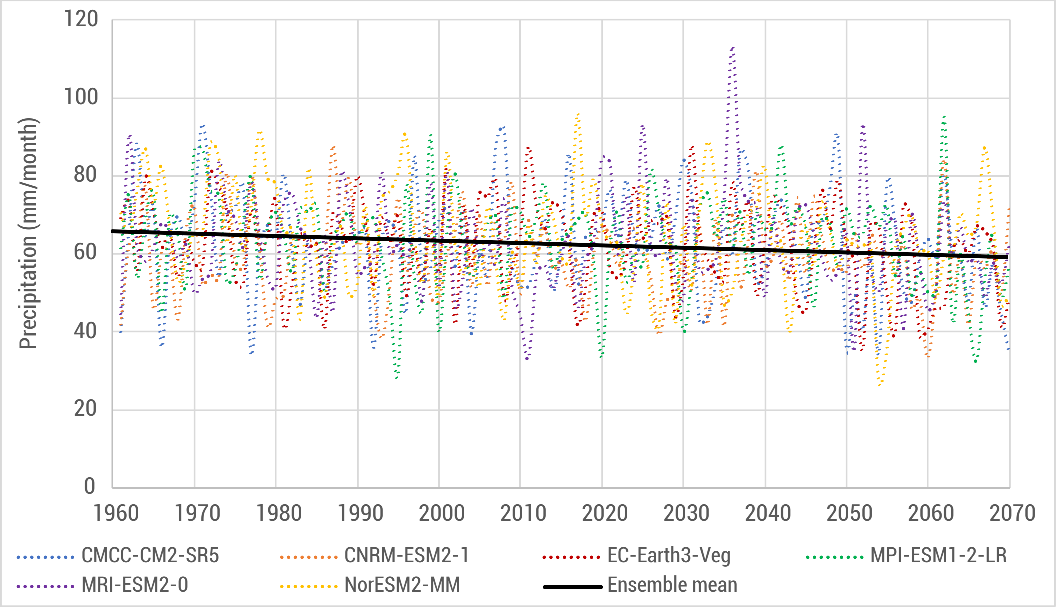
2. Precipitation and related extreme climate indices

Although all models predicted a decrease in precipitation (figure 9), inter-annual variability was wide, probably owing to a complex microclimate in the basin (ESCWA and BGR, 2010) stemming from the Homs Gap fault (ESCWA and BGR, 2013), the Mediterranean Meteorological Water Line (Abou Zakhem and Hafez, 2010) and other phenomena. Observed precipitation ranged from 65.3 mm/month (Halba: 34° 33′ 2″ N 36° 4′ 41″ E, 119 m) to 78.4 mm/month (Sir el Denniyeh: 34° 23′ 12″ N, 36° 1′ 46″ E; 915 m) (NCSR-ESCWA, 2002). Precipitation during the reference period (1995–2014) ranged from 30.1 mm/month in the north-east corner of the basin to 88.5 mm/month adjacent to the coast (figure 10). Spatial-temporal variability was apparent when comparing projected changes between the two reported future periods. The near-term (2021—2040) signalled some increasing precipitation, particularly in the uppermost basin, but shifted to declining precipitation in the mid-term (2041—2060).

This precipitation variability gives rise to a “weather whiplash”, which includes extreme event shifts between two opposing weather conditions. Time series analysis comparing the maximum length of consecutive dry days (CDD; figure 11) to consecutive wet days

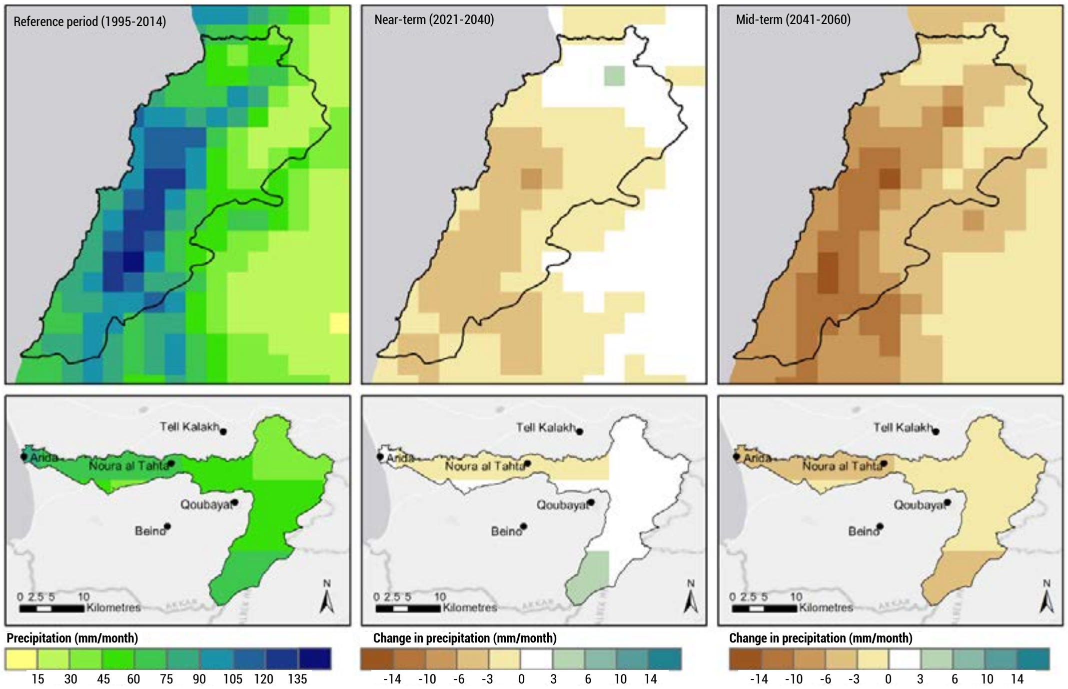
(CWD; figure 12) illustrated no definitive temporal trend for either index, consistent with a previous study (ACSAD-ESCWA, 2017). The reference period reported a mean CDD of 125 days/year, suggesting that 69 per cent of the April–September dry season was devoid of measurable precipitation. By the near-term, CDD was nearly the same on average, but was slightly higher by mid-term (2.7 days/year). Although the changes in CDD were small, no spatial-temporal trends were evident; the maximum change by mid-term was estimated at 6 per cent increase (figure 13).

FIGURE 9: Time series analysis for mean annual precipitation in the Nahr el Kabir basin for six climate models obtained from the Mashreq Domain, SSP5-8.5



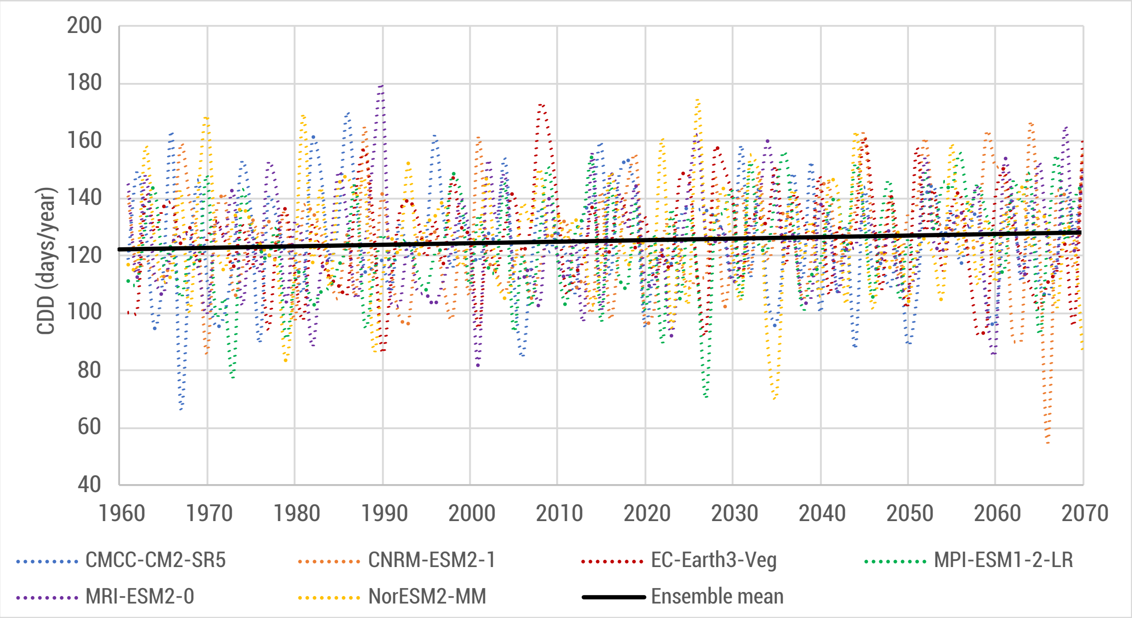
Source: Authors.

FIGURE 10: Mean change in annual precipitation compared to the reference period based on an ensemble of six models from the Mashreq Domain, SSP5-8.5



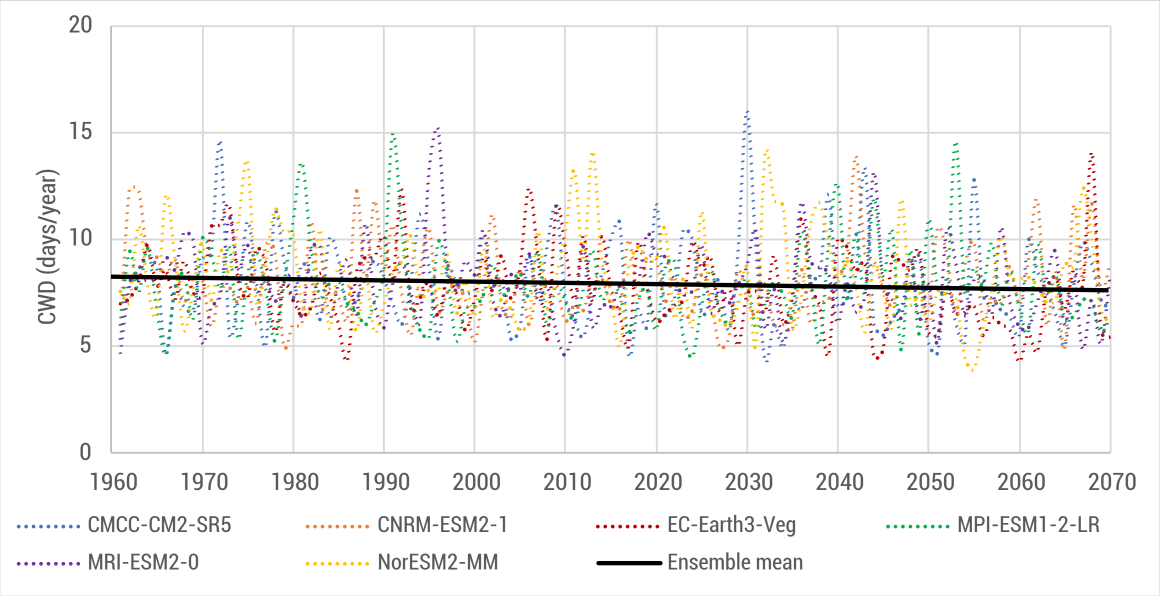
Source: Authors.

FIGURE 11: Time series analysis for the maximum length of dry spell (CDD: consecutive days with precipitation <1 mm) in the Nahr el Kabir basin for six climate models obtained from the Mashreq Domain, SSP5-8.5



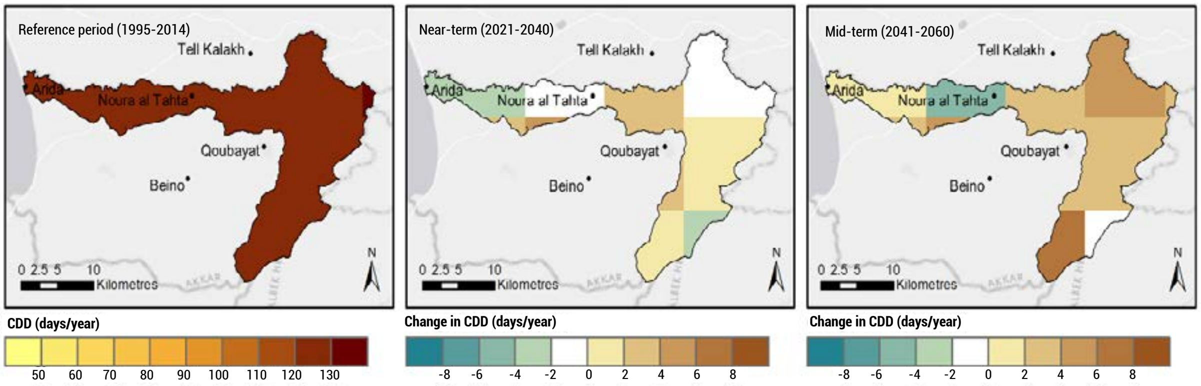
Source: Authors.

FIGURE 12: Time series analysis for the maximum length of wet spell (CWD; consecutive days with precipitation ≥1 mm) in the Nahr el Kabir basin for six climate models obtained from the Mashreq Domain, SSP5-8.5



Source: Authors.

FIGURE 13: Mean change in the maximum length of dry spell (CDD; consecutive days with precipitation <1 mm) compared to the reference period based on an ensemble of six bias-corrected models from the Mashreq Domain, SSP5-8.5


Reference period (1995-2014)

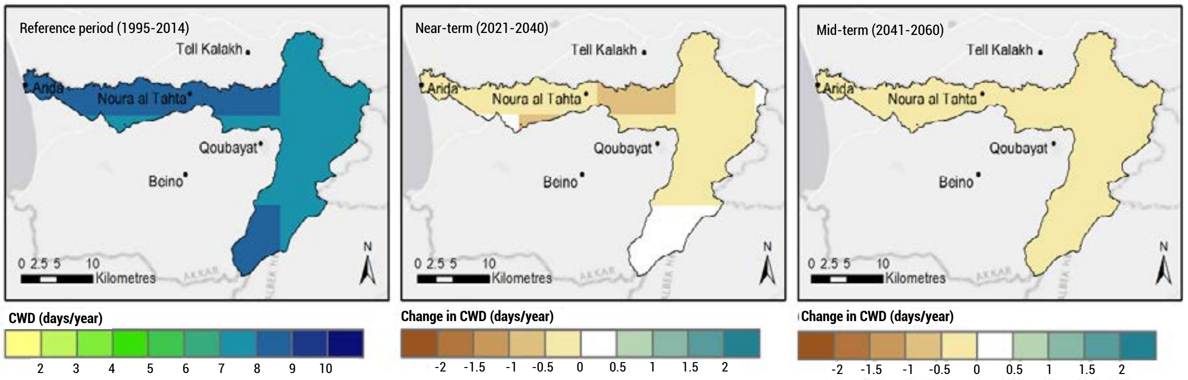
Near-term (2021-2040)

Mid-term (2041-2060)

Source: Authors.

In terms of CWD, the reference period exhibited little spatial variation, indicating a mean CWD of 8 days/year (4 per cent of the October–March wet season). Projected changes were minimal, decreasing slightly in the near- and mid-term periods (figure 14).

FIGURE 14: Mean change in the maximum length of wet spell (CWD; consecutive days with precipitation ≥1 mm) compared to the reference period based on an ensemble of six bias-corrected models from the Mashreq Domain, SSP5-8.5


Reference period (1995-2014)

Near-term (2021-2040)

Mid-term (2041-2060)

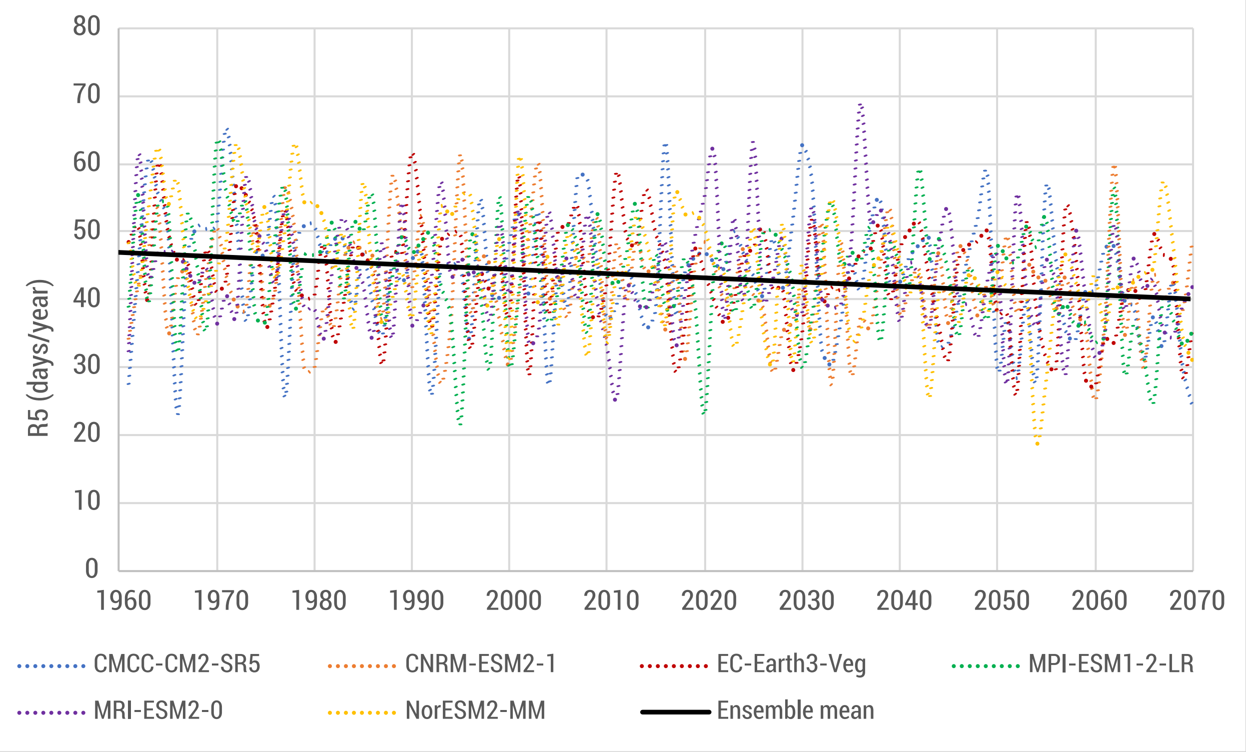
Source: Authors.

The number of annual precipitation days (R5; precipitation days >5 mm) showed a general decline (figure 15), but also wide variability. The reference period exhibited a similar spatial pattern as the other precipitation datasets; the number of precipitation days was lowest in the north-east corner of the watershed and highest near the coast. The mean number of days during this timeframe was 42.5 days/year (figure 16). Projected results for the near- and mid-term periods were consistent with the declining trend.

Projected precipitation and the evaluated extreme event indices must be jointly evaluated to assess climate risks. For example, simultaneous increasing precipitation, increasing CDD, increasing CWD and decreasing R5 in the uppermost basin for the near-term may result in soil erosion. The lengthening of the dry season (CDD) causes low soil moisture content. The said moisture condition, coupled with sequential rains, may lead to high runoff and sediment transport (Wang and others, 2018). Moreover, because these conditions were projected in the upper basin, flood risk is also a concern in the Akkar plain downstream.

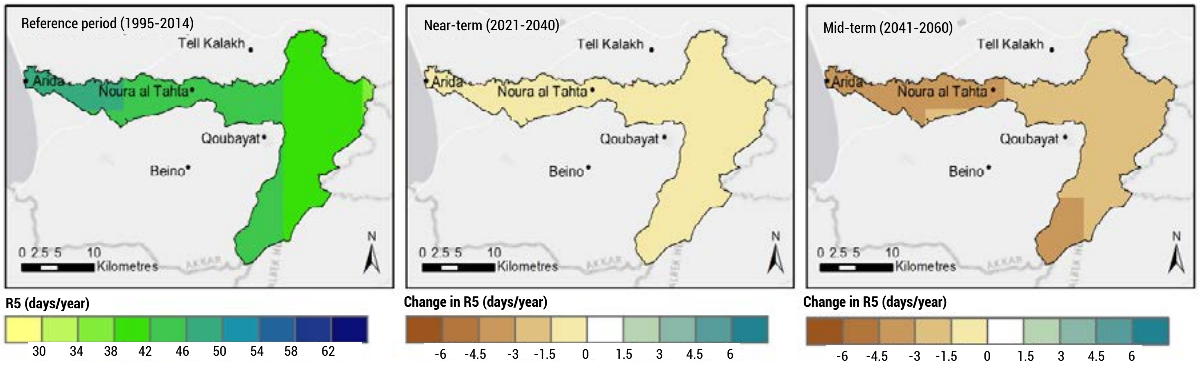
The climate change signal was clearer for the mid-term; all precipitation parameters implied an increased drought risk. Although consecutive dry days were expected to shorten near Noura al Tahta, no precipitation was projected for one third of the year.

FIGURE 15: Time series analysis for the annual number of precipitation days (R5; days with precipitation >5 mm) in the Nahr el Kabir basin for six climate models obtained from the Mashreq Domain, SSP5-8.5



Source: Authors.

FIGURE 16: Mean change in the annual number of precipitation days (R5; days with precipitation >5 mm) compared to the reference period based on an ensemble of six bias-corrected models from the Mashreq Domain, SSP5-8.5



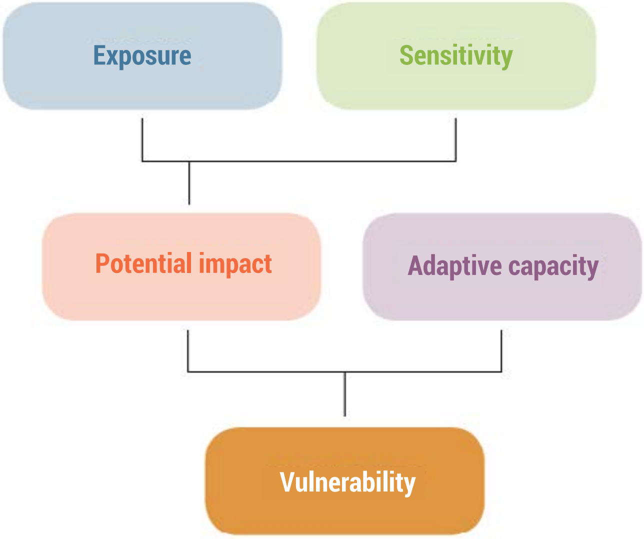
Source: Authors.

4 INTEGRATED VULNERABILITY ASSESSMENT

A. Methodology

Vulnerability is a complex concept that can be used to describe the relationship between climate change and its impacts on a specific system. As proposed by IPCC in its Fourth Assessment Report (AR4) and adopted by RICCAR (ESCWA and others, 2017a; 2017b), vulnerability comprises three primary components: exposure, sensitivity and adaptive capacity. In this context, exposure refers to quantifiable climate change, such as changes in temperature or precipitation. Sensitivity refers to the description of the natural and physical environment, as well as different population groups that are most susceptible to climate change. Exposure and sensitivity combine to describe the potential impact that is countered by the adaptive capacity, a term that describes the ability to cope, mitigate and adapt to climate change. The net difference between the potential impact and adaptive capacity defines vulnerability (figure 17).

FIGURE 17: Components constituting vulnerability based on 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). 2017. Integrated Vulnerability Assessment: Arab Regional Application. RICCAR technical note, Beirut, E/ESCWA/SDPD/2017/RICCAR/Technical Note.

B. Impact chain

The integrated VA methodology, which uses appropriate geospatial indicators to analyse the water sector's vulnerability to climate change, is described in the technical note 2 entitled Integrated Vulnerability Assessment: Arab Regional Application.[3] The approach is an iterative procedure that uses geospatial approaches to spatially conduct VAs across the basin.

Indicators identification

Appropriate indicators were selected based upon the three components of exposure, sensitivity and adaptive capacity and aggregated together to evaluate vulnerability (figure 18). An iterative process was principally used for this selection, based on a number of considerations, most importantly data availability. The previously reported RCM outputs were used to generate exposure indicators.

A total of 13 georeferenced sensitivity indicators were chosen based on socioeconomic, environmental, ecological and anthropogenic aspects affecting the water sector in the basin (table 1). Sixteen adaptive capacity indicators were selected based on elements significant to the water sector in the basin that can improve adaptability (table 2). Indicator factsheets and maps are presented in annex 3.

TABLE 1: Sensitivity indicators selected for the water sector VA

Indicator name	Data type	Source	Year
Population density	Raster	WorldPop	2021
Refugee population	Tabular	UNHCR/OCHA	2015
Slope gradient	Raster	USGS	2022
Soil storage capacity	Vector	NCSR	2006
Soil erosion hazard	Vector	NCSR	2012
Croplands	Vector	NCSR	2017
Woodland-grassland	Vector	NCSR	2017
Land degradation	Vector	MoA-AFDC	2020
Fire risk	Vector	UoB	2016
Land productivity	Raster	Trends.Earth	2019
River and coastal flood hazards	Raster	Dottori and others	2021
Irrigated areas	Vector	ACSAD	2022
River	Vector	NCSR	2017

Source: Authors.

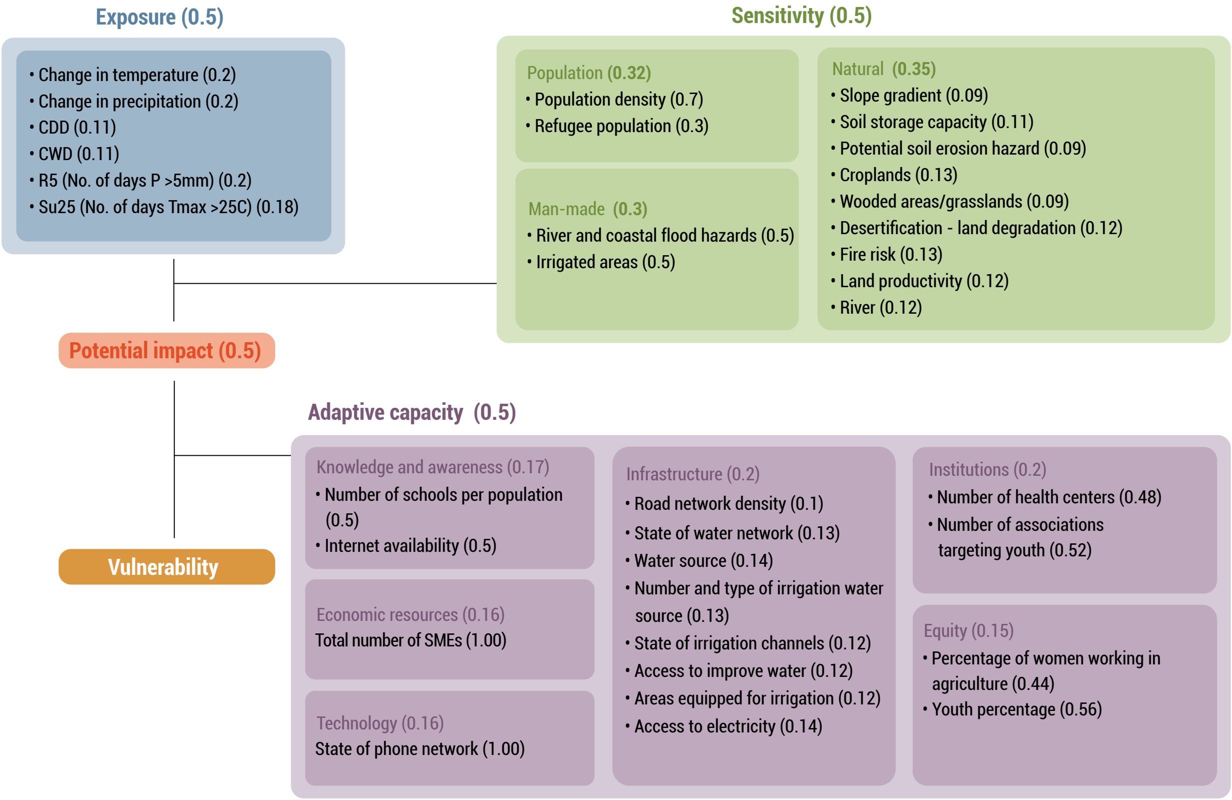
TABLE 2: Adaptive capacity indicators selected for the VA

Indicator name	Data type	Source	Year
Road density	Raster	Tragsa fire project	2012
State of the water network	Tabular	IMPACT	2022
Water source	Tabular	IMPACT	2022
Number and type of irrigation water source	Tabular	IMPACT	2022
State of irrigation channels	Tabular	IMPACT	2022
Access to improved water	Tabular	IMPACT	2022
Areas equipped for irrigation	Tabular	IMPACT	2022
Access to electricity	Tabular	IMPACT	2022
State of phone network	Tabular	IMPACT	2022
Number of schools per town/village population	Tabular	IMPACT	2022
Internet availability	Tabular	IMPACT	2022
Total number of Small and medium enterprises (SMEs)	Tabular	IMPACT	2022
Percentage of women working in agriculture	Tabular	IMPACT	2022
Youth percentage (15–24 years)	Tabular	IMPACT	2022
Number of health centres	Tabular	IMPACT	2022
Number of associations targeting youth	Tabular	IMPACT	2022

Source: Authors.

Typically, impact chains are developed as the initial stage in integrated VAs. They are often used to develop ideas for causality relationships between indicators, their components and vulnerability. However, for this study, the impact chain was developed after the indicator data were collected to provide a clear understanding of what data were available for use. Figure 18 shows the several components of the final impact chain that were utilized to estimate the vulnerability of the water sector to climate change in the basin. Indicators were assigned weights to measure their relative importance for a given climate change impact and were determined using a multi-step process based on expert opinions.

FIGURE 18: Impact chain for the water sector in the Nahr el Kabir basin to assess the water sector's vulnerability to climate change



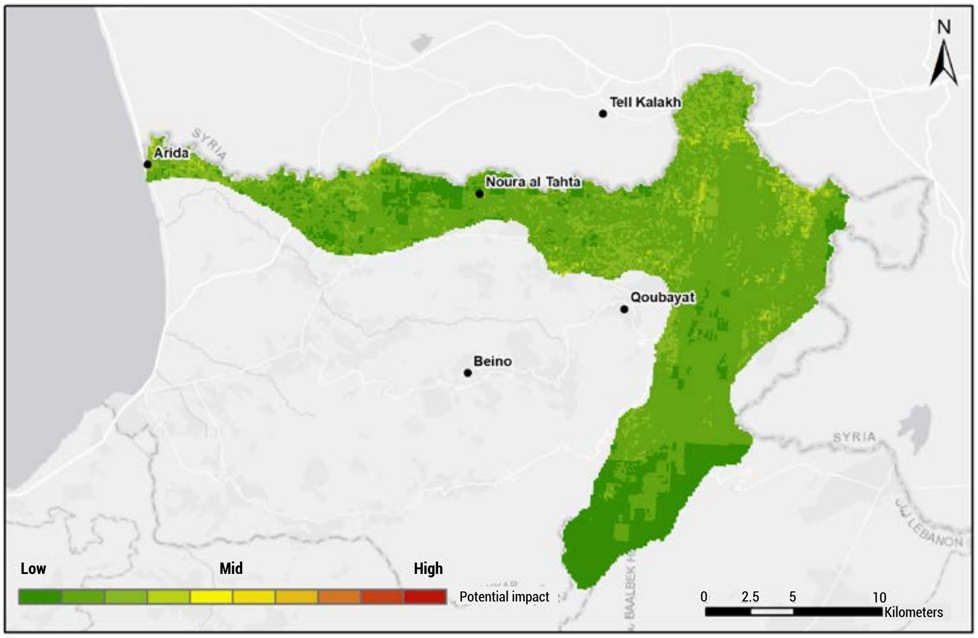
Source: Authors.

C. Potential impact

Potential impact reflected the aggregation of exposure and sensitivity, which were weighted equally. In the absence of available adaptation measures, potential impact was projected to gradually increase from the reference period (figure 19) to the near-term period (figure 20) and subsequently to the mid-term period (figure 21).

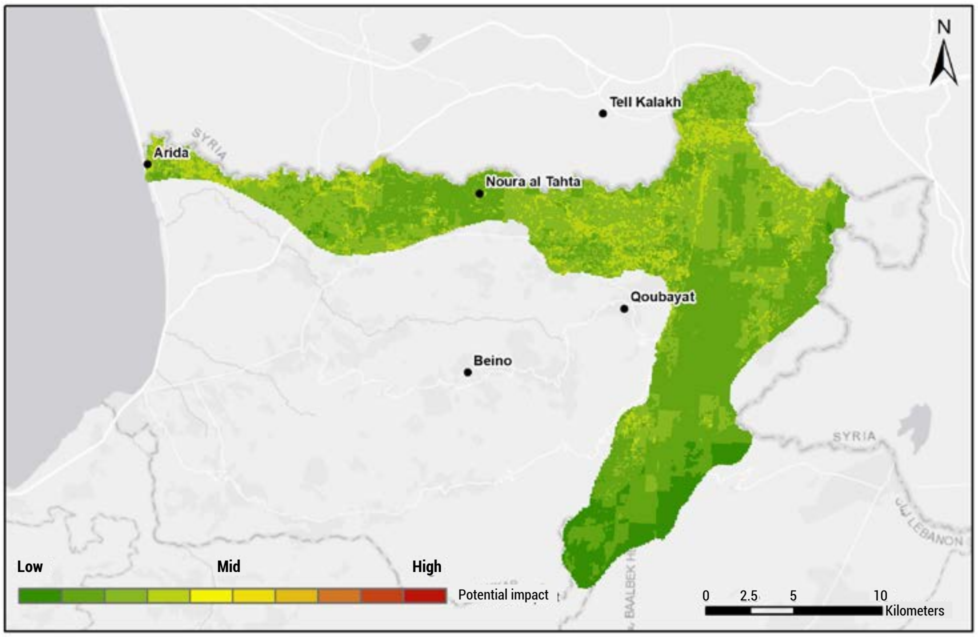
Most of the study area signalled low to moderate potential impact in the reference period. However, relatively high increases in potential impact were observed at the near-term period, indicating moderate potential impact, and especially indicating that areas of high potential impact tended to be correlated with areas of high exposure.

FIGURE 19: Potential impact composite indicator of reference period (1995–2014)



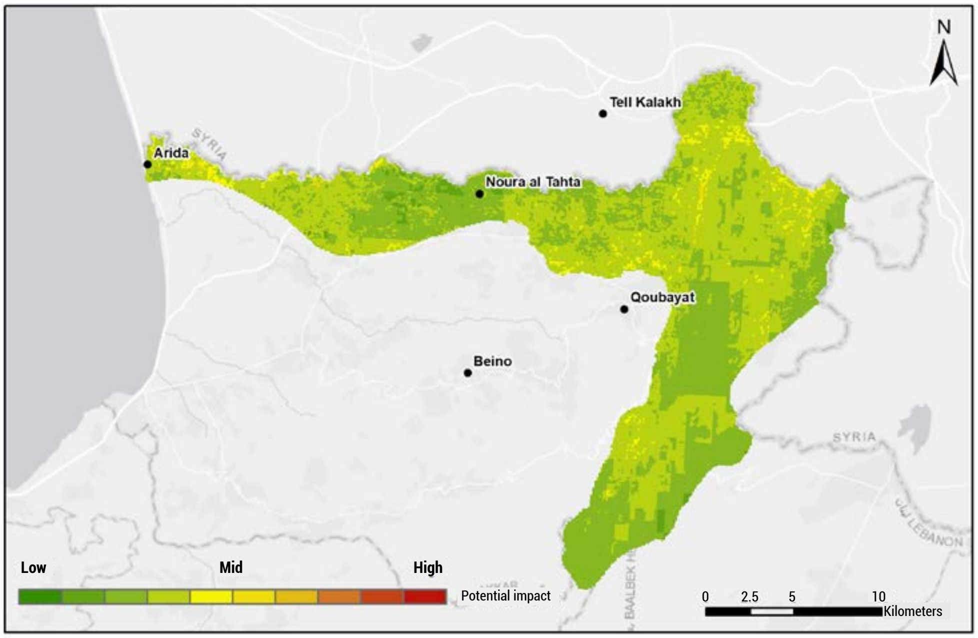
Source: Authors.

FIGURE 20: Potential impact composite indicator of near-term period (2021–2040)



Source: Authors.

FIGURE 21: Potential impact composite indicator of mid-term period (2041–2060)

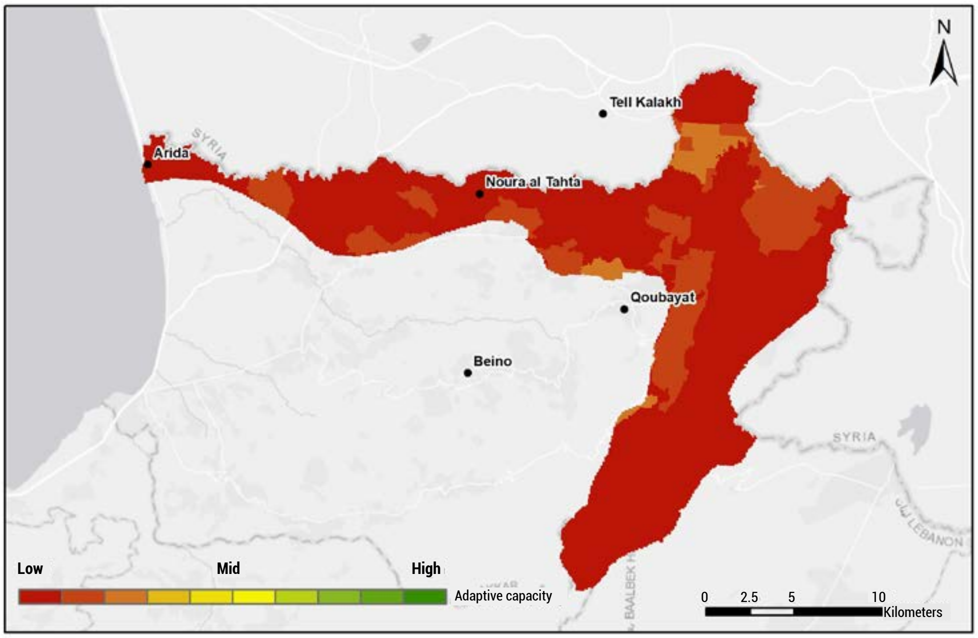


Source: Authors.

3. Adaptive capacity

The adaptive capacity reflects the ability of the water sector within the basin to cope with the impacts of climate change. As expected, the adaptive capacity was observed to range from very low to low throughout the basin (figure 22), mainly due to the marginalization of rural areas in Akkar in terms of services for a relatively long period of time. Although contributing indicators were based upon current conditions, the adaptive capacity might either increase or decrease in the future based on evolving coping mechanisms.

FIGURE 22: Adaptive capacity composite indicator



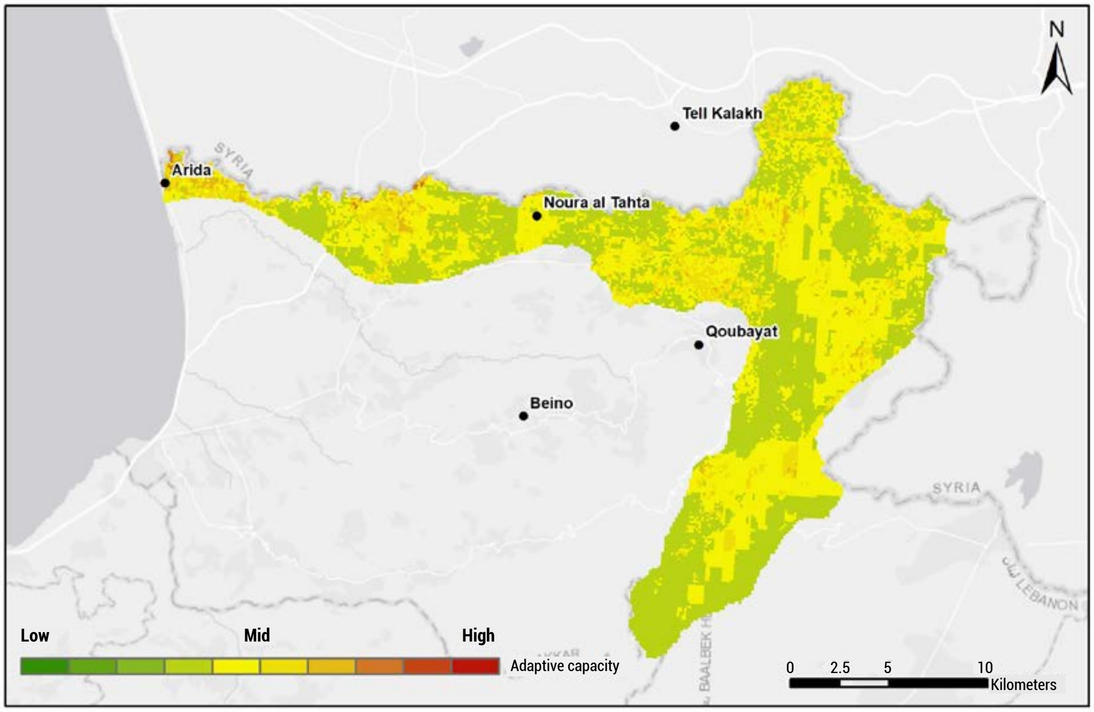
Source: Authors.

4. Vulnerability assessment results

In the reference period, a relatively large area of the basin exhibited moderate vulnerability (figure 23). This increased for the near-term period when most of the basin area signalled higher vulnerability (figure 24). For the mid-term period, the basin generally exhibited very high vulnerability (figure 25) mostly toward the coastal areas (covered by relatively large croplands and highly exposed to floods), and the upper part of the basin (covered by dense forests mostly exposed to a high risk of fires and post-fire impact on soil and water with increased risk of flash floods). Table 3 shows the change in spatial distribution of vulnerability classes across the three periods.

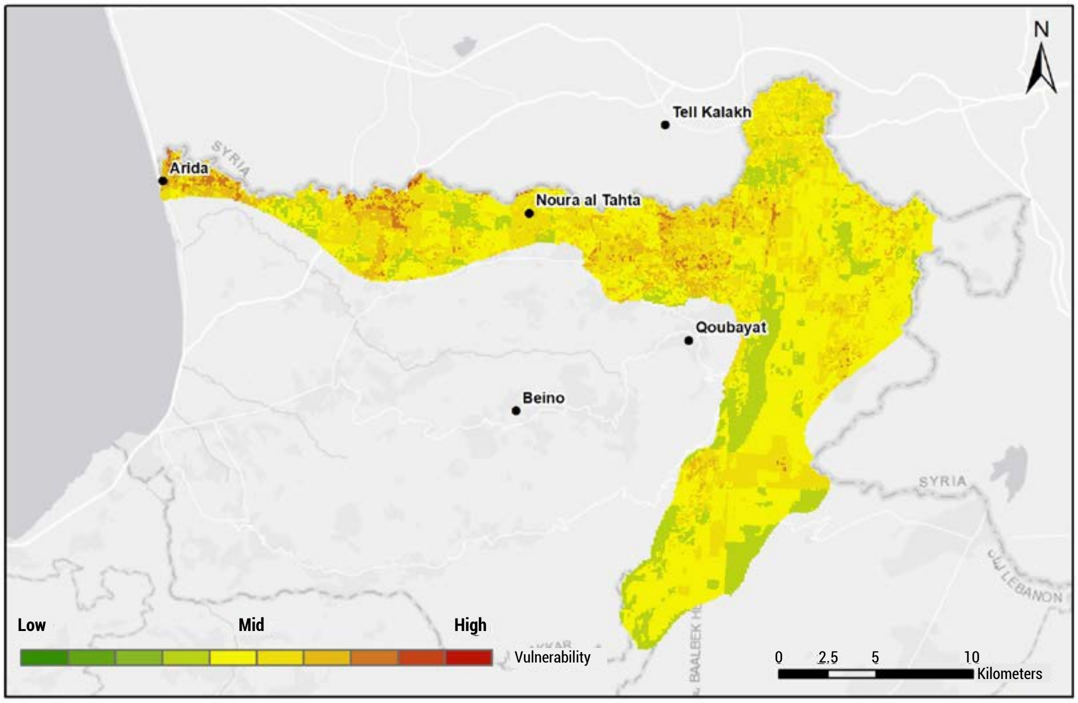
High vulnerability was strongly impacted by low adaptive capacity and sustained a modest impact from sensitivity. Thus, enhancing adaptive capacity measures would have the greatest potential effect in reducing percentage coverage of the projected high vulnerability classes in both the near- and mid-term periods.

FIGURE 23: Vulnerability composite indicator of reference period (1995–2014)



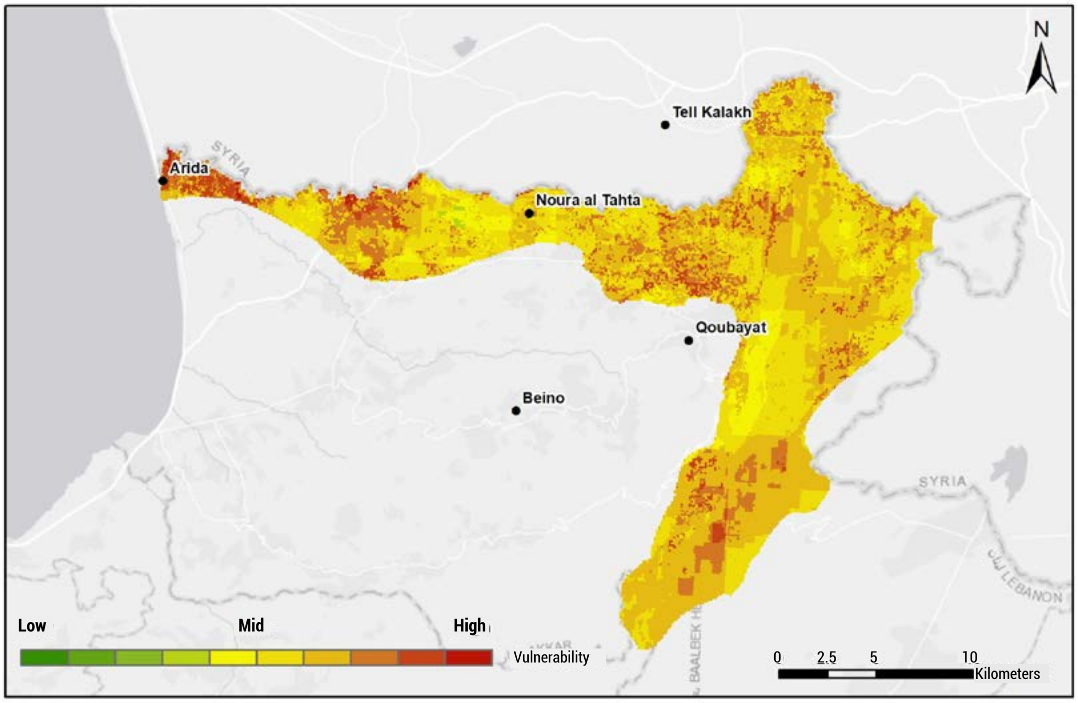
Source: Authors.

FIGURE 24: Vulnerability composite indicator of near-term period (2021–2040)



Source: Authors.

FIGURE 25: Vulnerability composite indicator of mid-term period (2041–2060)



Source: Authors.

TABLE 3: Percentage distribution of vulnerability classes across the three periods

	Vulnerability (percentage area of the study area)			
Scenario	Low (class 1-4)	Moderate (class 5-6)	Moderate-high (class 7)	High (class 8-10)
Reference period	46.1	52.1	1.7	0.1
Near-term period	15.1	75.3	7.7	1.9
Mid-term period	0.2	39.7	42.9	17.2

Source: Authors.

5. Hotspots

Hotspots are critical areas that reveal the highest vulnerability. In reference to the mid-term period, approximately 17.2 per cent of the basin area was affected by high vulnerability (i.e., classes from 8 to 10), to be hence considered as hotspots in the water sector (figure 26). Relatively large and condensed areas of hotspots were primarily located in three different zones, among others (table 4):

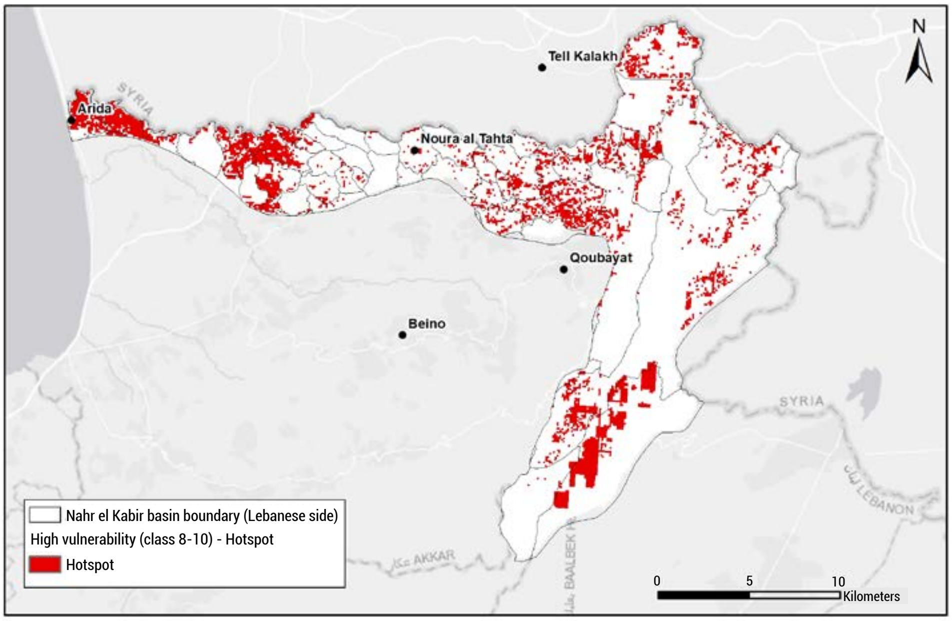
Akroum/Sharbine/Chadra: hotspot areas expanding over mountainous lands with a relatively dense tree cover. First, this area was dominated by high sensitivity stemming from various factors, including the presence of refugees, fire risk, steep slopes and soil erosion. Second, this part of the basin showed a low adaptive capacity due to certain limitations in the water sector.

Machta Hassan/Aaidamoun/Monjez: hotspot areas covering the middle part of the basin mostly characterized by agricultural land with relatively high sensitivity in the water sector.

El Aarida/Es Sammaqiye/El Massaoudiye: hotspot areas covering coastal cropland areas. This area was dominated by high exposure associated with extreme climatic conditions and high sensitivity stemming from the presence of agricultural land, exposure to land degradation and flood hazard. In addition, this part of the basin showed a low adaptive capacity due to certain limitations in the water sector.

Overall, forest within the basin affected by high vulnerability amounted to a total area of 1,459 ha. In addition, cropland, grassland and rivers covered by high vulnerability classes equalled areas of 2,960 ha, 78 ha and 42.2 ha, respectively.

FIGURE 26: Vulnerability hotspots for mid-term period



Source: Authors.

TABLE 4: Distribution of vulnerability hotspots per villages/towns

Town/village	Hotspot area (ha)	Total area (ha)	Percentage area (decreasing order)
El Aabboudiye	13	14	93.4
Hokr ed Dahri	26	28	92.1
Jouret Srar	50	62	80.4
Es Sammaqiye	223	285	78.4
El Aarida	239	327	72.9
Nabaa el Ghzaile	50	73	69.1
Machta Hassan	67	109	62.0
Chir Hmairine	282	455	61.9
Saidnaya	4	7	61.4
Tell Hmaira	195	339	57.6
Cheikh Zennad	21	41	52.1
Aaidmoun	363	751	48.4
El Massaoudiye	54	117	46.3
Darine	183	412	44.5
Khalsa	41	98	41.9
El Barde	72	180	39.9
Douar Fatne	81	255	31.6
Rmah	60	191	31.2
Khirbet er Roummane	52	172	30.6
Arida	270	1 055	25.6
Soultane Brahim	26	105	25.0
Haouchab	4	16	24.9
Sharbine	750	3113	24.1
El Qsair	20	90	22.4
El Aamriye	45	219	20.5
Al Bireh	63	312	20.3
Cheikhlar	51	259	19.8
Monjez	98	570	17.1
Saadine	44	261	17.1
El Fraidis	21	137	15.3
Ouadi el Haour	10	73	13.8
El Majdal	187	1 565	11.9
Tell Aabas el Charqi	11	94	11.3
Chadra	65	604	10.7
Hnaider	25	254	9.9
Noura al Tahta	36	373	9.7
Ed Dibbabiye el Gharbiye	33	355	9.3
Akroum	644	6947	9.3
Haitla	22	245	9.1
Mzeihme	13	143	9.0
Kfar Noun	13	153	8.5
Et Tleil	14	180	7.8
Mchta Hammoud	92	1 181	7.8

Town/village	Hotspot area (ha)	Total area (ha)	Percentage area (decreasing order)
Aandqet	162	2 399	6.8
El Aarme	8	156	5.0
Janine	12	243	4.8
Dahr El Maqam	7	154	4.5
Tell Biri	16	421	3.8
Ghzaile	7	208	3.1
El Kouachra	9	318	2.9
Srar	5	199	2.6
Qachlaq	3	196	1.5
Qoubayat	4	279	1.4
Es Souaidie	11	1 109	1.0
El Baghdadi	1	107	1.0
Aamaret el Bikat	0	335	0.0

Source: Authors.

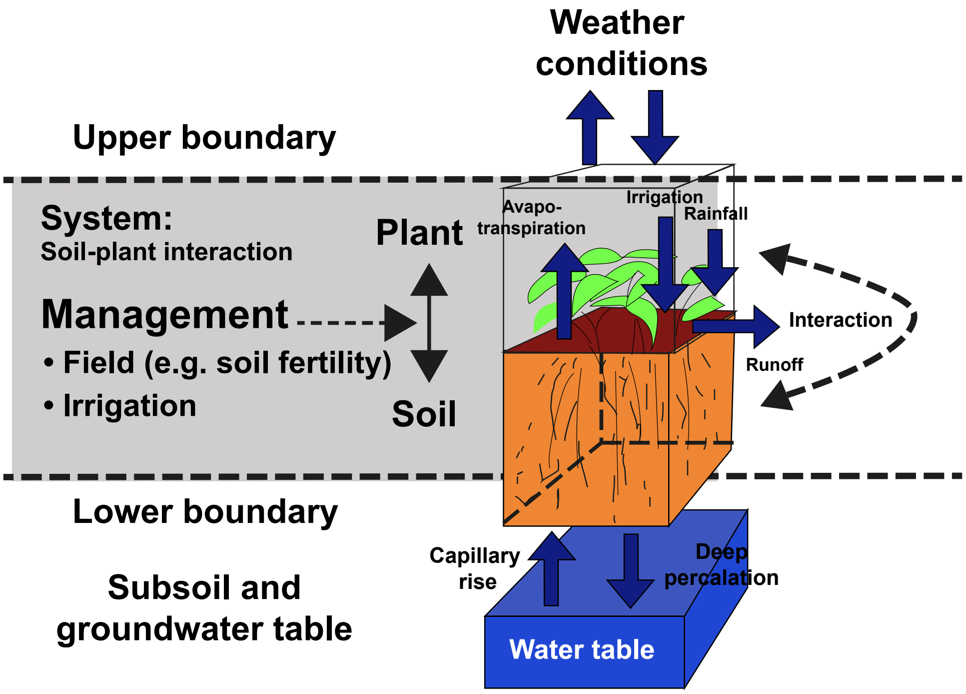
5 CLIMATE CHANGE IMPACTS ON BARLEY PRODUCTION IN AKKAR PLAIN IN THE NAHR EL KABIR BASIN

Consultations with farmers and local stakeholders in the area showed that barley is a key crop cultivated in the Nahr el Kabir basin. Given that cereal crops such as barley and wheat are sensitive to the impact of climate change, including the adverse impact of temperature extremes on crop phenology and yield, the climate change impact on barley production in the Akkar plain in the Nahr el Kabir basin was further studied in the following section.

A. Methodology

The AquaCrop model was employed to assess climate change impacts on crops in the Akkar plain in the Nahr el Kabir basin on the Lebanese side. AquaCrop is a crop simulation model that describes the interactions between the plant and the soil (figure 27). From the root zone, the plant extracts water and nutrients. Field management (e.g., soil fertility) and irrigation management are taken into account, as these elements affect the interaction between the plant and the soil. The system described above is linked to the atmosphere through the upper boundary that determines the evaporative demand (ET_0) and supplies CO_2 and energy for crop growth. Water drains from the system to the subsoil and the groundwater table through the lower boundary. If the groundwater table is shallow, water can move upward to the system via capillaries.

FIGURE 27: Components of the AquaCrop model



Source: FAO, AquaCrop training handbooks, April 2017.

AquaCrop was developed by FAO to address food security needs and to assess the effect of environment and management on crop production. When designing the model, an optimum balance between simplicity, accuracy and robustness was pursued. To be widely applicable, AquaCrop only uses a relatively small number of explicit parameters, and mostly relies on intuitive input variables that can be determined by simple methods. The calculation procedures are founded on basic and often complex biophysical processes to guarantee an accurate simulation of a crop response in the plant-soil system.

In general, AquaCrop can be used as a planning tool or to assist in management decisions for both irrigated and rainfed agriculture. More specifically, AquaCrop is particularly useful to:

- Understand a crop response to environmental changes.
- Compare attainable and actual yields in a field, farm or region.
- Identify constraints limiting crop production and water productivity (benchmarking tool).
- Develop strategies under water deficit conditions to maximize water productivity through irrigation strategies, e.g., deficit irrigation.
- Identify crop and management practices: e.g., adjusting planting date, cultivate selection, fertilization management, use of mulches and rainwater harvesting.
- Study the effect of climate change on food production, by running AquaCrop with both historical and future weather conditions.
- Undertake certain planning tasks by analysing scenarios useful for water administrators and managers, economists, policy analysts and scientists.

All data needed for calibration (i.e., crop, soil, field management and climatic data) were collected for use in the assessment of rainfed barley crop within the study areas.

After calibration, projected climate change data from Mashreq Domain (10 km resolution) for the six GCMs were extracted for the study area. It was then necessary to rerun AquaCrop using the calibrated data to assess the impact of climate changes on crop yield, crop water use, also known as evapotranspiration (ET), and the growing cycle length.

B. Findings

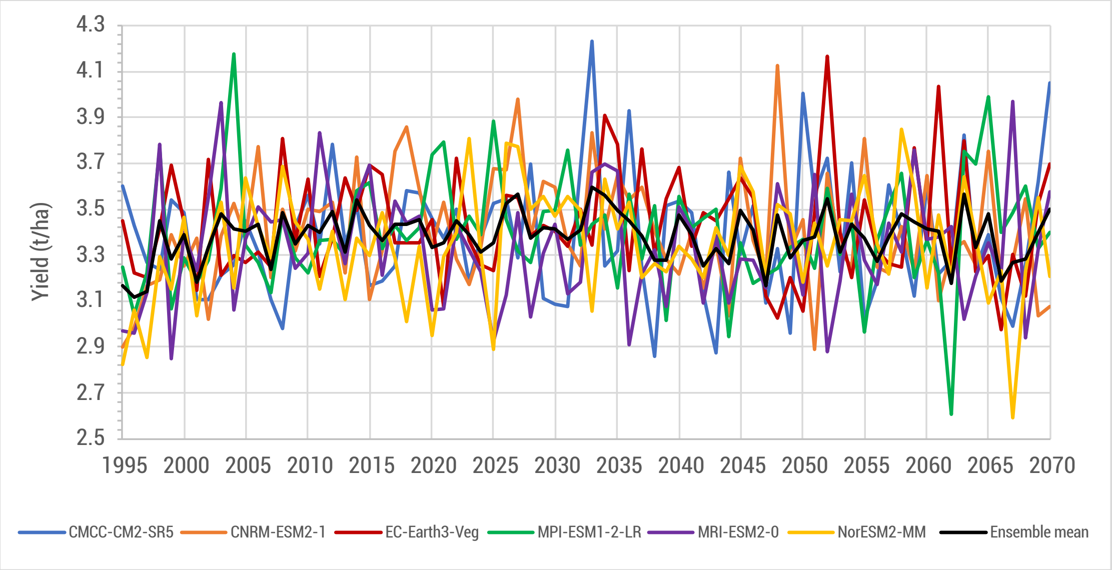
1. Change in barley yield

To evaluate the impact of climate change on crop yield, the AquaCrop model was applied both with and without concurrent elevations of atmospheric CO_2 concentration, as in the SSP5-8.5 scenario.

(a) With fixed atmospheric CO_2 concentration

Figure 28, figure 29 and table 5 summarize simulated barley yield in response to projected climate scenario SSP5-8.5, without including elevated CO_2 effects on barley growth. It can be seen that yield is projected to increase by 0.9 per cent during the period (2041–2060) in comparison to the reference period (1995–2014).

FIGURE 28: Projected barley yield for the period (1995–2070) in the Akkar plain, Lebanon, for the six RCMs, assuming a fixed CO_2 concentration at 400 ppm



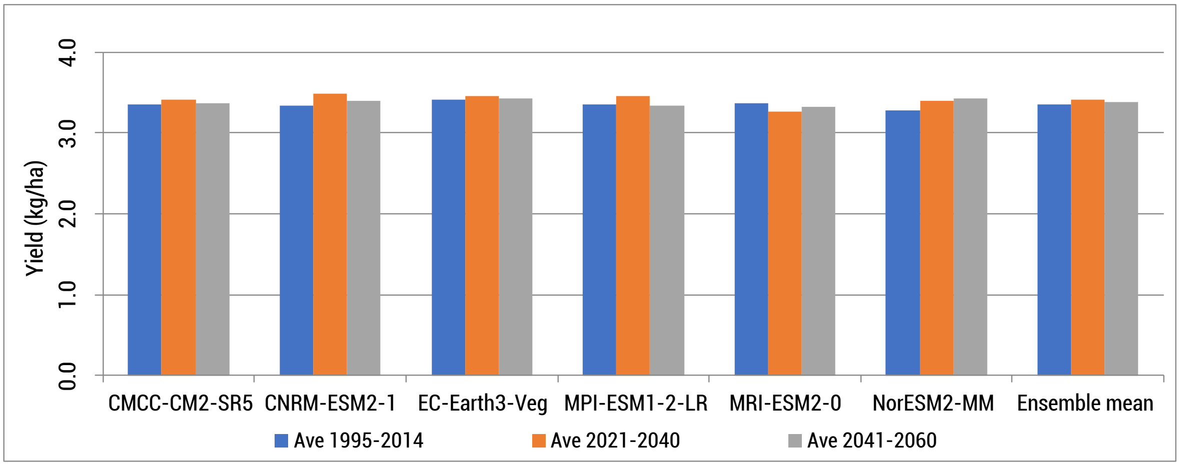
Source: Authors.

TABLE 5: Projected barley yield (t/ha) for the periods (2021–2040) and (2041–2060) compared to the reference period (1995–2014) in the Akkar plain, Lebanon, for six RCMs, assuming a fixed CO_2 concentration at 400 ppm

Time period	Barley yield (t/ha)						
	CMCC-CM2-SR5	CNRM-ESM2-1	EC-Earth3-Veg	MPI-ESM1-2-LR	MRI-ESM2-0	NorESM2-MM	Ensemble mean
1995–2014	3.35	3.34	3.41	3.36	3.37	3.28	3.35
2021–2040	3.42	3.49	3.46	3.46	3.26	3.41	3.42
2041–2060	3.38	3.39	3.42	3.34	3.33	3.42	3.38
Relative change (mid-term/reference period)	0.6%	1.5%	0.5%	-0.5%	-1.1%	4.4%	0.9%

Source: Authors.

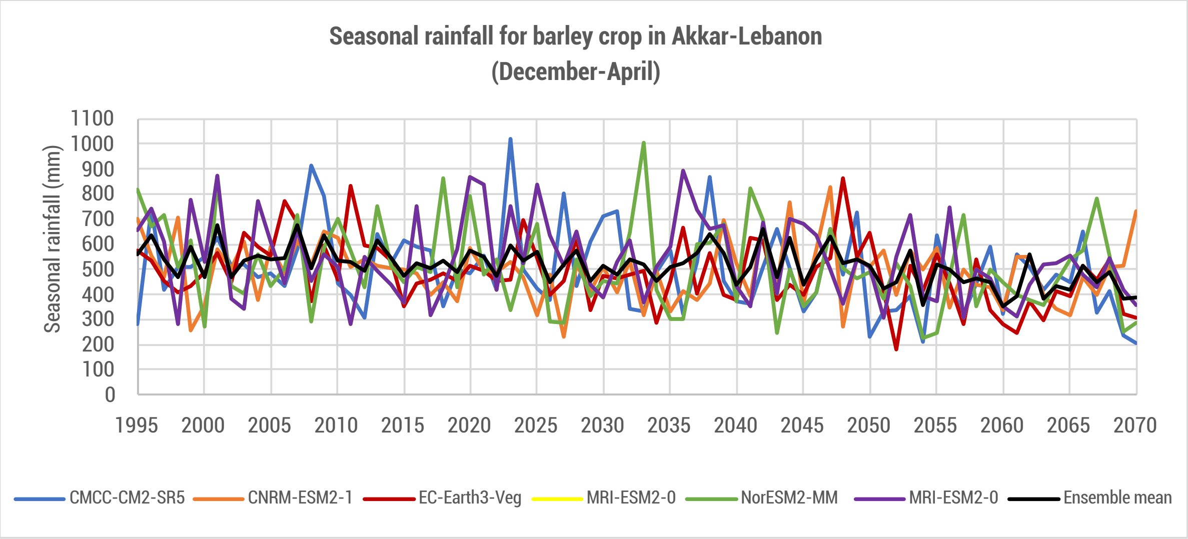
FIGURE 29: Projected barley yield for the periods (2021–2040) and (2041–2060) compared to the reference period (1995–2014) in the Akkar plain, Lebanon, for six RCMs, assuming a fixed CO_2 concentration at 400 ppm



Source: Authors.

Even though the seasonal rainfall is decreasing during the barley growing season (figure 30), the average rainfall is estimated at approximately 400 mm. The estimated amount remains above the barley ETc. This accounts for the fact that there has been no reduction in barley yield associated with the decrease in rainfall amount, assuming a fixed CO_2 concentration.

FIGURE 30: Seasonal precipitation time series evolution based on six driving GCMs for rainfed barley production in the Akkar/Hamidiye plain for six RCMs

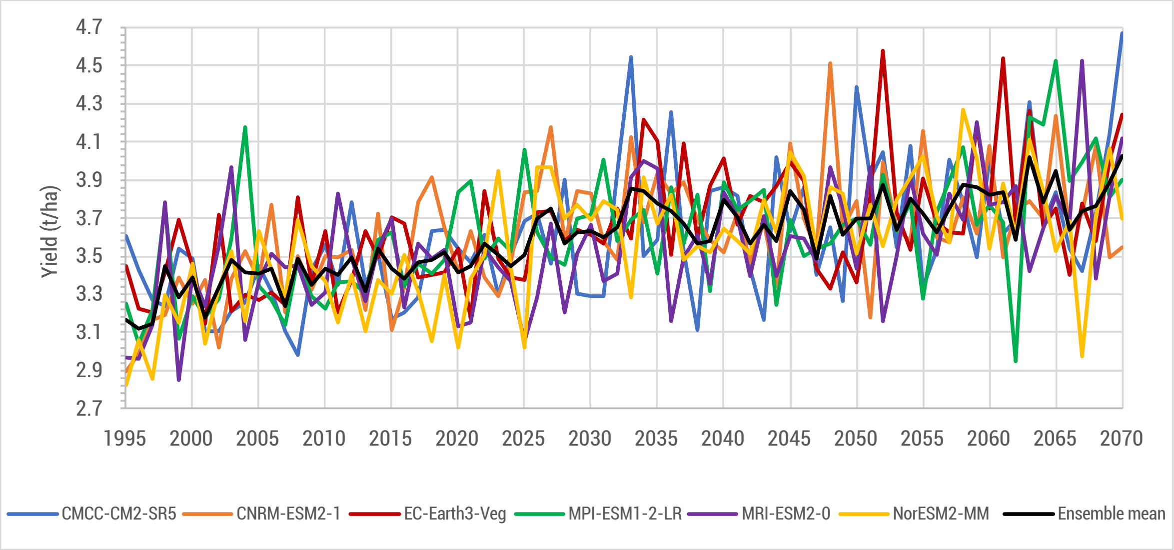


Source: Authors.

(a) With an elevated atmospheric CO_2 concentration

When the effect of elevated CO_2 is added, future climate changes are beneficial for barley production and the yield is projected to increase by 11 per cent during the period (2041–2060) in comparison to the reference period (1995–2014) (figure 31, figure 32 and table 6). The effect of CO_2 depends on the nature of the photosynthetic process in each plant species. The so-called C3 plants (such as barley) are more sensitive to a higher CO_2 concentration than C4 plants. Knox and others (2010) found that CO_2 fertilization offset the impacts of climate change, and that the doubling of CO_2 concentration by 2050 would lead to an increase in sugarcane yield by 15 per cent. However, the potential CO_2 effects on plant biomass depend on the nutrient and water level (Derner and others, 2003).

FIGURE 31: Projected barley yield (t/ha) for the periods (1995–2070) in the Akkar plain, Lebanon, for six RCMs with an elevated atmospheric CO_2 concentration



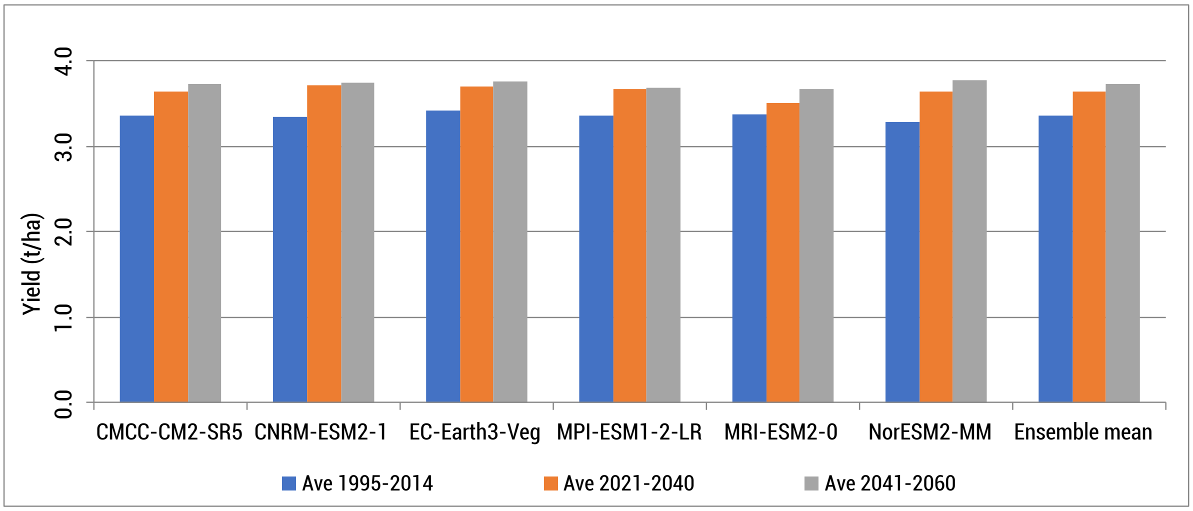
Source: Authors.

TABLE 6: Projected barley yield (t/ha) for the periods (2021–2040) and (2041–2060) compared to the reference period (1995–2014) in the Akkar plain, Lebanon, for six RCMs, with an elevated atmospheric CO_2 concentration

Time period	Barley yield (t/ha)						
	CMCC-CM2-SR5	CNRM-ESM2-1	EC-Earth3-Veg	MPI-ESM1-2-LR	MRI-ESM2-0	NorESM2-MM	Ensemble mean
1995–2014	3.35	3.34	3.41	3.36	3.37	3.28	3.35
2021–2040	3.63	3.71	3.69	3.67	3.50	3.64	3.64
2041–2060	3.72	3.74	3.76	3.68	3.66	3.77	3.72
Relative change (mid-term/reference period)	10.9%	11.8%	10.2%	9.5%	8.7%	14.9%	11.0%

Source: Authors.

FIGURE 32: Projected barley yield (t/ha) for the periods (2021–2040) and (2041–2060) compared to the reference period (1995–2014) in the Akkar plain, Lebanon for six RCMs with an elevated atmospheric CO_2 concentration

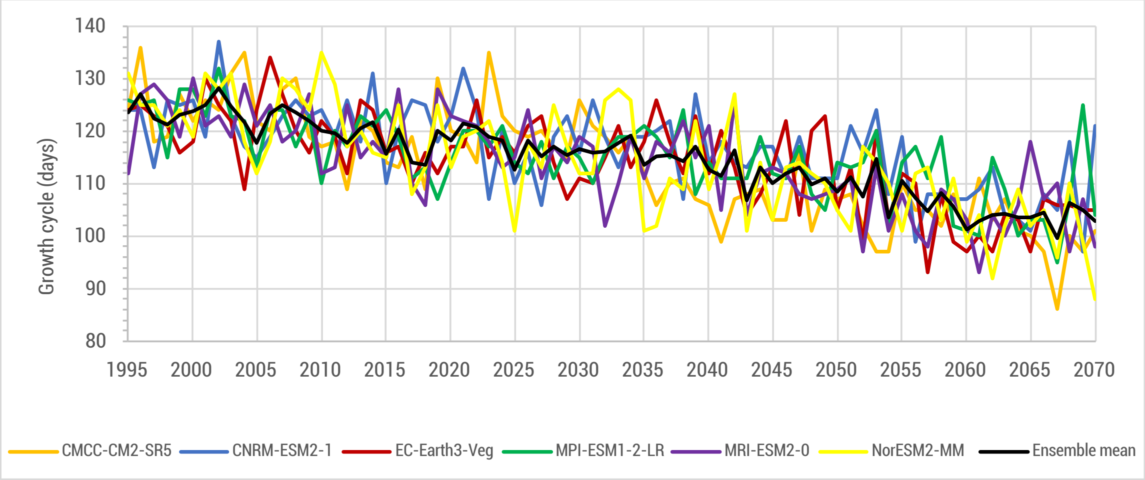


Source: Authors.

2. Change in barley growth cycle

The expected increase in temperature in the Nahr el Kabir basin will cause faster rates of development and shorter growth periods for cultivated crops. The growing cycle for barley is projected to decrease by 6 days and 14 days during the periods (2021–2040) and (2041–2060), respectively, in comparison to the reference period (1995–2014), (figure 33, figure 34 and table 7).

FIGURE 33: Projected barley growth cycle for the periods (1995–2070) in the Akkar plain, Lebanon, for six RCMs



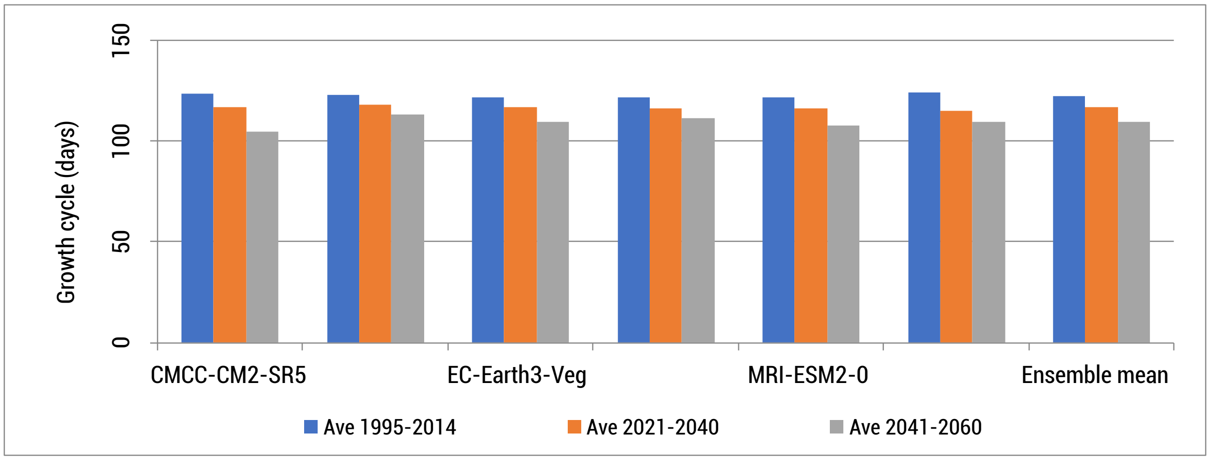
Source: Authors.

TABLE 7: Projected barley growth cycle (days) for the periods (2021–2040) and (2041–2060) compared to the reference period (1995–2014) in the Akkar plain, Lebanon, for six RCMs

Time period	Barley yield (t/ha)						
	CMCC-CM2-SR5	CNRM-ESM2-1	EC-Earth3-Veg	MPI-ESM1-2-LR	MRI-ESM2-0	NorESM2-MM	Ensemble mean
1995–2014	123	123	122	122	121	124	123
2021–2040	117	118	117	117	116	115	117
2041–2060	105	113	109	112	108	110	109
Relative change (mid-term/reference period)	-15.0%	-8.1%	-10.3%	-8.5%	-11.4%	-11.5%	-10.8%

Source: Authors.

FIGURE 34: Projected barley growth cycle for the periods (2021–2040) and (2041–2060) compared to the reference period (1995–2014) in the Akkar plain, Lebanon, for six RCMs

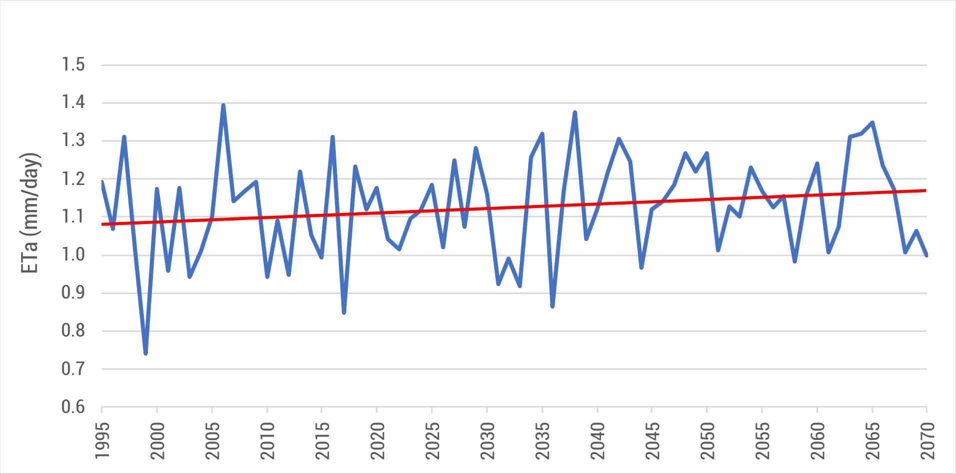


Source: Authors.

3. Change in barley water requirement

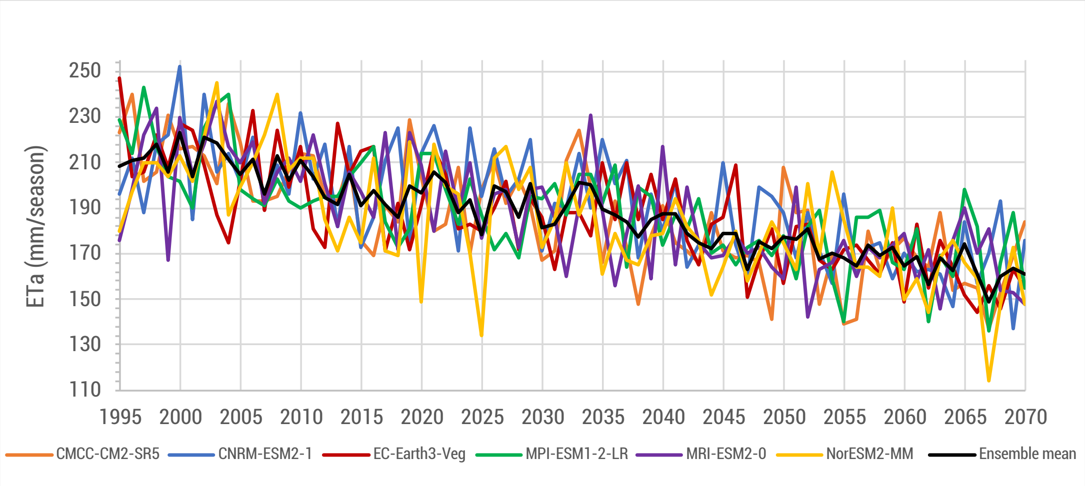
Figure 35 shows that daily actual evapotranspiration (ETa) of barley is projected to increase owing to the increase in minimum and maximum temperatures, yet the seasonal ETa is projected to decrease. The projected reduction in ETa for barley is 17 mm (8.1 per cent) and 35 mm (16.8 per cent) for the periods (2021–2040) and (2041–2060), respectively, in comparison to the reference period (1995–2014) (figure 36, figure 37 and table 8). This reduction in ETa could be attributed to the decrease in the length of the growth period.

FIGURE 35: Changes in average daily ETa of barley for January in the Akkar plain for six RCMs



Source: Authors.

FIGURE 36: Projected average seasonal ETa for the periods (1995–2070) in the Akkar plain for six RCMs



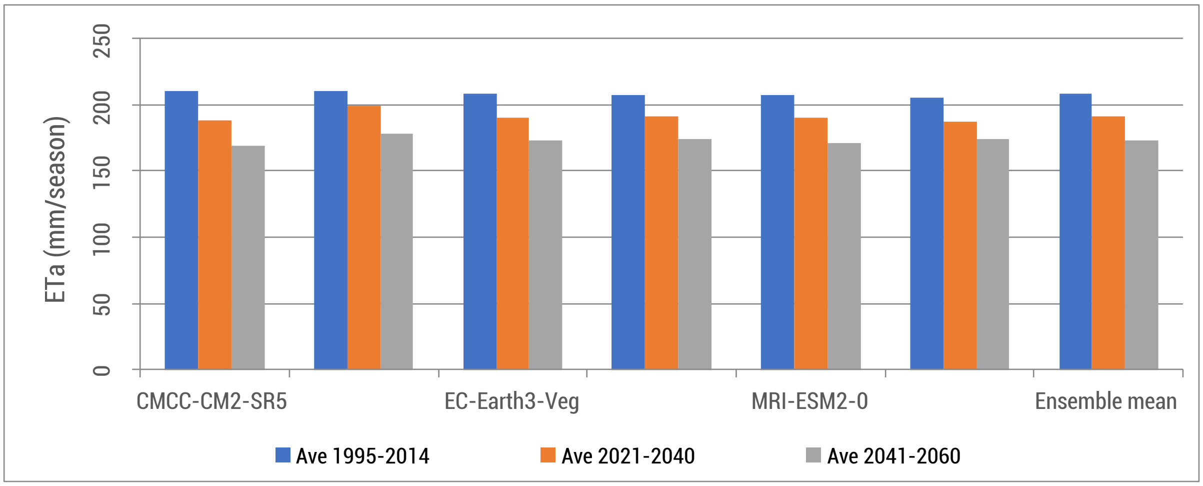
Source: Authors.

TABLE 8: Projected seasonal ETa (mm) of barley for the periods (2021–2040) and (2041–2060) compared to the reference period (1995–2014) in the Akkar plain, Lebanon, for six RCMs

Time period	Seasonal ETa (mm)						
	CMCC-CM2-SR5	CNRM-ESM2-1	EC-Earth3-Veg	MPI-ESM1-2-LR	MRI-ESM2-0	NorESM2-MM	Ensemble mean
1995–2014	211	210	208	208	208	206	208
2021–2040	188	200	190	191	190	187	191
2041–2060	169	178	174	174	171	174	173
Relative change (mid-term/reference period)	-19.6%	-15.4%	-16.5%	-16.1%	-17.7%	-15.2%	-16.8%

Source: Authors.

FIGURE 37: Projected seasonal ETa (mm) of barley for the periods (2021–2040) and (2041–2060) compared to the reference period (1995–2014) in the Akkar plain, Lebanon, for six RCMs



Source: Authors.

C. Conclusions

- The increase in temperature will lead to shortening of the growth period of barley by about 11 per cent.
- The results showed an increase in the daily water consumption of barley as a result of climatic change, but this did not lead to an increase in water consumption during the entire growing season, which is projected to be shortened.
- Climate change will have only minimum positive effect on barley yield (a 1 per cent increase by 2070), unless the positive impact of CO_2 is taken in consideration (i.e., taking this into account, the barley yield is projected to increase by 11 per cent)
- In terms of recommendations, there is a need to:
  - Encourage deficit irrigation, which will allow for more efficient use of scarce water supplies and lead to greater increases in water productivity.
  - Opt for more drought-and heat-resistant species.
  - Change planting dates and cropping patterns.

PART 2. CLIMATE-PROOF WATERSHED MANAGEMENT DESIGN AND RESILIENCE PACKAGE

1 PROPOSED INTERVENTIONS

The VA results showed that most of the communities in the Nahr el Kabir basin had to confront a range of challenges in the water sector, including risks from degraded water quality, water scarcity and drought, flooding from both rivers and stormwater, as well as wildfires and their post-fire impact on water resources. For much of the basin, these challenges were projected to increase as a result of climate change over the next several decades.

There is no doubt that addressing these challenges necessitates diverse solutions, implemented from the scale of small communities to wide regions across the basin, with interventions ranging from local investments in specific infrastructure of water-related projects to broad policy reforms.

However, there is growing evidence that nature-based solutions (NbS) should be included among these solutions and interventions (Liu and others, 2021), especially given that NbS also have potential to address societal challenges.

The most recent European Commission report on NbS stated that the “concept of nature-based solutions embodies new ways to approach socioecological adaptation and resilience, with equal reliance upon social, environmental and economic domains” (Dumitru and Wendling, 2021). The report proposed a long list of NbS to effectively address water challenges in the Nahr el Kabir basin in response to reduced water availability, reduced water quality, drought, wildfires and freshwater flooding, in addition to addressing the need for knowledge and capacity development, as well as management improvement (table 9). Nevertheless, NbS should not be viewed as an ultimate substitute for the needed investments in infrastructure.

For implementation, the proposed interventions will require further investigation, field assessments and a detailed costing.

TABLE 9: Long list of proposed interventions

Response to reduced water availability	Adapt to climate change in the Nahr el Kabir basin by establishing traditional water storage systems such as hill lakes, small dams and water ponds.
	Manage and utilize water and related natural resources sustainably, and thereby alleviate poverty and improve livelihoods.
Response to reduced water quality	Provide multipurpose green infrastructure (a series of constructed wetlands) for water pollution control.
	Provide incentives to reduce water pollution from the source.
Response to drought and land degradation	Facilitate drought risk adaptation in a changing climate through rural land use management.
	Apply a set of mitigation and adaptation strategies to combat land degradation and drought.
Response to disasters	Undertake preventive silviculture practices to promote resilience and reduce wildfire hazard.
	Undertake post-fire restoration activities to stabilize soil, as well as reduce soil erosion and flash floods on fire affected sites.
	Establish functioning flood plains, ditches, inland wetlands, stream beds and banks to slow and attenuate floodwater.
Capacity building, knowledge and management	Strengthen the water resource management and governance framework in the context of climate change.
	Improve knowledge management in the water sector at the basin level.

Selected list of interventions

Selected interventions were identified in an attempt to: (1) provide solutions for challenges covering a relatively large area of the basin; (2) correspond to the VA results; and (3) directly link NbS to climate change adaptation outcomes based on consultations with local and national stakeholders. Accordingly, these interventions were selected:

- Adapt to climate change in the Nahr el Kabir basin by establishing traditional water storage systems.
- Provide multi-purpose green infrastructure (a series of constructed wetlands) for water pollution control.
- Apply a set of mitigation and adaptation strategies to combat land degradation and drought.
- Improve forest management to reduce wildfires and strengthen resilience in the Nahr el Kabir.
- Improve knowledge management in the water sector at the regional level.

2 INTERVENTION MEASURES

A. Selected intervention 1

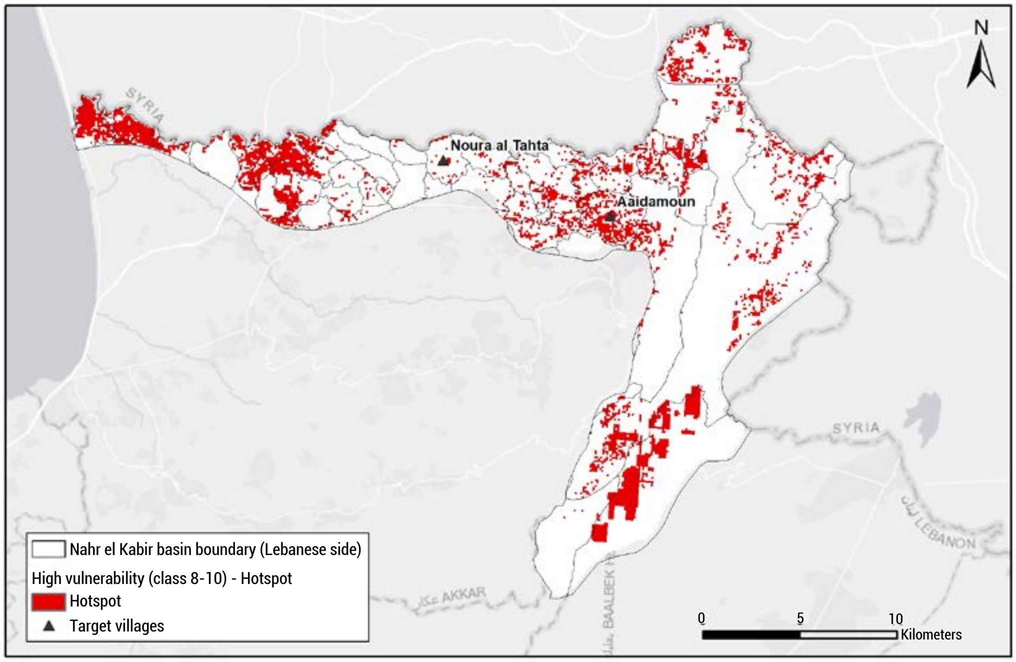
Title: Adapt to climate change in the Nahr el Kabir basin by establishing traditional water storage systems and surface water management.

Summary description: climate change is projected to significantly alter rainfall patterns, in terms of periodicity and intensity, among others, hence causing implications related to water supply expected for households, traditional industries and agriculture, especially rainfed agriculture. In addition, frequent floods are expected as a result of short-lived heavy rainfall events. This intervention describes activities designed to restore traditional water management systems (in the form of hill lakes, check dams and ponds), designed to mitigate the effects of increased climate variability and the frequency of weather extremes.

Type: NbS (restoration and construction).

Targeted area: villages/towns with largest 'hotspot' areas, specifically in the lower (i.e., Noura al Tahta westwards) and middle (i.e., between Noura al Tahta and Aaidamoun) parts of the basin, and to a certain extent in the upper part of the basin (i.e., Aaidamoun eastwards) (figure 38).

FIGURE 38: Vulnerability hotspots for the mid-term period in the Nahr el Kabir basin



Source: Authors.

1. Objective

To mitigate the effects of increased climate variability and the frequency of weather extremes while securing enough water resources for households, irrigation and industries in times of need and reducing flood risk resulting from weather extremes.

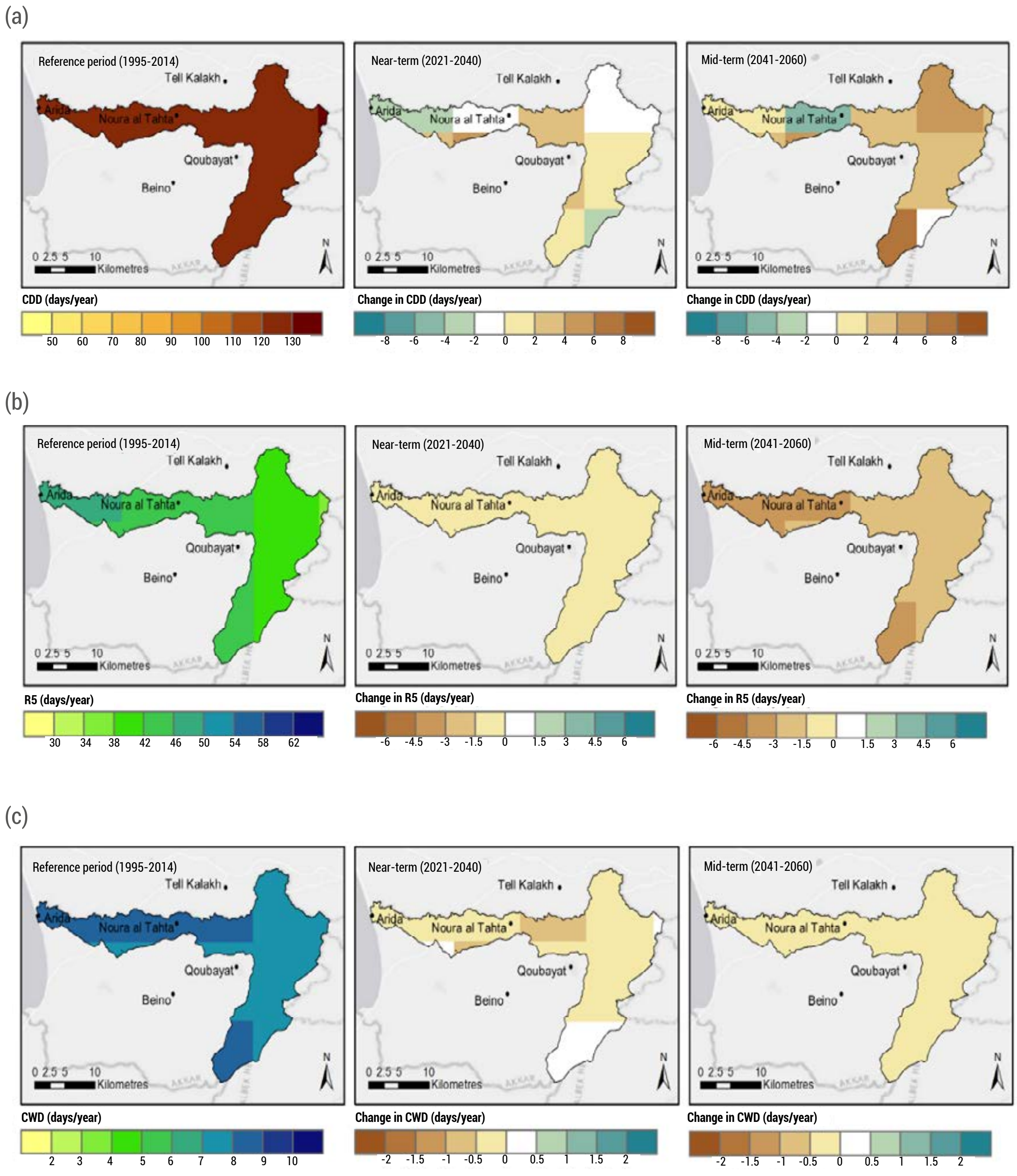
2. General description

The basin's water needs are expected to grow by the near-term period, with demand potentially increasing well beyond current supplies as a result of an increase in population and in agricultural activities. At the same time, the expected impact of climate change is that the volumes of water stored in aquifers and in the form of snow will be reduced and precipitation will be mostly lost through water surface run-off. Therefore, additional water supplies need to be secured to avoid a major water crisis. The natural reduction in the volumes stored must be compensated artificially through the construction of retention hill lakes and check dams, provided it is financially, technically and environmentally feasible. In this context, the challenge is to devise practical methods and NbS that improve water availability and meet current demands, while providing enough water supply to meet future demand in light of the uncertainty resulting from climate change. Priority 1 is for check dams and water ponds in areas facing severe shortages in water for irrigation purposes (e.g., the lower part of the basin), or in areas that have witnessed a drastic and rapid increase in irrigated lands in the past few years (e.g., the middle part of the basin). Priority 2 is for hill lakes in areas facing less severe shortages in water for irrigation purposes, or in areas that witness a relatively stable or slight increase in irrigated areas (e.g., toward the upper part of the basin). Some of these areas may not face current water shortages, but this could change in the future, therefore requiring additional water sources. In parallel, weather extremes in form of heavy rainfall can inundate large areas if no mitigation measures are taken to reduce flood risks.

3. Justification

Climate change is likely to add further complexity to the water management challenge in the basin. Greater increases in heavy rainfall induce floods, whereas greater decreases in precipitation can contribute to drought. In this context, flooding is a recurrent issue in the basin, causing losses to farmers and damage along the river. In 2003, the river flooded villages, destroying several houses, damaging crops and causing the loss of livestock. As a result, the Government of Lebanon built a two-metre-high flood wall (currently in need of restoration) over a distance of 4.5 km in the Bouqaiaa plain, starting at the Ain Farash spring. Also, greater increases in heat waves have an adverse impact on water availability. The projected increase in the number of CDDs and the decrease in the number of precipitation days (R5), as well as in the number of CWDs can contribute to drought, thereby decreasing water availability (figure 39). The main approach of this intervention is to undertake rain and snow melt harvesting by constructing storage hill lakes and ponds, which can also be fed by any other source of surface water. Hill lakes and small dams (i.e., check dams) play an important role in the mobilization and management of water and soil resources (Boufaroua and others, 2013). In addition, studies have showed that check dams can play an important role in controlling soil erosion, moderating water and sediment flows and improving land biophysical conditions (Lucas-Borja and others, 2021).

FIGURE 39: Climate change impact on maximum length of dry spell, annual number of precipitation days and maximum length of wet spell in the Nahr el Kabir basin



Source: Authors.

Note: (a) Mean change in the maximum length of dry spell (CDD; consecutive days with precipitation <1 mm) compared to the reference period, based on an ensemble of six bias-corrected models from the Mashreq Domain, SSP5-8.5. Blue areas represent decreasing CDDs (wetter conditions) and brown areas represent increasing CDDs (drier conditions). (b) Mean change in the annual number of precipitation days (R5; days with precipitation >5 mm) compared to the reference period, based on an ensemble of six bias-corrected models from the Mashreq Domain, SSP5-8.5, (c) Mean change in the maximum length of wet spell (CWD; consecutive days with precipitation ≥1 mm) compared to the reference period, based on an ensemble of six bias-corrected models from the Mashreq Domain, SSP5-8.5. Blue areas represent increasing CWDs (wetter conditions) and brown areas represent decreasing CWDs (drier conditions).

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

The proposed intervention suggests that traditional water management methods can be both socially and economically effective in coping with variability in precipitation patterns, thus improving water supply to households and industries while also improving crop productivity. In addition to the possibility of expanding the extent of irrigated lands, farmers can benefit from reduced water and fuel costs, as well as reduced pumping ground water costs. Improved livelihood is consequently another expected positive outcome owing to saving money on buying water. Main SDGs directly addressed: SDG 2 (targets 2.3, 2.4); SDG 6 (targets 6.4, 6.6, 6.b); and SDG 13 (target 13.1). In addition, this intervention responds to target 6.4 of the updated National Water Sector Strategy of 2020 for ensuring sustainable supply of freshwater to correct water scarcity and substantially reduce the number of people suffering from it. It also comes in line with the resource exploitation strategic priority and responds to the strategy requirements for rain and snow melt harvesting by constructing hill lakes and ponds. The proposed intervention provides alternative solutions (and/or provides a supplement) to an uncompleted plan for the construction of a dam and reservoir at Noura al Tahta to capture surplus water in winter for agricultural use, while at the same time controlling flooding in the coastal plain.

5. Stakeholders – institutions, partners and implementing agencies

Farmers, industries, municipalities, unions of municipalities, the MoEW and NLWE, the MoA, Green Plan and NGOs.

6. Activities

- Activity 1: assess and propose a plan to restore and establish traditional water storages.
  - Activity 1.1: use map of existing traditional water storage infrastructure facilities (check dams, hill lakes, small ponds, cisterns) and identify locations for new ones.
  - Activity 1.2: conduct a feasibility study for restoring existing traditional water infrastructure facilities or for establishing new ones.

- Activity 2: develop water resources by increasing water harvesting through promoting and implementing hill lakes and small water ponds/reservoirs/cisterns.
  - Activity 2.1: implement hill lakes planned in the updated National Water Sector Strategy of 2020: hill lakes for the Bouqaiaa/Machta Hammoud/Machta Hassan Scheme and Omar El Breiket hill lake.
  - Activity 2.2: implement three traditional water storage infrastructure facilities, one per hotspot conglomerate,[4] to provide additional water points for users and farmers.

- Activity 3: assess and propose a restoration plan for traditional ditches along the Nahr el Kabir in the lower part of the basin, as well as for establishing check dams on permanent and seasonal streams, gullies and torrents.

- Activity 4: develop policy tools for promoting the establishment of small dams and hill lakes as an effective, ecologically sound method for improving water management without compromising food security and economic prosperity.

- Activity 5: improve knowledge on the adoption and dissemination of traditional water storage at the local level.
  - Activity 5.1: capacity development targeting extension services of MoA, MoEW and local authorities (water establishments, municipalities) regarding traditional water storage.
  - Activity 5.2: awareness raising among local communities on traditional water storage.

7. Constraints

Financial constraints and the lack of maintenance may affect the implementation and sustainability of such interventions. Governance constraints may also play a role in determining management, maintenance and financing.

8. Estimated duration

Thirty-six months

No.	Activity	Time period											
		Year 1				Year 2				Year 3			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1.1	Use map of existing traditional water storage infrastructure facilities and identify locations for new ones.	▨	▨										
1.2	Conduct a feasibility study for restoring existing traditional water infrastructure facilities or for establishing new ones.		▨	▨									
2	Promote and implement pilot hill lakes and small water ponds/reservoirs/cisterns.			▨	▨	▨	▨	▨	▨	▨	▨		
3	Assess and propose a restoration plan for traditional ditches along the Nahr el Kabir, as well as for establishing check dams.		▨	▨	▨								
4	Develop policy tools for promoting the establishment of small dams and hill lakes.					▨	▨	▨					
5.1	Capacity development targeting extension services of MoA, MoEW and local authorities (water establishments, municipalities).							▨	▨	▨	▨	▨	▨
5.2	Awareness raising among local communities.		▨	▨			▨	▨			▨	▨	

9. Estimated cost

Activity	Approximate cost ($)
Devise map of existing traditional water storage infrastructure facilities and identify locations for new ones.	30 000
Conduct a feasibility study for restoring existing traditional water infrastructure facilities or for establishing new ones.	20 000
Implement hill lakes planned in the updated National Water Sector Strategy of 2020.	2 370 000[a]
Implement three traditional water storage infrastructure facilities, one per hotspot conglomerate.	170 000
Assess and propose a restoration plan for traditional ditches along the Nahr el Kabir, as well as for establishing check dams.	50 000
Develop policy tools for promoting the establishment of small dams and hill lakes.	15 000
Capacity development targeting extension services of MoA, MoEW and local authorities (water establishments, municipalities).	20 000
Awareness raising among local communities.	15 000
Total cost	2 690 000

Note: As these numbers are estimates of each activity cost, an extensive assessment, involving field visits and data collection, is needed to define costs more accurately.

[a] The construction costs of hill lakes for the Bouqaiaa/Machta Hammoud/Machta Hassan Scheme and the construction of Omar El Breiket hill lake were estimated at $1,166,000 and $1,170,000, respectively, based on the updated National Water Sector Strategy of 2020.

B. Selected intervention 2

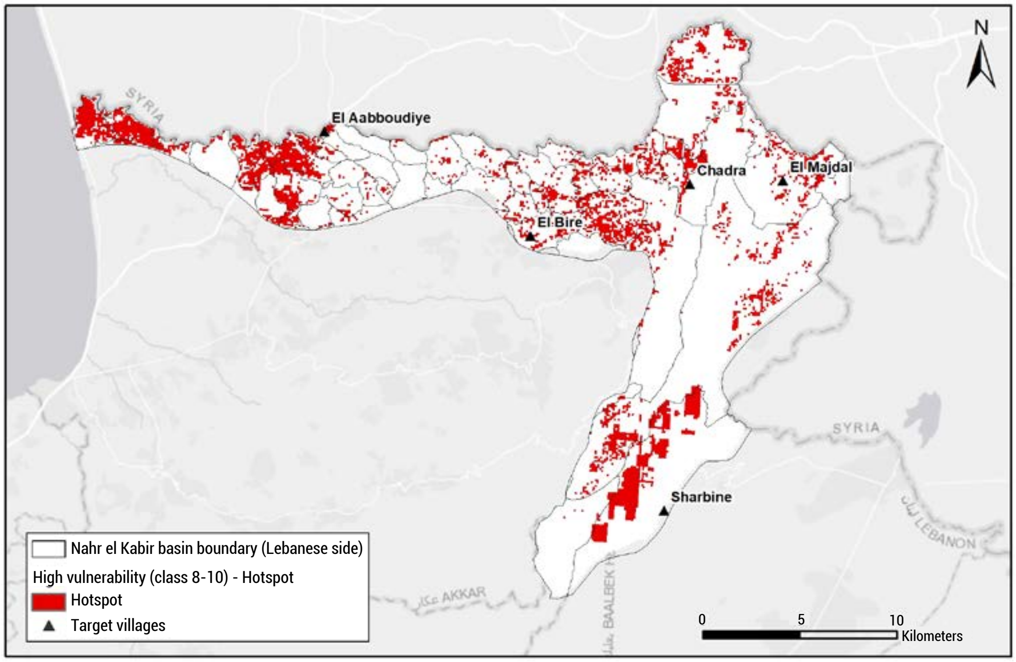
Title: Provide multi-purpose green infrastructure (construction of a series of treatment wetlands or waste stabilization ponds) for water pollution control.

Summary description: as an NbS intervention, constructed wetlands make use of the natural purification processes of soils, vegetation and microbes, to remove contaminants from a local discharge. Uses of constructed wetlands for water purification can include applications in municipal wastewater, limited industrial and agricultural wastewater, and even storm water. It is a relatively low-cost technology for improving water security and access, making it key in climate change adaptation. Simultaneously, green vegetation cover created by wetlands produces habitats for wildlife and may offer a recreational value if properly managed.

Type: NbS (construction).

Targeted area: villages/towns with the largest hotspot areas, with a focus on areas with limited access to improved water (e.g., low, middle and upper parts of the basin), and while giving priority to villages/towns with an increasing number of population and agro-industries (such as El Aabboudiye, El Majdal, Chadra, Al Bireh and Sharbine) (figure 40).

FIGURE 40: Targeted areas of intervention 2 in the Nahr el Kabir basin



Source: Authors.

1. Objective

Provide a low-cost and ecologically sustainable method of wastewater treatment to enhance water security by making treated wastewater available to face restricted access to usable water sources, especially under a climate change scenario.

2. General description

As natural technologies, treatment wetlands efficiently treat many different types of polluted water. They are designed to optimize processes found in natural environments and are hence considered environmentally friendly and sustainable wastewater treatment options. In comparison to other wastewater treatment technologies, treatment wetlands have low operation and maintenance requirements. Such wetlands can effectively treat raw, primary, secondary or tertiary treated sewage (i.e., depending on the type/content of wastewater), as well as many types of agricultural and industrial wastewater (Dotro and others, 2017).

The quality of both surface and groundwater in the basin is rapidly deteriorating because of uncontrolled disposal of untreated domestic sewage, animal and solid waste, and unsustainable agricultural practices (ESCWA and BGR, 2013). Initially, a number of sites need to be selected in reference to the spatial distribution of hotspot areas defined by the VA. Selection typically includes a low-lying area so that discharge can be easily collected (e.g., next to a road, near municipal water storage tanks or similar locations). Some of the key variables to consider include the size of required and available lands, desired water retention capacity, water retention time depending on site capacity and purification needs and level of the water table. An environmental impact assessment would be needed before proceeding with such intervention. Construction activities typically include placing a geomembrane at the site, topping the basin with tailored soil, and planting vegetation, generally giving native species preference over non-native ones. Monitoring and maintenance of the wetland remains essential in the post-construction phase, including clearing clogs and monitoring water flow and water quality (i.e., pollution removal efficiency).

3. Justification

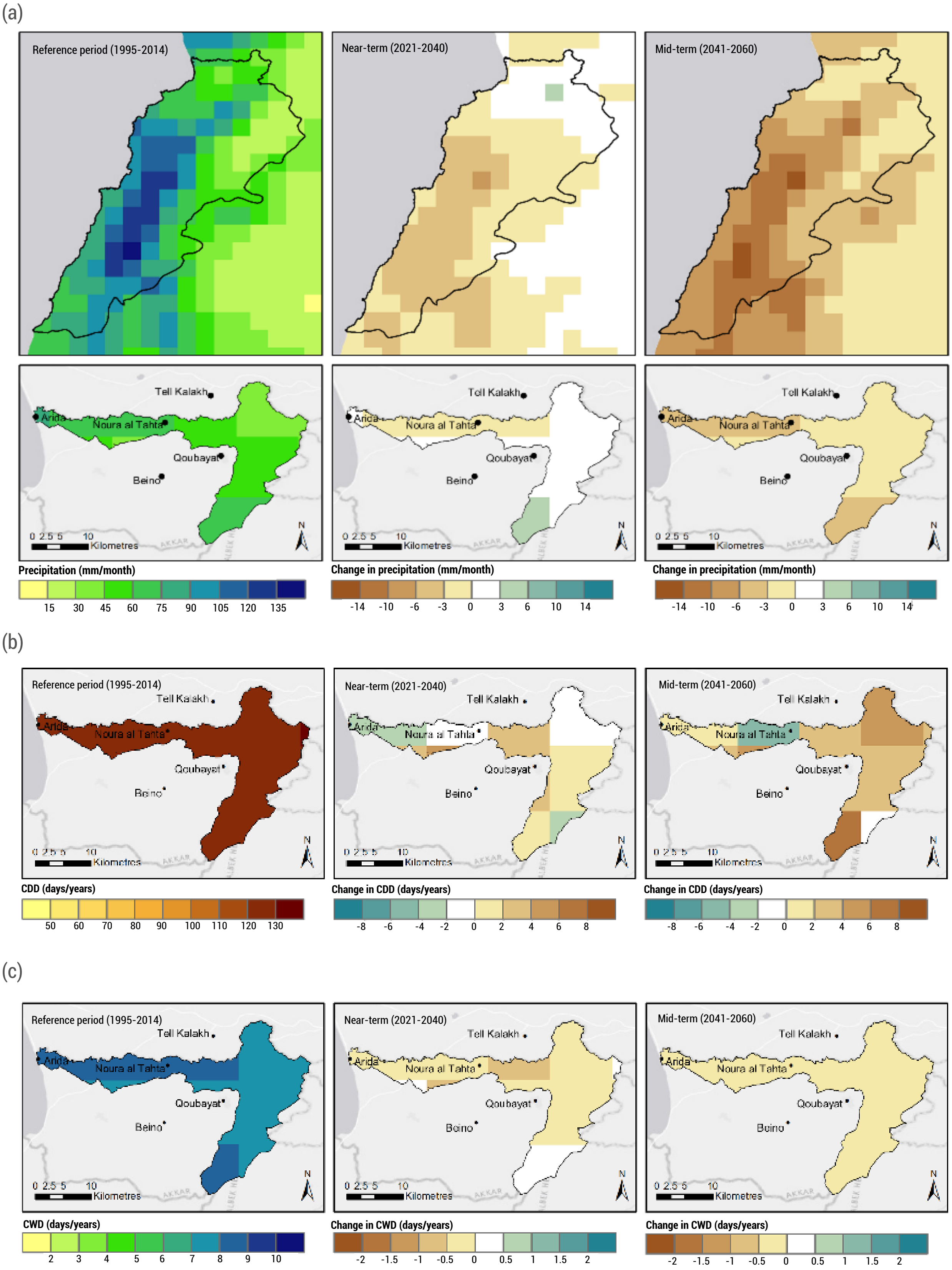
Constructing a series of wetlands for pollution control offers various potential opportunities, including:

- Lowering energy costs, especially in light of the rising fuel prices, as the cost of construction and operation is often much cheaper than that of conventional treatment plants.
- Decreasing investments in treatment infrastructure.
- Offering a decentralized solution, as the wetlands are often operated at the community level.
- Producing multiple benefits, including climate change adaptation and biodiversity benefits
- Specific co-benefits and suitability to the basin include (Stefanakis, 2016):
- Improving climate change adaptation to extreme conditions and giving a certain level of flood control (box).
- Providing water purification and biological control and improving water quality.
- Providing habitats, green spaces, wildlife habitats, as well as recreational and educational areas.
- Providing a feasible technology option in rural areas of Akkar, as constructed wetlands are a low-maintenance, ecologically sustainable, simple, robust, low cost and low energy technology.
- Operating at community level, and are therefore located close to communities.
- Providing aesthetic, recreational and educational value for local populations.
- Reducing costs of water treatment.

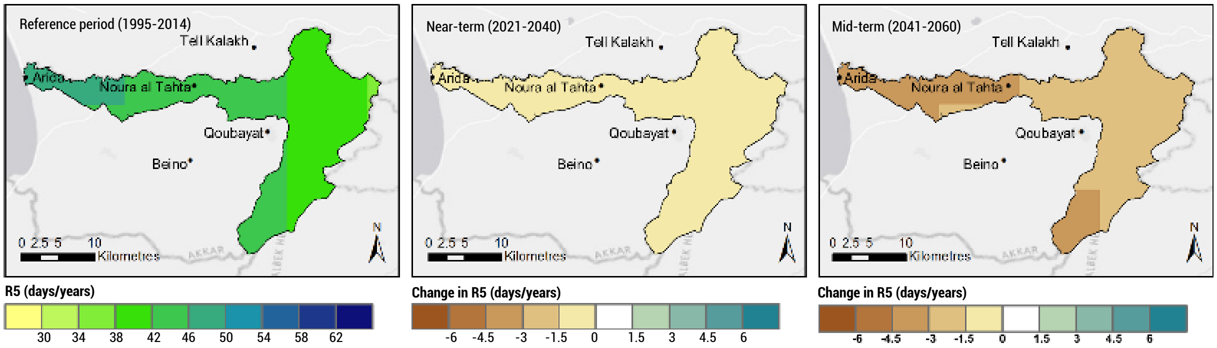
Climate change impact on increasing flood risk in the Nahr el Kabir lower basin

Climate change projections in the Nahr el Kabir reveal increasing precipitation particularly in the uppermost basin for the near-term (2021–2040), increasing CDDs, increasing CWDs and decreasing number of annual precipitation days (R5). Soil erosion may occur following probable simultaneous occurrence of these phenomena in the uppermost basin for the near-term. The lengthening of the dry season causes low soil moisture content. The said moisture condition, coupled with sequential rains, may lead to high runoff and sediment transport (Wang and others, 2018). Moreover, because these conditions were projected in the upper basin, flood risk is also a concern in the Akkar plain downstream (figure 41).

FIGURE 41: Climate change impact on annual precipitation, maximum length of dry spell, maximum length of wet spell and annual number of precipitation days in the Nahr el Kabir basin



(d)



Source: Authors.

Note: (a) Mean change in annual precipitation compared to the reference period, based on an ensemble of six models from the Mashreq Domain, SSP5-8.5. (b) Mean change in the maximum length of dry spell (CDD; consecutive days with precipitation <1 mm) compared to the reference period, based on an ensemble of six bias-corrected models from the Mashreq Domain, SSP5-8.5. Blue areas represent decreasing CDD (wetter conditions) and brown areas represent increasing CDD (drier conditions). (c) Mean change in the maximum length of wet spell (CWD; consecutive days with precipitation ≥1 mm) compared to the reference period, based on an ensemble of six bias-corrected models from the Mashreq Domain, SSP5-8.5. Blue areas represent increasing CWD (wetter conditions) and brown areas represent decreasing CWD (drier conditions). (d) Mean change in the annual number of precipitation days (R5; days with precipitation >5 mm) compared to the reference period, based on an ensemble of six bias-corrected models from the Mashreq Domain, SSP5-8.5.

The principal goal of a treatment wetland is to purify wastewater and provide a final effluent of high quality. This is considered an absolutely necessary process, not only to mitigate the impact of climate change on water scarcity, but also to protect the natural environment and the habitat, and, most importantly, to protect human health.

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

Main SDG directly addressed: SDG 6 (targets 6.1, 6.3, 6.4 and 6.b).

This intervention responds to target 6.3 of the updated National Water Sector Strategy of 2020 for improving water quality by reducing pollution. Also, it comes in line with the strategic priority under the precautionary principle stipulating undertaking preventive measures, to avoid or reduce any risk of water resource pollution. In this context, plans for constructing new wastewater treatment plants in the basin are still not completed for the region of Al Bireh/Monjez in Lebanon.

5. Stakeholders – institutions, partners, implementing agencies

Farmers, communities, municipalities, unions of municipalities, MoEW and NLWE, MoE and NGOs.

6. Activities

- Activity 1: develop comprehensive design processes and conduct required studies for site selection of wetlands and pre-treatment implementation, as needed in the targeted high vulnerability areas, while incorporating an understanding of the complex biophysical and chemical aspects of the technology.
- Activity 2: implement two pilot treatment wetlands, each having an approximate size of 0.5 ha in the targeted area (middle and upper parts of the basin).
- Activity 3: develop local stakeholders' capacities in terms of technical know-how to plan, design and implement such wetlands.
- Activity 4: develop guidelines for treatment wetland replicability in, and transferability to other sites.
- Activity 5: monitor and evaluate wetland operation (carried out by the local authorities).

7. Constraints

- Wetlands require relatively large areas, which can create difficulties in some villages/towns, and it is expensive to gain land occupancy rights. The issue of acceptance by local communities needs to be properly addressed.
- Wastewater containing high volumes of contaminants (e.g., metals), can have negative effects on plants/animals and may not be suitable for wetland treatment. If industries are included, then pre-treatment may be required.
- Surface wetland systems may harbour mosquitos, increasing risk of vector-borne diseases. Unexpected events (e.g., disease or invasive species) may disrupt habitat functions if not properly addressed.
- Inappropriate design may result in odour problems; however, if properly designed and constructed, such wetlands generally do not cause odour issues.
- Geological/soil constraints need to be considered in advance.

8. Estimated duration

The duration of implementation depends on the number of wetlands to be constructed. It is estimated that at least 12 months are required for the design, construction and initial monitoring of one wetland sized 0.5 ha approximately, for example.

No.	Activity	Months																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Develop comprehensive design processes and conduct the required studies for site selection.	▨	▨	▨	▨														
2	Implement pilot treatment wetlands.					▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		
3	Develop local stakeholders' capacities.									▨	▨	▨							
4	Develop guidelines for treatment wetland replicability in, and transferability to other sites.														▨	▨	▨	▨	
5	Monitor and evaluate wetland operation.													▨	▨	▨	▨	▨	▨

9. Estimated cost

Activity	Approximate cost ($)
Develop comprehensive design processes and conduct the needed studies for site selection	70 000
Implement two pilot treatment wetlands	700 000
Develop local stakeholders' capacities	20 000
Develop guidelines for treatment wetland replicability in, and transferability to other sites	20 000
Monitor and evaluate wetland operation	40 000
Total cost	850 000

Note: These numbers are estimates of each activity cost. An extensive assessment, involving field visits and data collection, is needed to define costs more accurately.

C. Selected intervention 3

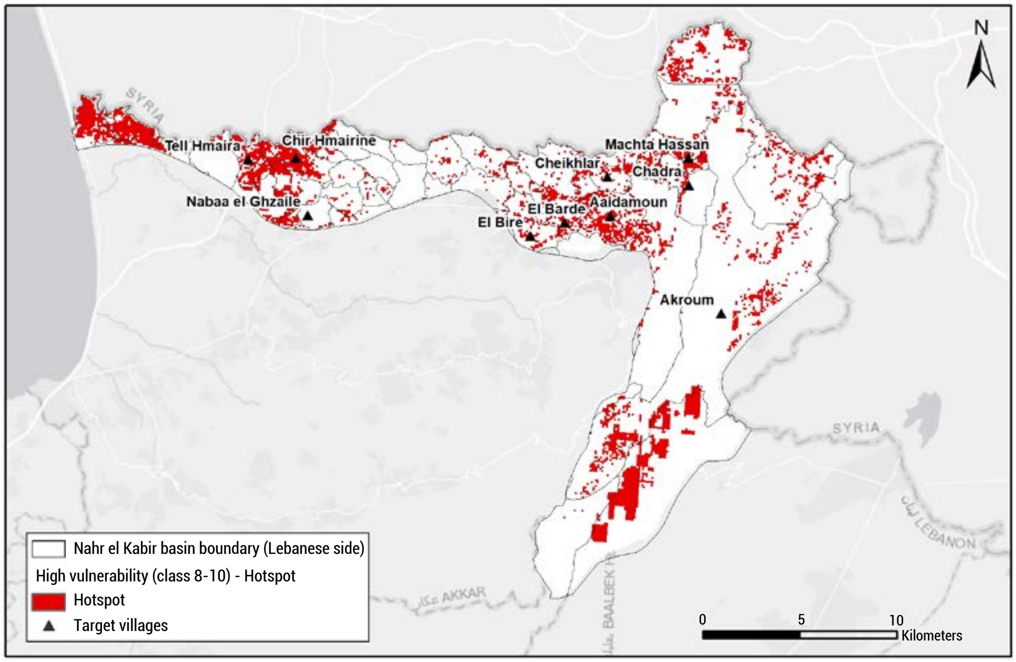
Title: Apply a set of mitigation and adaptation strategies to combat land degradation and drought.

Summary description: frequent drought and water scarcity in the basin is expected to severely disrupt water supply and agricultural production, as well as pose a substantial threat to farmers' livelihoods. The management of rural land use has proven to be efficient in mitigating drought risk, ensuring food security and improving farmers' livelihoods.

Type: NbS (land cover/land use management).

Targeted area: villages/towns with the largest hotspot areas of cropland, especially in Nabaa el Ghzaile, Darine, Tell Hmaira, Chir Hmairine, Al Bireh, Aaidamoun, El Barde, Rmah, Cheikhlar, Chadra, Machta Hassan and Akroum (figure 42).

FIGURE 42: Targeted areas for intervention 3 in the Nahr el Kabir basin



Source: Authors.

1. Objective

Address the issue of land degradation to improve land and water productivity and protect rural livelihoods.

2. General description

It is well documented that land degradation reduces water productivity at field and landscape scales (Bossio and others, 2010). In addition, it affects water quantity, quality and storage. To improving water management in agriculture, it is necessary to mitigate or prevent land degradation, especially when taking into consideration linkages between land and water productivity. It is possible to conserve water resources, while simultaneously boosting agricultural production and using resource-conserving farming technologies. In this context, the main directions of this intervention are to (1) afforest and reclaim lands undergoing degradation;

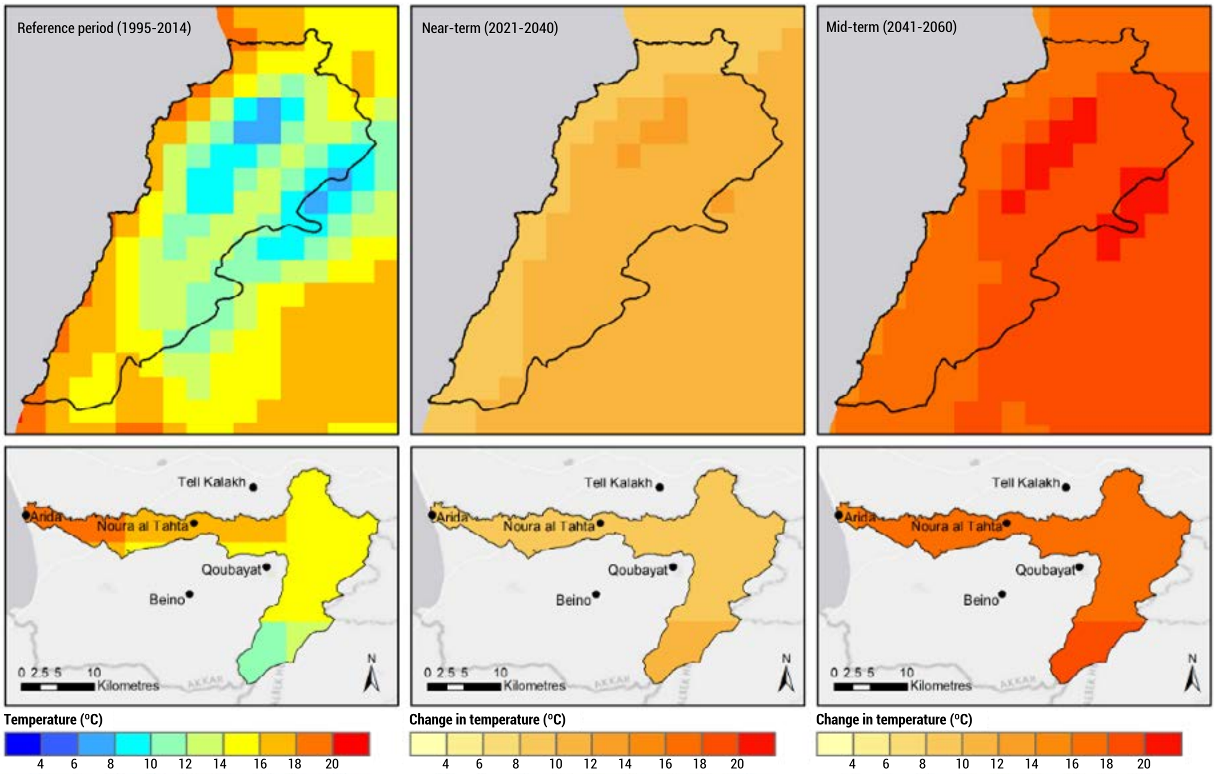
(2) conserve soil to encourage practices that prevent or reduce physical loss of soil; (3) regenerate pastures to obtain a permanent vegetation cover on degraded soils; (4) rehabilitate soil by eliminating and reducing physical and/or chemical impediments in soils suitable for agriculture; and (5) facilitate the conversion of inadequate irrigation systems into more efficient ones.

3. Justification

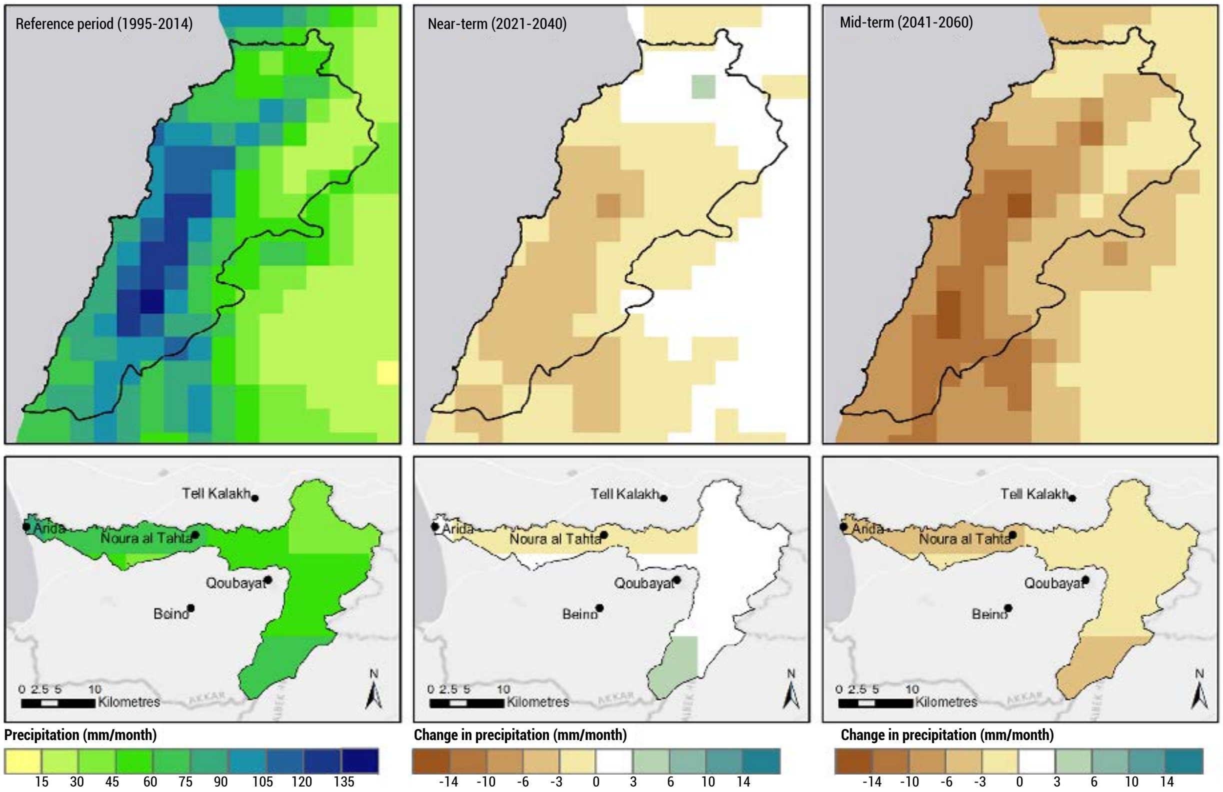
Climate change impacts vegetation and soil cover. Temperature and precipitation constitute principal factors in determining the state of both vegetation and soil. In general, high temperatures and low precipitation in the dry lands lead to poor organic matter production (figure 43). In turn, low organic matter leads to poor aggregation and low aggregate stability, thus causing a high potential of wind and water erosion. Overall, the severity, frequency and extent of erosion are likely to be mostly altered by changes in the rainfall amount and intensity. Also, extreme events, such as droughts, floods, heat waves and wildfires, have a significant impact on land degradation. In the Nahr el Kabir basin, climate change is likely to add further complexity to the above challenges, as greater increases in heavy rainfalls induce floods, whereas greater decreases in precipitation contribute to drought. The projected increase in the number of CDDs, as well as the projected decrease in the number of precipitation days and in that of CWDs are expected to significantly contribute to exacerbating drought conditions. Therefore, attempting to mitigate land degradation is expected to improve land and water productivity.

FIGURE 43: Climate change impact on annual temperature and annual precipitation in the Nahr el Kabir basin

(a)



(b)



Source: Authors.

Note: (a) Mean change in annual temperature compared to the reference period based on an ensemble of six models from the Mashreq Domain, SSP5-8.5. (b) Mean change in annual precipitation compared to the reference period, based on an ensemble of six models from the Mashreq Domain, SSP5-8.5.

In summary, investing in improved land management (e.g., with resource-conserving technologies), can considerably improve on-farm water productivity in both rainfed and irrigated agricultural systems (Bossio and others, 2008). Resource-conserving agriculture (e.g., soil management practices, nutrient management and adaptation of cropping systems) covers a broad range of systems that have the potential to improve water productivity and water management in a variety of ways, especially in low-yielding rainfed systems (Hatfield and others, 2001; Pretty and others, 2006).

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

Main SDGs directly addressed: SDG 15 (targets 15.1. 15.2, 15.3 and 15.5), SDG 6 (target 6.6) and SDG 2 (targets 2.3 and 2.4).

This intervention responds to target 6.6 of the updated National Water Sector Strategy of 2020 for protecting and restoring water-related ecosystems, including mountains, forests, wetlands, etc. It also responds to Lebanon's national voluntary targets regarding Land Degradation Neutrality (LDN), as declared and adopted on July 10, 2017, in the Grand Serail.

5. Stakeholders – institutions, partners, implementing agencies

Farmers, agricultural cooperatives, NGOs, municipalities, unions of municipalities, as well as the MoA, MoE, LARI and NCSR.

6. Activities

- Activity 1: identify smallholder farmers in the targeted area to support their sustainable functioning.
- Activity 2: based on a needs assessment, implement one or a combination of the below activities most suited for each small farmer with an associated capacity development. This will be deployed through 3 pilot projects per sub-activity.

- Activity 2.1: introduce/promote organic farming to avoid artificial additives to the farming system (e.g., inorganic fertilizers and agrochemicals) and to ensure increasing soil organic matter.
- Activity 2.2: introduce crop varieties that are resistant to the impact of climate change.
- Activity 2.3: promote conservation agriculture by combining non-inversion tillage (e.g., minimum or zero tillage) with mulching or cover cropping, and crop rotation.
- Activity 2.4: undertake agroforestry by incorporating trees into agricultural systems and stressing the multifunctional value of trees within those systems.
- Activity 2.5: use an integrated pest management, building on ecosystem resilience and diversity for pest, disease and weed control, while seeking to use pesticides only when other options are ineffective.
- Activity 2.6: work towards an integrated nutrient management, with the objective of balancing the need to fix nitrogen within farm systems with the need to import inorganic/organic sources of nutrients, as well as reducing nutrient losses through erosion control.
- Activity 2.7: adopt integrated livestock systems with the objective of raising overall productivity, diversifying production, using crop byproducts and producing manure.
- Activity 2.8: promote irrigation efficiency by properly designing and implementing pilot drip irrigation network projects, to show farmers how small modifications in irrigation systems can increase irrigation efficiency by up to 40 per cent.

7. Constraints

Stimulating resource-conserving agriculture calls for developing and adopting a policy and interventions at the local level, together with measures to develop an understanding of land use at the landscape level. The introduction of new crop varieties and the adoption of relatively new practices, such as conservation agriculture, agroforestry, integrated pest management and nutrient management, and integrated livestock systems, necessitate national and international support, in view of the lack of resources and the need for extensive experience in these fields.

8. Estimated duration

Forty-eight months

No.	Activity	Time period															
		Year 1				Year 2				Year 3				Year 4			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Identify smallholder farmers in the targeted area.	▨	▨														
2.1	Introduce/promote organic farming.			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
2.2	Introduce crop varieties resistant to the impact of climate change.			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
2.3	Promote conservation agriculture.			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
2.4	Undertake agroforestry.			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
2.5	Use an integrated pest management approach.			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
2.6	Work towards integrated nutrient management.			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
2.7	Adopt integrated livestock systems.			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
2.8	Promote irrigation efficiency by properly designing and implementing pilot drip irrigation network projects.				▨	▨			▨	▨			▨	▨			

9. Estimated cost

A purely indicative cost of $525,000 is estimated for the national forest programme, to mitigate the effect of climate change on selected vulnerable terrestrial ecosystems across the country. Activities covered by this programme include ones similar to those proposed by the intervention in question, mainly activities 2.1 to 2.7.

Activity	Approximate cost ($)
Identify smallholder farmers in the targeted area.	30 000
Introduce/promote organic farming.	100 000
Introduce crop varieties resistant to the impact of climate change.	100 000
Promote conservation agriculture.	50 000
Undertake agroforestry.	100 000
Use an integrated pest management approach.	60 000
Work towards integrated nutrient management.	90 000
Adopt integrated livestock systems.	60 000
Design and implement pilot drip irrigation network projects.	100 000
Total cost	690 000

Note: These numbers are estimates of each activity cost. An extensive assessment, involving field visits and data collection, is needed to define costs more accurately.

D. Selected intervention 4

Title: Improve forest management to reduce wildfires and enhance resilience in the Nahr el Kabir basin.

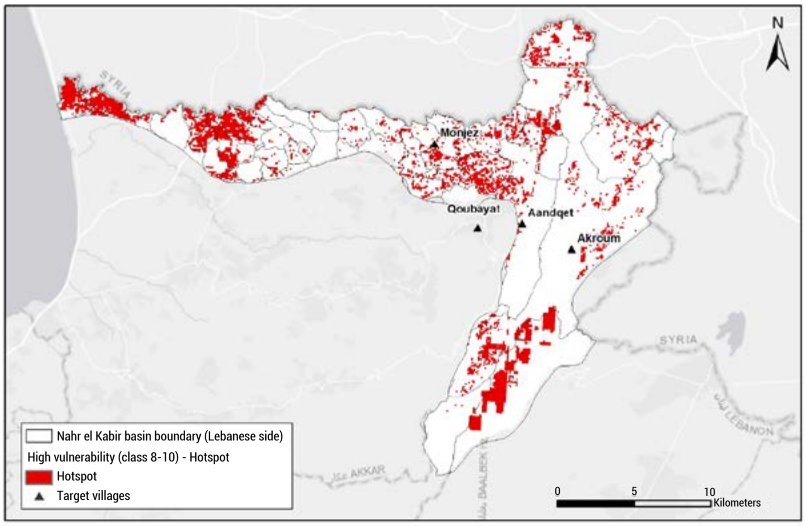
Summary description: the fire risk map of the study area shows relatively large areas of high risk of fires within the basin, mostly in its upper part, where most of the dense forests are located (Mitri and others, 2015). Fire risk management is highly interlinked with the water sector: (1) fire suppression necessitates large volumes of water often not available during the fire season; (2) fire-affected areas are increasingly impacted by flash floods and soil erosion; and (3) the vegetation cover loss due to fires affects both the quality and quantity of water in the basin.

This intervention addresses the need to reduce fire risk mostly through silviculture treatment. The national guidelines for forest management serve as an important toolbox for use in devising local forest management plans based on forest inventories and forest harvesting plans (UNDP, 2019). As a result, managed forests are expected to be less prone to intense and severe fires, and by extension to the impact on soil, water quality and water quantity.

Type: NbS (restoration).

Targeted area: villages/towns with largest hotspot areas of forest lands, especially in the upper part of the basin (e.g., Monjez, Qoubayat, Akroum, Aandqet) (figure 44).

FIGURE 44: Targeted areas for intervention 4 in the Nahr el Kabir basin



Source: Authors.

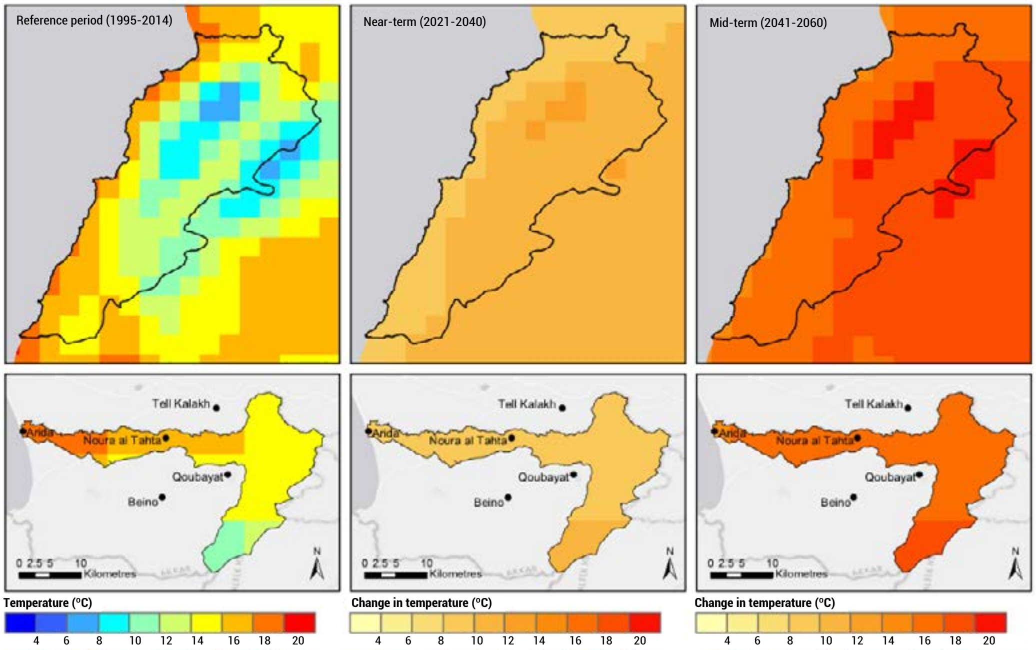
1. Objective

To reduce wildfire risk through vegetation fuel treatment as a means to avoid flash floods and water deterioration in quantity and quality, as well as to reduce using water sources in case of fire events.

2. General description

Uncontrolled and frequent wildfires can have severe negative impacts on human health, livelihoods, natural assets, air and water quality, and biodiversity. Increasing temperatures and drought resulting from climate change are expected to lead to more severe and larger fires at a more frequent basis (figure 45).

FIGURE 45: Mean change in annual temperature in the Nahr el Kabir basin compared to the reference period, based on an ensemble of six models from the Mashreq Domain, SSP5-8.5



Source: Authors.

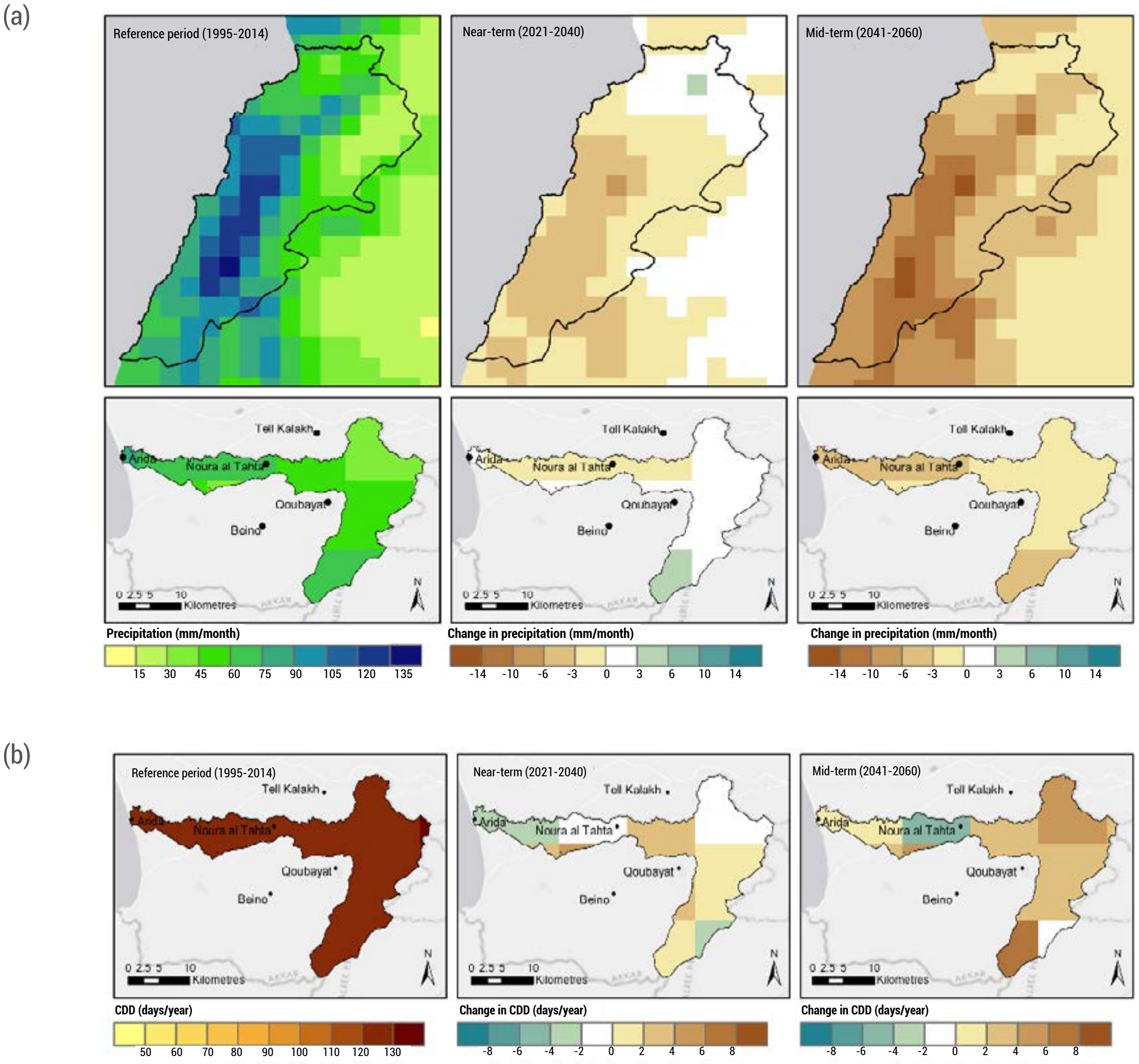
An approach known as integrated fire management is gaining an increased recognition. It entails five key elements (also known as the five Rs): review (monitoring and analysis), risk reduction (prevention), readiness (preparedness), response (suppression) and recovery. The five Rs approach was also adopted in Lebanon's National Forest Fire Management Strategy (Decision No. 52/2009).

Often, wildfires do not stop at the edges of forests, and they may also originate outside forests. Consequently, integrated fire management should encompass other, non-forest land uses and vegetation types, such as agriculture and rangelands.

3. Justification

Greater decreases in precipitation can contribute to drought, and, therefore, to an increased risk of wildfires (figure 46 (a)). Also, greater increases in heavy rainfall following fire events can induce flash floods in fire-affected lands. Moreover, heat waves adversely impact fire spread. Both an increase in the number of CDDs (figure 46 (b)) and a decrease in the number of CWDs can contribute to drought, as well as increase fire hazard.

FIGURE 46: Climate change impact on annual precipitation and maximum length of dry spell in the Nahr el Kabir basin



Source: Authors.

Note: (a) Mean change in annual precipitation in the Nahr el Kabir basin compared to the reference period, based on an ensemble of six models from the Mashreq Domain, SSP5-8.5. (b) Mean change in the maximum length of dry spell (CDD; consecutive days with precipitation <1 mm) compared to the reference period, based on an ensemble of six bias-corrected models from the Mashreq Domain, SSP5-8.5. Blue areas represent decreasing CDDs (wetter conditions) and brown areas represent increasing CDDs (drier conditions).

During the past decade, the basin has experienced its most disastrous fire events, which have affected thousands of hectares of forest, cropland and grassland. Also, unprecedented fires affected forests in high mountain lands (cedar, fir and juniper). Most of these forests are not adapted to fires. In 2021, early in the fire season, more than 1,500 ha in Akkar were lost to fire in only a few days. As wildfires are expected to become more frequent, and increase in intensity and extent, the water quantity and quality, as well as aquatic ecosystems will be impacted. Furthermore, fires can directly impact developed landscape water resources due to fires burning in the wildland-urban interface (WUI), home to a relatively large portion of the basin's population. That being said, risk reduction can reduce dependence on water supplied in case of a fire event and mitigate the impact of fire on water resources.

Overall, Lebanon's National Forest Fire Management Strategy highlights the importance of reducing risk through undertaking targeted silviculture treatment at the local level. The proposed activities under this intervention mostly address interrelationships between water and fires.

Burnt standing trees from the 2021 Qobayat fire-affected forest (photo credit: George Mitri).

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

Main SDGs directly addressed: SDG 15 (targets 15.1. 15.2, 15.4 and 15.5) and SDG 6 (target 6.6).

This intervention responds to target 6.6 of the updated National Water Sector Strategy of 2020 for protecting forests. Also, it responds to the provision and priorities of the National Forest Programme 2015–2025, as well as those of the National Fire Management Strategy and the updated 2020 Nationally Determined Contribution (NDC) of Lebanon. In addition, a strategic plan for managing forests in the area was recently devised by the United Nations Development Programme (UNDP) Land Degradation Neutrality (LDN) project. Two forest management plans were previously developed in the region, one for Monjez forest and another one for Aandqet forest. In addition, a regional forest fire management plan was developed for the Union of North Akkar municipalities.

5. Stakeholders – institutions, partners, implementing agencies

Land managers and landowners, agricultural cooperatives, NGOs, municipalities, unions of municipalities and the MoA.

6. Activities

- Activity 1: update existing forest management plans (for Aandqet and Monjez) and complete the development of additional forest management plans (for Qobayat and Akroum).
- Activity 2: assess the establishment of additional strategic hill lakes or ponds for fire extinguishing purposes.
- Activity 3: undertake preventive silviculture practices, including forest fuel management actions (i.e., grubbing, tree thinning and pruning, brushwood crushing, prescribed burning and controlled grazing) as part of existing forest management plans.
- Activity 4: reduce tree density to minimize tree competition for soil water, as well as curb dieback processes, and dry biomass to speed up tree growth and break continuity between forest layers.

- Activity 5: break landscape homogeneity (i.e., large scrubland territories after agricultural land abandonment) in fire-prone landscapes and facilitate ecological succession processes. The location of the main proposed firebreaks (i.e., defence elements) was identified in the Union of Municipalities of Northern Akkar fire response plan (Mitri, 2018).
- Activity 6: in selected high priority areas, undertake active post-fire restoration procedures, namely soil erosion protection, treatment of burnt trees and assisted recovery, among others.
- Activity 7: apply the best practices of silvo-pastoral systems to reduce fire risk on private and public forest lands.
- Activity 8: enhance the capacity of local authorities, especially through technical training on fire prevention.

7. Constraints

This intervention demands active coordination and engagement between the public and the private sectors. Local community engagement is also needed to ensure adopting the defined activities. Most importantly, effective, constructive and positive communication is key to increase awareness and knowledge about fire risk, while international and national donor engagement and commitment to supporting the activities are essential elements in implementation.

8. Estimated duration

Thirty-six months

No.	Activity	Time period											
		Year 1				Year 2				Year 3			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Update existing forest management plans (for Aandqet and Monjez) and complete the development of additional forest management plans (for Qobayat and Akroum).	■	■										
2	Assess the establishment of hill lakes for fire extinguishing purposes.			■									
3	Undertake preventive silviculture practices.	■				■				■			
4	Reduce tree density.	■				■				■			
5	Break landscape homogeneity in fire-prone landscapes and facilitate ecological succession processes.			■	■			■	■			■	■
6	Undertake active post-fire restoration procedures.				■				■				■
7	Apply best practices of silvo-pastoral systems to reduce fire risk on private and public forest lands.	■				■				■			
8	Enhance the capacity of local authorities through technical training on fire prevention.		■				■				■		

9. Estimated cost

Activity	Approximate cost ($)
Update existing forest management plans and complete the development of additional forest management plans.	200 000
Assess the establishment of hill lakes for fire extinguishing purposes.	20 000
Undertake preventive silviculture practices.	140 000
Reduce tree density.	70 000
Break landscape homogeneity in fire-prone landscapes and facilitate ecological succession processes (1 pilot action for an estimated area of 1 ha).	70 000
Undertake active post-fire restoration procedures in selected areas.	2 000 000
Apply best practices of silvo-pastoral systems to reduce fire risk on private and public forest lands.	140 000
Enhance the capacity of local authorities through technical training on fire prevention.	15 000
Total cost	2 655 000

Note: These numbers are estimates of each activity cost. An extensive assessment, involving field visits and data collection, is needed to define costs more accurately.

E. Selected intervention 5

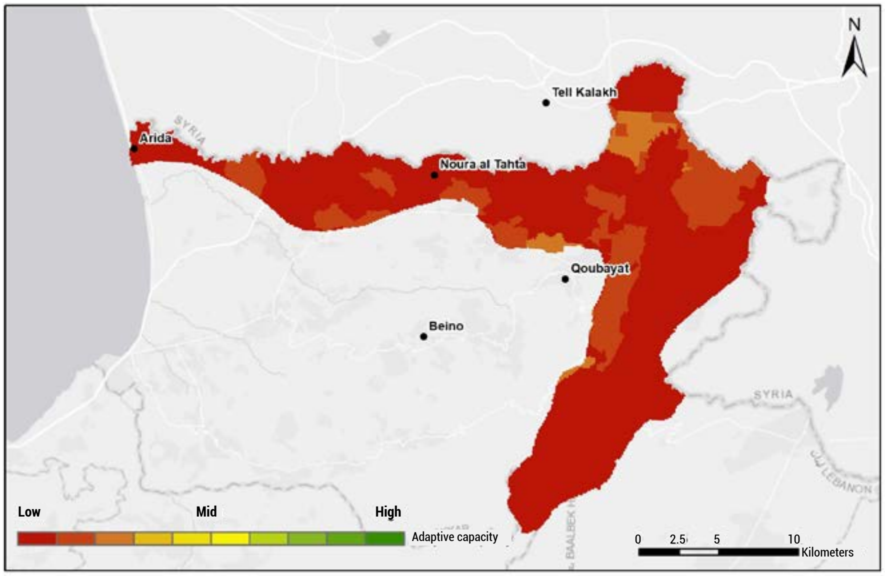
Title: Improve knowledge management in the water sector at the basin level and build local stakeholders' capacities.

Summary description: proper water management for improved resilience at the basin level is particularly dependent on strong capacity, solid knowledge base and awareness at all levels, including individuals (with their knowledge, experience, skills and attitudes), organizations (operating through procedures, knowledge management and incentive systems), sector institutions, and what may be termed the enabling environment (i.e., the legal, fiscal, policy and administrative frameworks). Nevertheless, getting all levels to operate in a coherent manner is very challenging. Given the reliance on up-to-date, relevant scientific knowledge and experience, as well as comprehensive data collection routines and monitoring of the physical environment and technological infrastructure, regional stakeholders at the basin level need to have access to sound knowledge management in the water sector and other closely dependent sectors (e.g., agriculture).

Type: knowledge-based.

Targeted area: the entire basin has a low adaptive capacity (figure 47). This is mostly due to the marginalization of rural areas in Akkar in terms of services for a relatively long period of time. This intervention aims at improving water governance and knowledge in the water sector at the level of the Nahr el Kabir basin to increase its climate adaptive capacity and reduce its vulnerability.

FIGURE 47: Adaptive capacity composite indicator in the Nahr el Kabir basin



Source: Authors.

1. Objective

This intervention aims to improve water resource management through building capacities, and through the generation and dissemination of reliable, scientific information and knowledge pertaining to the water sector and other dependent sectors.

2. General description

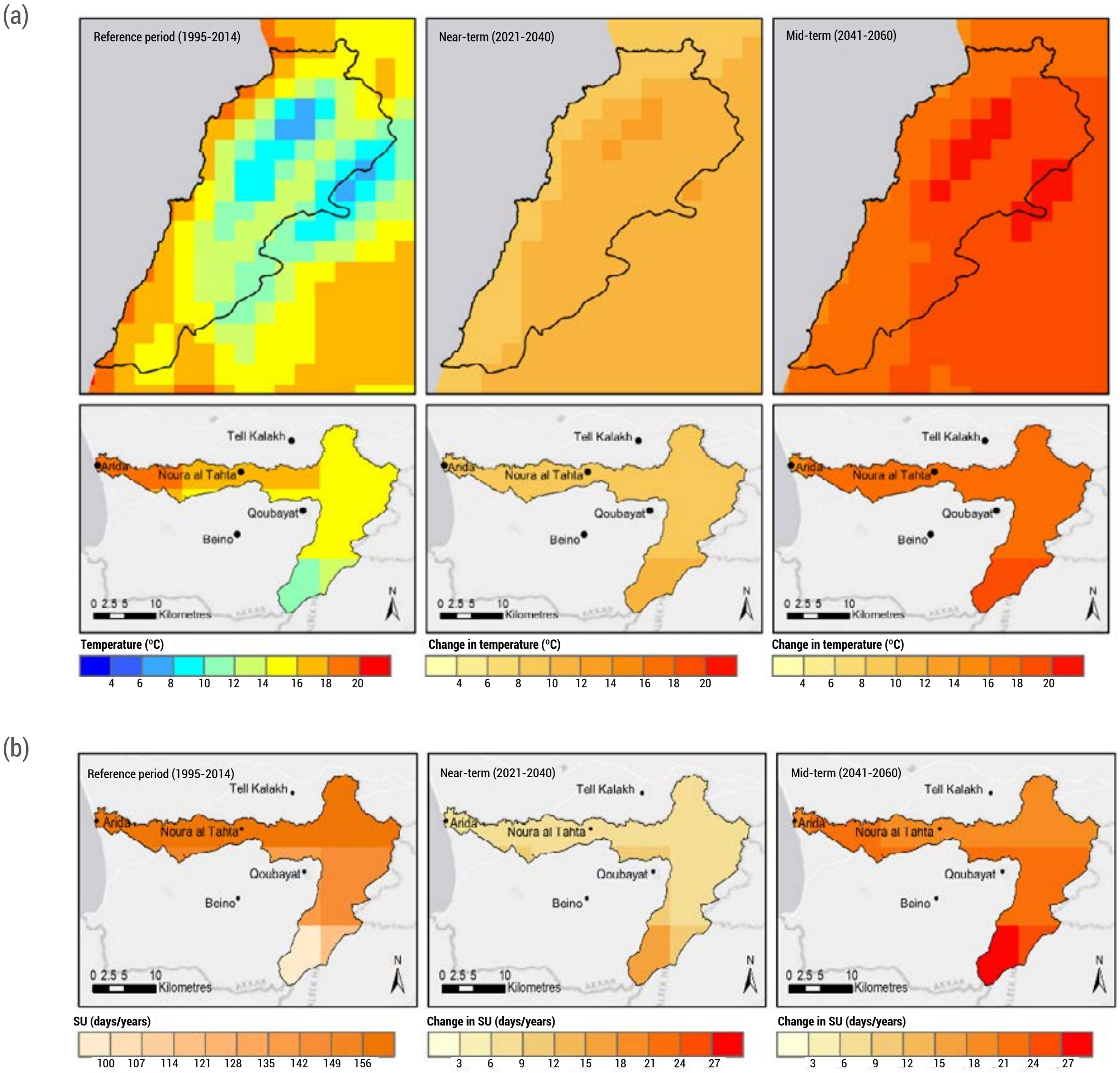
The management of water resources for sustainable use is a technically and politically difficult challenge for certain societies, especially in the rural areas of Akkar. To be effective, knowledge systems that support decisions about water resource management and water conservation in agriculture must link research and experience-based knowledge to practices across a broad range of challenges.

It is expected that increased stakeholder engagement and integration in planning and implementation activities, greater attention to resolving uncertainties, and improved focus on adaptive management will lead to a more efficient, sustainable use of water resources, while optimizing water use in other dependent sectors, such as agriculture.

3. Justification

Given the uncertainty in the climate change sector, scientists, policy makers and water users need to engage with scientific knowledge throughout a lengthy and complex decision-making process. The said scientific knowledge pertains to water quality and freshwater resources. On that basis, the actors involved need to undertake the appropriate mitigation and adaptation measures in due time. Projected increases in temperature in the Nahr el Kabir basin averaged 1°C for the near-term (2021–2040) and 2°C for the mid-term (2041–2060), with a minimum to maximum rising gradient from the sea to the mountains (figure 48 (a)). Crops are sensitive to temperature extremes, inducing adverse results on crop phenology and yield. Temperature thresholds for cereal crops, such as wheat and barley, are well defined. For this reason, it is important to evaluate temperature extremes in tandem with average annual temperature. Furthermore, correlating with temperature, climate projections reveal an increase in the number of summer days (SU)[5] for the basin area by about 4.6 days per decade. During the reference period, the SU was highest nearest the coast and followed a decreasing gradient as the elevation increased. However, the SU change was projected to be greater in mountainous areas (figure 48 (b)).

FIGURE 48: Climate change impact on annual temperature and annual number of summer days in the Nahr el Kabir basin



Source: Authors.

Note: (a) Mean change in annual temperature in the Nahr el Kabir basin compared to the reference period, based on an ensemble of six models from the Mashreq Domain, SSP5-8.5. (b) Mean change in the annual number of summer days (SU; days when Tmax >25°C) compared to the reference period, based on an ensemble of six bias-corrected models from the Mashreq Domain, SSP5-8.5.

In this context, there is a need to build up knowledge about climate-resistant crops and improve communication with farmers. The selection of such crops should rely on studies to assess their financial feasibility and viability, and, most importantly, their industrial processing that can provide farmers with higher returns. The wastewater issue is an example of the need to better communicate with farmers and give them evidence to show that improved water quality reflects positively on their yield and financial income. In terms of management, previously conducted consultations with local and national stakeholders highlighted the need to:

- Adopt an integrated water management approach and an efficient coordination mechanism among all stakeholders.
- Seek an efficient mechanism to apply the existing Law 192/2020 stipulating the establishment of a water users' association; the Law has not been enacted yet.

Overall, it is increasingly important to collect more scientific knowledge about the sustainable use of water and other natural resources, and to share this knowledge with as many people and organizations as possible. Sharing knowledge can lead to training people who can further develop and disseminate this knowledge.

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

Main SDGs directly addressed: SDG 4 (target 4.7) and SDG 6 (targets 6.5, 6.a and 6.b).

This intervention responds to target 6.5 of the updated National Water Sector Strategy of 2020 for implementing integrated water resource management.

5. Stakeholders – institutions, partners, implementing agencies

Land managers and landowners, agricultural cooperatives, NGOs, municipalities, unions of municipalities, as well as the MoEW, NLWE, MoA, MoE, LARI and NCSR.

6. Activities

- Activity 1: assess existing agrometeorological stations, direct-reading rainfall stations, and flows and water yields measuring stations, as well as identify locations for new stations in collaboration with relevant institutions, such as the MoEW, LARI, LRA and the Meteorological Department at the Directorate General of Civil Aviation, as well as other relevant institutions and stakeholders. This activity may also take into consideration existing work on water accounting.
- Activity 2: deploy new automatic agrometeorological stations and direct-reading rainfall stations in collaboration with mandated institutions, such as the MoEW, LARI, LRA and the Meteorological Department at the Directorate General of Civil Aviation, as well as other relevant institutions and stakeholders.
- Activity 3: establish stations for measuring flows and water yields in collaboration with mandated institutions, such as the MoEW and LRA.
- Activity 4: select a pilot hotspot area to conduct a hydrological study and an assessment of the impact of rainfall patterns variations on crop variation and yield in the project area.
- Activity 5: research the introduction and adoption of new crop varieties better adapted to trending climatic conditions and devise a communication plan with the relevant stakeholders.
- Activity 6: devise and adopt a drought mitigation plan for the Nahr el Kabir basin, establish a drought early warning protocol, and develop an organizational framework to implement and update the plan at the basin level. This should be done in collaboration with relevant national stakeholders, and taking into account the drought action plan and early warning system under development by the MoEW.
- Activity 7: improve local knowledge on climate resilience of the water sector
    - Activity 7.1: organize capacity building sessions for local and regional water actors on the integration of meteorological data and climate risk into planning, as well as on methods, techniques and tools for optimizing the management of water resources and services.
    - Activity 7.2: improve thematic dialogue on water resources and climate resilience, and consequently pool regional stakeholder resources through creating a community of experts on water sector climate resilience.

- Activity 7.3: develop awareness and training materials for users and beneficiaries on water quality and quantity under a climate change scenario. Awareness and training can be used to set up an early warning and disaster risk reduction operational plan, for example.
- Activity 7.4: raise awareness among local elected authorities and other stakeholders on climate change risks impacting the water sector.

7. Constraints

It is essential to: (i) build an operational and sustainable institutional framework to ensure proper management of the water sector, while allowing the development of sustainable and efficient services; (ii) set up financial mechanisms allowing the sustainability and financial balance of the services; and (iii) involve all actors in the service chain and establish sustainable collaboration and coordination mechanisms to improve sector monitoring and transparency. Other constraints include the ability to install and operate automated agrometeorological stations because of their relatively high maintenance and operation costs.

8. Estimated duration

Twenty-four months

No.	Activity	Time period							
		Year 1				Year 2			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Assess agrometeorological stations, direct-reading rainfall stations, and flows and water yields measuring stations, as well as identify locations for new stations.	■	■						
2	Deploy new automatic agrometeorological stations and direct-reading rainfall stations.			■	■	■			
3	Establish stations for measuring flows and water yields.			■	■	■			
4	Select a pilot hotspot area to conduct a hydrological study and an assessment of the impact of rainfall patterns variations on crop variation and yield in the project area.			■					
5	Research the introduction and adoption of new crop varieties better adapted to trending climatic conditions and devise a communication plan with relevant stakeholders.			■	■	■			
6	Devise and adopt a drought mitigation plan, establish a drought early warning protocol and develop an organizational framework to implement and update the plan.					■	■	■	
7.1	Organize capacity building sessions for local and regional water actors on the integration of meteorological data and climate risk into planning, as well as on methods, techniques and tools for optimizing the management of water resources and services.						■	■	■
7.2	Improve thematic dialogue on water resources and climate resilience and consequently pool regional stakeholder resources through creating a community of experts on water sector climate resilience.					■	■	■	■
7.3	Develop awareness and training materials for users and beneficiaries on water quality and quantity under a climate change scenario.			■	■				
7.4	Raise awareness among local elected authorities and other stakeholders on climate change risks affecting the water sector.					■	■	■	■

9. Estimated cost

In reference to the updated version of the water sector strategy 2020, the following costs were estimated at the basin level based on various assumptions: (1) $75,000 for enhancing water sector monitoring, (2) $50,000 to enhance communication with users, (3) S35,000 for meteorological network expansion and (4) $42,600 for selected hydrometric network improvement.

Activity	Approximate cost ($)
Assess agrometeorological stations, direct-reading rainfall stations, and flows and water yields measuring stations, as well as identify locations for new stations.	75 000
Deploy new automatic agrometeorological stations and direct-reading rainfall stations.	35 000
Establish stations for measuring flows and water yields.	45 000
Select a pilot hotspot area to conduct a hydrological study and an assessment of the impact of rainfall patterns variations on crop variation and yield in the project area.	15 000
Research the introduction and adoption of new crop varieties better adapted to trending climatic conditions, and devise a communication plan with relevant stakeholders.	45 000
Devise and adopt a drought mitigation plan, establish a drought early warning protocol and develop an organizational framework to implement and update the plan.	50 000
Organize capacity building sessions for local and regional water actors on the integration of meteorological data and climate risk into planning, as well as on methods, techniques and tools for optimizing the management of water resources and services.	20 000
Improve thematic dialogue on water resources and climate resilience, and consequently pool regional stakeholder resources through creating a community of experts on water sector climate resilience.	30 000
Develop awareness and training materials for users and beneficiaries on water quality and quantity under a climate change scenario.	15 000
Raise awareness among local elected authorities and other stakeholders on climate change risks affecting the water sector.	20 000
Total cost	350 000

Note: These numbers are estimates of each activity cost. An extensive assessment, involving field visits and data collection, is needed to define costs more accurately.

ANNEX 1. FIELD SURVEY FORMS

Increasing the Nahr el Kabir basin resilience to climate change

تعزيز منعة حوض نهر الكبير لمواجهة آثار تغيّر المناخ

Agricultural crops

المحاصيل الزراعية

	Survey number رقم الاستمارة
	Date التاريخ

Name | الاسم		
Family Name | الشهرة		
Organization | اسم المؤسّسة		
Position within the organization | المسمّى الوظيفي ضمن المؤسّسة		
Location of the organization | موقع المؤسّسة		
Gender | الجنس	☐ **Male** | رجل	☐ **Female** | امرأة
Phone | رقم الهاتف		
Email | البريد الإلكتروني		

The answers you provide in this form are confidential and will neither be disclosed nor discussed under your name.

الأجوبة التي تمنحها ضمن هذه الاستمارة هي أجوبة سرّية ولن يتم الكشف عنها أو مداولتها تحت اسمك.

1. In your opinion, should attention be lent to the impact of climate change on crop production?

في رأيك، هل يجب الاهتمام بآثار تغيّر المناخ في إنتاج المحاصيل؟

☐	(a) Certainly, crop production is a priority in ensuring food security.	(أ) بالتأكيد، فإنتاج المحاصيل أولويّة لضمان الأمن الغذائي.
☐	(b) It seems very likely that climate change has an impact on crop production.	(ب) من المرجّح جدًا أنّ لتغيّر المناخ تأثير في المحاصيل.
☐	(c) It does not count as a great concern in light of the other challenges at hand.	(ج) ليس مصدر قلق كبير، فتواجه البشريّة تحدّيات أخرى.
☐	(d) Climate change is not a priority for the basin.	(د) تغيّر المناخ ليس أولويّة بالنسبة إلى الحوض

2. In your opinion, what are the most important agricultural crops (other than fruit trees) that should be studied to determine the effects of climate on productivity?

في رأيك، ما هي أهم المحاصيل الزراعيّة (من غير الأشجار المثمرة) التي يجب دراستها لتحديد آثار المناخ في الإنتاجيّة؟

	(a) Crop (أ) المحصول	(b) Reason for importance (ب) سبب الأهميّة	(c) Do you deal with this crop? (ج) هل تتعامل بهذا المحصول؟	(d) If the answer is yes, how? (agriculture, trade, processing, research...) (د) إذا كانت الإجابة نعم، الرجاء تحديد طبيعة التعامل (زراعة أم تجارة أم تصنيع أم إجراء أبحاث...)؟
1				
2				
3				
4				
5				

3. In your opinion, what are the main priorities that should be addressed to increase the resilience of crops threatened by climate change?

في رأيك، ما هي أبرز الأولويات التي يجب تناولها لتعزيز منعة المحاصيل المهدّدة بفعل تغيّر المناخ؟

☐	(a) Training on technology use	(أ) التدريب على استخدام التكنولوجيا
☐	(b) Ensuring energy availability and affordability	(ب) توافر الطاقة بكلفة ميسّرة
☐	(c) Enhancing education and research	(ج) تعزيز التعليم والبحث
☐	(d) Encouraging public participation	(د) تشجيع المشاركة العامّة
☐	(e) Providing of financial support	(هـ) تقديم الدعم المادّي
☐	(f) Other, please specify	(و) غير ذلك، يُرجى التحديد

Increasing the Nahr el Kabir basin resilience to climate change
تعزيز منعة حوض نهر الكبير لمواجهة آثار تغيّر المناخ

Indicators for assessing the vulnerability of the water sector in the basin
مؤشّرات تقييم قابليّة تأثّر قطاع المياه في الحوض

Survey number **رقم الاستمارة**	
Date **التاريخ**	

Name | الاسم **Organization | اسم المؤسّسة** **Position within the organization | المسمّى الوظيفي ضمن المؤسّسة**		**Family name | الشهرة**	
Location of the organization **موقع المؤسّسة**			
Gender | الجنس	**Male | رجل**		**Female | امرأة**
Phone | رقم الهاتف			
Email | البريد الإلكتروني			

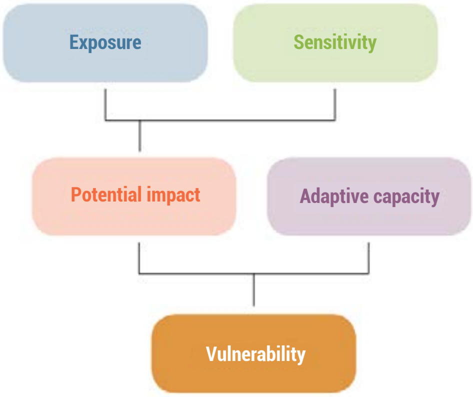
The answers you provide in this form are confidential and will neither be disclosed nor discussed under your name.

الأجوبة التي تمنحها ضمن هذه الاستمارة هي أجوبة سريّة ولن يتم الكشف عنها أو مداولتها تحت اسمك.

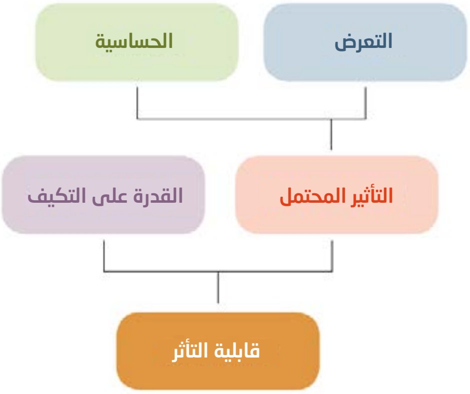
The integrated vulnerability assessment methodology is based on an understanding of vulnerability as a function of a system's climate change exposure, sensitivity and adaptive capacity to cope with climate change effects. The potential impact is determined by the combination of a system's exposure and sensitivity to climate change.

تستند المنهجيّة المتكاملة لتقييم قابليّة التأثّر إلى فهم الأخيرة من منظور تعرّض النظام لتغيّر المناخ، والحساسية له، والقدرة على التكيف مع آثاره. والأثر المحتمل هو الجمع بين تعرّض النظام لتغيّر المناخ وحساسيته له.

Components of vulnerability based on the IPCC AR4 approach



مكوّنات قابلية التأثر استناداً إلى تقرير التقييم الرابع للهيئة الحكومية الدولية المعنية بتغيّر المناخ



Part 1. Exposure

Exposure refers to changes in climate parameters that may affect socioecological systems. Such parameters include factors such as temperature and precipitation, which climate change alters in terms of quantity and quality, as well as spatial and temporal distribution.

يشير التعرّض إلى التغيّرات في البارامترات المناخيّة التي قد تؤثّر في النظم الإيكولوجيّة-الاجتماعيّة. وتشمل هذه البارامترات، على سبيل المثال، درجة الحرارة والمتساقطات، التي تتغيّر بفعل تغيّر المناخ من ناحية الكميّة والنوعيّة والتوزّع المكاني والزمني

Assign a grade of 1 to 10 for each indicator according to its negative impact on the water sector in the basin towards climate change.

ضع علامة من 1 إلى 10 لكل مؤشر حسب تأثيره السلبي على قطاع المياه في الحوض من حيث تغيّر المناخ

Indicator type **نوع المؤشّر**	**Suggested indicators** **Indicators for assessing the vulnerability of the water sector in the basin** **المؤشّرات المقترحة** **مؤشّرات تقييم قابليّة تأثّر قطاع المياه في الحوض**	**Grade (1 to 10; 1 for least important negative impact and 10 for most important)** **العلامة (من 1 إلى 10، على أن تمثّل علامة 1 التأثير السلبي الأقل أهميّة و10 الأكثر أهميّة)**
Climate modelling النمذجة المناخيّة	Change in temperature تغيّر في درجة الحرارة	
	Change in precipitation تغيّر في هطول الأمطار	
Hydrological modelling النمذجة الهيدرولوجيّة	Change in run-off تغيّر في معدّل الجريان السطحي	
	Change in evapotranspiration تغيّر في التبخّر والنتح	
Indicators of extreme weather events مؤشّرات الظواهر الجويّة الشديدة	Change in snow cover (in terms of area) تغيّر في النسبة المئوية للغطاء الثلجي (من حيث المساحة)	
	Change in snow depth تغيّر في عمق الثلج	
	Change in the number of hot days تغيّر في عدد الأيّام الحارّة	
	Change in the number of days of heavy precipitation تغيّر في عدد أيّام هطول الأمطار الغزيرة	
	Change in the frequency of drought (number of years and their proximity to each other) تغيّر في وتيرة الجفاف (عدد السنين وتقارب بعضها من البعض الآخر)	
	Change in drought severity تغيّر في شدّة الجفاف	
	Change in the maximum length of dry periods (in the same year) تغيّر في الطول الأقصى لفترات الجفاف (في العام نفسه)	
Other - please specify Please specify the source of data on the indicator غير ذلك - يُرجى التحديد كذلك يُرجى تحديد مصدر البيانات حول المؤشّر		

Part 2. Sensitivity

Sensitivity provides information about the status quo of the physical and natural environment that makes the affected systems particularly susceptible to climate change. For example, a sensitivity factor could be topography, land use, land cover, distribution and density of population, built environment, proximity to the coast, etc.

تقدّم الحساسيّة معلومات عن الوضع الحالي للبيئة الماديّة والطبيعيّة التي تجعل النظم تتأثّر بتغيّر المناخ بشكل خاص. فعلى سبيل المثال، قد يتمثّل عامل الحساسية بالتضاريس، واستخدام الأراضي وغطائها، وتوزّع السكّان والكثافة السكّانيّة، والبيئة المبنيّة، والقرب من الساحل، وما إلى ذلك

Assign a grade from 1 to 10 for each indicator according to its importance that makes the environmental and physical systems, especially those related to the water sector, particularly affected by climate change.

ضع علامة من 1 إلى 10 لكل مؤشّر حسب أهميّته على مستوى جعل النظم البيئيّة والماديّة تتأثر بتغيّر المناخ بشكل خاص، ولا سيّما تلك المتعلّقة بقطاع المياه

Indicator type نوع المؤشّر	Suggested indicators Indicators for assessing the vulnerability of the water sector in the basin المؤشّرات المقترحة مؤشّرات تقييم قابليّة تأثّر قطاع المياه في الحوض	Grade (from 1 to 10: 1 for least important 10 for most important) العلامة (من 1 إلى 10، على أن تمثّل علامة 1 الأهميّة الأقل و10 الأهميّة الأكبر)
Population السكّان	Percentage of elderly (age 65+) نسبة كبار السن (65+ سنة)	
	Population density الكثافة السكانيّة	
	Total available renewable water per capita إجمالي المياه المتجدّدة المتوافرة للفرد الواحد	
	Water consumption per capita استهلاك المياه للفرد الواحد	
	Share of water consumption in agriculture نسبة استهلاك المياه في الزراعة	
	Refugee population السكّان اللاجئين	

Natural environment البيئة الطبيعيّة	Slope gradient درجة الانحدار	
	Soil type (storage capacity) نوع التربة (سعة التخزين)	
	Potential soil erosion hazard مخاطر الانجراف	
	Land cover and land use (including urban extent) الغطاء الأرضي واستخدام الأراضي (بما فيها النطاق الحضري)	
	Grassland and agricultural biomass (above-ground carbonated biomass) الكتلة الحيويّة للأراضي العشبيّة والزراعيّة (الكتلة الحيويّة الكربونيّة فوق الأرض)	
	Desertification - land degradation التصحّر - تدهور الأراضي	
	Fire risk التعرّض للحرائق	
	Livestock density كثافة الثروة الحيوانيّة (الماشية)	
	Land productivity إنتاجيّة الأراضي	
Human-caused بفعل الإنسان	River and coastal flood hazards خطورة الفيضانات النهريّة والساحليّة	
	Percentage of irrigation using groundwater نسبة الري باستخدام المياه الجوفيّة	
.Other - please specify Please specify the data .source on the indicator غير ذلك - يُرجى التحديد كذلك يُرجى تحديد مصدر البيانات حول المؤشّر		

Part 3. Adaptation

Assign a grade from 1 to 10 for each indicator according to its significance in contributing to adaptation to climate change, in particular in the water sector.

ضع علامة من 1 إلى 10 لكلّ مؤشّر بحسب أهميّته في الإسهام بالتكيف مع تغيّر المناخ وخاصّة في قطاع المياه

Indicator type نوع المؤشّر	Suggested indicators Indicators for assessing the vulnerability of the water sector in the basin المؤشّرات المقترحة مؤشّرات تقييم قابليّة تأثّر قطاع المياه في الحوض	Grade (from 1 to 10: 1 for least important 10 for most important) العلامة (من 1 إلى 10، على أن تمثّل علامة 1 الأهميّة الأقل و10 الأهميّة الأكبر)
Infrastructure - water and sanitation services البنية التحتيّة - المياه وخدمات الصرف الصحّي	Road network density كثافة شبكة الطرقات	
	State of water network حالة شبكة المياه	
	Water source (multiple drinking water sources: public network, artesian well, bottled water…) مصدر المياه (تعدّد مصادر مياه الشفة: شبكة عامّة، بئر ارتوازية، مياه معبأة…)	
	Number and type of irrigation water sources عدد مصادر مياه الري ونوعها	
	State of irrigation channels حالة قنوات الري	
	Access to improved water الحصول على مياه محسّنة	
	Access to improved sanitation services الحصول على خدمات الصرف الصحّي المحسّنة	
	Areas equipped for irrigation المناطق المجهّزة للري	
	Areas served by dams المناطق التي تخدمها سدود	
Infrastructure - energy البنية التحتية - الطاقة	Access to electricity الحصول على الكهرباء	
	Energy consumption استهلاك الطاقة	
Technology التكنولوجيا	حالة شبكة الهاتف State of phone network	
	شبكات البيانات الخلويّة Cellular data networks	

Knowledge and awareness المعرفة والوعي	Number of schools per town/village population عدد المدارس بالنسبة إلى عدد سكّان البلدة/ القرية	
	Enrolment in university education الالتحاق بالتعليم الجامعي	
	Internet availability توافر الإنترنت	
Economic resources الموارد الاقتصادية	Total number of SMEs إجمالي عدد المؤسّسات التجاريّة المتوسّطة والصغيرة الحجم	
Equity الإنصاف	Percentage of women working in agriculture نسبة النساء العاملات في الزراعة	
	Literacy rate of women compared to men معدل إلمام النساء بالقراءة والكتابة مقارنة بالرجال	
	Youth percentage (24-15 years) نسبة الشباب (24-15 سنة)	
	Immigrant/refugee index مؤشّر المهاجرين/اللاجئين	
Institutions المؤسّسات	Number of health centres عدد المراكز الصحيّة	
	Number of associations targeting youth عدد الجمعيّات التي تستهدف الشباب	
	Disaster Risk Management Committees اللجان المعنيّة بالحد من مخاطر الكوارث	
Other - please specify. Please specify the source of data on the indicator غير ذلك - يُرجى التحديد يرجى تحديد مصدر البيانات حول المؤشّر		

ANNEX 2. STAKEHOLDER MAPPING

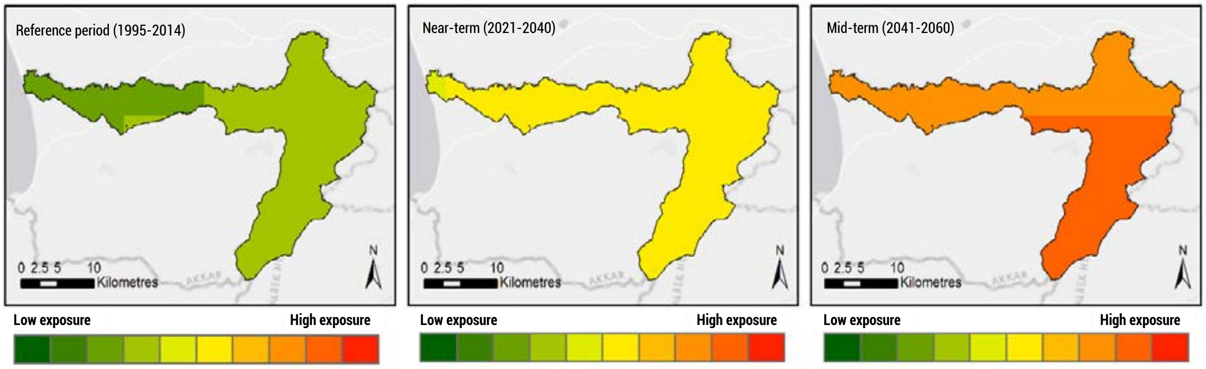
Responsibilities of governmental and non-governmental organizations in the water sector toward the basin.

	Responsibilities	MoEW	NLWE	LRA	MoE	MoPH	MoA (including DGC and GP)	MoI	MoIM	MoPWT	CDR	Municipalities	Union of municipalities	Cooperatives	LARI	Research centres	Industries	NGOs	INGOs
Policy making	Define sector policy, institutional roles and structures; enactment of regulation	X																	
Planning	Establish water and wastewater public plans	X			X						x								
	Undertake water rationalization	X	X	X			X					X	X				X	x	
	Assess infrastructure and investment requirement	X	X	X			X				X	X	X				X		
	Prepare potable and irrigation water transmission, as well as distribution networks projects	X	X	X			X		X										
	Execute plans and investment programmes	X	X	X			X				X	X	X				X		
	Ensure environmental safeguarding of plans and major projects (e.g., SEAs, EIAs/IEEs)				X														
	Allocate water resources across regions	X	X	X	X		X					X	X						
	Promote water conservation campaigns	X	X	X	X		X					X	X						
Planning and implementation (land)	Review and approve urban master plans									X		X	X						
	Review decisions related to construction and parcelling licences									X		X	X						
	Devise and review urban master plans									X		X	X						
	Undertake zoning classification				X		X	X		X		X	X						
	Determine environmental conditions for zoning classification	X			X		X												
	Conduct land terracing and water harvesting						X												
Regulation and enforcement (water)	Issue and enforce water resource protection regulations and standards	X			X	X		X	X										
	License wells and all water extractions (e.g., groundwater, rivers and public water resources)	X																	
	Practice oversight over all public institutions working in the sector	X																	
	Ensure compliance of drinking water with local and international standards					X													

	Responsibilities	MoEW	NLWE	LRA	MoE	MoPH	MoA (including DGC and GP)	MoI	MoIM	MoPWT	CDR	Municipalities	Union of municipalities	Cooperatives	LARI	Research centres	Industries	NGOs	INGOs
Regulation and enforcement (land)	Propose urban planning regulations									X		X							
	Enforce urban and zoning regulations								X										
	Enforce EIA and/or IEE				X														
	Review, update and enforce forest laws and regulations						X												
	Protect rivers and waterways	X			X												X		
Operation and distribution (water)	Prepare land-use programmes and plans	X																	
	Recommend tariffs on water		X														X		
	Maintain and renew infrastructure		X								X	X	X						
	Monitor local weather forecast, alerts and monitoring														X				
Operation and distribution (land)	Provide advice in the licensing and operation of quarries and mines	X			X					X			X						
	Improve land productivity						X								X				
	Increase the competitiveness of vegetable value chain																X	X	X
Control and monitoring	Undertake continuous hydrogeological studies and data gathering	X	X	X								X	X				X		
	Implement service quality and contingency planning	X	X									X	X				X		
	Monitor the quality of water resources	X		X								X	X						
	Monitor drinking water quality		X			X						X	X						
Research and innovation (water and land)	Advance research on water and watershed themes Promote innovative tools for improved management of resources															X		X	X
Awareness and capacity building and emergency response (water and land)	Undertake awareness activities on water saving and efficient use Build capacities of local authorities for improved management of water resources													X				X	
	Manage refugees' needs response											X						X	X

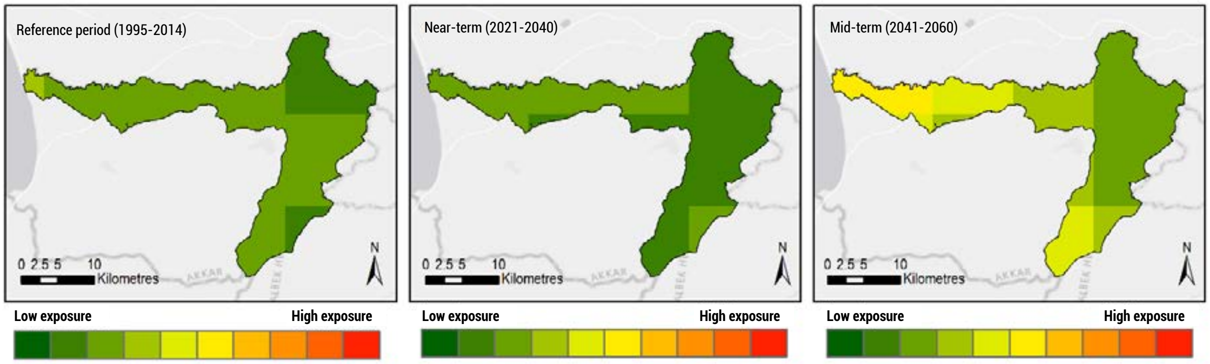
ANNEX 3. INDICATORS, FACT SHEETS AND MAPS

Change in temperature		
Vulnerability component	Exposure	
Description	Change in temperature for reference period (1995–2014), near-term (2021–2040) and mid-term (2041–2060), based on an ensemble of six bias-corrected regional climate modelling outputs for the SSP5-8.5 scenario.	
VA classes and ranges	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	An increase 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 of value classification and transformation	Manual classification based on equal intervals	
Indicator maps		



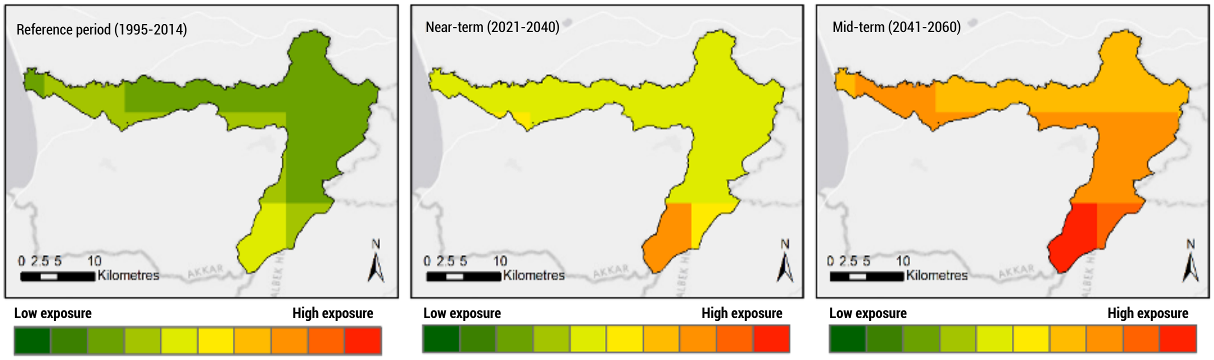
Source: Authors.

<table>
<tr><th colspan="3">Change in precipitation</th></tr>
<tr><td>Vulnerability component</td><td colspan="2">Exposure</td></tr>
<tr><td>Description</td><td colspan="2">Change in precipitation for reference period (1995–2014), near-term (2021–2040) and mid-term (2041–2060), based on an ensemble of six bias-corrected regional climate modelling outputs for the SSP5-8.5 scenario.</td></tr>
<tr><td rowspan="10">VA classes and ranges</td><td>1 (low exposure):</td><td>0 mm/month</td></tr>
<tr><td>2:</td><td>|0.0–1.5|</td></tr>
<tr><td>3:</td><td>|1.5–3.0|</td></tr>
<tr><td>4:</td><td>|3.0–4.5|</td></tr>
<tr><td>5:</td><td>|4.5–6.0|</td></tr>
<tr><td>6:</td><td>|6.0–7.5|</td></tr>
<tr><td>7:</td><td>|7.5–9.0|</td></tr>
<tr><td>8:</td><td>|9.0–10.5|</td></tr>
<tr><td>9:</td><td>|10.5–12.0|</td></tr>
<tr><td>10 (high exposure):</td><td>|>12|</td></tr>
<tr><td>Influence on vulnerability</td><td colspan="2">Greater increases in precipitation can induce floods, whereas greater decreases in precipitation can contribute to drought.</td></tr>
<tr><th colspan="3">Data information</th></tr>
<tr><td>Type of data</td><td colspan="2">Raster</td></tr>
<tr><td>Resolution</td><td colspan="2">10 km x 10 km projections</td></tr>
<tr><td>Unit of measurement</td><td colspan="2">mm/month</td></tr>
<tr><td>Methodology of value classification and transformation</td><td colspan="2">Manual classification based on equal intervals</td></tr>
<tr><th colspan="3">Indicator maps</th></tr>
</table>



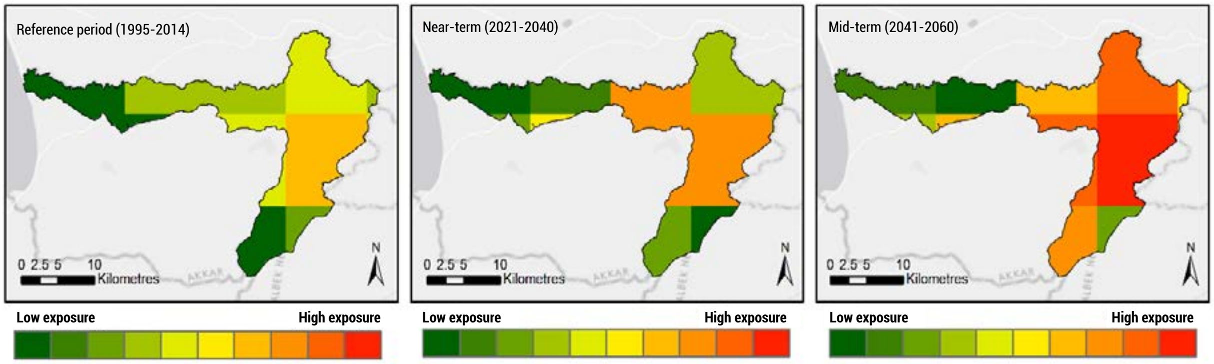
Source: Authors.

Change in number of summer days (SU25)		
Vulnerability component	Exposure	
Description	Change in number of summer days/days when Tmax >25°C for reference period (1995–2014), near-term (2021–2040) and mid-term (2041–2060), based on an ensemble of six bias-corrected regional climate modelling outputs for the SSP5-8.5 scenario.	
VA classes and ranges	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	Heat waves adversely impact water availability.	
Data information		
Type of data	Raster	
Resolution	10 km x 10 km projections	
Unit of measurement	Days/year	
Methodology of value classification and transformation	Manual classification based on equal intervals	
Indicator maps		



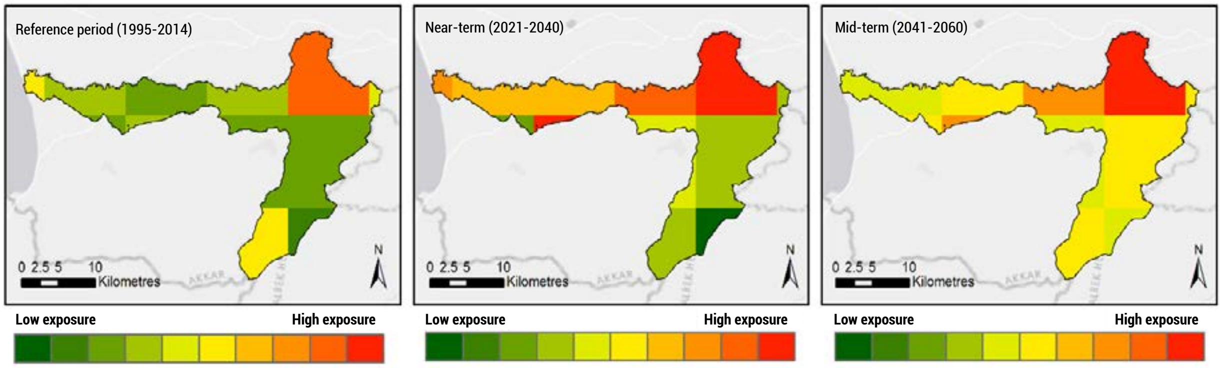
Source: Authors.

Change in consecutive dry days (CDD)		
Vulnerability component	Exposure	
Description	Change in CDD (<1 mm)/maximum length of dry spell for reference period (1995–2014), near-term (2021–2040) and mid-term (2041–2060), based on an ensemble of six bias-corrected regional climate modelling outputs for the SSP5-8.5 scenario.	
VA classes and ranges	1 (low exposure):	≤0 days/year
	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	An increase in the number of CDD can contribute to drought and decrease water availability. Areas with no change or decreasing CDD have low exposure.	
Data information		
Type of data	Raster	
Resolution	10 km x 10 km projections	
Unit of measurement	Days/year	
Methodology of value classification and transformation	Manual classification based on equal intervals	
Indicator maps		



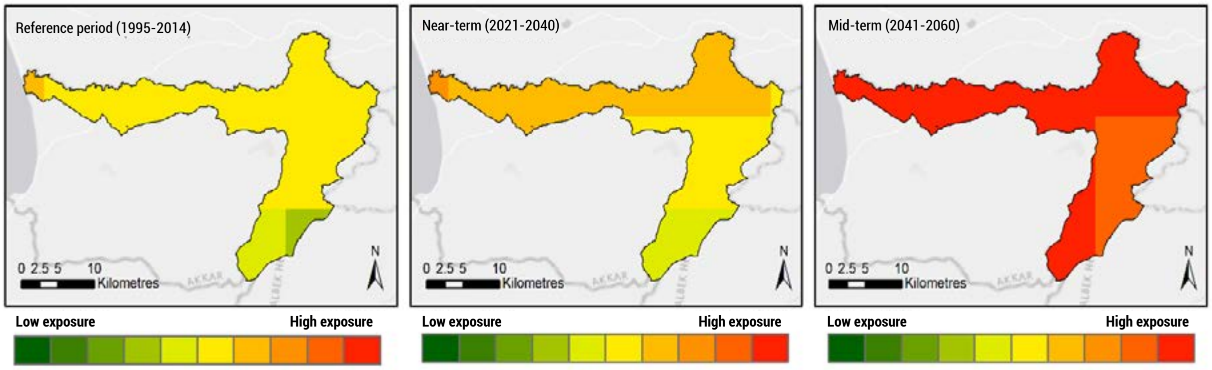
Source: Authors.

Change in number of consecutive wet days (CWD)		
Vulnerability component	Exposure	
Description	Change in CWD (≥1 mm)/maximum length of wet spell for reference period (1995–2014), near-term (2021–2040) and mid-term (2041–2060), based on an ensemble of six bias-corrected regional climate modelling outputs for the SSP5-8.5 scenario.	
VA classes and ranges	1 (low exposure):	≥0 days/year
	2:	|0–0.1|
	3:	|0.1–0.2|
	4:	|0.2–0.3|
	5:	|0.3–0.4|
	6:	|0.4–0.5|
	7:	|0.5–0.6|
	8:	|0.6 – 0.7|
	9:	|0.7–0.8|
	10 (high exposure):	|>0.8|
Influence on vulnerability	A decrease in the number of CWD can contribute to drought and decrease water availability. Areas with no change or increasing CWD have low exposure.	
Data information		
Type of data	Raster	
Resolution	10 km x 10 km projections	
Unit of measurement	Days/year	
Methodology of value classification and transformation	Manual classification based on equal intervals	
Indicator maps		



Source: Authors.

Change in number of precipitation days (R5)		
Vulnerability component	Exposure	
Description	Change in number of precipitation days (≥5 mm) for reference period (1995–2014), near-term (2021–2040) and mid-term (2041–2060), based on an ensemble of six bias-corrected regional climate modelling outputs for the SSP5-8.5 scenario.	
VA classes and ranges	1 (low exposure):	≥0 days/year
	2:	|0–0.6|
	3:	|0.6–1.2|
	4:	|1.2–1.8|
	5:	|1.8–2.4|
	6:	|2.4–3.0|
	7:	|3.0–3.6|
	8:	|3.6–4.2|
	9:	|4.2–4.8|
	10 (high exposure):	|>4.8|
Influence on vulnerability	A decrease in the number of precipitation days can contribute to drought and decrease water availability.	
Data information		
Type of data	Raster	
Resolution	10 km x 10 km projections	
Unit of measurement	Days/year	
Methodology of value classification and transformation	Manual classification based on equal intervals	
Indicator maps		

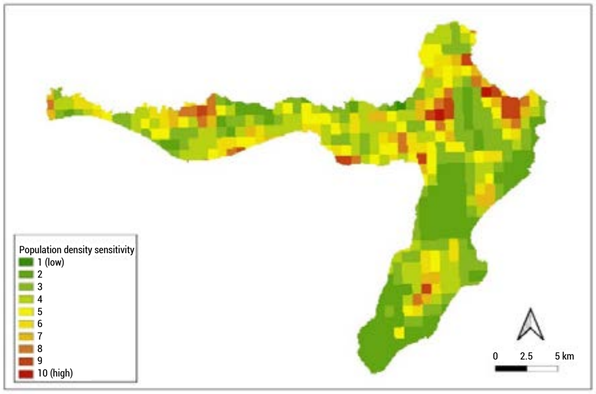

Reference period (1995-2014)
Near-term (2021-2040)
Mid-term (2041-2060)

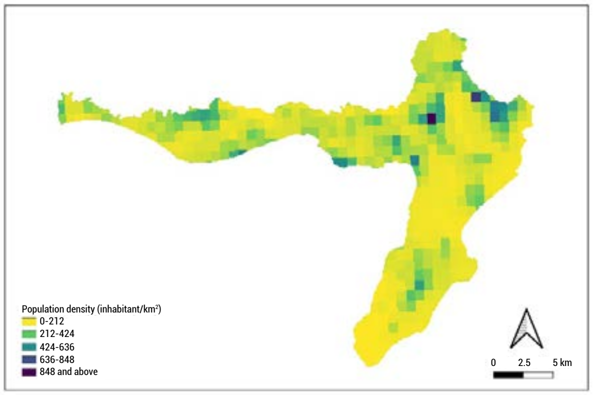
Source: Authors.

Population density		
Vulnerability component	Sensitivity	
Description	Map derived from global dataset (WorldPop)	
VA classes and ranges	1 (low sensitivity):	0
	2:	0–21
	3:	21–41
	4:	41–71
	5:	71–106
	6:	106–151
	7:	151–222
	8:	222–336
	9:	336–532
	10 (high sensitivity):	532–849
Influence on vulnerability	Dense population centres are more affected by the availability of water than less densely populated area due to food and water security, access and cost considerations.	

Data information	
Type of data	Raster
Resolution	100 m x 100 m
Unit of measurement	Inhabitant/km^2
Methodology of value classification and transformation	Natural breaks

Indicator maps

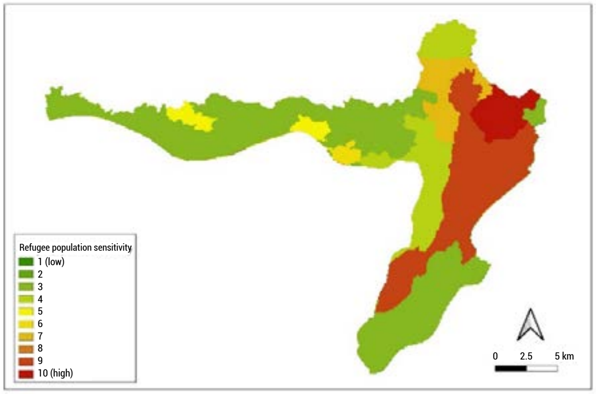


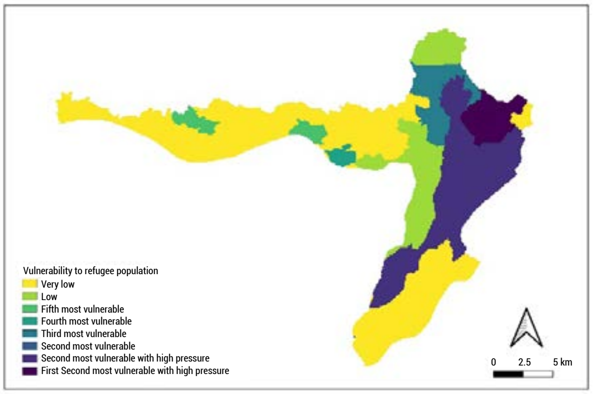


Source: Authors.

Refugee population		
Vulnerability component	Sensitivity	
Description	Source: UNHCR/OCHA Initial values: vulnerable localities (i.e., villages/towns)	
VA classes and ranges	1 (low sensitivity):	
	2:	
	3:	Very low
	4:	Low
	5:	Fifth most vulnerable
	6:	Fourth most vulnerable
	7:	Third most vulnerable
	8:	Second most vulnerable
	9:	Second most vulnerable with high pressure
	10 (high sensitivity):	First most vulnerable with high pressure
Influence on vulnerability	Areas with an increasing number of refugees are under a higher pressure in terms of water availability.	
Data information		
Type of data	Vector	
Resolution	Cadastral unit	
Unit of measurement	Qualitative	
Methodology of value classification and transformation	Manual classification	

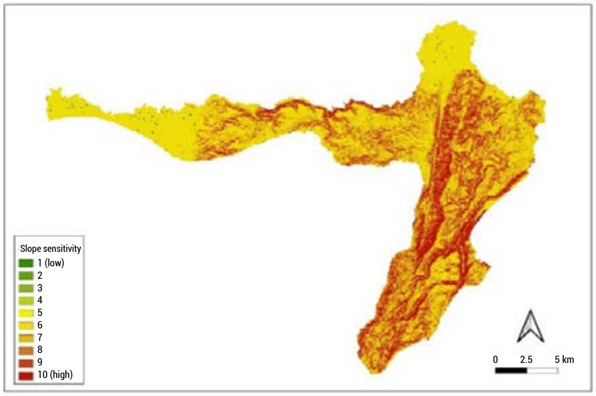
Indicator maps

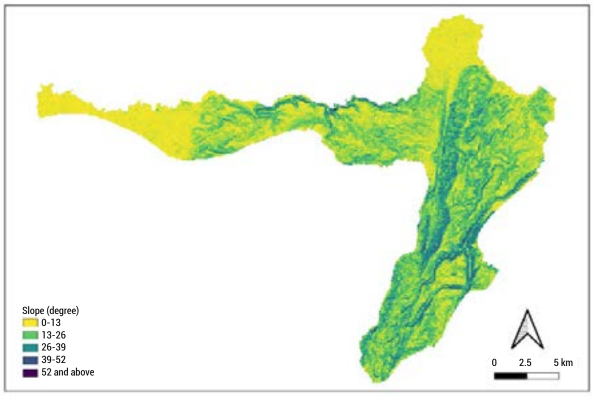




Source: Authors.

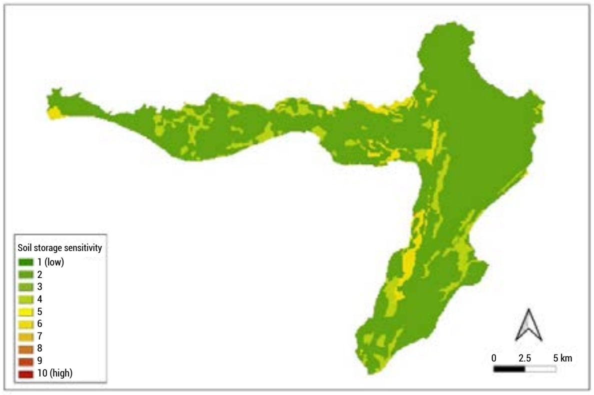
Slope gradient		
Vulnerability component	Sensitivity	
Description	Source: Digital Elevation Model (DEM) of Lebanon - USGS Slope derived from DEM in degree	
VA classes and ranges	1 (low sensitivity):	0
	2:	
	3:	
	4:	
	5:	
	6:	0–5.165
	7:	5.165–10.95
	8:	10.95–17.36
	9:	17.36–25.41
	10 (high sensitivity):	25.41–53
Influence on vulnerability	Steeper slopes are more sensitive because of fast-draining soils.	
Data information		
Type of data	Raster	
Resolution	30 m x 30 m	
Unit of measurement	Degree	
Methodology of value classification and transformation	Manual classification	
Indicator maps		

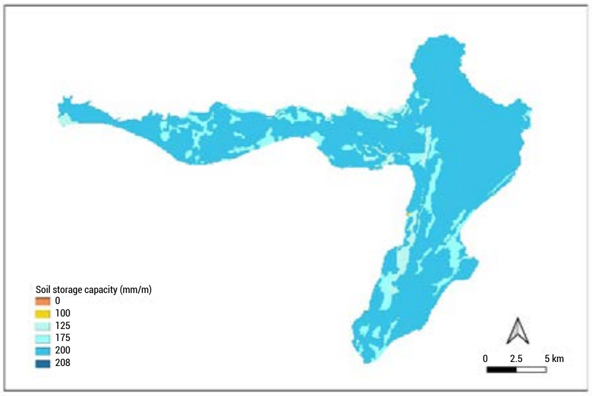




Source: Authors.

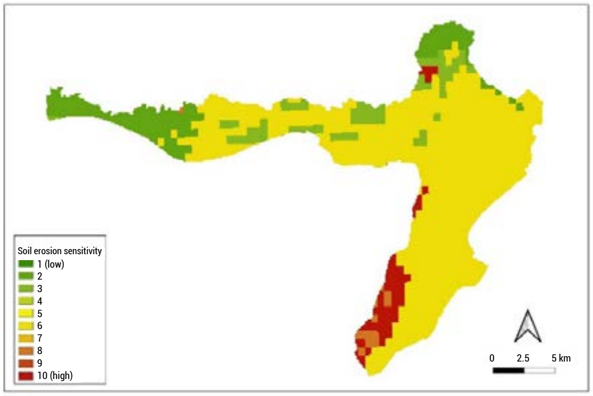
Soil storage capacity		
Vulnerability component	Sensitivity	
Description	Source: Soil map of Lebanon, National Council for Scientific Research. In general, soil storage capacity is defined as the total amount of water stored in the soil within the plant's root zone.	
VA classes and ranges	2:	200
	3:	
	4:	175
	5:	
	6:	125
	7:	
	8:	100
	9:	
	10 (high sensitivity):	
	Areas with less capacity to store water have adverse impacts on crops and water drainage.	
Influence on vulnerability	Steeper slopes are more sensitive because of fast-draining soils.	
Data information		
Type of data	Vector	
Resolution	1: 50,000	
Unit of measurement	mm/m depth	
Methodology of value classification and transformation	Manual classification	
Indicator maps		

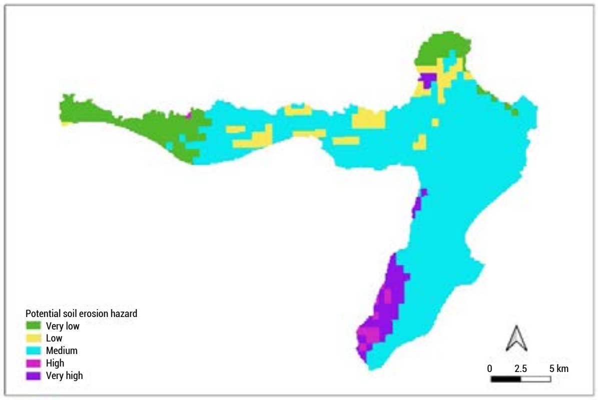




Source: Authors.

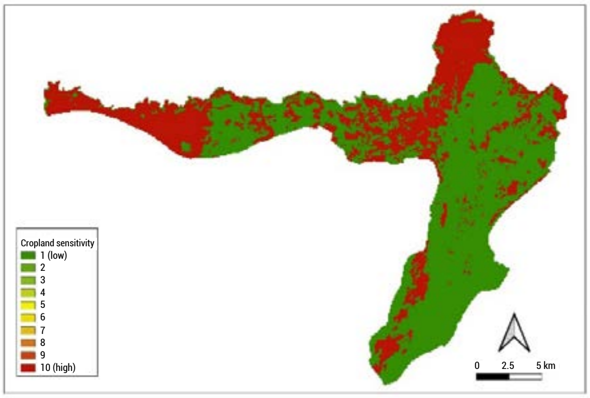
Potential soil erosion hazard		
Vulnerability component	Sensitivity	
Description	Source: National Council for Scientific Research	
VA classes and ranges	1 (low sensitivity):	
	2:	Very low
	3:	Low
	4:	
	5:	
	6:	Medium
	7:	
	8:	High
	9:	
	10 (high sensitivity):	Very high
Influence on vulnerability	Areas with a high risk of erosion are more affected by surface water runoff. Erosion risk is also driven by climatic conditions. Areas prone to soil erosion can lead to loss of crops.	
Data information		
Type of data	Vector	
Resolution	1: 100,000	
Unit of measurement	Descriptive	
Methodology of value classification and transformation	Manual classification	
Indicator maps		

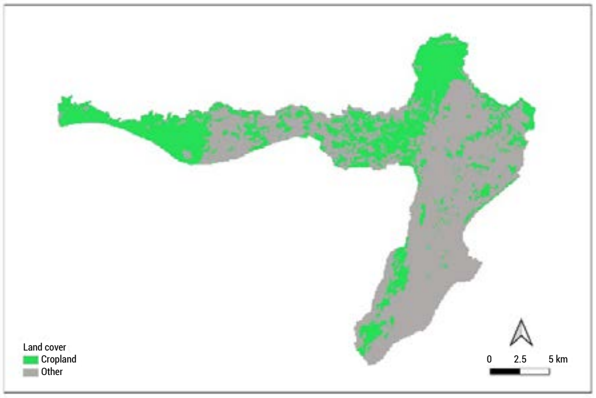




Source: Authors.

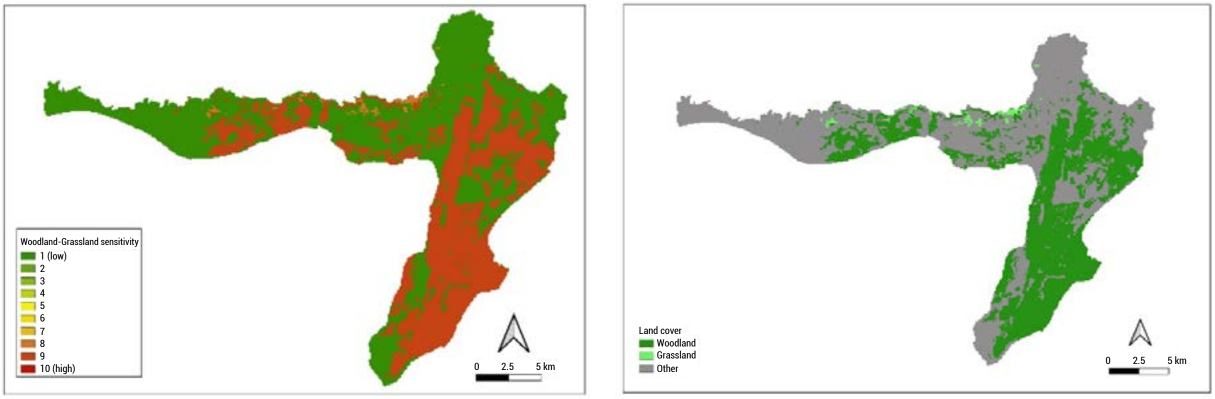
Croplands		
Vulnerability component	Sensitivity	
Description	Source: National Council for Scientific Research. Cropland areas taken from Lebanon's most recent land cover/land use map of 2017.	
VA classes and ranges	1 (low sensitivity):	No cropland
	2:	
	3:	
	4:	
	5:	
	6:	
	7:	
	8:	
	9:	
	10 (high sensitivity):	Cropland
Influence on vulnerability	Areas with cropland areas depend on water for irrigation and are, therefore, highly sensitive.	
Data information		
Type of data	Vector	
Resolution	1: 20,000	
Unit of measurement	Descriptive	
Methodology of value classification and transformation	Manual classification	
Indicator maps		





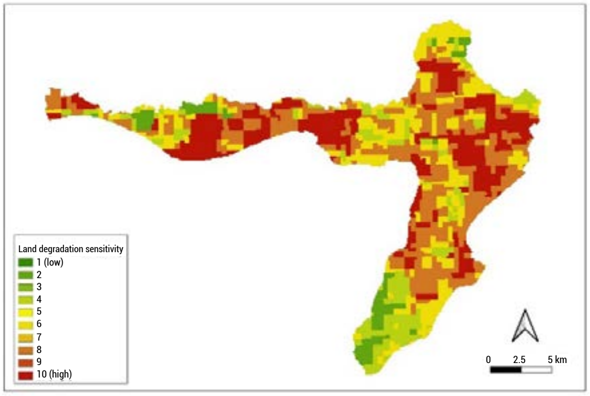
Source: Authors.

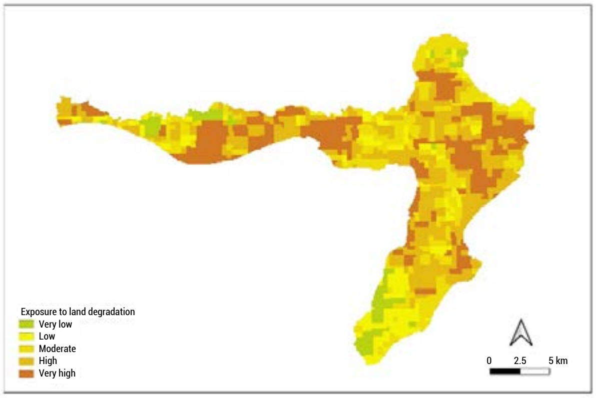
Woodland-grassland		
Vulnerability component	Sensitivity	
Description	Source: National Council for Scientific Research Woodland-grassland areas were derived from Lebanon's most recent land cover/land use map of 2017.	
VA classes and ranges	1 (low sensitivity):	Other
	2:	
	3:	
	4:	
	5:	
	6:	
	7:	
	8:	Grassland
	9:	Woodland
	10 (high sensitivity):	
Influence on vulnerability	Woodlands as well as grasslands are affected by climate extremes, such as drought. Hence, such land cover types are more vulnerable to stresses and disturbances.	
Data information		
Type of data	Vector	
Resolution	1: 20,000	
Unit of measurement	Descriptive	
Methodology of value classification and transformation	Manual classification	
Indicator maps		



Source: Authors.

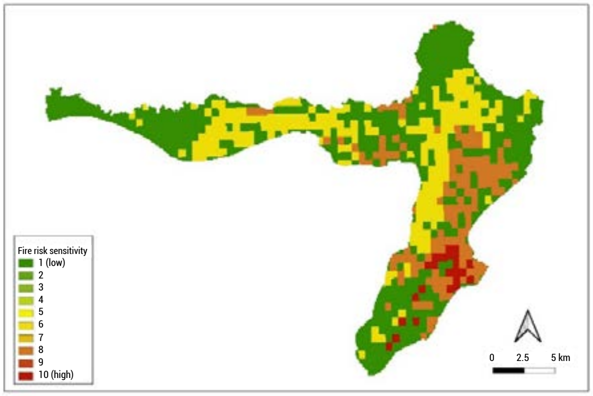
Woodland-grassland		
Vulnerability component	Sensitivity	
Description	Source: Land Degradation Neutrality Project, AFDC-MoA, Lebanon	
VA classes and ranges	1 (low sensitivity):	
	2:	Very low
	3:	
	4:	Low
	5:	
	6:	Moderate
	7:	
	8:	High
	9:	
	10 (high sensitivity):	Very high
Influence on vulnerability	Areas prone to degradation are linked to a decline in water infiltration and 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 of value classification and transformation	Manual classification	
Indicator maps		

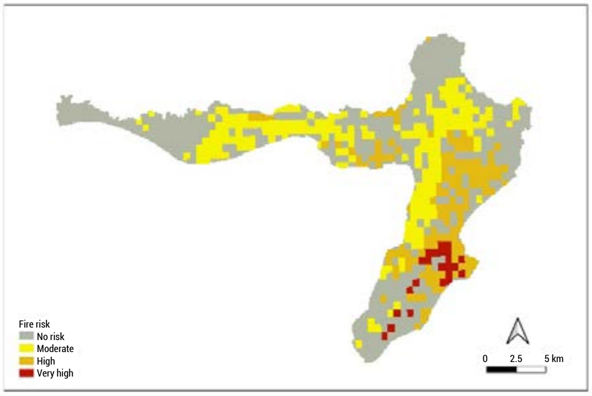




Source: Authors.

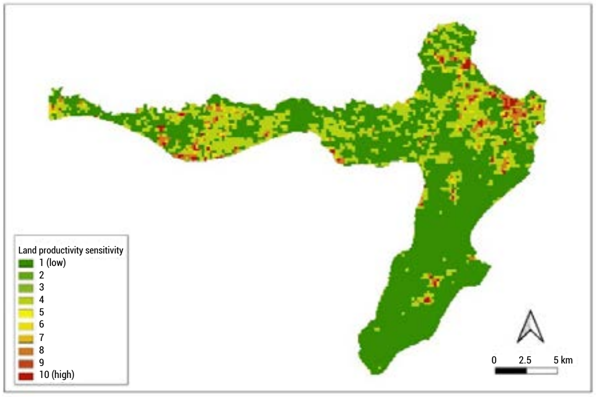
Fire risk		
Vulnerability component	Sensitivity	
Description	Source: Lebanon's fire risk map – University of Balamand	
VA classes and ranges	1 (low sensitivity):	No risk
	2:	
	3:	
	4:	
	5:	
	6:	Moderate
	7:	
	8:	High
	9:	
	10 (high sensitivity):	Very high
Influence on vulnerability	Water quantity and quality are affected by post-fire conditions on the site: flash floods are increasingly observed in post-fire areas across the basin; fire suppression operations require significant amounts of water resources; and water infrastructure in the wildland-urban interface is increasingly exposed to fire.	
Data information		
Type of data	Vector	
Resolution	1: 20,000	
Unit of measurement	Descriptive	
Methodology of value classification and transformation	Manual classification	
Indicator maps		

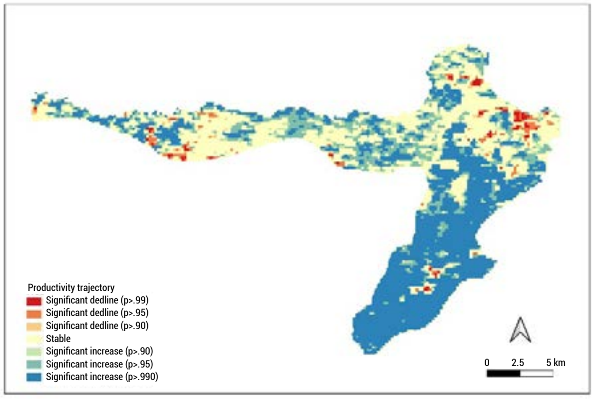




Source: Authors.

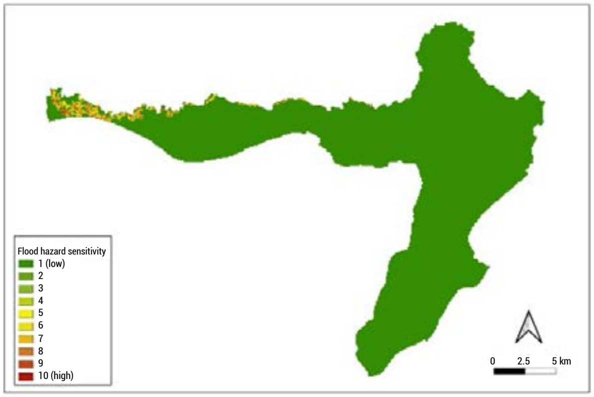
Land productivity		
Vulnerability component	Sensitivity	
Description	Source: Trends Earth Productivity trajectory (2001–2019)	
VA classes and ranges	1 (low sensitivity):	No significant decline
	2:	
	3:	
	4:	Stable
	5:	
	6:	-1 (significant decline p>.90)
	7:	
	8:	-2 (significant decline p>.95)
	9:	
	10 (high sensitivity):	-3 (significant decline p>.99)
Influence on vulnerability	Decline in land productivity results in an increased need for water resources. Trends in land productivity are also driven by climatic conditions.	
Data information		
Type of data	Vector	
Resolution	250 m x 250 m	
Unit of measurement	Descriptive	
Methodology of value classification and transformation	Manual classification	
Indicator maps		

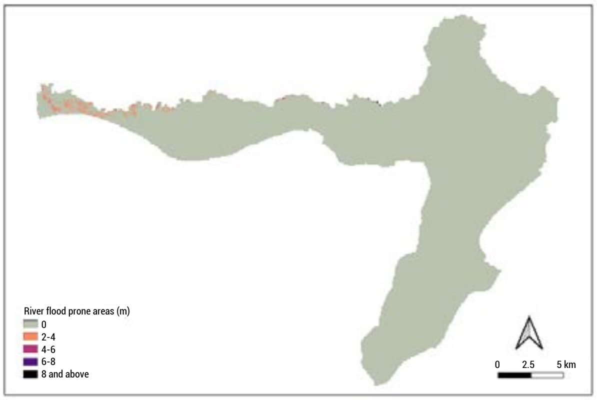




Source: Authors.

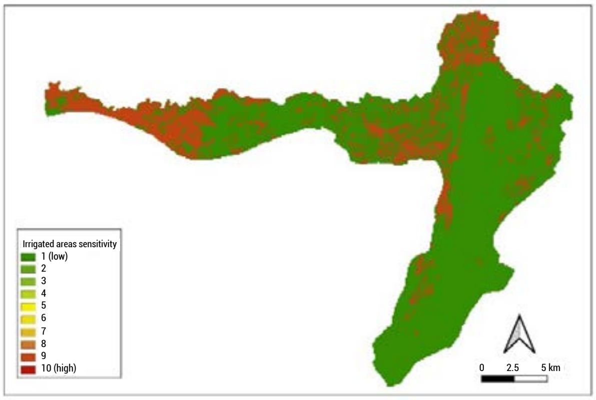
Land productivity		
Vulnerability component	Sensitivity	
Description	Source: Areas prone to river flood events in the Nahr el Kabir basin (on a 1 in 10 years of frequency) were derived from Dottori and others, 2021.	
VA classes and ranges	1 (low sensitivity):	0
	2:	
	3:	
	4:	
	5:	
	6:	0-0.36
	7:	0.36-1.05
	8:	1.05-1.83
	9:	1.83-3.72
	10 (high sensitivity):	3.72-8.32
Influence on vulnerability	Areas with higher flood risks are prone to an increased damage in built-up areas and agricultural lands. Flood events are also affected by climatic conditions.	
Data information		
Type of data	Raster	
Resolution	100 m x100 m	
Unit of measurement	m	
Methodology of value classification and transformation	Manual classification	
Indicator maps		

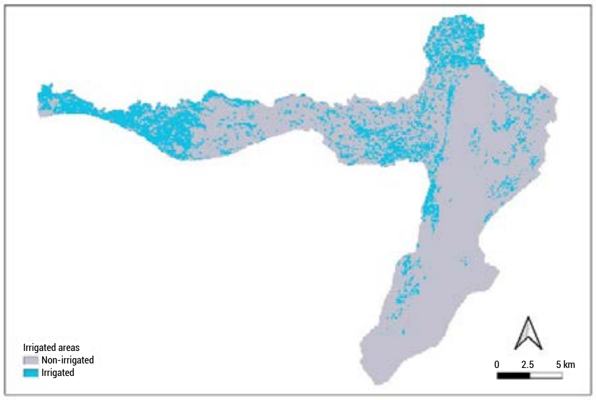




Source: Authors.

Irrigated areas		
Vulnerability component	Sensitivity	
Description	Source: Arab Center for the Studies of Arid Zones and Dry Lands The map shows irrigated versus non-irrigated areas.	
VA classes and ranges	1 (low sensitivity):	Non-irrigated areas
	2:	
	3:	
	4:	
	5:	
	6:	
	7:	
	8:	
	9:	Irrigated
	10 (high sensitivity):	
Influence on vulnerability	The combination of changes in irrigation requirements, evaporation from existing reservoirs and the unavailability of fresh water supplies increases vulnerability of irrigated areas. With the absence of information about the percentage of irrigated land Akkar, it was assumed that most non-irrigated areas have low dependence on water supplies (i.e., either different land cover types other than agricultural lands or abandoned agricultural fields, possibly including fields for annually harvested non-permanent crops).	
Data information		
Type of data	Vector	
Resolution	-	
Unit of measurement	Descriptive	
Methodology of value classification and transformation	Manual classification	
Indicator maps		

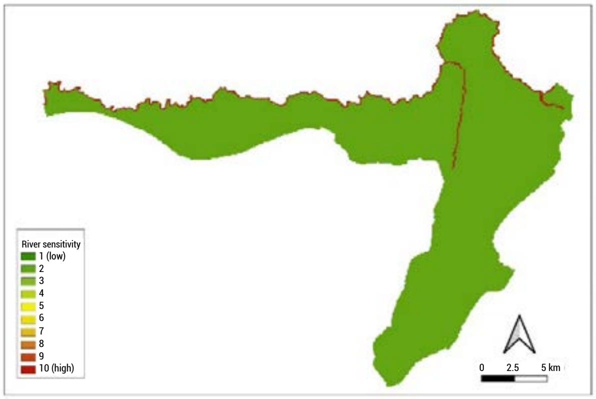


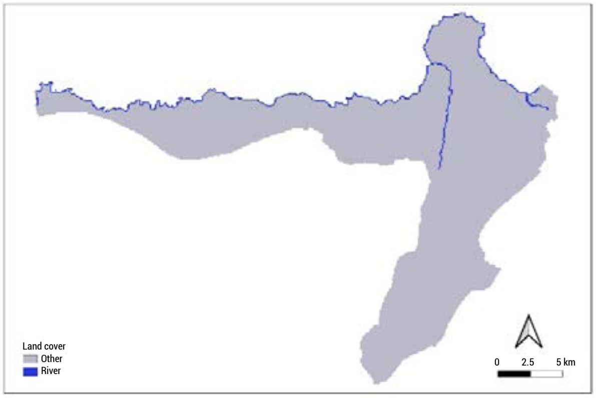


Source: Authors.

River		
Vulnerability component	Sensitivity	
Description	Source: National Council for Scientific Research – Lebanon (CNRS-L) Land cover/land use map of 2017 The river and its tributaries taken from the land cover/land use maps of 2017	
VA classes and ranges	1 (low sensitivity):	No river
	2:	
	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, mostly climate extreme incidents, therefore making rivers and river tributaries highly sensitive.	
Data information		
Type of data	Vector	
Resolution	1: 20,000	
Unit of measurement	Descriptive	
Methodology of value classification and transformation	Manual classification	

Indicator maps





Source: Authors.

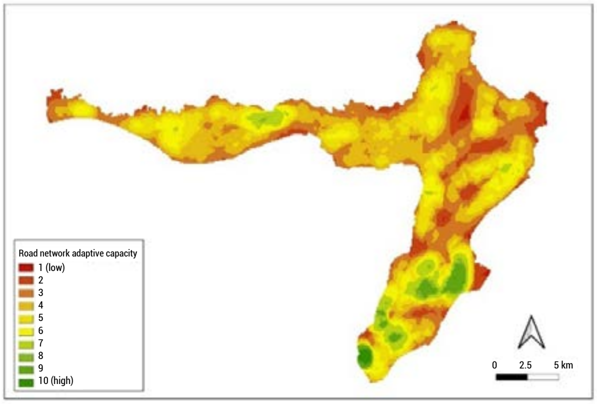
Road density

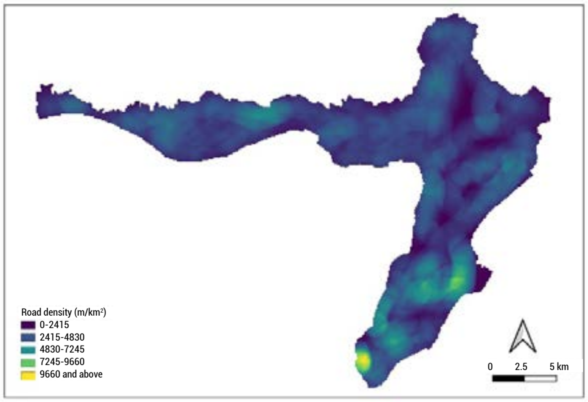
Vulnerability component	Adaptive capacity	
Description	Source: TRAGSA forest fire project in Lebanon – 2012	
VA classes and ranges	1 (low adaptive capacity):	0
	2:	0-985
	3:	985-1705
	4:	1705-2274
	5:	2274-2879
	6:	2879-3675
	7:	3675-4622
	8:	4622-4948
	9:	4948-7729
	10 (high adaptive capacity):	7729-9661
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	Vector
Resolution	-
Unit of measurement	m/km^2
Methodology of value classification and transformation	Natural breaks

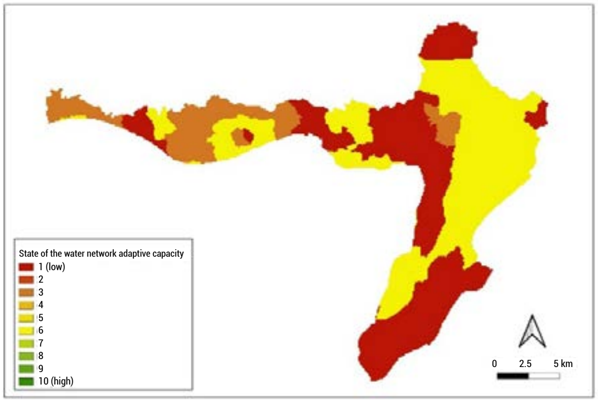
Indicator maps

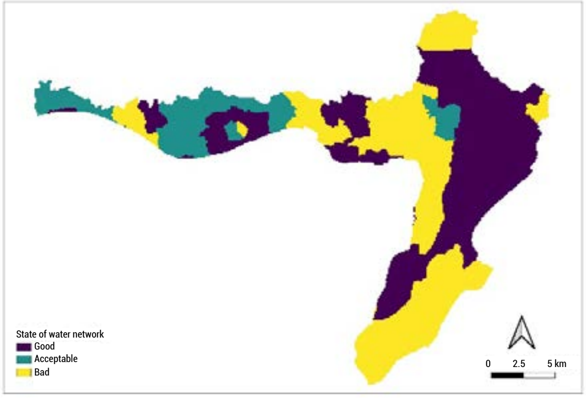




Source: Authors.

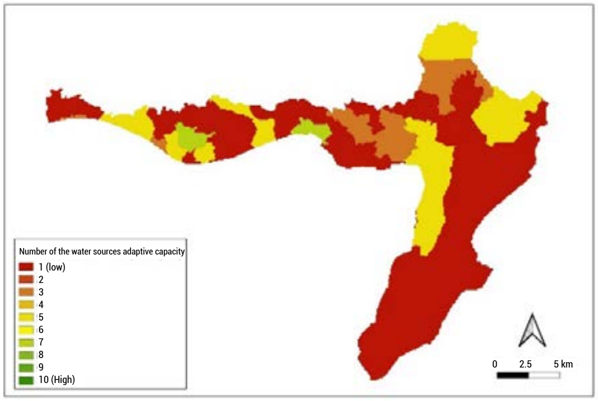
State of the water network		
Vulnerability component	Adaptive capacity	
Description	Source: IMPACT (https://impact.cib.gov.lb/home). Description of the state of the water network	
VA classes and ranges	1 (low adaptive capacity):	Bad
	2:	
	3:	Acceptable
	4:	
	5:	
	6:	Good
	7:	
	8:	
	9:	
	10 (high adaptive capacity):	
Influence on vulnerability	A good water network reduces water losses due to leakages and ensures better water supply.	
Data information		
Type of data	Vector	
Resolution	Municipality level	
Unit of measurement	Descriptive	
Methodology of value classification and transformation	Manual classification	
Indicator maps		

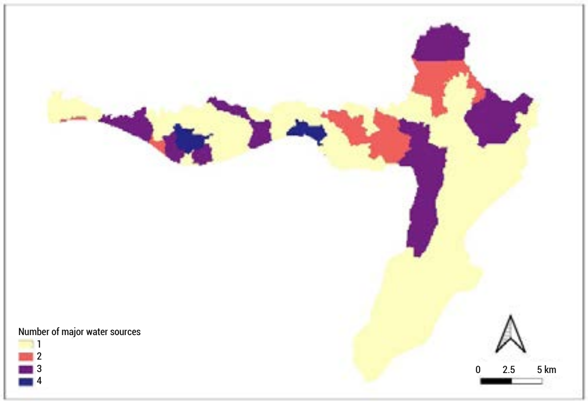




Source: Authors.

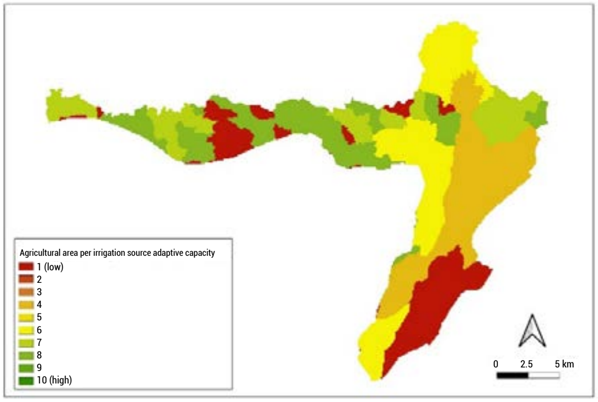
Water sources		
Vulnerability component	Adaptive capacity	
Description	Source: IMPACT. Number of major water sources per cadastral unit	
VA classes and ranges	1 (low adaptive capacity):	1
	2:	
	3:	2
	4:	
	5:	3
	6:	
	7:	4
	8:	
	9:	
	10 (high adaptive capacity):	
Influence on vulnerability	A high number of water sources mitigates possible incidents of water shortage.	
Data information		
Type of data	Vector	
Resolution	Municipality level	
Unit of measurement	Descriptive	
Methodology of value classification and transformation	Manual classification	
Indicator maps		

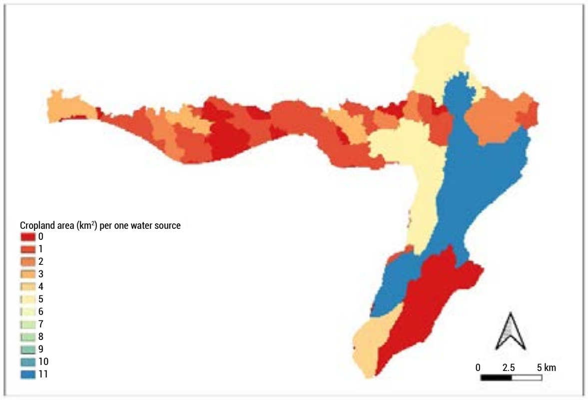




Source: Authors.

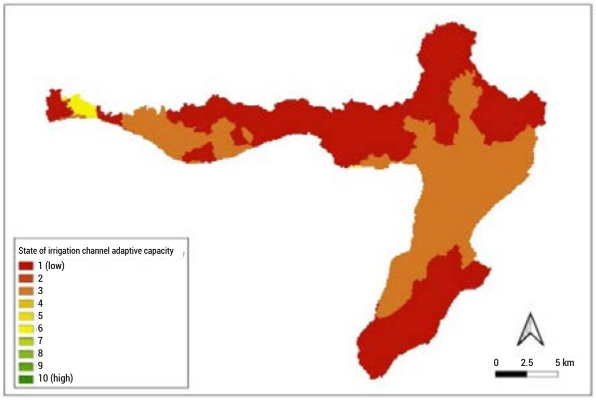
Number and type of irrigation water sources		
Vulnerability component	Adaptive capacity	
Description	Source: IMPACT. Covered agricultural area per irrigation water source	
VA classes and ranges	1 (low adaptive capacity):	0
	2:	
	3:	
	4:	5-11
	5:	
	6:	3-5
	7:	1-3
	8:	0-1
	9:	
	10 (high adaptive capacity):	
Influence on vulnerability	Allocating an available irrigation water source to smaller agricultural areas increases its potential to cover irrigation needs in dry periods.	
Data information		
Type of data	Vector	
Resolution	Municipality level	
Unit of measurement	Area in km^2 per available irrigation source	
Methodology of value classification and transformation	Manual classification	
Indicator maps		

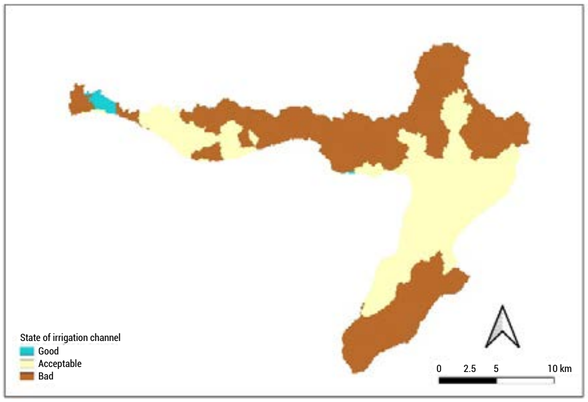




Source: Authors.

State of irrigation channels		
Vulnerability component	Adaptive capacity	
Description	Source: IMPACT. Description of the state of irrigation channels (bad, acceptable or good).	
VA classes and ranges	1 (low adaptive capacity):	Bad
	2:	
	3:	Acceptable
	4:	
	5:	
	6:	Good
	7:	
	8:	
	9:	
	10 (high adaptive capacity):	
Influence on vulnerability	Improving irrigation channels ensures fewer water leakages and better water supply.	
Data information		
Type of data	Vector	
Resolution	Municipality level	
Unit of measurement	Descriptive	
Methodology of value classification and transformation	Manual classification	
Indicator maps		

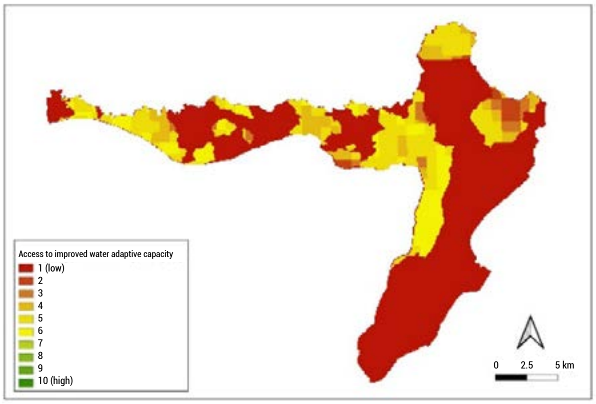


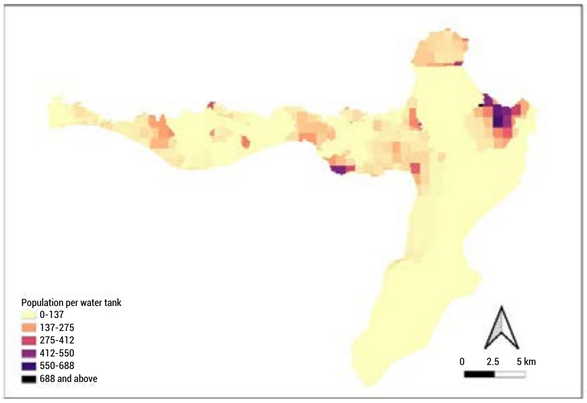


Source: Authors.

Access to improved water		
Vulnerability component	Adaptive capacity	
Description	Source: IMPACT. An improved quality of water is made accessible to the public from water tanks. Population number per water tank is factored.	
VA classes and ranges	1 (low adaptive capacity):	0
	2:	308–689
	3:	151–308
	4:	71–151
	5:	21–71
	6:	0–21
	7:	
	8:	
	9:	
	10 (high adaptive capacity):	
Influence on vulnerability	A lower population number per water tank allows better access to an improved quality of water.	
Data information		
Type of data	Vector	
Resolution	Municipality level	
Unit of measurement	Total population number per available water tank	
Methodology of value classification and transformation	Manual classification	

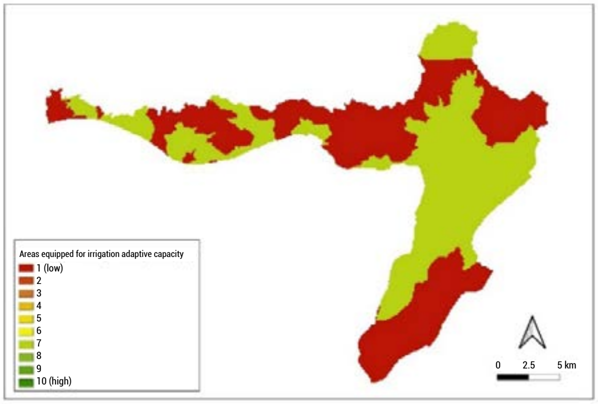
Indicator maps

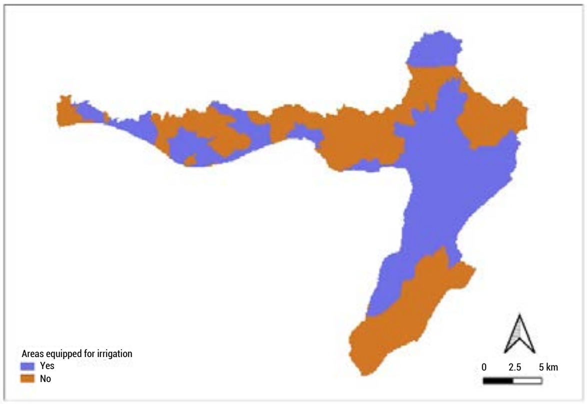




Source: Authors.

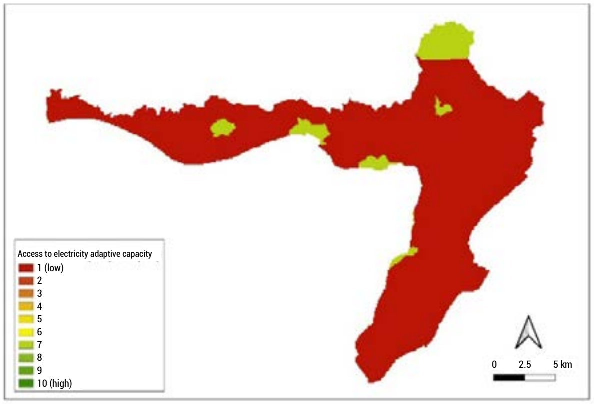
Areas equipped for irrigation		
Vulnerability component	Adaptive capacity	
Description	Source: IMPACT. Binary classification of villages/towns by existence/non-existence of areas equipped for irrigation.	
VA classes and ranges	1 (low adaptive capacity):	Non-existence
	2:	
	3:	
	4:	
	5:	
	6:	
	7:	Existence
	8:	
	9:	
	10 (high adaptive capacity):	
Influence on vulnerability	Available equipment for irrigation supports more efficient water use.	
Data information		
Type of data	Vector	
Resolution	Municipality level	
Unit of measurement	Descriptive (yes/no)	
Methodology of value classification and transformation	Manual classification	
Indicator maps		

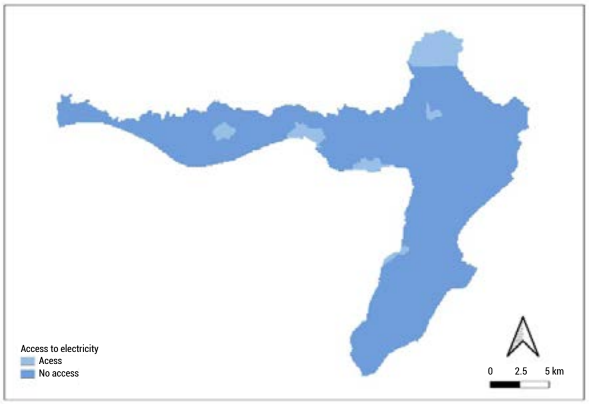




Source: Authors.

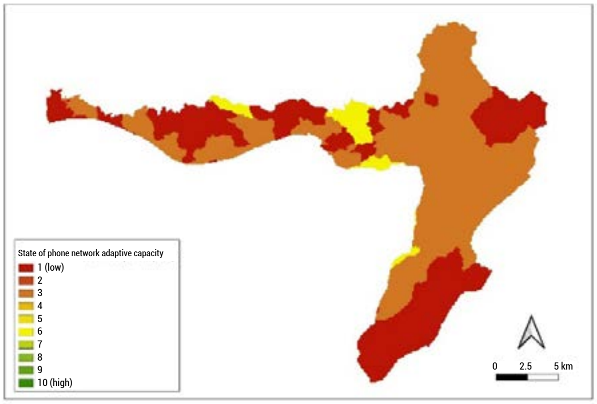
Access to electricity		
Vulnerability component	Adaptive capacity	
Description	Source: IMPACT. Binary classification of villages/towns by access versus lack of access to electricity.	
VA classes and ranges	1 (low adaptive capacity):	No access
	2:	
	3:	
	4:	
	5:	
	6:	
	7:	Access
	8:	
	9:	
	10 (high adaptive capacity):	
Influence on vulnerability	Access to electricity ensures water pumping from artesian wells and other water sources.	
Data information		
Type of data	Vector	
Resolution	Municipality level	
Unit of measurement	Descriptive (yes/no)	
Methodology of value classification and transformation	Manual classification	
Indicator maps		

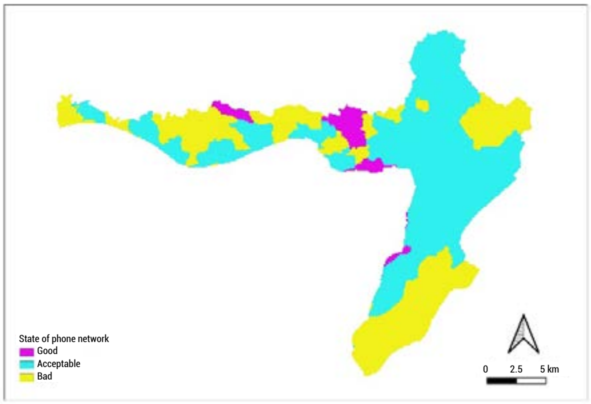




Source: Authors.

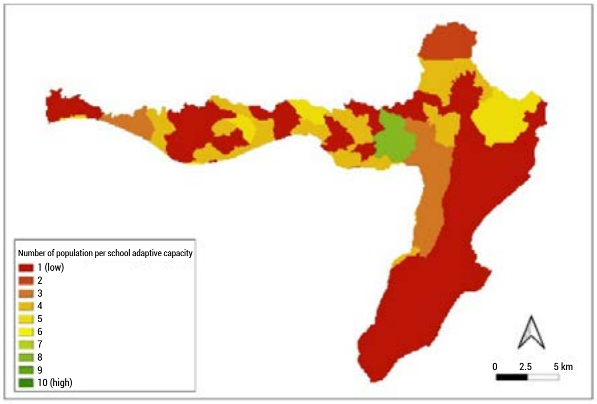
State of phone network		
Vulnerability component	Adaptive capacity	
Description	Source: IMPACT. Classification of villages/towns in terms of the state of the phone network therein (bad, acceptable or good).	
VA classes and ranges	1 (low adaptive capacity):	Bad
	2:	
	3:	Acceptable
	4:	
	5:	
	6:	Good
	7:	
	8:	
	9:	
	10 (high adaptive capacity):	
Influence on vulnerability	Effective climate adaptation and mitigation planning requires a reliable communication network.	
Data information		
Type of data	Vector	
Resolution	Municipality level	
Unit of measurement	Descriptive (bad, acceptable or good)	
Methodology of value classification and transformation	Manual classification	
Indicator maps		

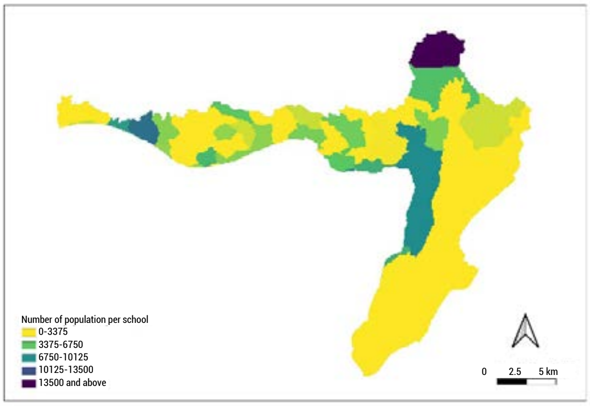




Source: Authors.

Number of schools per town/village population		
Vulnerability component	Adaptive capacity	
Description	Source: IMPACT. This refers to the population count per school in each town/village.	
VA classes and ranges	1 (low adaptive capacity):	0
	2:	8500–13500
	3:	5000–8500
	4:	2000–5000
	5:	214–2000
	6:	
	7:	
	8:	0–214
	9:	
	10 (high adaptive capacity):	
Influence on vulnerability	A high number of schools is linked to increased knowledge and awareness and, thus, an increased adaptive capacity. Accordingly, high population numbers per available school reflect a lower adaptive capacity.	
Data information		
Type of data	Vector	
Resolution	Municipality level	
Unit of measurement	Population number per school	
Methodology of value classification and transformation	Manual classification	
Indicator maps		





Source: Authors.

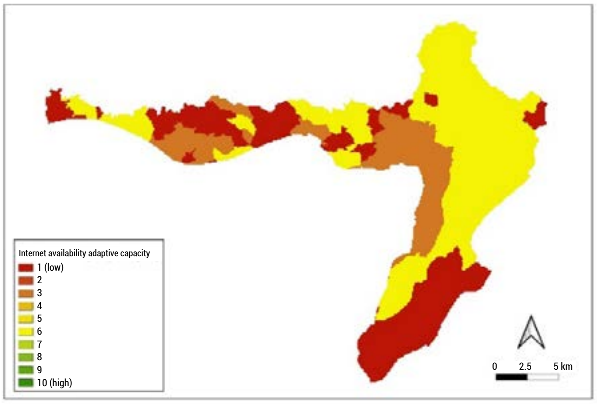
Internet availability

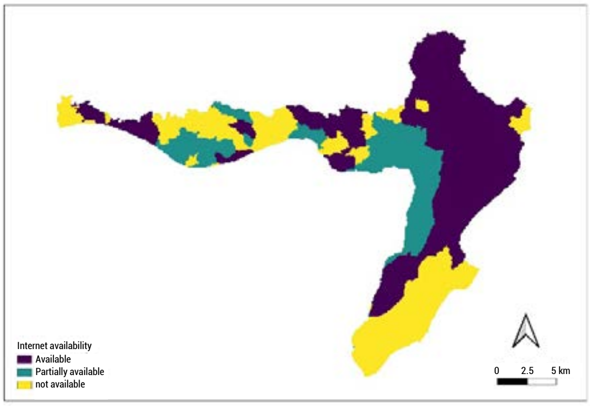
Vulnerability component	Adaptive capacity	
Description	Source: IMPACT. Description of internet availability per town/village: not available (3), partially available (2) or available (1).	
VA classes and ranges	1 (low adaptive capacity):	Not available
	2:	
	3:	Partially available
	4:	
	5:	
	6:	Available
	7:	
	8:	
	9:	
	10 (high adaptive capacity):	
Influence on vulnerability	Effective climate adaptation and mitigation planning requires digital means to access information. In addition, internet availability supports data acquisition and transmission.	

Data information

Type of data	Vector
Resolution	Municipality level
Unit of measurement	Descriptive (not available, partially available or available)
Methodology of value classification and transformation	Manual classification

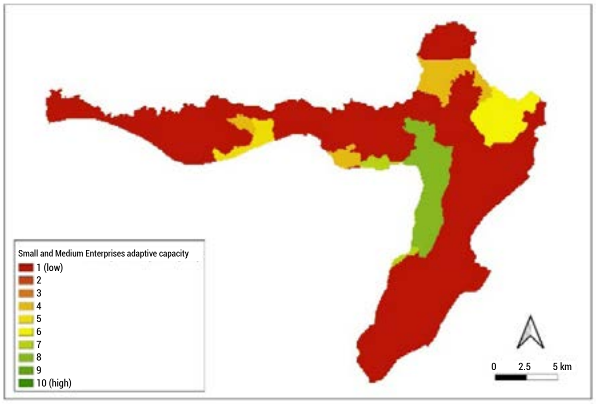
Indicator maps

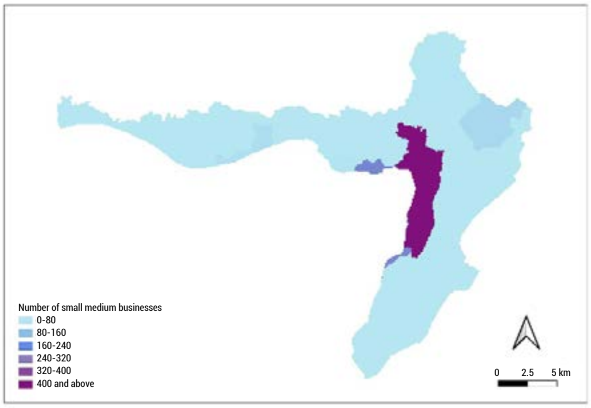




Source: Authors.

Total number of SMEs		
Vulnerability component	Adaptive capacity	
Description	Source: IMPACT. This indicates the total number of small and medium-sized businesses per town/village.	
VA classes and ranges	1 (low adaptive capacity):	0
	2:	
	3:	
	4:	0–10
	5:	10–20
	6:	20–30
	7:	30–200
	8:	200–400
	9:	
	10 (high adaptive capacity):	
Influence on vulnerability	SMEs provide innovative means for responding to matters related to water scarcity and shortages. Therefore, a larger number of SMEs means a higher adaptive capacity.	
Data information		
Type of data	Vector	
Resolution	Municipality level	
Unit of measurement	Total number of SMEs	
Methodology of value classification and transformation	Manual classification	
Indicator maps		

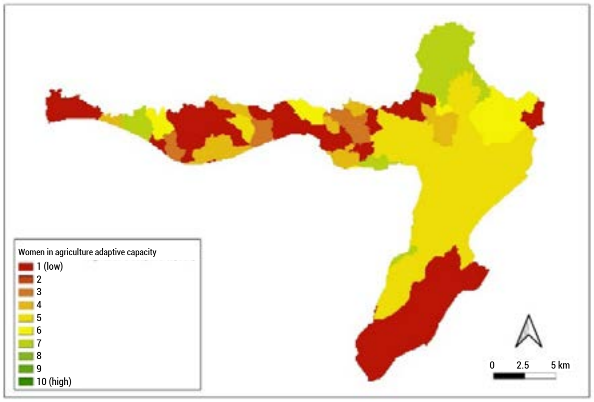


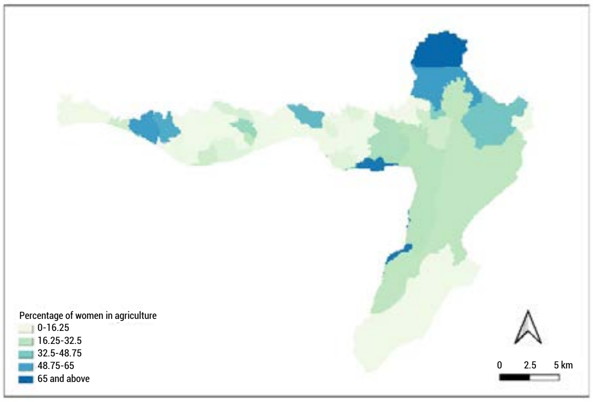


Source: Authors.

Percentage of women working in agriculture		
Vulnerability component	Adaptive capacity	
Description	Source: IMPACT. This indicates the percentage of women working in agriculture in each town/village.	
VA classes and ranges	1 (low adaptive capacity):	0
	2:	
	3:	0–2
	4:	2–10
	5:	10–25
	6:	25–45
	7:	45–65
	8:	
	9:	
	10 (high adaptive capacity):	
Influence on vulnerability	Women play an important role in reducing food and water insecurity through their knowledge of crop production, local biodiversity and local water resources. Furthermore, women working in agriculture provide additional family support, thus allowing the family to cope better with changing environmental conditions.	
Data information		
Type of data	Vector	
Resolution	Municipality level	
Unit of measurement	Percentage	
Methodology of value classification and transformation	Manual classification	

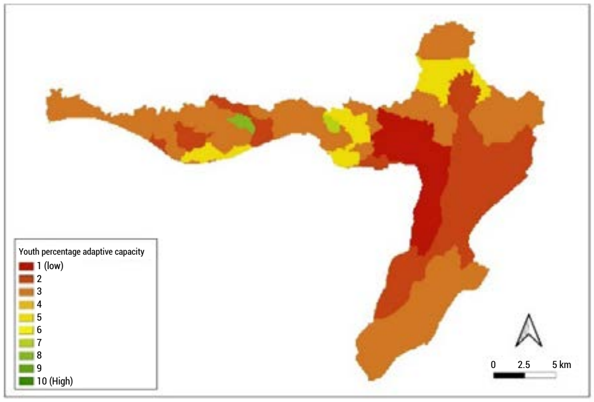
Indicator maps

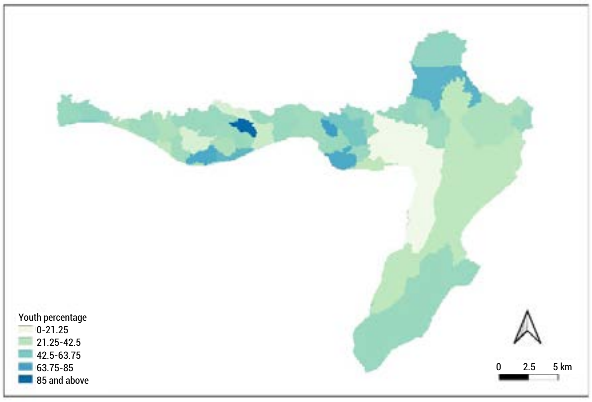




Source: Authors.

Youth percentage (15-24 years)		
Vulnerability component	Adaptive capacity	
Description	Source: IMPACT. This represents the percentage of young people per town/village.	
VA classes and ranges	1 (low adaptive capacity):	1
	2:	0–20
	3:	20–40
	4:	
	5:	40–-60
	6:	
	7:	60–80
	8:	80–100
	9:	
	10 (high adaptive capacity):	
Influence on vulnerability	Young people at this age group have an impact on livelihood, especially in rural areas, thus increasing its adaptive capacity. More specifically, young people are recognized as belonging to an age group with great potential to address the climate change problem that spans every generation.	
Data information		
Type of data	Vector	
Resolution	Municipality level	
Unit of measurement	Percentage	
Methodology of value classification and transformation	Manual classification	
Indicator maps		

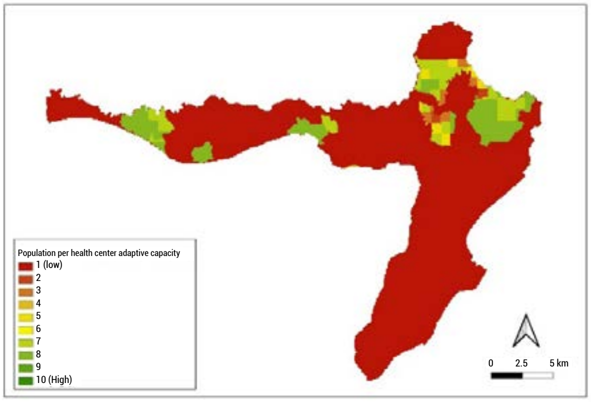


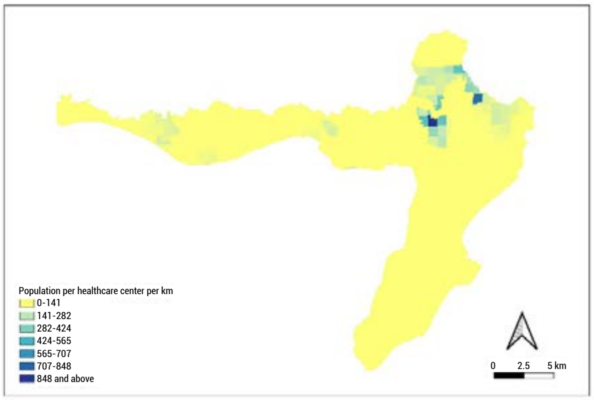


Source: Authors.

Number of health-care centres		
Vulnerability component	Adaptive capacity	
Description	Source: IMPACT. Population number per health-care center per km^2.	
VA classes and ranges	1 (low adaptive capacity):	0
	2:	420–850
	3:	253–420
	4:	
	5:	136–253
	6:	
	7:	60–136
	8:	0–60
	9:	
	10 (high adaptive capacity):	
Influence on vulnerability	Providing a greater number of health-care centres can address health threats posed by climate change and water-related problems more effectively.	
Data information		
Type of data	Vector	
Resolution	Municipality level	
Unit of measurement	Population number per health-care center per km^2	
Methodology of value classification and transformation	Manual classification	

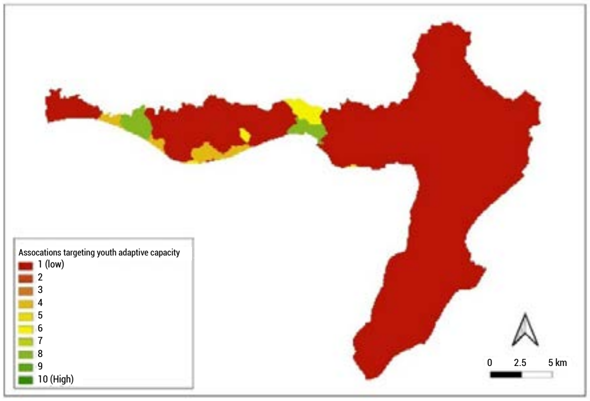
Indicator maps

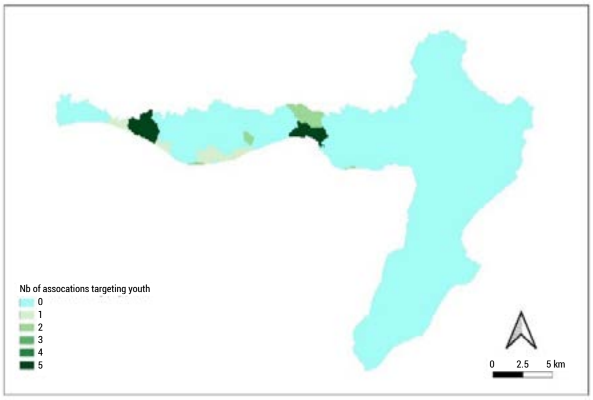




Source: Authors.

Number of associations targeting young people		
Vulnerability component	Adaptive capacity	
Description	Source: IMPACT. Number of associations targeting young people.	
VA classes and ranges	1 (low adaptive capacity):	0
	2:	
	3:	
	4:	1
	5:	
	6:	2
	7:	
	8:	5
	9:	
	10 (high adaptive capacity):	
Influence on vulnerability	The existence of a greater number of associations targeting young people can contribute to a higher level of knowledge and awareness among the young population and thus create a high adaptive capacity. Young people can make a meaningful contribution towards climate resilient development, provided an enabling environment is created by such associations.	
Data information		
Type of data	Vector	
Resolution	Municipality level	
Unit of measurement	Number of associations targeting young people	
Methodology of value classification and transformation	Manual classification	
Indicator maps		





Source: Authors.

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Endnotes

1. Project entitled: “Implementing the 2030 Agenda for Water Efficiency, Productivity and Sustainability in the Near East and North Africa Countries (WEPS-NENA)”.
2. قانون المياه رقم 192 تاريخ 2020/10/16، (ج.ر. عدد 41 تاريخ 2020/10/22).
3. Technical note available at https://www.riccar.org/publications/integrated-vulnerability-assessment-arab-regional-application.
4. Hotspots conglomerates based on climate change vulnerability assessment in the Nahr el Kabir:

   Akroum-Sharbine/Chadra: hotspot areas expanding over mountainous lands with relatively dense tree cover. First, this area is mostly charactarized by high sensitivity stemming from presence of refugees, fire risk, steep slopes and soil erosion, among others. Second, this part of the basin has a low adaptive capacity owing to certain limitations in the water sector.

   Machta Hasan/Aidamoun/Monjez: hotspot areas covering the middle part of the basin mostly characterized by agricultural land with relatively high sensitivity in the water sector.

   El Aarida/Es Sammaqiye/El Massaoudiye: hotspot areas covering coastal cropland areas. This area was dominated by high exposure associated with extreme climatic conditions and high sensitivity stemming from the presence of agricultural land, as well as exposure to land degradation and flood hazard. In addition, this part of the basin indicated a low adaptive capacity due to certain limitations in the water sector.
5. The number of summer days (SU) is defined by ETCCDI as the count of days when daily maximum temperature is above 25°C.

Arab States are particularly affected by water stress, taking 85 per cent of total available freshwater resources, compared to a global average of 21 per cent. Lebanon does not escape the challenge of water management. The Lebanese environment has become increasingly vulnerable to the effects of climate change, particularly rising temperatures, droughts and flooding. Therefore, an integrated assessment of the vulnerability, institutional mapping, regional climate projections, crop simulation and participatory consultations firmly based on a scientific approach have carried out in the Nahr el Kabir basin to strengthen the resilient management of watersheds and improve adaptation to climate change at the watershed level.

This study was carried out within the framework of the inter-institutional contribution agreement (FAO-ESCWA) aimed at “Increasing watershed resilience to climate change: Implementing the 2030 Agenda for water efficiency/productivity and water sustainability in NENA countries – Work Package Component on achieving SDG 6.4” to support the implementation of the FAO project entitled “Implementing the 2030 Agenda for Water Efficiency, Productivity and Sustainability in the Near East and North Africa Countries (WEPS-NENA)”. This project is led by FAO with funding from the Swedish Cooperation Agency International Development Agency (SIDA) and extends over the period between December 2016 and December 2022. This technical report was prepared through a collaborative partnership between ESCWA and the Arab Center for the Study of Arid Zones and Dry Lands (ACSAD) in consultation with the Ministry of Energy and Water of Lebanon.

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