RICCAR

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

Integrated Vulnerability Assessment Application on the Lebanese Agricultural Sector

TECHNICAL REPORT

Republic of Lebanon
Ministry of Agriculture

CNRS
National Council for Scientific Research

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

Ministry of Agriculture in Lebanon

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Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD)

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TECHNICAL REPORT

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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 launched in 2010.

RICCAR is implemented through a collaborative partnership involving 11 regional and specialized organizations, namely the United Nations Economic and Social Commission for Western Asia (ESCWA), the Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD), Food and Agriculture Organization of the United Nations (FAO), Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), the League of Arab States, Swedish Meteorological and Hydrological Institute (SMHI), United Nations Environment Programme (UN Environment), United Nations Educational, Scientific and Cultural Organization (UNESCO) Office in Cairo, United Nations Office for Disaster Risk Reduction (UNISDR), United Nations University Institute for Water, Environment and Health (UNU-INWEH), and World Meteorological Organization (WMO). ESCWA coordinates the regional initiative. Funding for RICCAR is provided by the Government of Sweden and the Government of the Federal Republic of Germany.

RICCAR is implemented under the auspices of the Arab Ministerial Water Council and derives its mandate from resolutions adopted by this council as well as the Council of Arab Ministers Responsible for the Environment, the Arab Permanent Committee for Meteorology and the 25th ESCWA Ministerial Session.

This report was prepared by ACSAD with technical support from ESCWA. The preparation of this report was made possible by the contribution of the Ministry of Agriculture in Lebanon and the National Council for Scientific Research (CNRS) who provided the datasets.

Funding for this report was provided by the German Federal Ministry for Economic Cooperation and Development (BMZ) through the Adaptation to Climate Change in the Water Sector in the MENA Region (ACCWaM)* programme implemented by GIZ.

* The Adaptation to Climate Change in the Water Sector in the MENA Region Programme (ACCWaM) was implemented by GIZ during 2011-2018 and aimed to improve the capacity of water management institutions in the Arab region to adapt to climate change. ACCWaM operated in collaboration with the Arab League (LAS) Arab Ministerial Water Council (AMWC), United Nations Economic and Social Commission for Western Asia (ESCWA), and the Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD).

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ACRONYMS AND ABBREVIATIONS

ACCWaM	Adaptation to Climate Change in the Water Sector in the MENA Region
ACSAD	Arab Center for the Studies of Arid Zones and Dry Lands
AMWC	Arab Ministerial Water Council
AR4	Fourth Assessment Report (IPCC)
BMZ	German Federal Ministry for Economic Cooperation and Development
CNRM-CM5	Centre National de Recherches Météorologiques- Climate Model 5
CORDEX	Coordinated Regional Climate Downscaling Experiment
EC-EARTH	ECMWF-based Earth-system model
ESCWA	United Nations Economic and Social Commission for Western Asia
ESD	Empirical Statistical Downscaling
EURO-CORDEX	Europe - Coordinated Regional Climate Downscaling Experiment
GCM	global climate model or general circulation model
GDP	gross domestic product
GHG	greenhouse gas
GIS	Geographic Information Systems
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
ha	hectare
HYPE	Hydrological Predictions for the Environment (hydrological model)
IPCC	Intergovernmental Panel on Climate Change
IPSL-CM5A-MR	Institut Pierre Simon Laplace Model Earth-system model
km	kilometres
km^2	square kilometres
LAS	League of Arab States
m	metres
MENA-CORDEX	Middle East North Africa - Coordinated Regional Climate Downscaling Experiment
mm	millimetres
mm/yr	millimetres per year
Mm^3	million cubic metres
RCA4	Rossby Centre Regional Atmospheric Model 4
RCM	Regional Climate Model
RCP	Representative Concentration Pathway
RHM	regional hydrological model
RICCAR	Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region
SMHI	Swedish Meteorological and Hydrological Institute
VIC	Variable Infiltration Capacity (hydrological model)
W/m^2	watts per square metre
°C	degree Celsius
%	percent

EXECUTIVE SUMMARY

Lebanon has been subjected to water scarcity as a consequence of population growth, migration, environmental degradation, and competing sectors, a situation which will be exacerbated by climate change. The agricultural sector is particularly vulnerable due to the increasing irrigation demand, as a result of the projected increases in temperature and decreases in precipitation over time. Adverse impacts to agriculture raise concerns for the future development of the country, including food security. The objective of this study is to provide a vulnerability assessment of the agricultural sector to climate change in Lebanon.

An integrated mapping methodology for the vulnerability assessment combined indicators that contribute to the characterization of the sensitivity, exposure, potential impact, and adaptive capacity components of vulnerability with respect to climate change. The methodology adopted here is the one applied in the Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR) and draws upon nationally appropriate and available indicators. The methodology in brief includes the following steps: development of impact chains, selection of indicators, data acquisition, normalization and classification of indicator data, and aggregation of indicators. This process was carried out using the ArcGIS software which enabled the production of vulnerability maps that display current and potential future vulnerabilities to climate change for the agricultural sector in Lebanon.

The vulnerability assessment results indicate that up to 14% of the study area is projected to exhibit high vulnerability compared to the rest of the country. Areas with the highest vulnerability, designated as hotspots, include areas within Hasbaya, Rachaya, and Akkar Cazas, as well as selected small areas located in the Beqaa Valley. These hotspot areas may induce adverse impacts to crops such as olives, grapes, apples, and vegetables.

Most croplands (84%) project moderate vulnerability with remaining areas suggesting low vulnerability relative to the study area. Areas with moderate vulnerability comprise areas adjacent to hotspots as well as Bcharre and Hermel Cazas. Potentially impacted crops include apples, almonds, and olives.

1 INTRODUCTION

As part of the Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR)[1], vulnerability assessments were conducted at a regional scale to evaluate the impacts of climate change on freshwater resources in differing sectors. Agriculture, one of the sectors, included two studied subsectors: water availability for crops and water availability for livestock. The former predicted moderate to high vulnerability while the latter signaled moderate vulnerability throughout Lebanon, both based on an extreme climate scenario (RCP8.5) at the end of the century (2081-2100).

Vulnerability assessments can be useful to decision makers, particularly as results can be visualized on a map. While regional assessments can offer an overall situational review and help facilitate comparisons, results are difficult to evaluate at a smaller scale. The RICCAR vulnerability assessment was indicator-based, using indicators that were suitable for a regional study, but may not be appropriate for areas like Lebanon.

The objective of this study is to conduct an integrated vulnerability assessment to evaluate climate change impacts upon the agricultural sector in Lebanon, with a focus on water availability for crops. The agricultural sector was selected, in part, due to its dependency on irrigation, which is expected to heighten due to projected increasing temperature and decreasing precipitation. Other threats include population growth, migration, environmental degradation, and competing sectors. Adverse impacts to agriculture give rise for concern regarding future development of the country, partly due to food security prospects. Results from the vulnerability assessment help identify agricultural areas deemed most critical.

2 STUDY AREA

2.1 Current climate

Lebanon is generally within a Mediterranean climate (Köppen climate classification: Csa), characterized by a hot dry season (April-October) and a cooler wet season (November-March). Wide topographical variation alters localized climatic conditions. During the dry season, precipitation is negligible and high pressure generally dominates the entire country. The diurnal temperature range is usually small along the coast due to proximity to the sea; however, summer temperatures can exceed 38°C during the day and drop below 16°C at night. Inland areas exhibit a more continental climate with a larger diurnal range in temperatures. The wet season occurs during winter when precipitation is abundant compared to elsewhere in the region. However, rain and snowfall is largely confined to few days during this period, falling in heavy cloudbursts. The average annual rainfall is 840 mm (Figure 1) but can widely vary from one year to the next. Precipitation is highest in the Lebanon Mountains and can produce snowfall. Inland areas east of the mountains are shielded from the influence of the sea resulting in less annual precipitation.

2.2 Agricultural sector

Lebanon is able to produce a wide variety of crops due to a favorable climate as well as localized conditions stemming from its diverse topography. Major crops include vegetables (especially potatoes and tomatoes), citrus and other fruits, cereals, olives, and grapes (Figure 2). Primary cultivated areas include the Bekaa Valley (which includes Zahle and West Bekaa), northern Lebanon (particularly Akkar and Koura), and the southern coastal areas (Figure 3). Other agricultural areas are largely fragmented and generally do not exceed 1 ha, but represent 20% of the total cultivated area.[2] Agricultural areas comprise 232,200 ha (23% of the country)[3] and include permanent crops, temporary crops, and greenhouses. Permanent crops represent 54% of the total cultivated area (Table 1). Temporary crops include cereals, pulses, vegetables, fodder crops, and industrial crops, and include 44% of cultivated areas. The remaining crop areas are located in greenhouses.

Although the agricultural sector provides only 6.3% of the GDP, commodities contribute 17% of the values of exports. Most of the rural population is dependent on the sector as a primary or secondary source of income.

Several challenges raise concerns for the sector. The semi-arid climate and projected climate change, indicating increasing temperature and decreasing precipitation, induce additional dependence on water resources. Additionally, the agricultural market is often volatile and can reduce rural incomes. Thirdly, the government role in terms of current research and technologies is limited.

FIGURE 1: Average annual precipitation

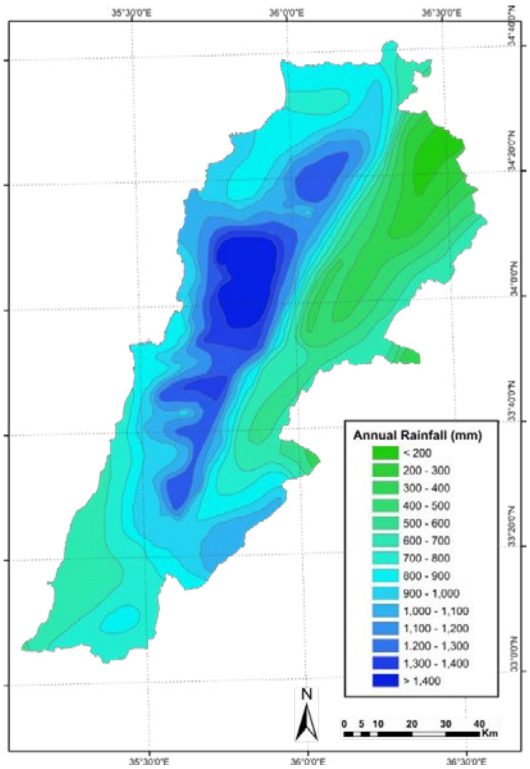


FIGURE 2: Agricultural output

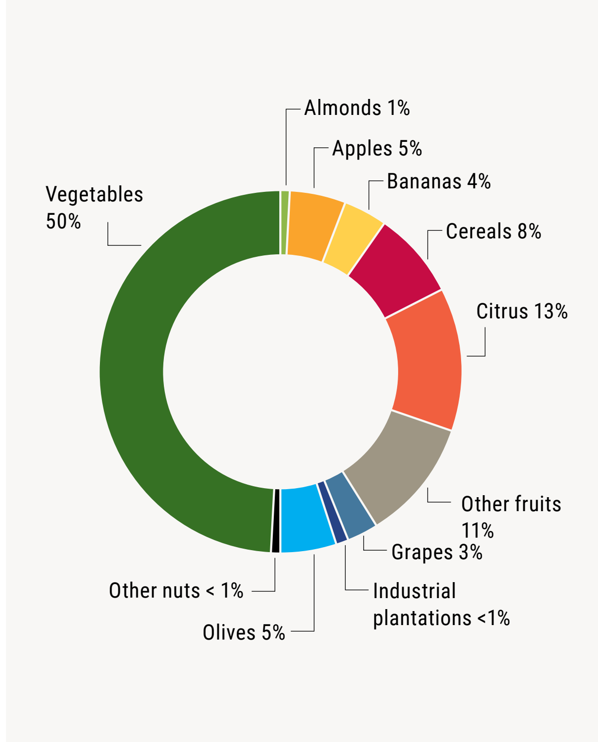


FIGURE 3: Cultivated areas in Lebanon

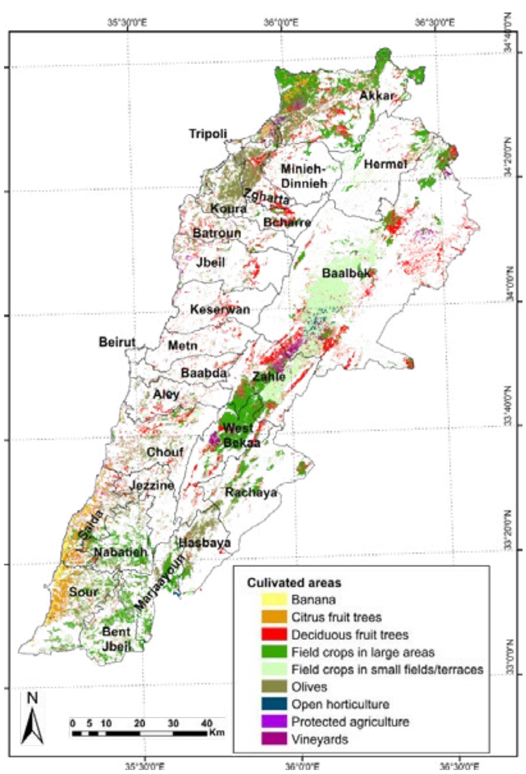


TABLE 1: Distribution of permanent crops by casa in Lebanon (FAO, 2010)

Caza	Total Permanent Croplands (ha)	% of Total Caza Area	% of Total Permanent Cropland Cultivated Area								
			Banana	Citrus	Apples	Other Fruit Trees	Almonds	Other Nuts	Grapes	Olives	Industrial Plantations
Akkar	16,688	20	< 0.1	8.3	10.7	4.1	9.8	1.8	5.3	59.6	0.2
Minieh-Dinnieh	5,334	17	< 0.1	11.3	30.3	3.6	34.5	0.6	0.7	18.7	0.2
Zgharta	5,037	28	< 0.1	8.1	7.6	2.1	2.4	< 0.1	1.6	77.9	0.1
Tripoli	221	8	0.1	14.7	< 0.1	3.0	0.3	< 0.1	< 0.1	81.6	0.2
Koura	5,989	33	< 0.1	2.2	0.4	1.6	0.4	< 0.1	2.3	93.1	< 0.1
Bcharre	1,495	9	-	0.1	85.4	1.5	6.4	0.3	2.3	3.9	0.1
Batroun	2,614	9	0.1	1.8	20.7	7.2	5.2	0.6	7.2	56.6	0.6
Jbeil	2,444	6	1.3	0.8	53.6	4.6	4.9	0.9	6.3	27.2	0.3
Keserwan	1,389	4	1.2	3.4	50.2	12.1	13.7	1.1	9.7	8.5	0.2
Metn	1,208	5	0.1	1.9	22.7	45.3	16.5	0.8	5.5	6.9	0.0
Baabda	3,321	17	< 0.1	0.9	13.1	64.9	4.9	0.7	4.3	11.3	0.0
Aley	2,322	9	< 0.1	2.5	7.9	28.3	11.5	0.6	12 .2	36.5	0.3
Chouf	6,468	13	2.0	1.7	9.1	21.4	8.7	1.2	4.5	51.1	0.2
Jezzine	2,954	12	< 0.1	3.9	5.0	43.8	1.9	0.9	6.0	38.3	0.1
Saida	7,647	28	17.7	41.3	0.3	9.6	1.1	0.0	1.1	28.3	0.5
Sour	9,552	23	15.3	32.3	0.3	2.5	0.5	0.1	0.2	47.6	1.2
Hermel	4,641	8	-	0.2	8.0	2.1	41.5	5.7	2.2	40.4	< 0.1
Baalbek	19,009	8	-	0.0	13.2	2.5	52.5	0.9	18.6	12.3	< 0.1
Zahle	5,046	12	-	-	12.4	2.8	47.9	0.5	33.8	2.1	< 0.1
West Bekaa	4,569	11	-	< 0.1	20.6	3.0	14.4	2.5	28.2	31.0	0.3
Rachaya	2,951	5	-	0.0	6.6	4.4	16.5	2.5	32.4	37.5	0.1
Hasbaya	4,576	17	< 0.1	0.8	2.6	10.6	3.3	0.6	2.3	79.9	0.1
Nabatieh	3,656	12	0.1	16.1	1.1	9.5	1.1	0.4	1.2	67.9	0.9
Marjaayoun	3,833	15	< 0.1	2.1	3.4	4.1	9.4	0.7	1.4	78.1	0.6
Bent Jbeil	2,963	11	< 0.1	0.8	2.1	8.9	5.2	0.4	3.8	77.4	1.5

2.3 Water Resources

2.3.1 Water use

Accurate values for water withdrawals in Lebanon are difficult to obtain due to gaps in long term data monitoring, system leakages, and other factors. In 2010, the total annual water demand was estimated at 1,530 Mm^3, divided between the agricultural (58%), domestic (31%) and industrial (11%) sectors.[4] Current agricultural demand is higher, approximately 85%.[5] Available water resources include surface water (~30%), groundwater (~53%), recycled irrigation drainage (~13%), desalinated water (~4%) and recycled wastewater (< 1%).[6] An estimated 1,420 km^2 of croplands depend on irrigation (51% of cultivated areas).[7]

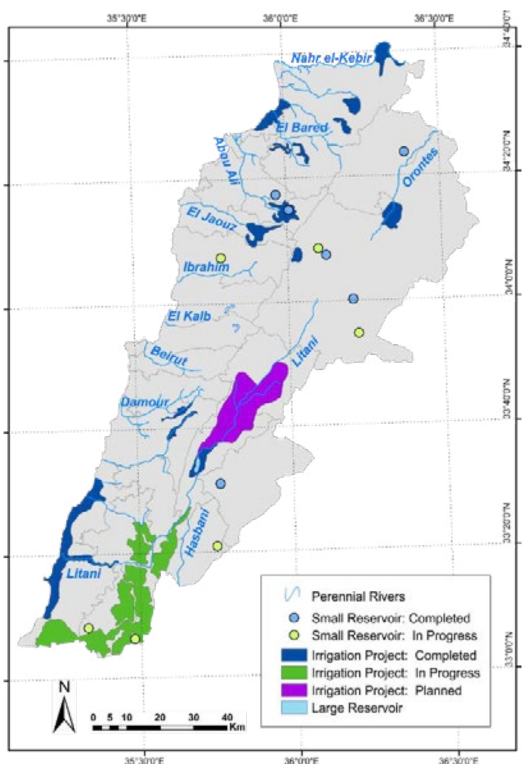
2.3.2 Surface use

Lebanon has 40 major streams, of which 17 are considered perennial (Figure 4) and are divided into four hydrologic regions:

- Orontes River (Nahr el Assi) Basin, located in the north
- Hasbani River Basin, in the southeast
- Litani River Basin, flowing from north-to-south in eastern Lebanon, and then westward toward the Mediterranean Sea in the south
- Major coastal river basins, including Nahr el-Kebir River Basin, located in the north along the border with Syria

The first three basins cover about 45% of Lebanon. Both the Orontes River and the Hasbani River are transboundary rivers, shared with Syria and Palestine, respectively. The Litani River is the longest in Lebanon, with a total length of 170 km and a catchment area of about 2,180 km^2. Discharge data is based on various studies (Table 2) and assumed to be much less currently.

FIGURE 4: Perennial rivers and irrigation projects



Source: adapted from CDR, 2016.

TABLE 2: Data for selected perennial rivers in Lebanon

River	Length (km)	Average annual discharge (Mm^3)
Orontes	46	480
Hasbani	21	151
Litani	170	793
El-Kebir	58	190

Source: El-Fadel et al., 2000

2.3.3 Groundwater

There are eight major aquifers in Lebanon, with a total estimated volume of 1,360 Mm^3 annually.[8] Aquifers are characterized as karst, formed by soluble limestone, which create fissures and fractures that promote the percolation and infiltration of precipitation. Groundwater is subsequently stored in aquicludes, reappears as springs at lower elevations, forms submarine springs, or is lost in deep layers.

Karstic phenomena generate challenges for groundwater studies and map development. Although there have been several studies to evaluate the extent, hydrologic associations, storage capacity, quality, and retention time of groundwater aquifers in Lebanon, data availability is limited. The most recent comprehensive study on groundwater resources in Lebanon has estimated groundwater extraction rates in public wells at 249 Mm^3/yr, without accurate estimates for private wells.[9] Overall average groundwater extraction rate were reported to range between 400 to 1,000 Mm^3 annually in earlier reports.[10]

2.3.4 Irrigation development

Main irrigated crops include cereals, potatoes, citrus, and vegetables. About 45% of croplands depend upon surface irrigation, primarily basin and furrow type. Typically, such schemes use diversion or intake structures on streams or springs with canals. Sprinkler irrigation is practiced in about 20% of croplands, particularly where sugar beet and potatoes are grown in the Bekaa Valley. Other areas, such as the coastal region, uses localized irrigation.[11] Public irrigation development includes dams and surface water reservoirs, pipelines, and canals (Figure 4).

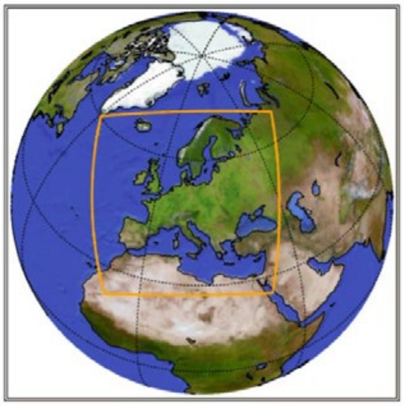
3 CLIMATE CHANGE IN LEBANON

3.1 Regional climate modelling overview

3.1.1 EURO-CORDEX

Global Climate Models (GCM) can offer general predictions of how the earth's climate may change in the future. However, the temporal and spatial scales of these models are too large to provide assessments at a regional level. Regional Climate Models (RCM) and Empirical Statistical Downscaling (ESD) can be applied over a limited area, coupled with GCM data, to supply climate data at a smaller scale. The Coordinated Regional Climate Downscaling Experiment (CORDEX) initiative engages multiple agencies to conduct regional climate modelling in differing domains across the globe. One such domain is the European Domain (EURO-CORDEX)[12], which extends beyond Europe to include North Africa and the Eastern Mediterranean (Figure 5).

FIGURE 5: EURO-CORDEX Domain



Source: Jacob et al., 2013

One of the primary advantages of EURO-CORDEX is that it provides data at a fine spatial resolution. Data is available at the general CORDEX resolution of 0.44° grid (~50km) as well as 0.11° (12.5 km). This is compared to the MENA-CORDEX domain, developed for the RICCAR project, which offers data at a coarser resolution (0.44°). Because of the small size of Lebanon, EURO-CORDEX was selected to best assess climate change at a country level.

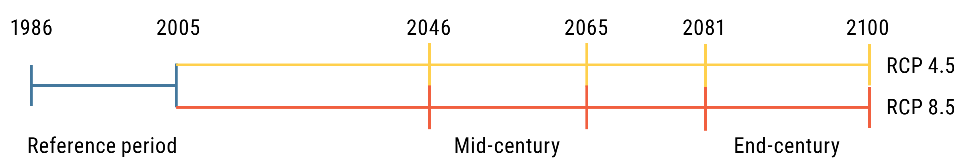
3.1.2 Reference and projection periods

When assessing future climate, modelling outputs are compared against a historical reference period which helps validate the ability of the model to represent the past. A reference period also serves to provide a baseline to compare future climate projections. In accordance with IPCC, three future 20-year time periods are evaluated: near-century (2016-2035), mid-century (2046-2065), and end-century (2081-2100).

There have been multiple approaches to provide climate projections including representations of increasing greenhouse gas (GHGs) emissions. Current IPCC practice is the use of representative concentration pathways (RCP), which correspond to radiative forcing projections expressed in watts per square metre (W/m^2). For this study, future climate was based on two projections: RCP4.5 and RCP8.5. The former (RCP4.5) represents a moderate emissions scenario while the latter (RCP8.5) represents an extreme scenario. In terms of context, average global increases in temperature by the end of this century are nearly 2°C for RCP4.5 and over 4°C for RCP8.5.[13]

For this study, mid-century and end-century were evaluated for both RCP4.5 and RCP8.5 (Figure 6), which were compared to the reference period. Near-century was excluded as it can be considered indicative of climate variability rather than climate change. Additionally, other scenarios (i.e. RCP2.6, RCP6.0) were also excluded due to data unavailability.

FIGURE 6: Time periods and scenarios studied



3.1.3 Ensemble analysis

Because differing models can produce diverging results, the use of an ensemble mean can best provide future climate projections. An ensemble should consist of at least three members which are then averaged. The ensemble was based on results driven by three GCM models: CNRM-CM5, EC-EARTH, and IPSL-CM5A-MR which were downscaled based on the Rossby Centre Regional Atmospheric Model (RCA4), developed by SMHI.

3.2 Regional climate modelling output in Lebanon

3.2.1 Change in temperature

Results from EURO-CORDEX projections at mid-century indicate that temperatures in Lebanon are projected to rise by an average of 2.7°C (RCP4.5) to 3.9°C (RCP8.5), with smaller increases toward the coast (Figure 7). The largest increases are projected in the northern Lebanon Mountains. At end-century, temperature is projected to increase by an average of 3.6°C (RCP4.5) to 6.6°C (RCP8.5), when compared to the reference period (Figure 8). Similar to mid-century, the smaller increases are projected near the coast while the largest change is located in the northern Lebanon Mountains.

RICCAR data reported more modest increases in temperature, averaging 1.2°C (RCP4.5) to 1.7°C (RCP8.5) at mid-century and 1.5°C (RCP4.5) to 3.2°C (RCP8.5). The coarse spatial resolution failed to capture localized climatic effects, including the increases displayed in the Lebanon Mountains.[14]

FIGURE 7: Change in temperature compared to the reference period at mid-century for (a) RCP4.5 and (b) RCP8.5 (0.11° grid resolution)

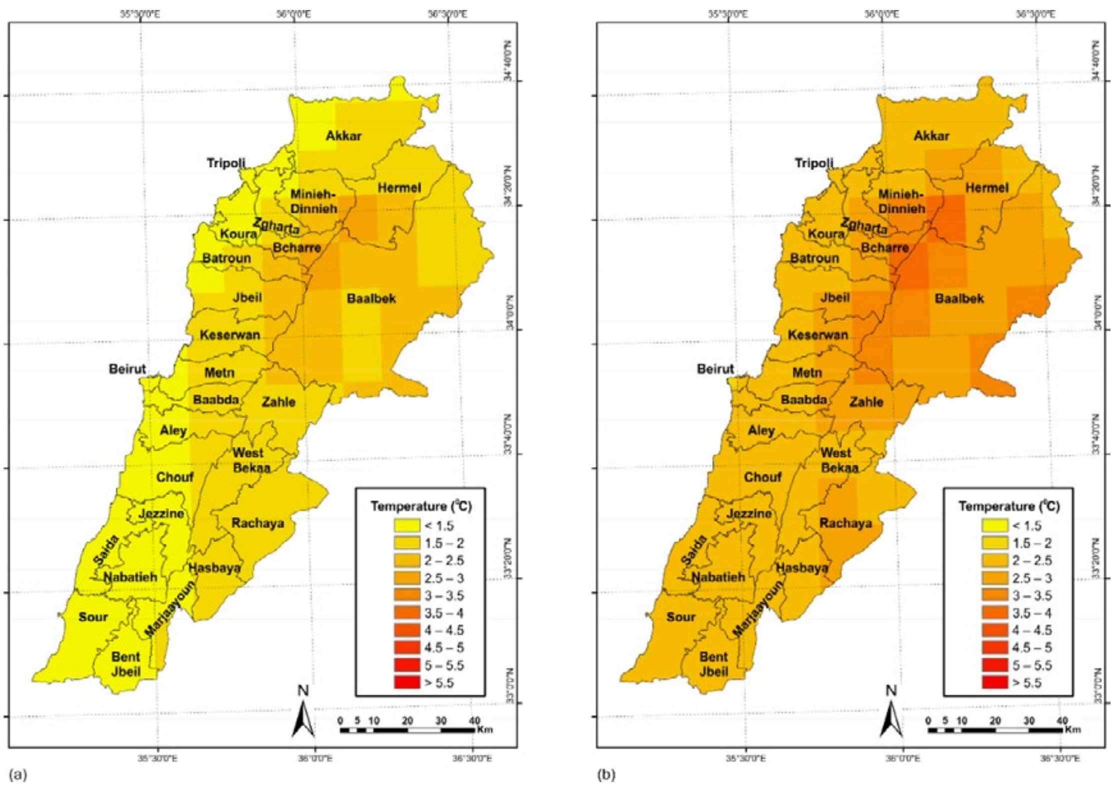
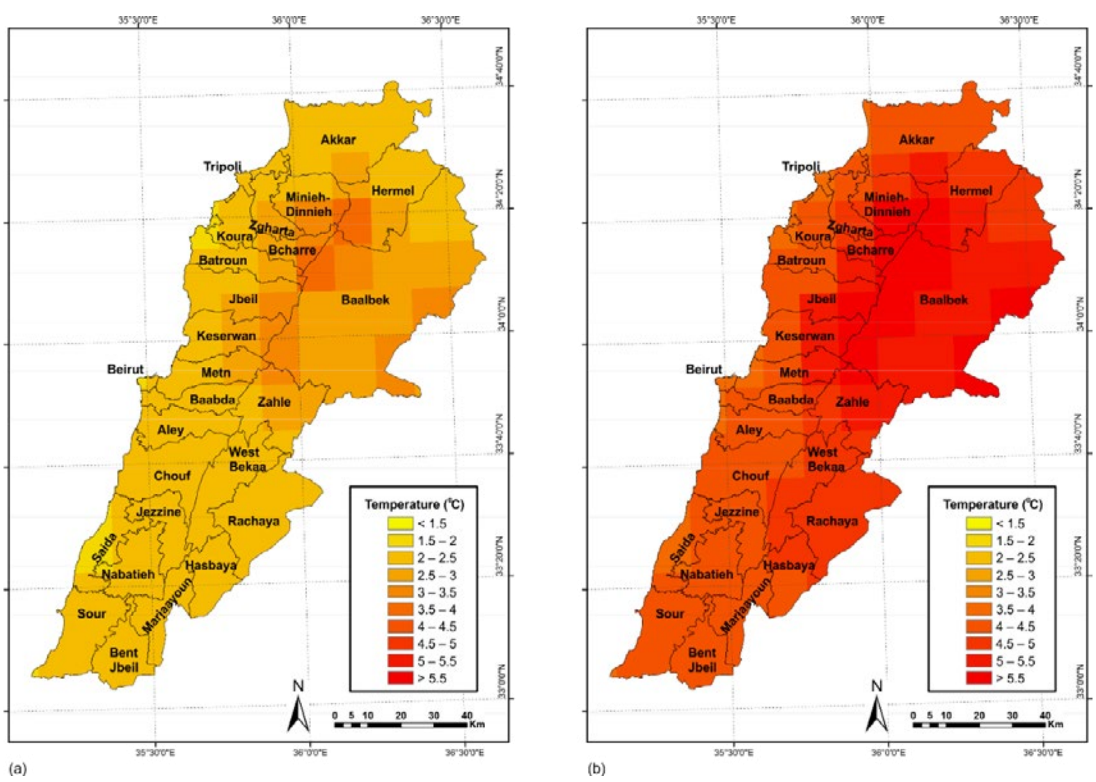


FIGURE 8: Change in temperature compared to the reference period at end-century for (a) RCP4.5 and (b) RCP8.5 (0.11° grid resolution)



3.2.2 Change in precipitation

Precipitation is projected to generally decrease by mid-century, with decreases ranging from 26 mm/year (RCP4.5) to 43 mm/year (RCP8.5) on average (Figure 9). The largest decreases are apparent adjacent to the Lebanon Mountains, which can adversely impact groundwater aquifers dependent on snowfall. Very slight increases (up to 4 mm/year) are detected in selected areas located in the Bekaa Valley and along the southern coast but will have likely negligible impact. By end-century, precipitation is projected to decrease across the entire study area, ranging from an average of 48 mm/year (RCP4.5) to 96 mm/year (RCP8.5) (Figure 10). Similar to mid-century, decreases at end-century are more modest in the north, northeast, and the south, but intensify in the mid-section of the study area.

These decreases which are based on EURO-CORDEX reflect an average decline of 5% (RCP4.5) to 9% (RCP8.5) at mid-century, and 6% (RCP4.5) to 11% (RCP8.5) at end-century. Comparatively, RICCAR data reported a slight increase of 1% for RCP4.5 but a decrease of 7% for RCP8.5 at mid-century. RICCAR values were similar for end-century, reporting an average decrease of 4% (RCP4.5) to 11% (RCP8.5).[15]

3.2.3 Change in total runoff

Similar to temperature and precipitation, runoff projections were based on climate model downscaling from EURO-CORDEX. This is in contrast to RICCAR, where runoff was modelled by inputting bias-corrected climate data into two different hydrological models: Hydrological Predictions for the Environment (HYPE) and Variable Infiltration Capacity (VIC) due to uncertainties stemming from data unavailability.[16] Because of the differing approaches, it is assumed that RICCAR runoff data is more accurate. However, similar to the RICCAR climate data, the corresponding spatial resolution in this study was too coarse and thus EURO-CORDEX data was used.

Data from EURO-CORDEX signals an average decrease of 29 mm/year for RCP4.5 and 45 mm/year for RCP8.5 at mid-century (Figure 11). For end-century, runoff projections indicate an average decline of 49 mm/year (RCP4.5) to 70 mm/year (RCP8.5), compared to the reference period (Figure 12). Comparatively, for the HYPE model, decreases of 9 mm/year (RCP4.5) to 60 mm/year (RCP8.5) are projected for mid-century. For end-century, decreases amplify from 24 mm/year (RCP4.5) to 81 mm/year (RCP8.5). On the other hand, the VIC model signaled an increase of 5 mm/year for RCP4.5, but a decrease of 41 mm/year for RCP8.5 at mid-century. At end-century runoff is projected to decrease by 11 mm/year (RCP4.5) to 57 mm/year (RCP8.5) for this model (Table 3).[17]

FIGURE 9: Change in precipitation compared to the reference period at mid-century for (a) RCP4.5 and (b) RCP8.5 (0.11° grid resolution)

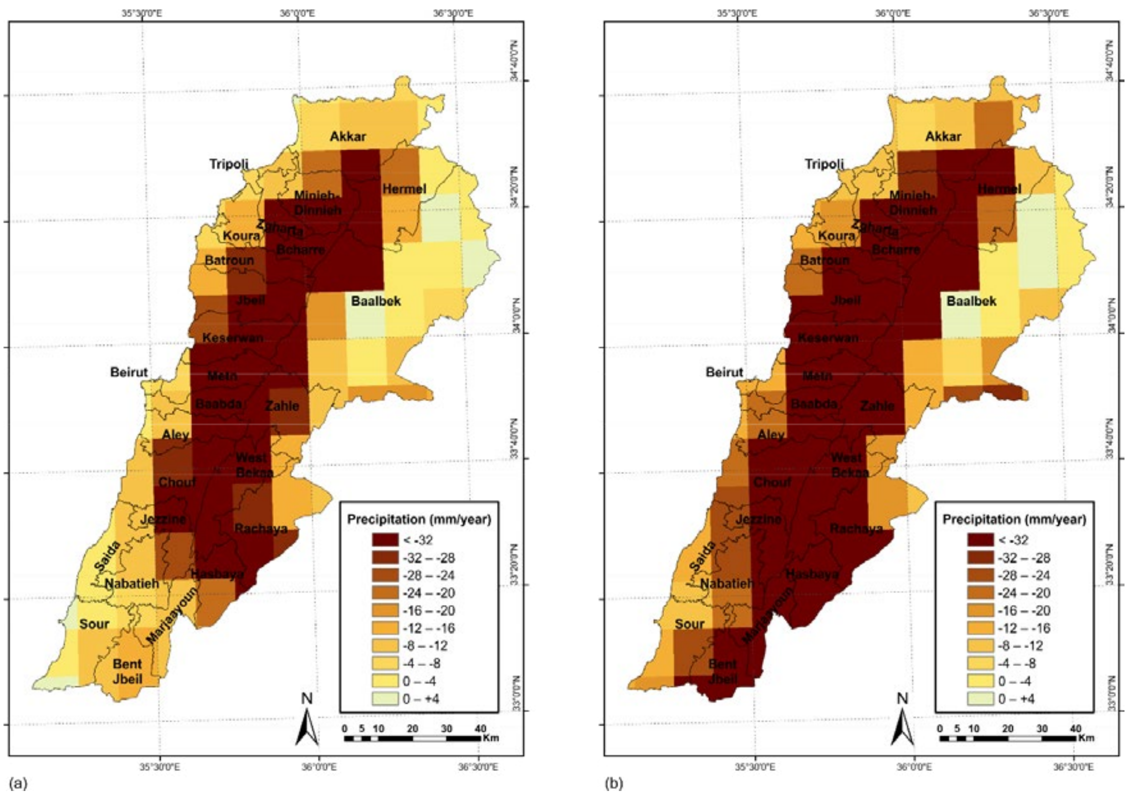


FIGURE 10: Change in precipitation compared to the reference period at end-century for (a) RCP4.5 and (b) RCP8.5 (0.11° grid resolution)

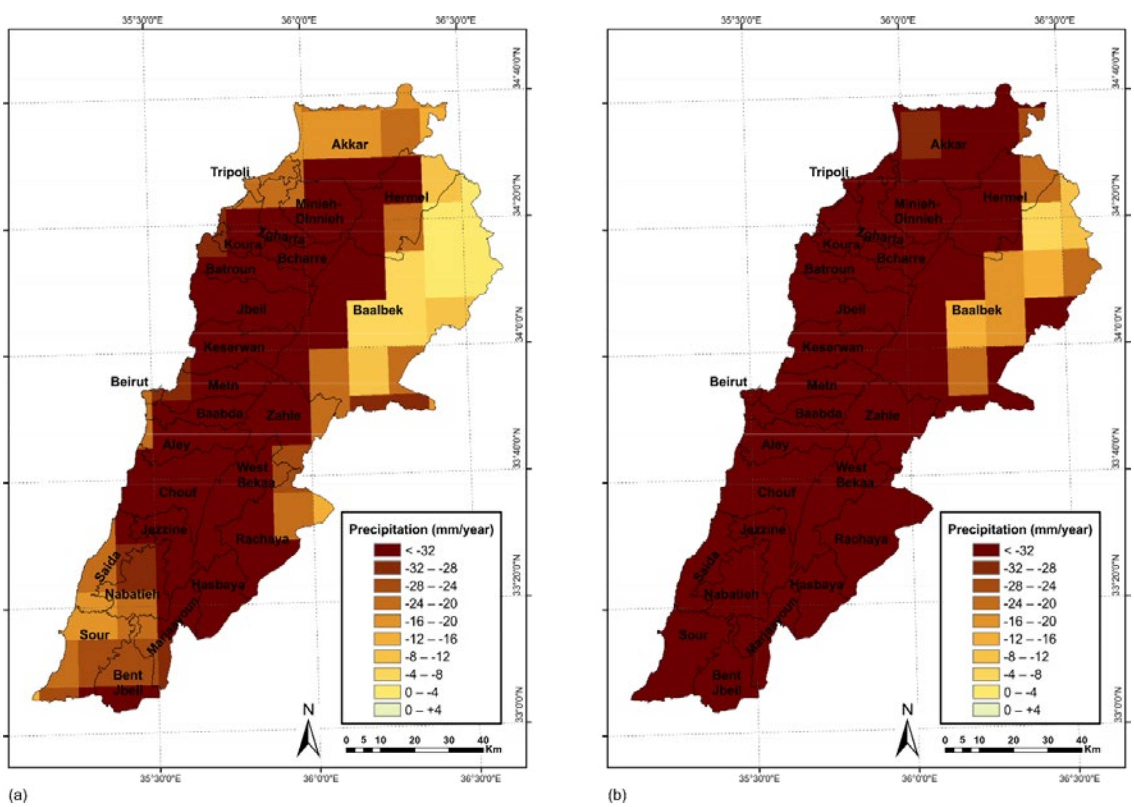


FIGURE 11: Change in runoff compared to the reference period at mid-century for (a) RCP4.5 and (b) RCP8.5 (0.11° grid resolution)

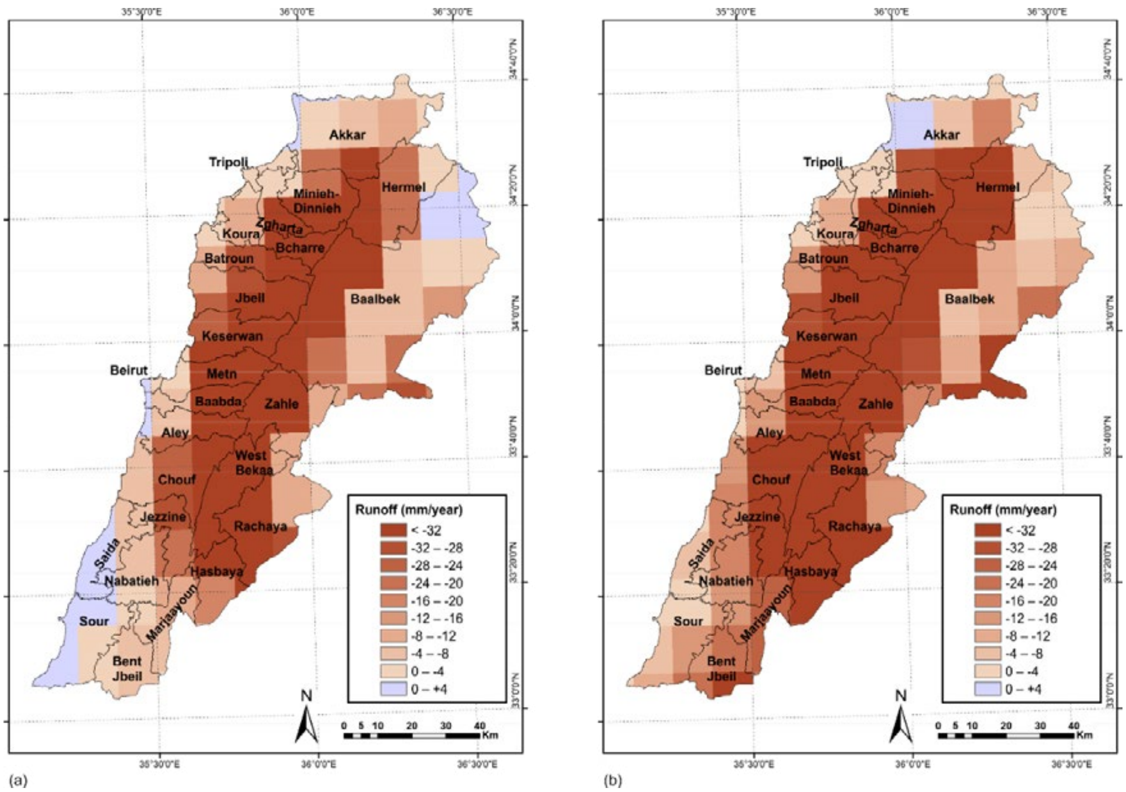


FIGURE 12: Change in runoff compared to the reference period at end-century for (a) RCP4.5 and (b) RCP8.5 (0.11° grid resolution)

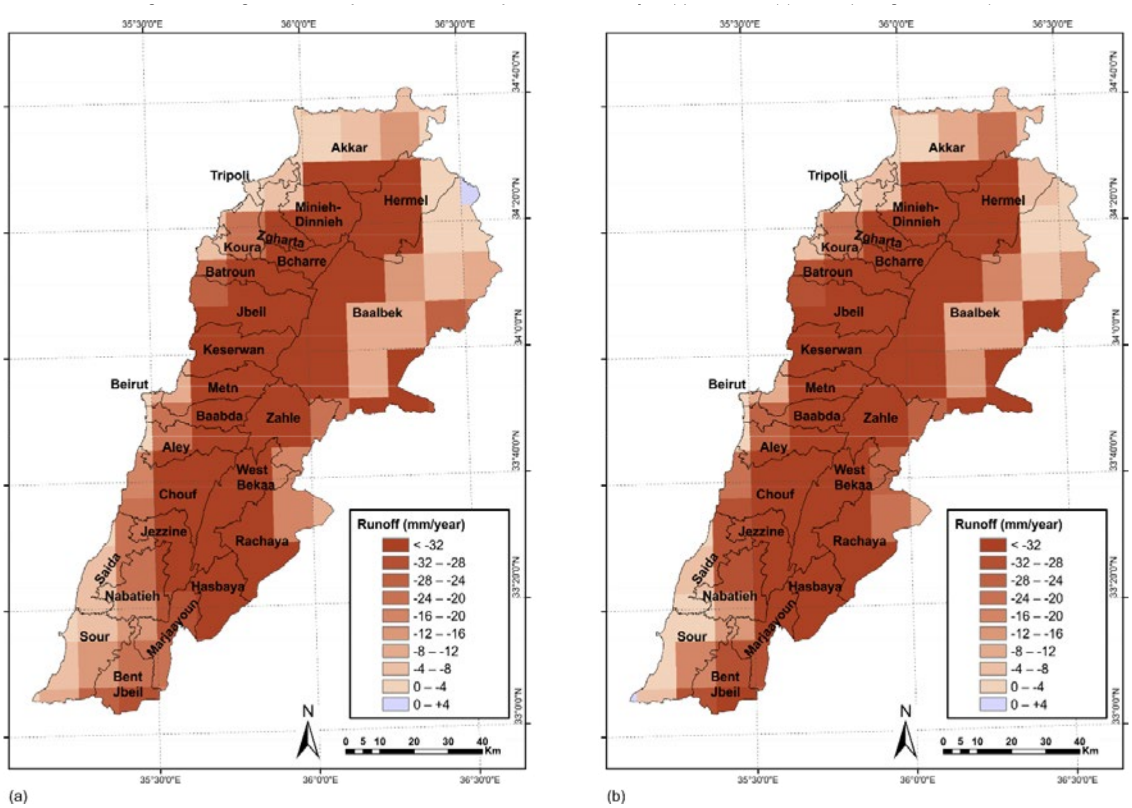


TABLE 3: Comparison of average change in runoff values for Lebanon

Scenario	Average change in runoff (mm/year)		
	EURO-CORDEX	RICCAR: HYPE	RICCAR: VIC
Mid-century RCP4.5	-29	-8.7	+4.6
Mid-century RCP8.5	-45	-59.9	-41.3
End-century RCP4.5	-49	-24.2	-10.7
End-century RCP8.5	-70	-81.5	-57.2

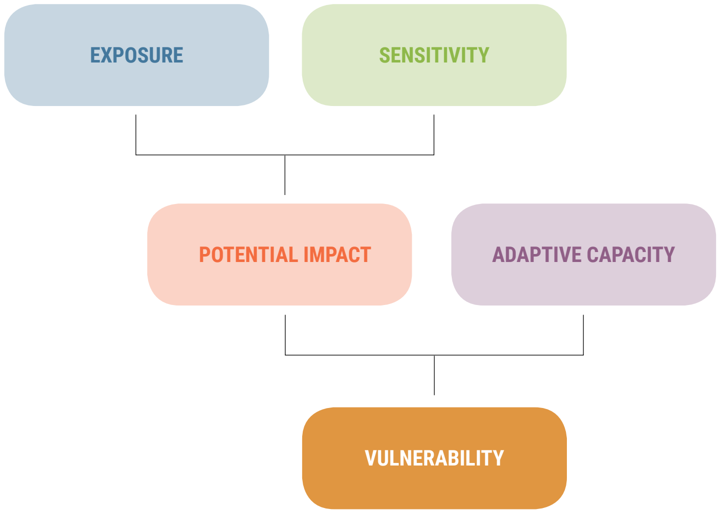
4 VULNERABILITY ASSESSMENT METHODOLOGY

4.1 Conceptual framework

Vulnerability is an evolving concept linking climate science and policy which can be applied to a socio-ecological system. Differing studies have applied varied approaches to vulnerability. Current trends adopt the methodology set forth by IPCC in its Fourth Assessment Report (AR4)[18], which is indicator-based and founded upon multiple components (Figure 13). Within this conceptual framework:

- **Exposure** describes the nature and extent to which a system is subjected to climatic phenomena. It can consider single climatic variables (i.e. local temperature), specific storm events, or most commonly, climate change impacts, which were evaluated for this study.
- **Sensitivity** depicts the weaknesses of a system, considering both the physical and natural environment. Typical indicators include land use, population density, and demographics.
- **Potential impact** portrays the prospective consequences of climate change on a system. It is based upon the combination of exposure and sensitivity.
- **Adaptive capacity** reflects the ability of a system to adjust to adverse impacts stemming from climate change. It can consider factors such as damage control, opportunities, or coping mechanisms.
- **Vulnerability**, in this context, is the degree to which a system is susceptible to the adverse impacts of climate change. It considers exposure, sensitivity, and the resultant potential impact, as well as adaptive capacity.

FIGURE 13: Components of vulnerability based on the IPCC AR4 approach



Source: IPCC, 2007

4.2 Vulnerability assessment indicators and aggregation

The integrated vulnerability assessment methodology is a multistep process described herein. In general, appropriate indicators are selected based upon three components (exposure, sensitivity, and adaptive capacity) and aggregated together to evaluate vulnerability. Indicators are temporally and spatially based and thus the eventual result can be depicted upon a map using the ArcGIS software. The methodology adopted for this study was based upon the approach applied for RICCAR.[19]

4.2.1 Development of impact chains

Impact chains are analytical tools which help describe the cause and effect relationships between indicators and climate change vulnerability for a given system. It is an iterative process which considers the system (i.e. agriculture) and the corresponding indicators characterizing it.

The final impact chain for this study is shown in Figure 14.

4.2.2 Selection of indicators and data acquisition

Indicators were chosen based on the impact chains to describe the factors contributing to vulnerability. Selection entailed an in-depth process, which considered multiple factors. These include, but were not limited to:

- **Relevance:** Is the indicator representative of one or more aspects relevant to agriculture in Lebanon as well as one of the three vulnerability components?
- **Homogeneity:** Is data available for the entire study area, from the same time period, and from the same source?
- **Validity:** Does the indicator have a precise definition?
- **Reliability:** Can the indicator be quantified and measured?

Three exposure indicators were selected based on the climate change and hydrological data obtained from EURO-CORDEX: temperature, precipitation, and runoff. The indicators are measured in terms of changes in values compared to the reference period rather than the actual values themselves. Four scenarios were evaluated based on two time periods (mid- and end-century) and two emission scenarios (RCP4.5 and RCP8.5).

A total of 15 sensitivity indicators were selected based on societal, environmental, ecological, and anthropogenic factors which place pressure upon agriculture in Lebanon. Considerations include population density and demographics, land use, and soil conditions, based on the latest available data (Table 4). Although conditions may change in the future, this data is considered more reliable than future speculative data. Details can be found in the Appendix.

FIGURE 14: Impact chain for agriculture

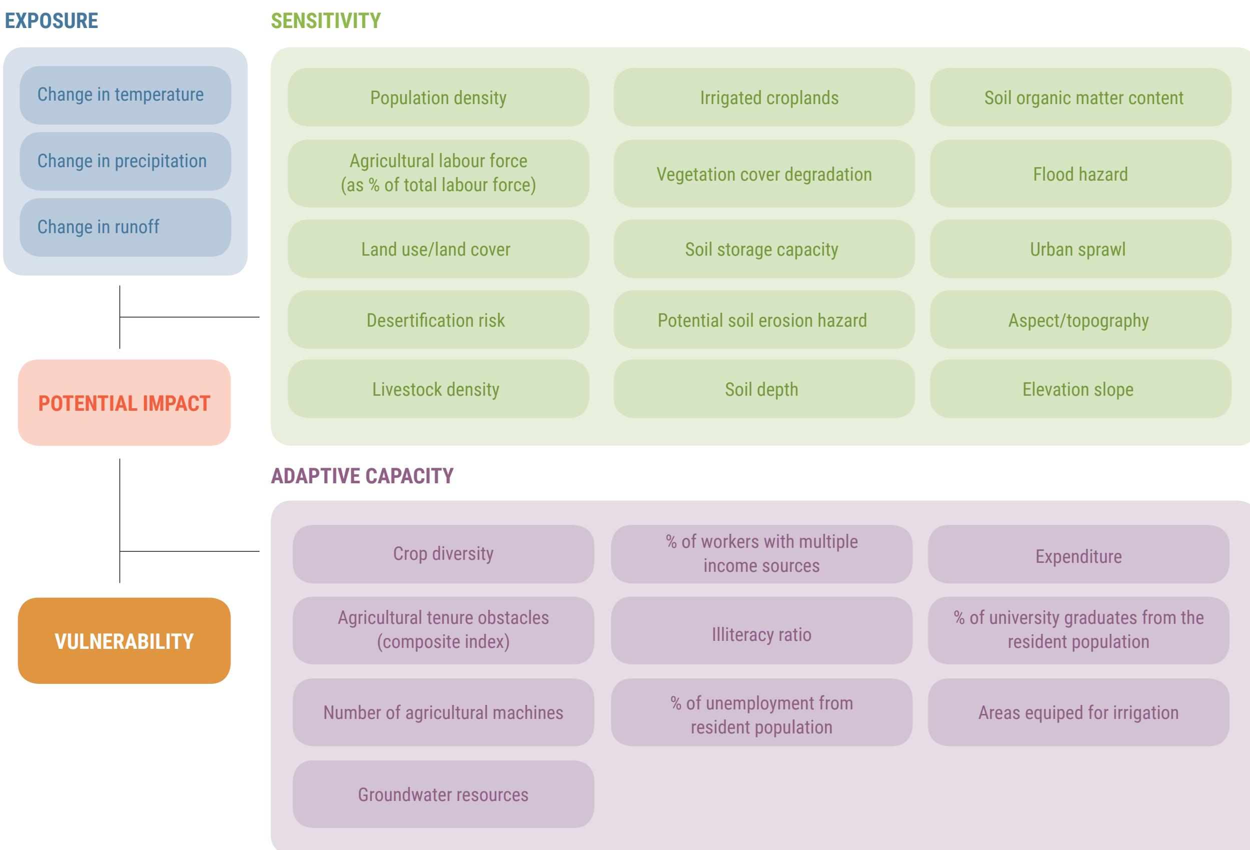


TABLE 4: Sensitivity indicators selected for the vulnerability assessment

Indicator Name	Data Type	Source	Year
Population density	Raster	Landscan Global Population Database	2015
Agricultural labour force	Tabular	Census of Lebanese Agricultural Ministry	2010
Land use/land cover	Raster	CNRS: LULC Map	2010
Desertification risk	Raster	National Action Program	2004
Livestock density	Tabular	Census of Lebanese Agricultural Ministry	2010
Irrigated croplands	Tabular	Census of Lebanese Agricultural Ministry	2010
Vegetation cover degradation	Raster	Based on MODIS remote sensing data	2000-2011
Soil storage capacity	Vector	CNRS: Soil map of Lebanon	2006
Potential soil erosion hazard	Raster	CNRS	2002
Soil depth	Vector	CNRS: Soil map of Lebanon	2006
Soil organic matter content	Vector	CNRS: Soil map of Lebanon	2006
Flood hazard	Raster	CNRS	2014
Urban sprawl	Raster	CNRS: LULC Map	2010
Aspect/topography	Raster	ALOS: AW3D 30 m	2016
Elevation slope	Raster	ALOS: AW3D 30 m	2016

Ten adaptive capacity indicators were selected based on factors relevant to agriculture in Lebanon which can help or hinder the ability to adapt (Table 5). Elements included demographic factors, advancements or obstacles affecting agriculture, and expenditures. Details can be found in the Appendix.

TABLE 5: Adaptive capacity indicators selected for the vulnerability assessment

Indicator Name	Data Type	Source	Year
Crop diversity	Tabular	Census of Lebanese Agricultural Ministry	2010
Agricultural tenure obstacles	Tabular	Census of Lebanese Agricultural Ministry	2010
Number of agricultural machines	Tabular	Census of Lebanese Agricultural Ministry	2010
Groundwater resources	Vector	UNDP	2014
% of workers with multiple income sources	Raster	RGA	1999
Illiteracy ratio	Raster	MoSA/UNFPA	2000
% of unemployment from resident population	Tabular	Central Agency of Statistics	1998
Expenditure	Raster	SDATL, Ministry of Lebanon	2005
% of university graduates from the resident population	Raster	Social Affairs Ministry	1996
Areas equipped for irrigation	Tabular	FAO	1998

Indicators were subsequently evaluated for GIS capability. All data was converted into raster format, a gridded matrix of cells organized into rows and columns, where each cell contains a discrete value. This format allows for aggregation of data. Thus, vector data was converted within GIS to raster format. Tabular data is based on statistics by caza; this data was added to the caza vector shapefile and then converted to raster.

Best results were obtained by using indicator datasets with a 100-m grid spatial resolution, which required resampling of some indicators. In particular, the exposure indicators obtained from EURO-CORDEX data needed to be resampled to 100 m from the original ~12.5 km resolution. The resampling resulted in negligible changes between the affected original datasets and the final indicators.

4.2.3 Normalization and classification of indicator data

Because the different indicators have varying magnitudes and units of measurement, they were reclassified based on a common scale from 1 to 5 prior to aggregation. In the case of exposure and sensitivity indicators, class 1 represents a favourable condition (e.g. low exposure or low sensitivity) and class 5 designates an unfavourable condition. For adaptive capacity, the inverse is applied; class 1 signifies an unfavourable condition (e.g. low adaptive capacity) and class 5 characterizes a favourable condition.

Indicators were classified using one of several methods available in GIS: manual interval, equal interval, and natural breaks. Manual interval was generally used for descriptive data, such as land use, or when other classification methods were inappropriate. Equal interval classification divides attribute values into identically-sized subranges. Natural breaks, also known as the Jenks optimization method[20], utilizes natural groupings inherent in the data based on similar values and maximizing differences between classes. Method determination was based on expert opinion and was generally founded on the best wide representation of classes across the study area.

The exposure indicators were classified based on equal intervals that were common to the four scenarios. Details regarding classification of the different sensitivity and adaptive capacity indicators are described in the indicator factsheets in the Appendix.

4.2.4 Weighting and aggregation of indicators

Weighting schemes can have a significant effect on the resultant vulnerability assessment. Weights represent the relative contribution of each indicator. Potential techniques to determine indicator weights include participatory approaches, statistical methods (i.e. principal component analysis, exploratory factor analysis), and comparison to literature. For this study, all indicators within a given component were judged to exhibit the same relative importance and thus were equally weighted. Individual aggregators were combined together using a geometric aggregation technique. This technique is a non-linear approach preferred to other methods because it is multiplicative and synergetic.[21] Arithmetic aggregation, often used due to its simplicity, has two primary disadvantages: it assumes that indicators and components have no influence upon one another and unfavourable indicators can easily be compensated by a favourable one.

Aggregation of indicators into a vulnerability component (exposure, sensitivity, and adaptive capacity) composite indicator (CI) is specified in Equation 1, where n is the number of indicators.

$$CI = (Indicator_1 \times Indicator_2 \times Indicator_3 \times \ldots \times Indicator_n)^{1/n} \qquad \text{Equation 1}$$

Subsequently, the potential impact (PI) is calculated by aggregating the exposure and sensitivity composite indicators (CI_{Exp} and CI_{Sens}, respectively) (Equation 2).

$$PI = (CI_{Exp} \times CI_{Sens})^{1/2} \qquad \text{Equation 2}$$

Because the adaptive capacity classification is reversed (i.e. 1 represents an unfavourable condition and 5 signifies a favourable condition) compared to the other components, this composite indicator (CI_{AC}) must first be inverted ($CI_{AC\text{-}inv}$) prior to calculating vulnerability (Equation 3).

$$CI_{AC} = 6 - CI_{AC\text{-}Inv} \qquad \text{Equation 3}$$

Finally, vulnerability (V) is the aggregated result of potential impact and adaptive capacity (Equation 4).

$$V = (PI \times CI_{AC\text{-}Inv})^{1/2} \qquad \text{Equation 4}$$

The net result suggests that exposure and sensitivity each contribute 25% toward vulnerability whereas adaptive capacity provides 50%. This approach implies that mankind's ability to cope with the impacts on climate change has a stronger influence than the impacts themselves.

4.3 Extracted area of interest

Rather than display results for all of Lebanon, it was determined to only reveal results in cultivated areas (Figure 3). This serves to focus attention upon the specific areas studied. The area of interest reflects approximately one-third of the total area of Lebanon and includes permanent and temporary cropland areas and greenhouses.

4.4 Final classification

It was determined that aggregated results portrayed a limited range of values and thus areas of low and high vulnerability were difficult to differentiate. For this reason, a final reclassification was conducted based on the minimum and maximum aggregated values from each of the components and distributed into five equal intervals (Table 6). It is noted that this was conducted solely for presentation purposes as the actual aggregated values were used for subsequent aggregation iterations. The result was presented using a stop-light colour scheme, such that red is indicative of an unfavourable condition and green represents a favourable condition.

TABLE 6: Ranges of aggregated values and final classification for all vulnerability assessment maps

Final classification	Range of aggregated values
Class 1	1.52 – 2.14
Class 2	2.14 – 2.77
Class 3	2.77 – 3.39
Class 4	3.39 – 4.02
Class 5	4.02 – 4.64

4.5 Hotspots

Hotspots, areas that are particularly vulnerable to climate change, can be used as an effective visual communication tool. Concepts and methodologies to define hotspots vary among differing studies and are affected by spatial scale as well as uncertainties in data and outputs. For this study, a methodology similar to that applied for RICCAR was adopted. Hotspots were identified based on the absolute highest vulnerability areas (top 30%) in the four scenarios.

5 VULNERABILITY ASSESSMENT RESULTS

5.1 Exposure

The exposure composite indicator reflects temperature, precipitation, and runoff, which are aggregated together with equal weights. At mid-century (Figure 15), low exposure is projected for most of the study area for RCP4.5. However, areas of moderate exposure are apparent (17% of study area) for RCP8.5. Exposure follows the same trends as its indicators such that the areas of increased exposure are located around the northern Lebanon Mountains.

Similarly, for end-century (Figure 16) areas of moderate exposure range from 14% (RCP4.5) to 37% (RCP8.5) of the study area and generally includes southern Akkar, southern Baalbek, Zahle, northern West Bekaa, Chouf, and Jezzine. Areas of high exposure are solely apparent for RCP8.5 (7% of study area) and include areas above 900 m, including areas within Hermel, western Baalbek, northern Zahle, southern West Bekaa, eastern Bcharre, eastern Jbeil, and eastern Keserwan.

5.2 Sensitivity

Sensitivity represents the aggregated result of 15 indicators which describe social, environmental, ecological, and anthropogenic factors contributing toward agricultural susceptibility to climate change in Lebanon. The sensitivity composite indicator (Figure 17) reveals areas of low, moderate, and high sensitivity (12%, 53%, and 35% of the study area, respectively). Areas with the highest sensitivity are located in Baalbek (~27,000 ha) and Akkar (~17,000 ha). The former (including the villages of Hermel, Baalbek, Brital, and Taraya) embody areas with high livestock density and include citrus and almond croplands. The latter (including the villages of Qabbair, Michmiche, Fneidek, Akkar el-Atika, and Akroum) primarily includes olives, apples, and vegetables.

Sensitivity reflects current conditions but can change greatly over time if values from one or more contributing indicators evolve. For example, increased population density and urbanization can result in the decrease of agricultural landscapes. Similarly, desertification and the expansion of vegetation cover degradation can signal crop failure, low economic returns, or soil salination. In the absence of reliable projected data, however, indicators were based on the latest available data. This approach can also be considered an incentive to minimize increased sensitivity.

FIGURE 15: Exposure composite indicator at mid-century for (a) RCP4.5 and (b) RCP8.5

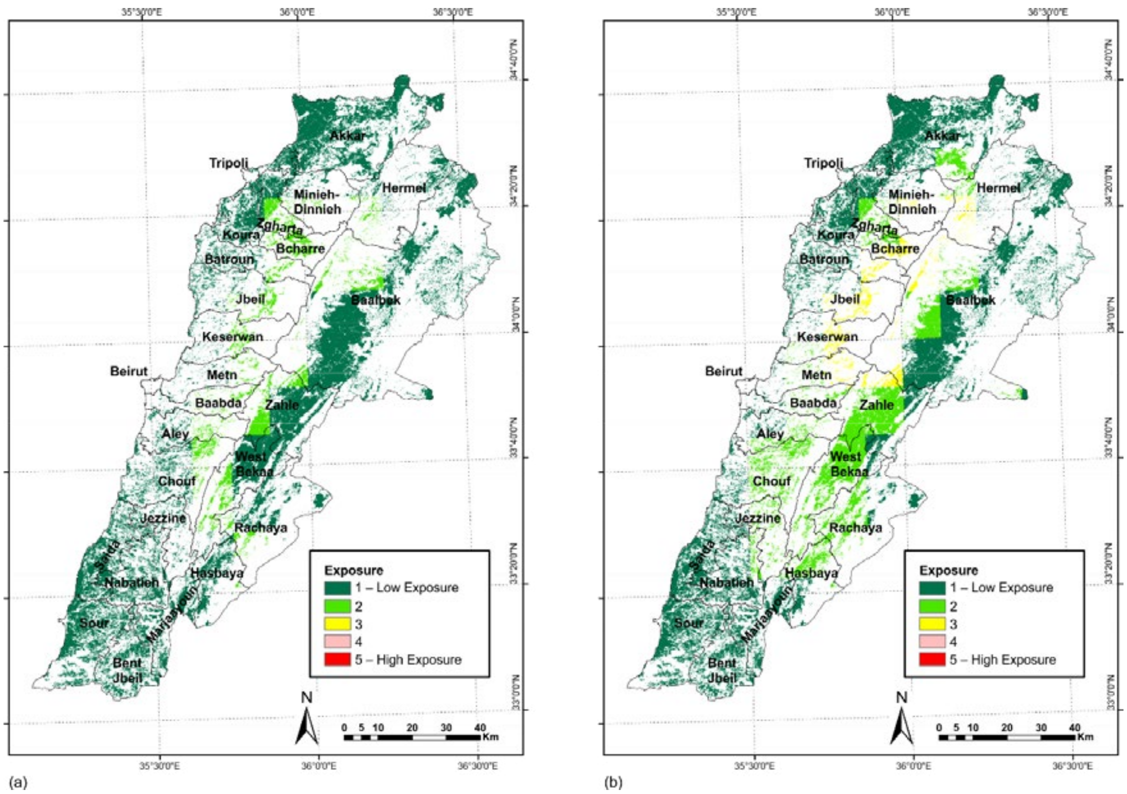


FIGURE 16: Exposure composite indicator at end-century for (a) RCP4.5 and (b) RCP8.5

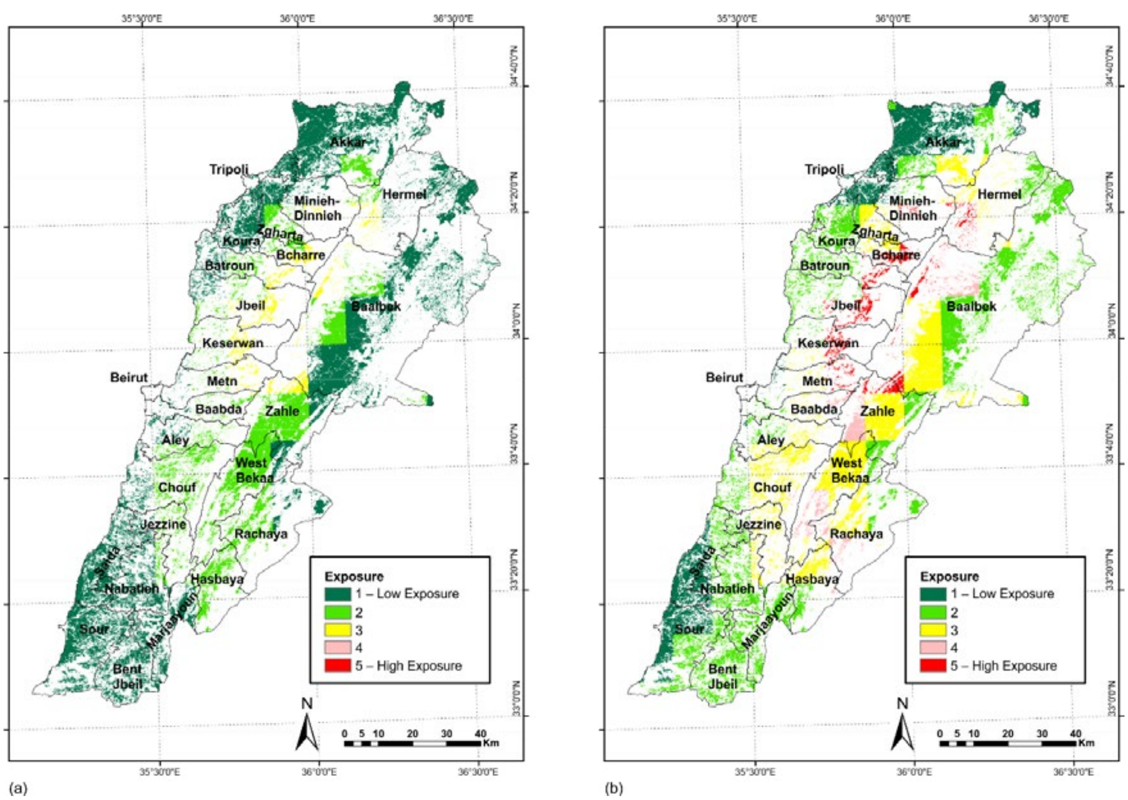
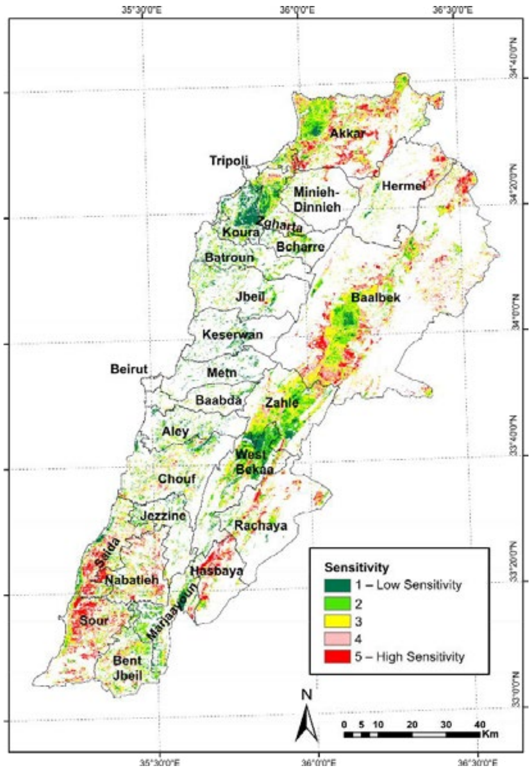


FIGURE 17: Sensitivity composite indicator



5.3 Potential impact

Potential impact reflects the aggregation of exposure and sensitivity, which are weighted equally. In the absence of available adaptation measures, potential impact is projected to increase from mid-century (Figure 18) to end-century (Figure 19) for both RCP4.5 and RCP8.5. For all scenarios, most of the study area signals moderate potential impact, affecting 70% (RCP4.5) to 80% (RCP8.5) of agricultural areas at mid-century. This increases slightly at end-century with projections of 74% (RCP8.5) to 85% (RCP4.5) of the study area indicating moderate potential impact. Areas of high potential impact are negligible at mid-century but range from 1% (RCP4.5) to 3% (RCP8.5) at end-century. Areas of high potential impact tend to be correlated with areas of high exposure.

Areas which exhibit increased potential impact include the Litani River valley in eastern Lebanon (Baalbek, Zahle, West Bekaa, Rachaya, and Hasbaya) and southeastern Akkar. Conversely, areas with lower potential impact are located in northern Lebanon near the coast until ~600 m in elevation and includes Zgharta and Koura.

FIGURE 18: Potential impact at mid-century for (a) RCP4.5 and (b) RCP8.5

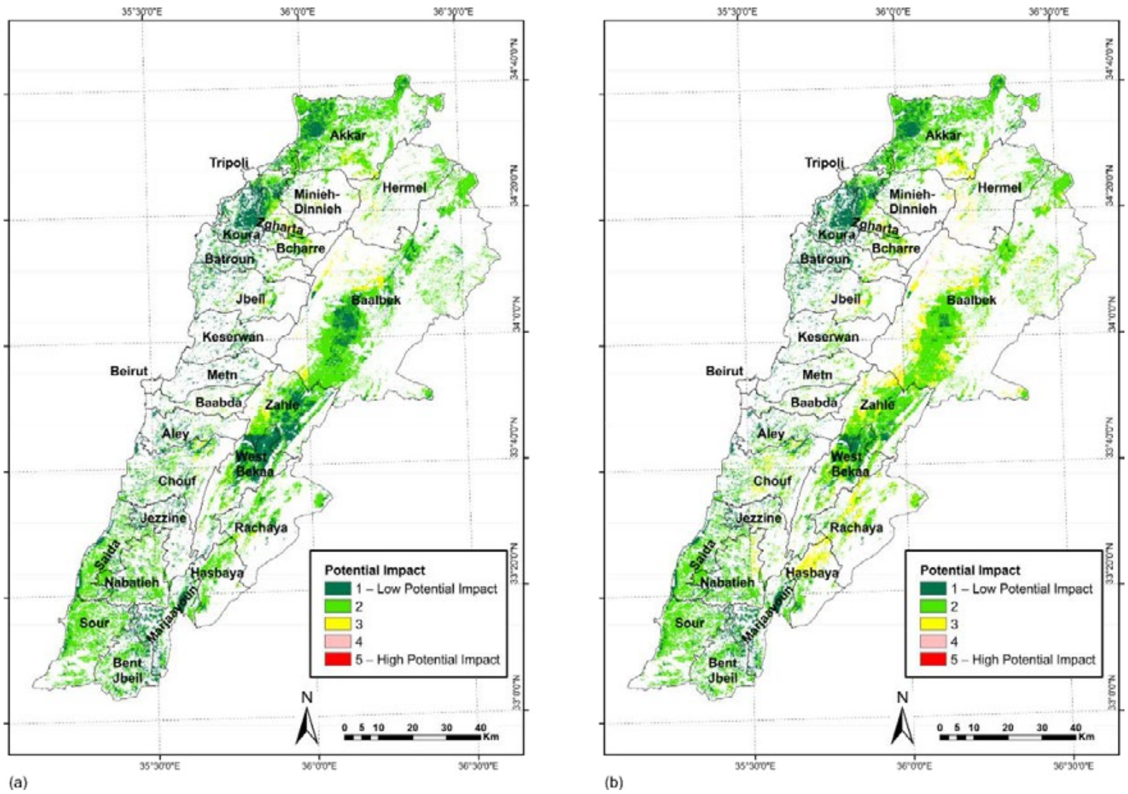
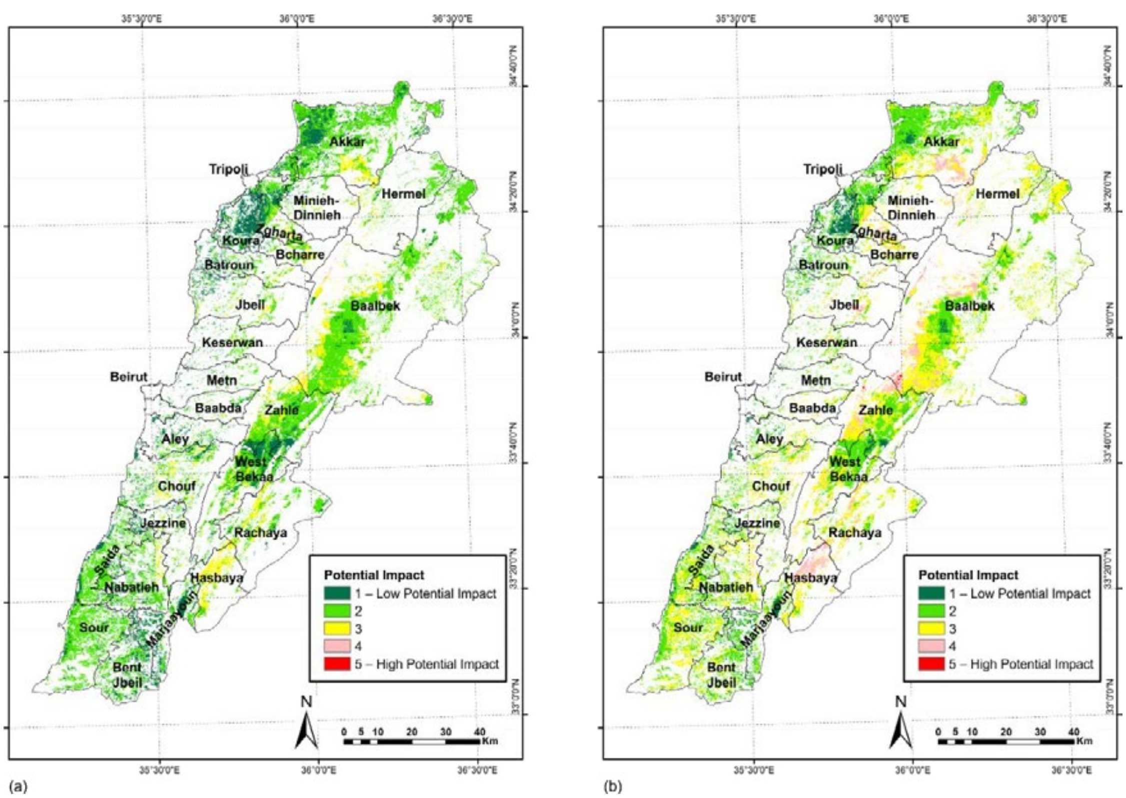


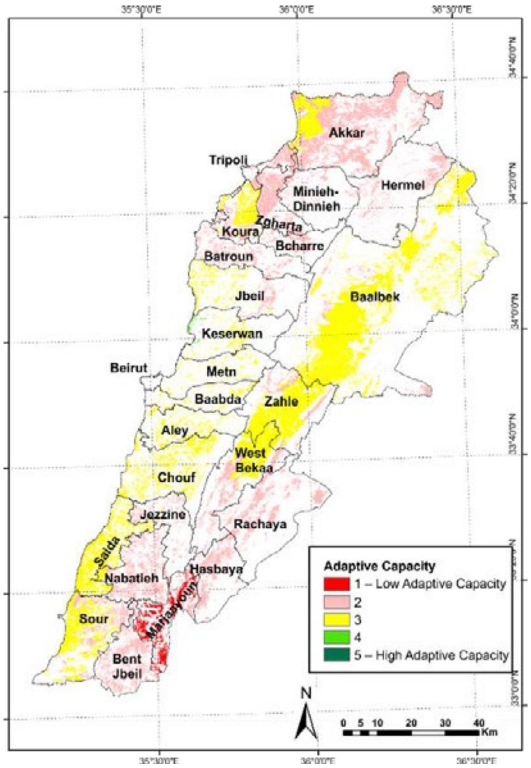
FIGURE 19: Potential impact at end-century for (a) RCP4.5 and (b) RCP8.5



5.4 Adaptive capacity

Adaptive capacity reflects the ability of the agricultural sector to cope with the impacts of climate change. It is generally low to moderate throughout the study area (Figure 20) but small areas near the coast (such as in Keserwan) exhibit relatively higher adaptive capacity. Although contributing indicators are based upon current conditions, adaptive capacity has the potential to either increase or decrease in the future based on evolving coping mechanisms.

FIGURE 20: Adaptive capacity composite indicator



5.5 Vulnerability

At mid-century, 82% (RCP4.5) to 87% (RCP8.5) of the study area is projected to exhibit moderate vulnerability, while 3% of the area signals high vulnerability (RCP8.5) (Figure 21). This increases for end-century, when 82% (RCP8.5) to 86% (RCP4.5) of the study area signals moderate vulnerability (Figure 22). High vulnerability areas are revealed in 3% to 14% of the study area.

For end-century RCP8.5, the cazas with the largest percentage of croplands (>50%) are classified as highly vulnerable and include Hasbaya, Bcharre, and Rachaya (Figure 23). Affected crops include field crops, such as vegetables, olives (particularly in Hasbaya), and deciduous fruit trees. Cazas with the largest areas (> 4,500 ha) of high vulnerability include Akkar, Rachaya, Hasbaya, and Baalbek.

Vulnerability exhibits a strong correlation with adaptive capacity and a modest correlation with sensitivity. Thus, enhancing adaptive capacity measures will have the greatest potential to reduce projected vulnerability. Correlation with exposure is relatively weak, although differences between scenarios are due to the exposure indicators. Examples include agricultural education centres, improved technology, and increased financial resources.

FIGURE 21: Vulnerability at mid-century for (a) RCP4.5 and (b) RCP8.5

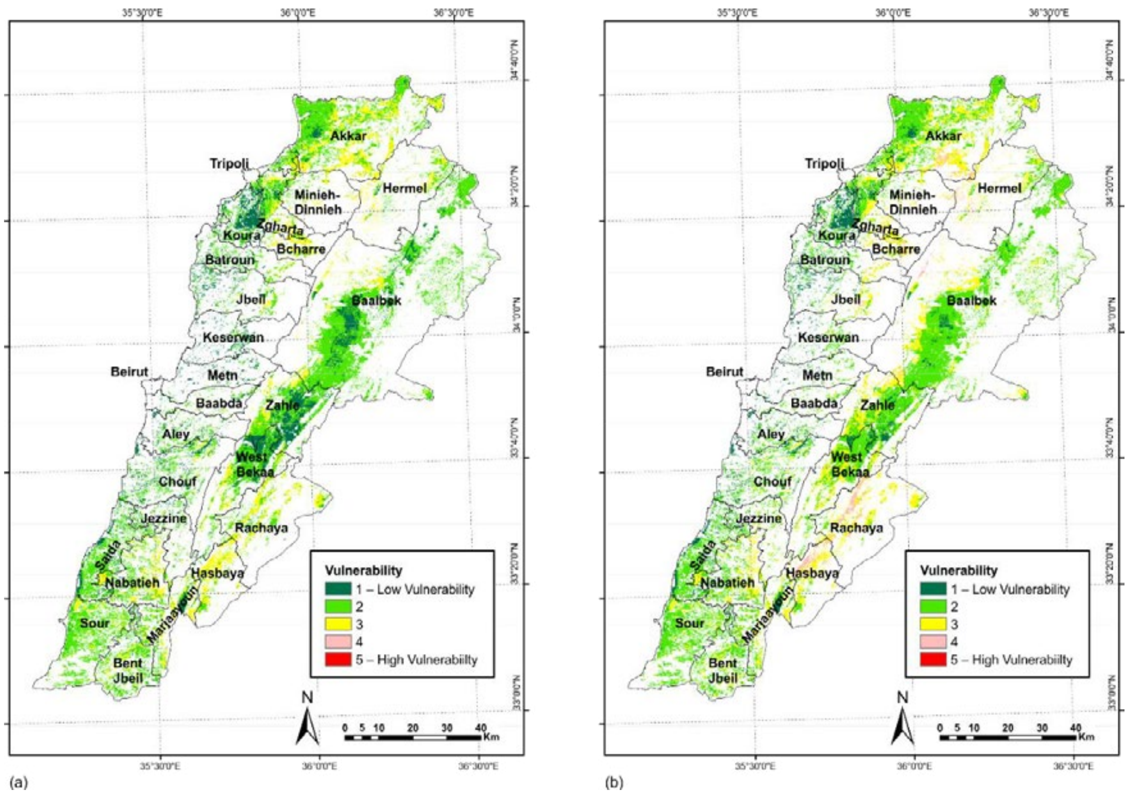


FIGURE 22: Vulnerability at end-century for (a) RCP4.5 and (b) RCP8.5

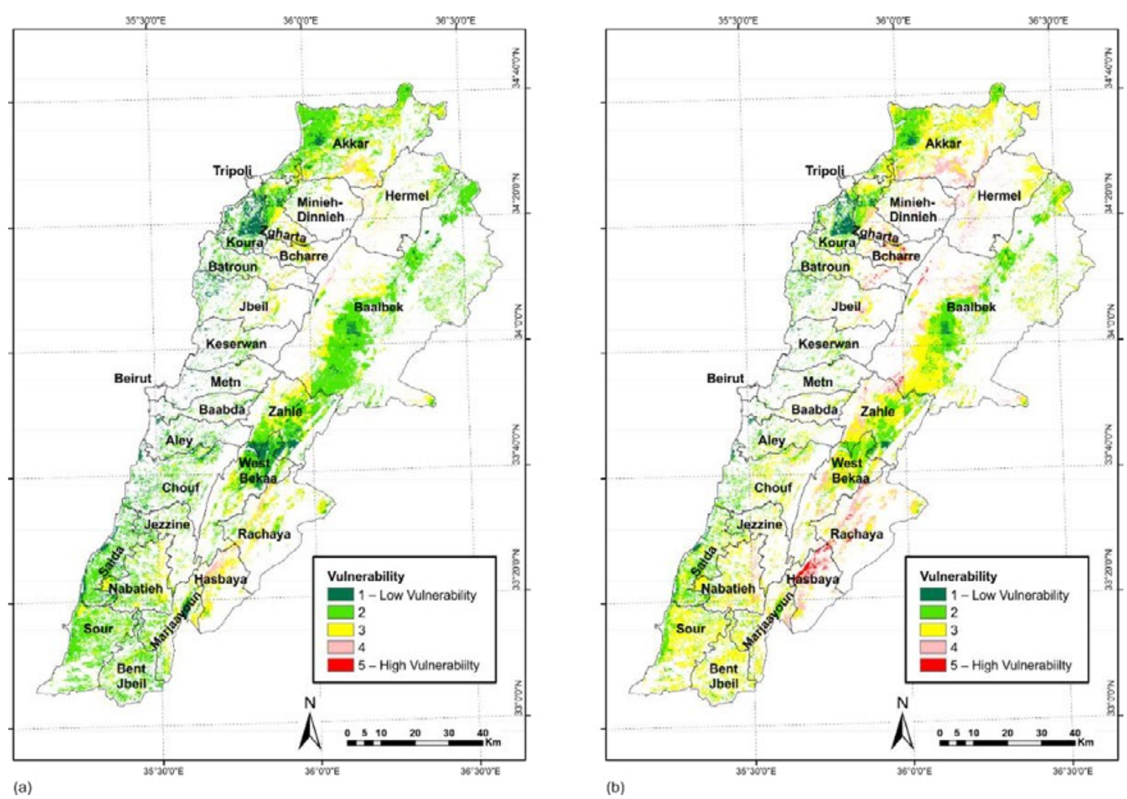
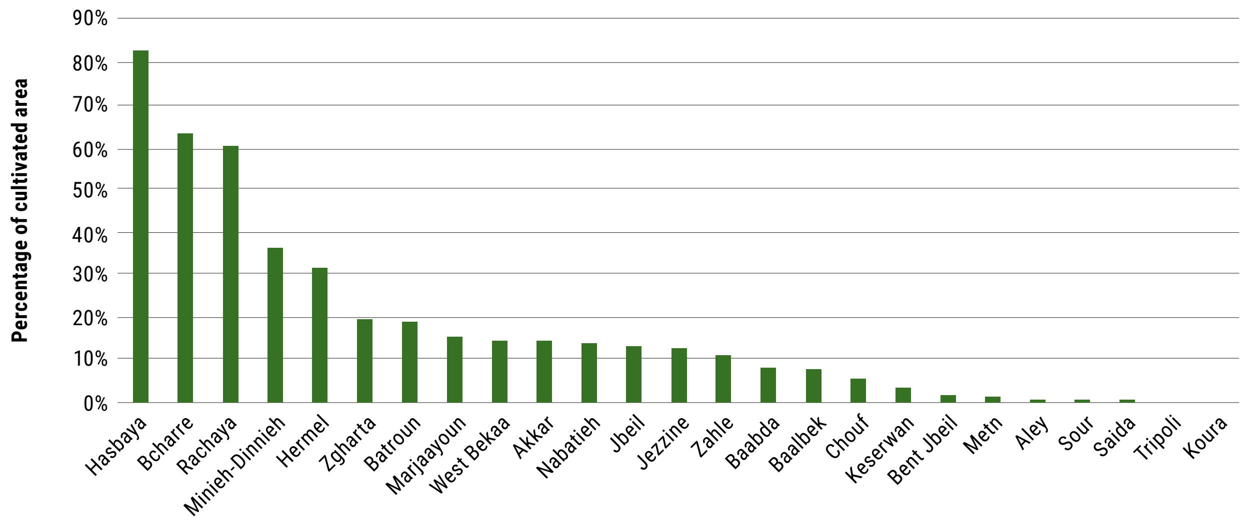


TABLE 7: Percentage of study area by vulnerability classification

Scenario	Vulnerability Classes (% of study area)				
	Low Vulnerability	Moderate Vulnerability		High Vulnerability	
	Class 1	Class 2	Class 3	Class 4	Class 5
Mid-century RCP4.5	18%	63%	19%	0%	0%
Mid-century RCP8.5	10%	63%	25%	3%	0%
End-century RCP4.5	11%	62%	25%	3%	0%
End-century RCP8.5	4%	33%	49%	13%	1%

FIGURE 23: Percentage of cultivated area with high vulnerability by caza (End-century RCP8.5)



5.6 Hotspots

Hotspots are critical areas which reveal the highest vulnerability. Up to 6% of the study area represents vulnerability hotspots for the agricultural sector (Figure 24), based on the worst-case scenario (end-century RCP8.5). Hotspots are primarily located in five areas as follows:

- **Southeastern Akkar** (Figure 25a): Hotspot areas are estimated at ~2,600 ha and include fruit trees and field crops. This area is dominated by high sensitivity stemming from steep slope, occurrence of flooding, and soil erosion. Secondly, this area signals low adaptive capacity due to poverty, low irrigation capacity, and limited groundwater resources.
- **Hasbaya** (Figure 25b): Hotspots are estimated at ~3,800 ha and include olives, field crops, and fruit trees. Limited irrigation capacity, high unemployment and illiteracy, and lack of crop diversification contribute toward low adaptive capacity. Moreover, sensitivity is elevated due to poor soil characteristics, including shallow depth, low storage capacity, and low organic content. Lastly, exposure is moderate due to decreasing precipitation coupled with increasing temperature.
- **Rachaya** (Figure 25c): Hotspots are estimated at ~2,600 ha and include field crops, olives, fruit trees, and vineyards. Very high sensitivity is revealed, combined with low adaptive capacity. The area signals limited irrigation capacity, high percentage of unemployment, and shortage of groundwater resources.
- **Baalbek and Zahle** (Figure 25d): Hotspots are estimated at ~2,000 ha and include fruit trees, field crops, and vineyards.
- **Zgharta and Bcharre** (Figure 25e): Hotspots are estimated at ~2,100 ha and include field crops, fruit trees, and olives.

FIGURE 24: Vulnerability hotspots for end-century RCP8.5

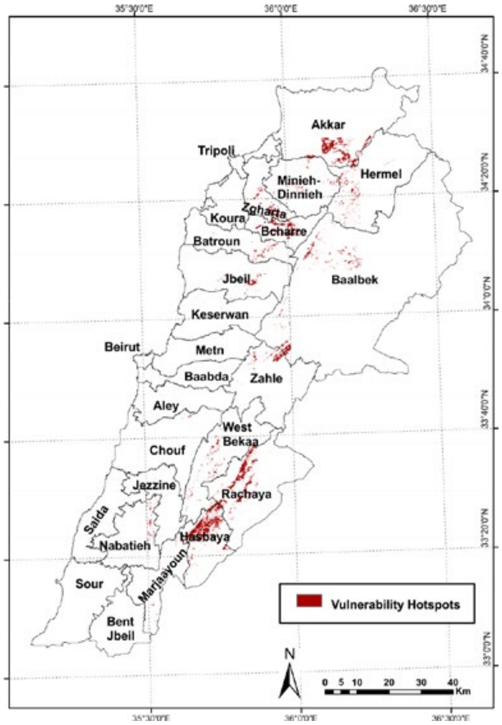
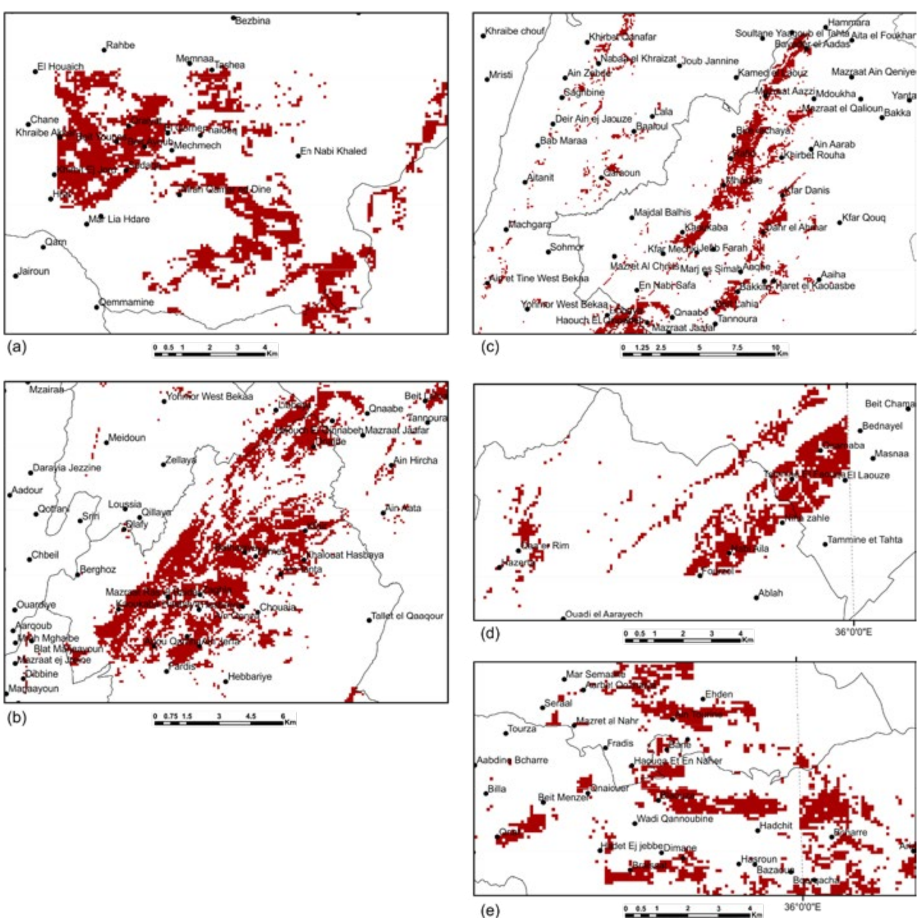


FIGURE 25: Selected vulnerability hotspots for end-century RCP8.5 in (a) Akkar, (b) Hasbaya, (c) Rachaya, (d) Baalbek and Zahle, and (e) Zgharta and Bcharre



6 CONCLUDING REMARKS

A majority of cultivated areas in Lebanon are projected to exhibit moderate-to-high vulnerability from mid-century onwards into the future. These areas include hotspot areas which are considered most critical and comprise up to 6% of the agricultural landscape. This assessment gives rise for concern due to food security, rural livelihoods, and cultural identity related issues.

Because adaptive capacity is based on current status and has a significant impact on resultant vulnerability, measures can be implemented to reduce vulnerability. While adaptation is often considered as a government policy response in agriculture, it also involves decision-making by agri-business and producers at the farm-level. Many potential agricultural adaptation options have been suggested, representing measures or practices that might be adopted to alleviate expected adverse impacts. This study shows that without adaptation, climate change could be problematic for agricultural production and for agricultural economies and communities. Suggested adaptation measures for the agricultural sector in Lebanon include:

- Adjust sowing dates according to temperature and rainfall patterns
- Use crop varieties better suited to new climate conditions (e.g. more resilient to heat and drought)
- Apply conservation agriculture
- Use non-conventional water resources for supplementary irrigation, including rainwater harvesting
- Change fertilizer application rate
- Apply crop rotation
- Modify irrigation depth and application time
- Enhance water productivity through efficient irrigation systems

ENDNOTES

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3. FAO, 2010
4. MoEW, 2010
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9. MoEW and UNDP, 2014
10. MoE, 2011; ERM, 1995
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APPENDIX A: EXPOSURE INDICATORS

Exposure indicators (change in temperature, precipitation, and runoff) were based on data obtained from EURO-CORDEX (Jacob et al., 2013). The actual indicator values (results) are presented in Section 3.2. The corresponding vulnerability classes were based upon the minimum and maximum values obtained from all scenarios and divided into five equal intervals.

Indicator	Class 1	Class 2	Class 3	Class 4	Class 5
Change in temperature (°C)	1.4 – 2.4	2.4 – 3.5	3.5 – 4.5	4.5 – 5.6	5.6 – 6.6
Change in precipitation (mm/year)	-256 – -204	-204 – -151	-151 – -99	-99 – -46	-46 – +6
Change in total runoff (mm/year)	-235 – -187	-187 – -140	-140 – -92	-92 – -44	-44 – +3

FIGURE A.1: Temperature classified values by mid-century for (a) RCP4.5 and (b) RCP8.5

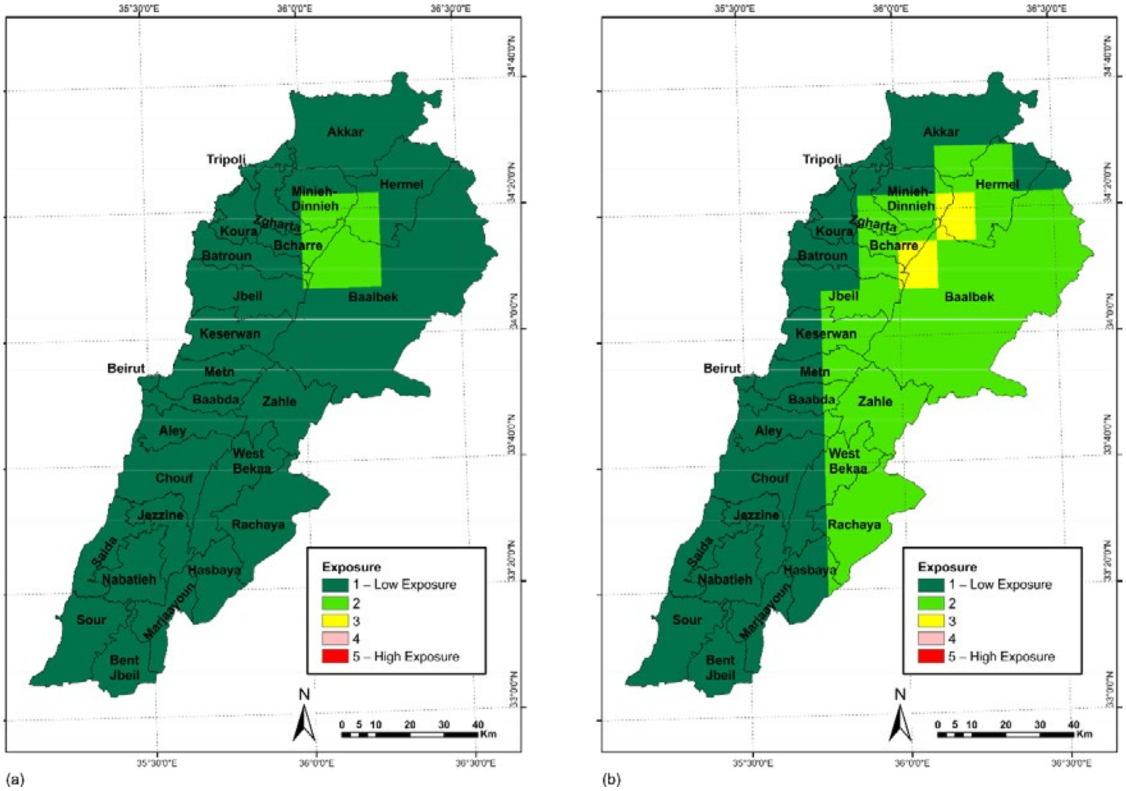


FIGURE A.2: Temperature classified values by end-century for (a) RCP4.5 and (b) RCP8.5

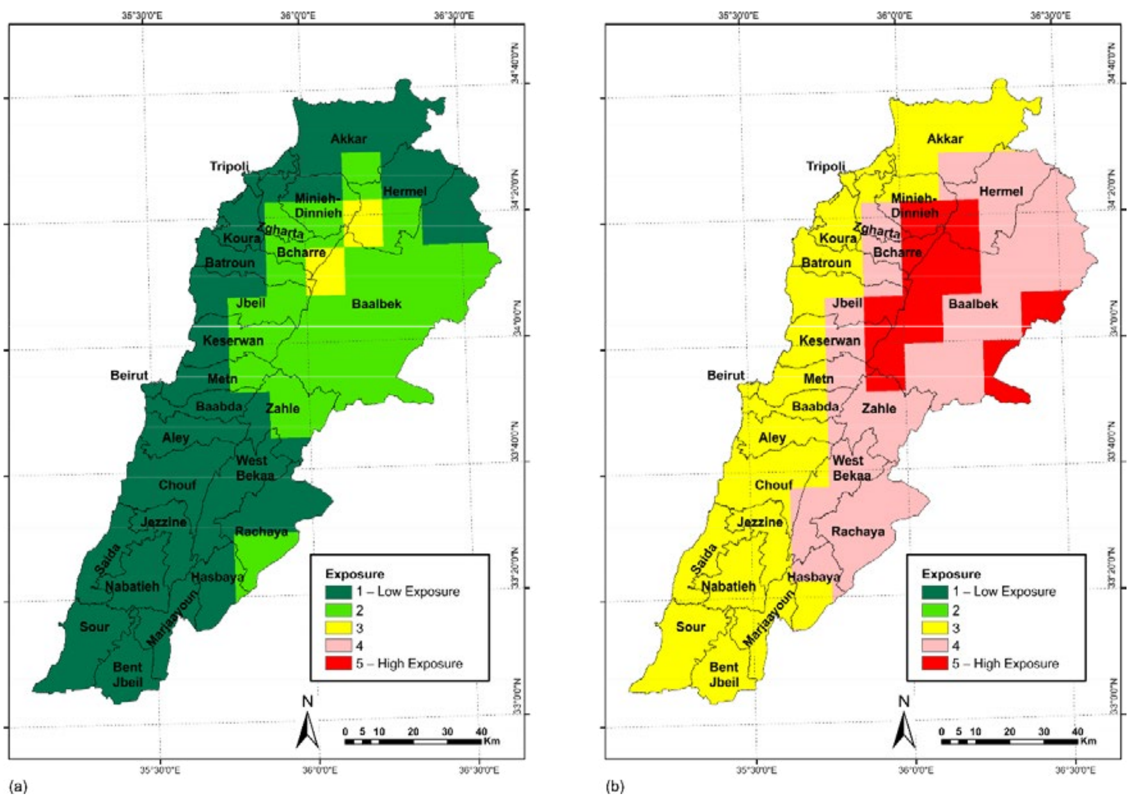


FIGURE A.3: Precipitation classified values by mid-century for (a) RCP4.5 and (b) RCP8.5

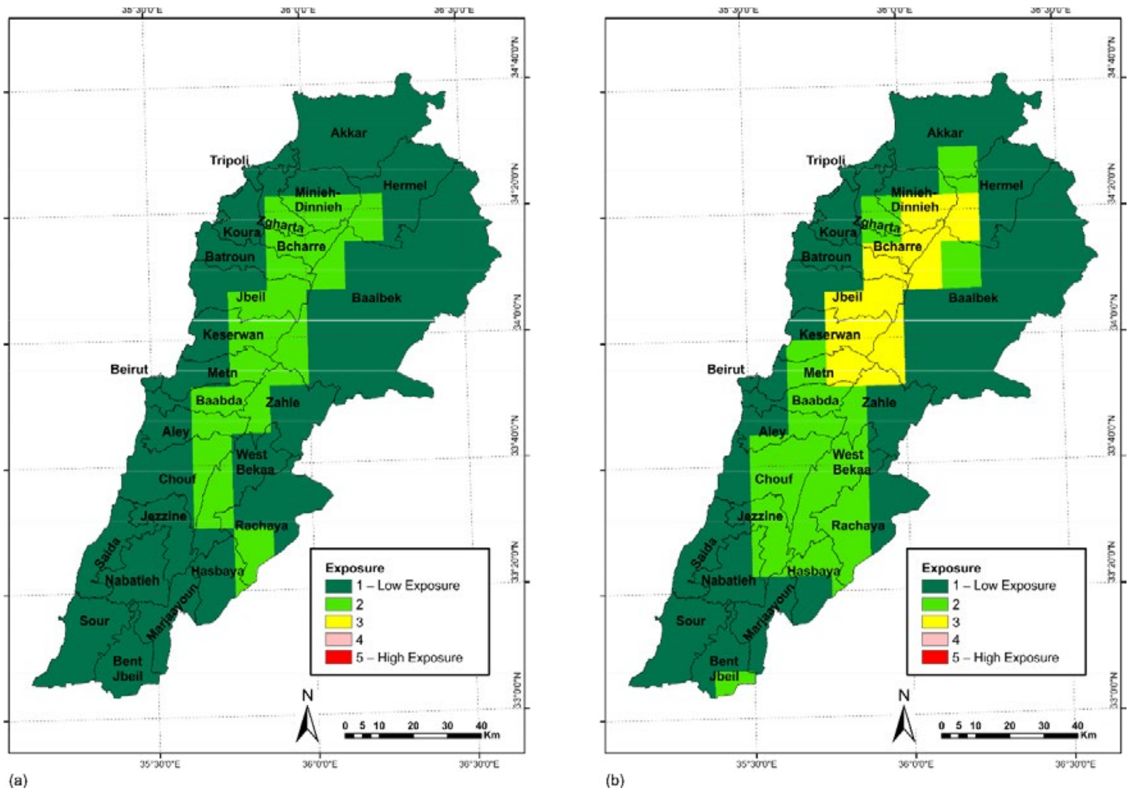


FIGURE A.4: Precipitation classified values by end-century for (a) RCP4.5 and (b) RCP8.5

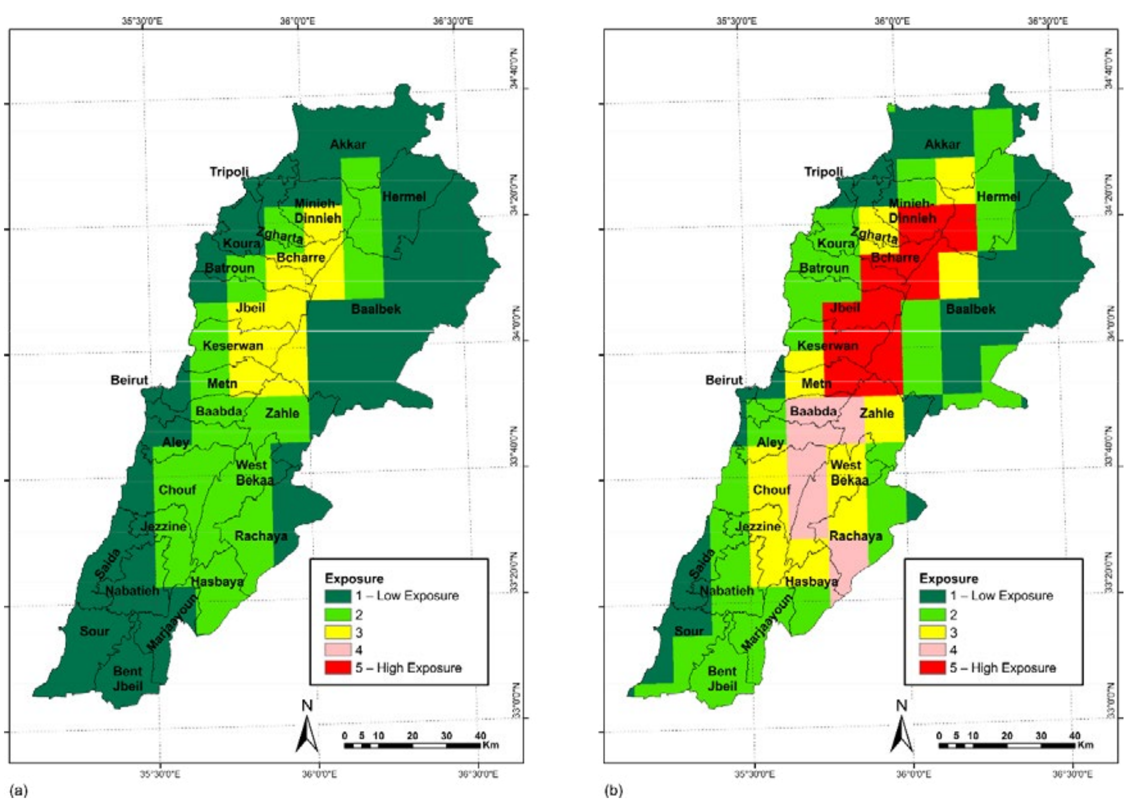


FIGURE A.5: Runoff classified values by mid-century for (a) RCP4.5 and (b) RCP8.5

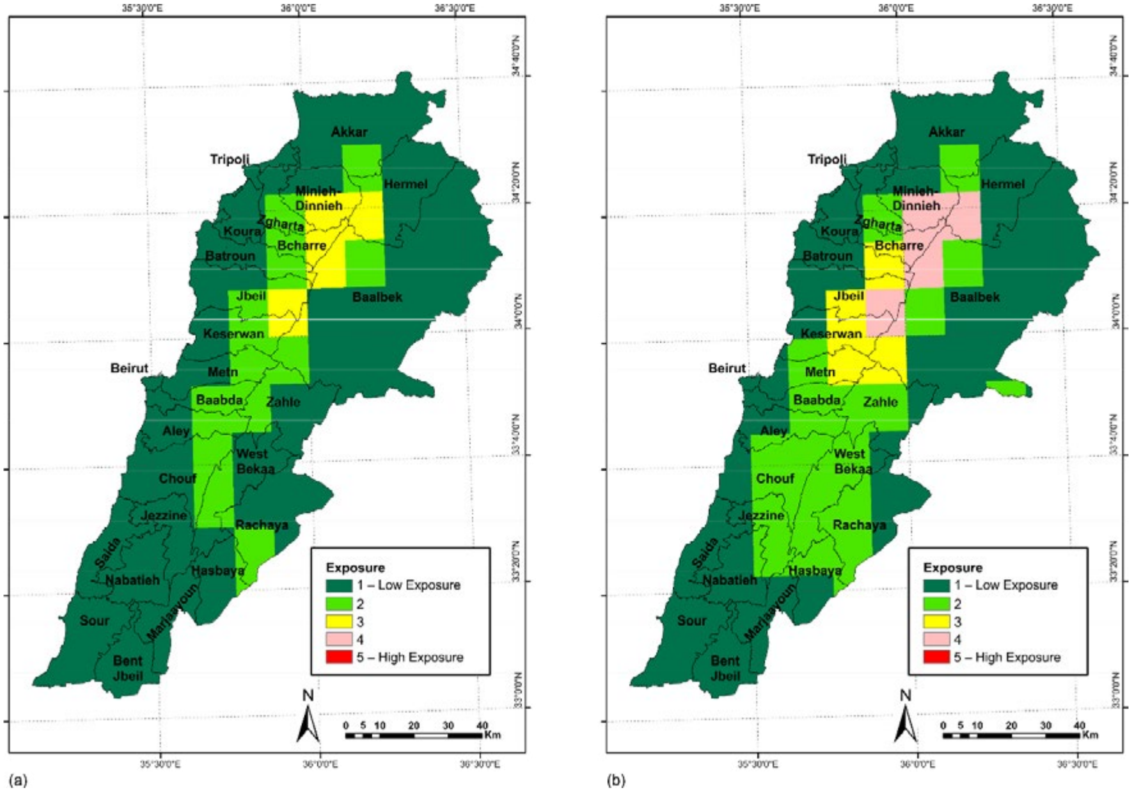
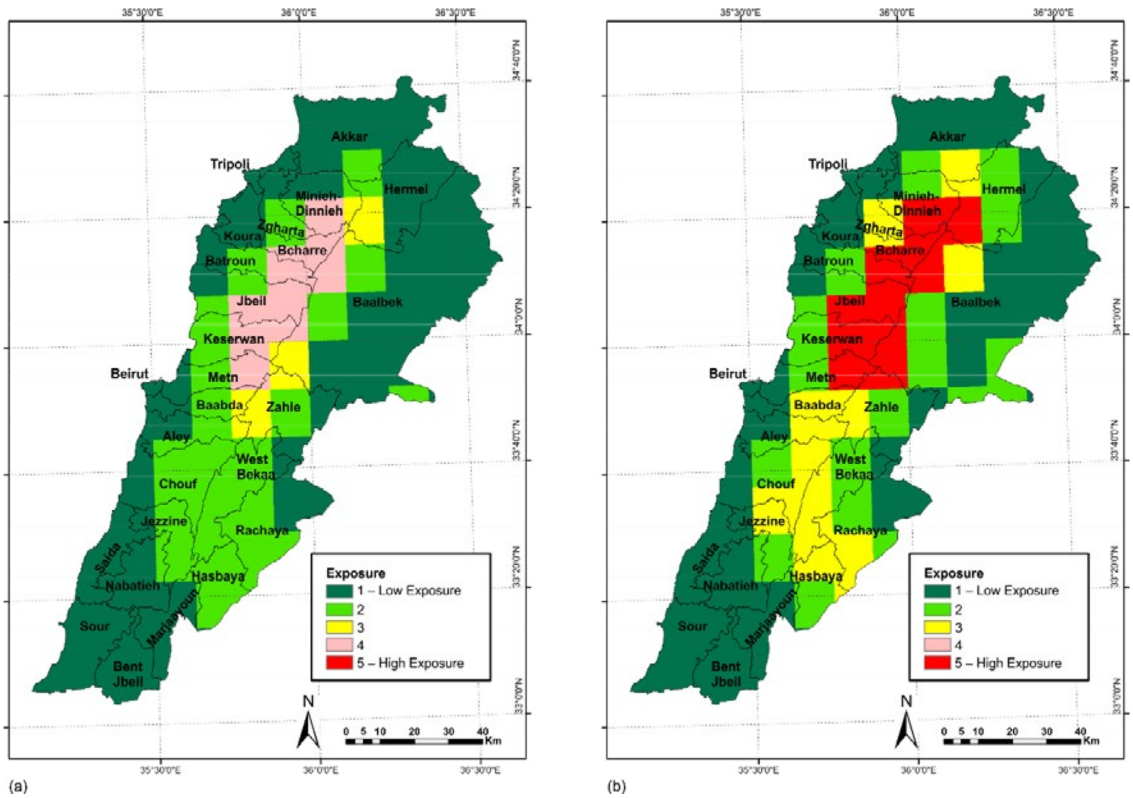


FIGURE A.6: Runoff classified values by end-century for (a) RCP4.5 and (b) RCP8.5

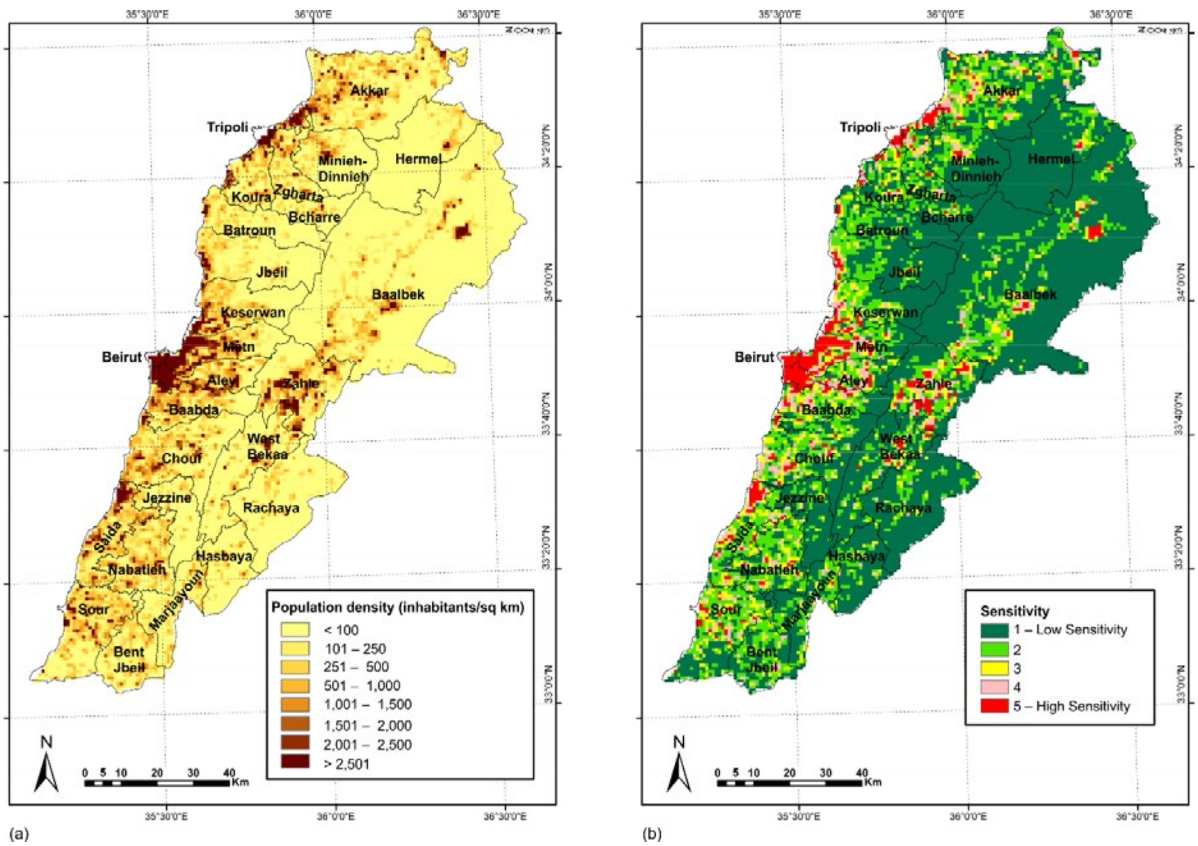


APPENDIX B: SENSITIVITY INDICATORS

Sensitivity indicators were selected based on elements which describe social, environmental, ecological, and anthropogenic factors which contribute toward agricultural susceptibility to climate change. For each indicator, maps showing actual values and the corresponding classified values are enclosed. In addition, a factsheet for each indicator is included which describes indicator details.

B.1. Population density

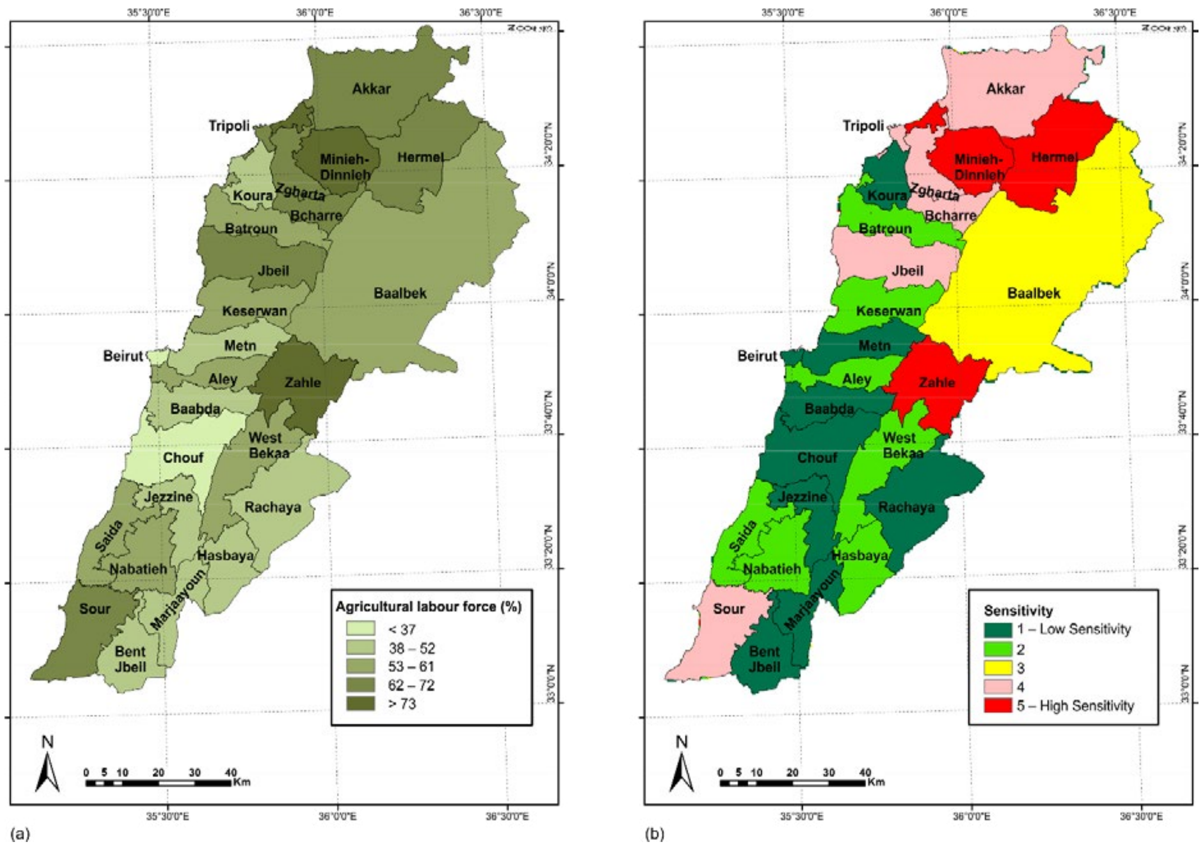
FIGURE B.1: Population Density (a) actual values and (b) classified values



Indicator fact sheet	
Indicator	**Population Density**
Vulnerability component	Sensitivity
Description	Number of inhabitants per km^2
Classes and ranges	Sensitivity 1 = < 100 Sensitivity 2 = 101 – 500 Sensitivity 3 = 501 – 1,000 Sensitivity 4 = 1,001 – 2,000 Sensitivity 5 = > 2,001
Influence on vulnerability	Dense population centres are more affected by agriculture due to food security, access, and cost
Data source	Landscan 2014 Global Population Database
Data information	
Type of Data	Raster
Resolution	1 km X 1 km Pixel
Time Reference	Updated based on 2010-2014 census data, adjusted to account for refugees and internally displaced people in 2015
Unit of Measurement	Inhabitants per km^2
Methodology for General Data Calculation	Data from the source
Methodology for classification and transformation of values	Classification was based on expert opinion.
Input-indicators needed	Not applicable
Data supply and acquisition	
Date of processing and publication	2015
Availability and costs	Proprietary source; All rights reserved to Landscan Global Population Database
Download-link	Not applicable
Date of acquirement	2015

B.2. Agricultural labour force (as % of total labour force)

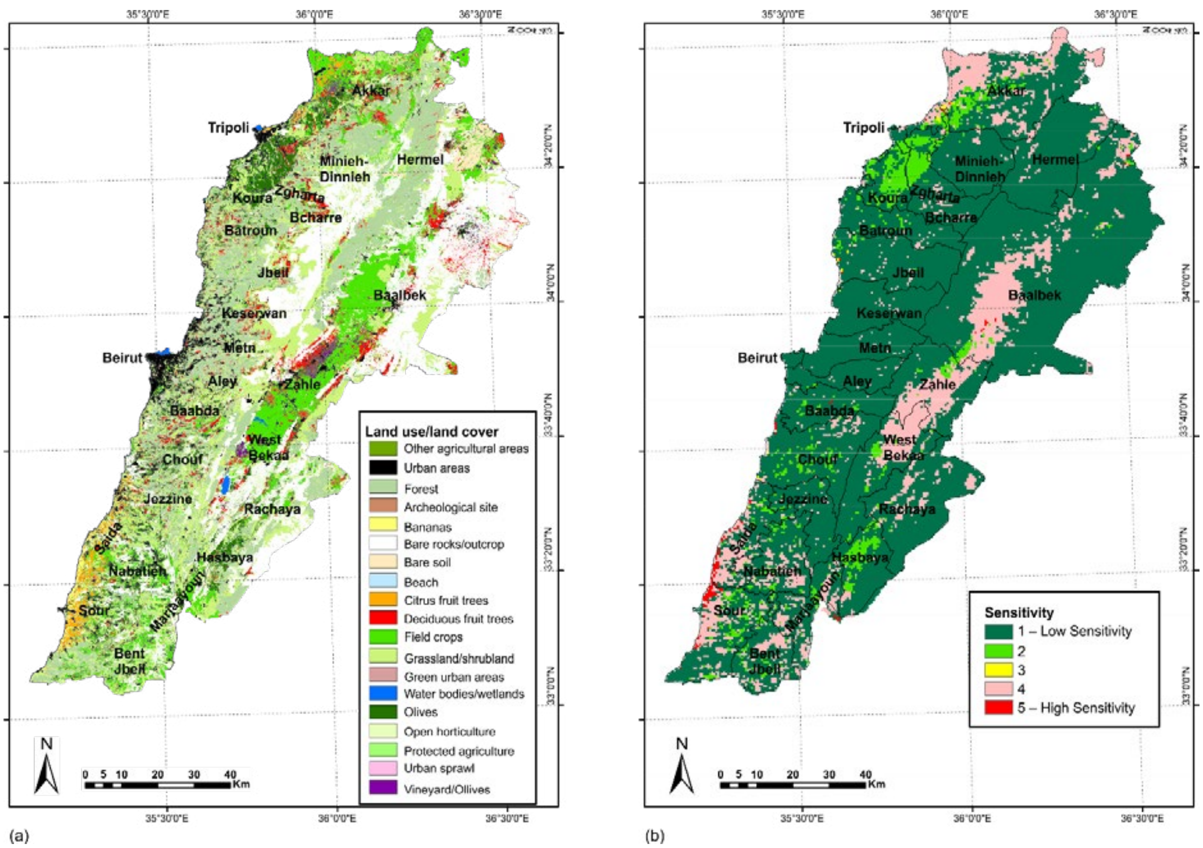
FIGURE B.2: Agricultural labour force (as % of total labour force) (a) actual values and (b) classified values



Indicator fact sheet	
Indicator	**Agricultural labour force (as % of total labour force)**
Vulnerability component	Sensitivity
Description	Percentage of workforce in the agricultural sector. Food and agricultural exports carry significant development value for Lebanon, since the agricultural sector represents roughly 7% of national GDP, and serves as a primary source of income for rural households. About 20 to 30% of the nation's labour force is employed in the sector (MOA, 2005)
Classes and ranges	Sensitivity 1 = < 37 Sensitivity 2 = 38 – 52 Sensitivity 3 = 53 – 61 Sensitivity 4 = 62 – 72 Sensitivity 5 = > 73
Influence on vulnerability	Areas with higher percentage of labour force in agriculture are most affected by adverse impacts to the sector and rural livelihoods.
Data source	Census of Lebanese Agricultural Ministry
Data information	
Type of Data	Tabular by caza
Resolution	Caza level
Time Reference	2010
Unit of Measurement	Percentage (%)
Methodology for General Data Calculation	The percentage of the labour in agriculture sector was calculated from the total labour force in a caza. Distribution of family and paid labour by agricultural and non- agricultural activity: (Permanent family labour (family members) working in the agricultural sector only) + (The permanent paid labour force working in the agricultural sector only) divided by (Total permanent labour (family and paid) working in the private, public and agricultural sector)
Methodology for classification and transformation of values	Natural breaks (Jenks optimization method)
Input-indicators needed	Not applicable
Data supply and acquisition	
Date of processing and publication	2010
Availability and costs	Available
Download-link	http://www.agriculture.gov.lb
Date of acquirement	2017

B.3. Land use/land cover

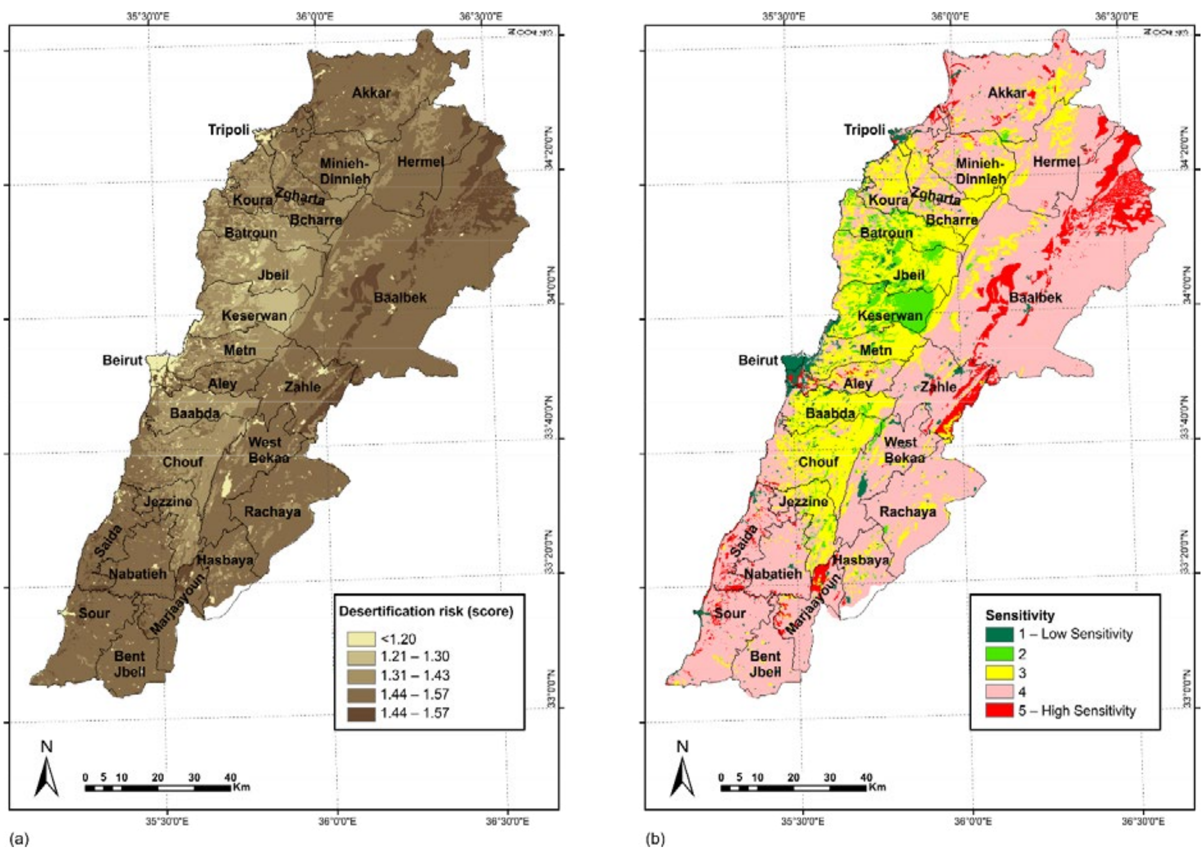
FIGURE B.3: Land use/land cover (a) actual values and (b) classified values



Indicator fact sheet	
Indicator	**Land use/land cover**
Vulnerability component	Sensitivity
Description	Agricultural areas include (LULC class description, CNRS) ● **Field Crops:** lands under a rotation system used for annually harvested plants and fallow lands, which are permanently or not irrigated. - Field crops in medium to large terrace: mainly found in Beqaa Valley and Akkar where large field crops dominate including crops such as wheat, barely, and potato. - Field Crops in small fields/terraces: agricultural areas where crops are planted on small fields or terraces. - Urban sprawl on field crops: describes the presence of urban units on field crops, where buildings must represent less than 30% of the total surface area. ● **Permanent crops:** all surfaces occupied by permanent crops not under a rotation system. Includes crops of standard cultures such as fruit trees, olives, and vineyards. - Olives: areas planted with olive trees, usually olive trees are planted 5 m apart. - Vineyards/grapes: Permanently irrigated areas planted with grape vines. - Fruit trees: parcels planted with fruit trees: single or mixed fruit species (except for citrus), fruit trees associated with permanently grassed surface. Fruit trees are usually denser than olive trees. - Citrus Fruit Trees: citrus trees can grow lemon, orange, and other citrus fruits, mainly presented at the coastal areas including Akkar, Saida, and Sour - Banana: area planted with banana trees, also mainly found in coastal areas - Urban sprawl on permanent Crops: presence of urban fabrics at areas of permanent crops where the total area of urban structure does not exceed 30% of the total surface. ● **Intensive agriculture:** Also known as industrial agriculture and can be protected agriculture at open horticulture. - Protected agriculture: cultivation of high value vegetables and other horticultural crops in greenhouses. - Urban sprawl on intensive agriculture: presence of urban structures in protected agricultural areas.
Classes and ranges	Sensitivity 1 = No agricultural areas Sensitivity 2 = Olives and vineyards/grapes Sensitivity 3 = Protected agriculture Sensitivity 4 = Field crops and citrus Sensitivity 5 = Bananas and open horticulture
Influence on vulnerability	Differing agricultural landscapes are more vulnerable to climate change impacts.
Data source	National Center for Scientific Research (CNRS)
Data information	
Type of Data	Raster
Resolution	100 m x 100 m
Time Reference	2010
Unit of Measurement	Descriptive
Methodology for General Data Calculation	Remote sensing technique (SPOT and IRS-1C) was used in 2000 to produce the land cover map of Lebanon at 1:20.000 scale by visual interpretation due to small and fragmented land ownership. This updated map replaced the previous version produced by FAO in 1990 at 1;50.000 scale. Currently, an update of this map using Ikonos images is being developed for CNRS-CRS.
Methodology for classification and transformation of values	Classification was based on expert opinion
Input-indicators needed	None
Data supply and acquisition	
Date of processing and publication	2017
Availability and costs	Available from CNRS
Download-link	Not available
Date of acquirement	2017

B.4. Desertification risk

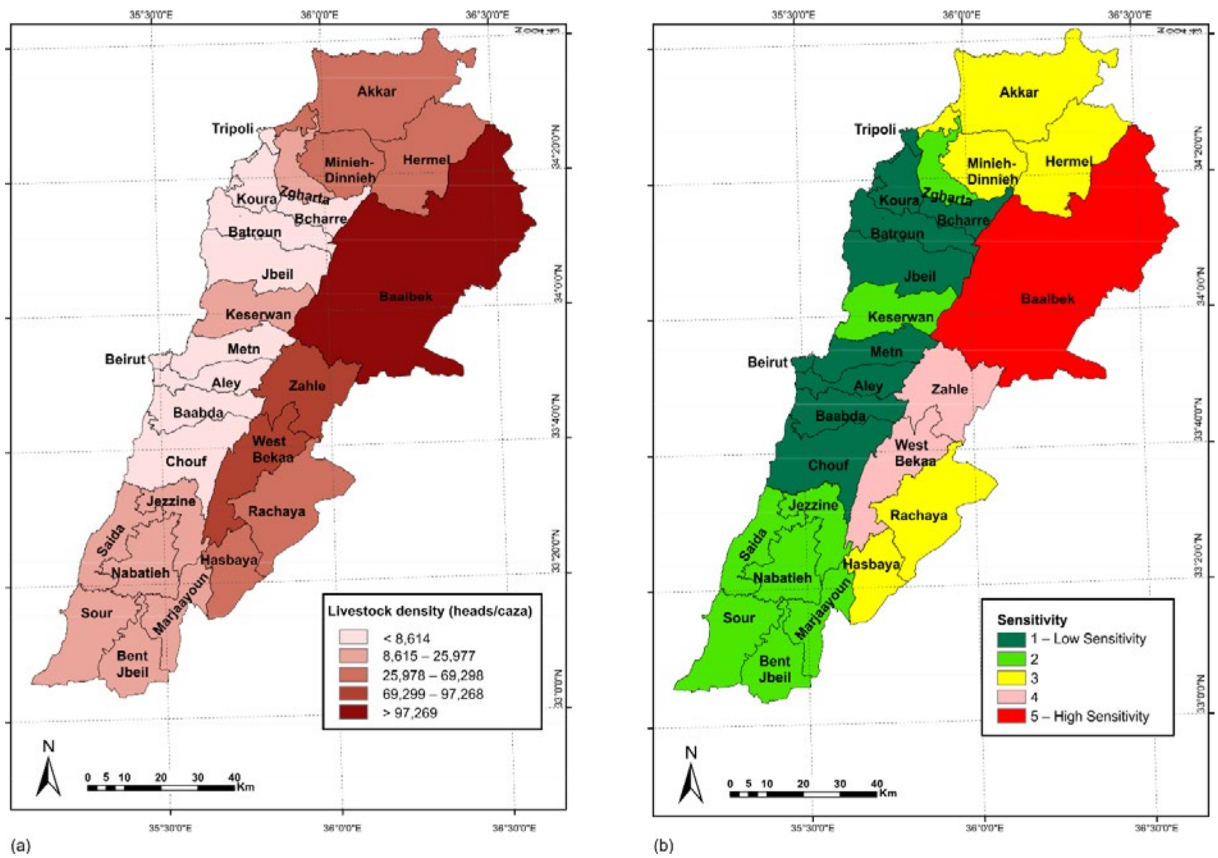
FIGURE B.4: Desertification risk (a) actual values and (b) classified values



Indicator fact sheet	
Indicator	**Desertification risk**
Vulnerability component	Sensitivity
Description	Desertification refers to land degradation in arid, semi-arid, and dry sub-humid areas resulting from various factors including climatic variations and human activities
Classes and ranges	Sensitivity 1 = < 1.20 Sensitivity 2 = 1.21 – 1.30 Sensitivity 3 = 1.31 – 1.43 Sensitivity 4 = 1.44 – 1.57 Sensitivity 5 = 1.44 – 1.57
Influence on vulnerability	Areas which are prone to desertification are linked to decline in agricultural landscape
Data source	United Nations Convention to Combat Desertification and Lebanese Ministry of Agriculture in cooperation with GTZ and UNDP; National Action Program to Combat Desertification
Data information	
Type of Data	Raster
Resolution	100 m x 100 m
Time Reference	2001
Unit of Measurement	Score
Methodology for General Data Calculation	Based on score from map output
Methodology for classification and transformation of values	Classification based on expert opinion
Input-indicators needed	Not applicable
Data supply and acquisition	
Date of processing and publication	2003
Availability and costs	Available from Ministry of Agriculture
Download-link	https://www.unccd.int/
Date of acquirement	2017

B.5. Livestock density

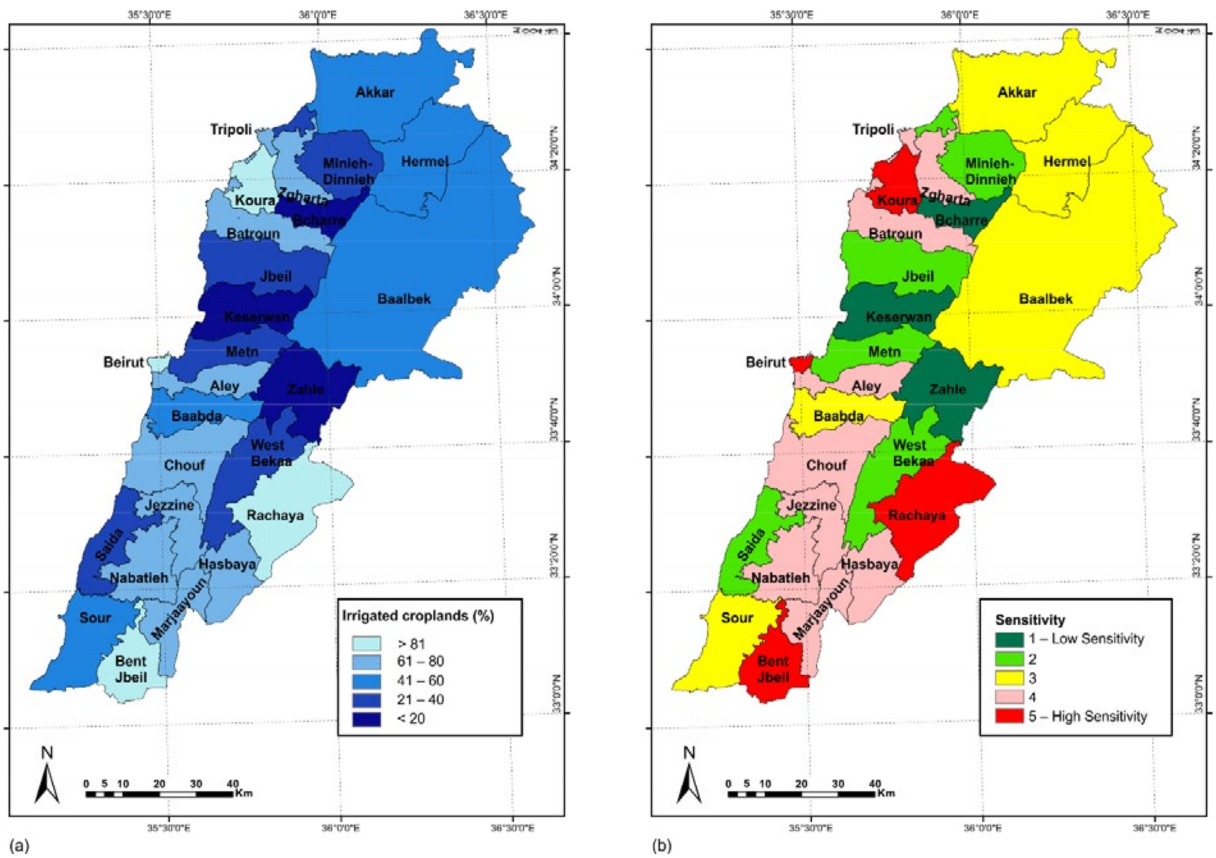
FIGURE B.5: Livestock density (a) actual values and (b) classified values



Indicator fact sheet	
Indicator	**Livestock density**
Vulnerability component	Sensitivity
Description	Number of sheep, goats, pigs, and cows per caza
Classes and ranges	Sensitivity 1 = < 8,614 Sensitivity 2 = 8,615 – 25,977 Sensitivity 3 = 25,978 – 69,298 Sensitivity 4 = 69,299 – 97,268 Sensitivity 5 = > 97,269
Influence on vulnerability	Livestock is part of the agricultural sector, but animals require grazing which can place pressure on the ecosystem
Data source	Census of Lebanese Agricultural Ministry
Data information	
Type of Data	Tabular
Resolution	Caza level
Time Reference	2010
Unit of Measurement	Heads per caza
Methodology for General Data Calculation	Data from the source
Methodology for classification and transformation of values	Quantile
Input-indicators needed	None
Data supply and acquisition	
Date of processing and publication	2010
Availability and costs	Available from Ministry of Agriculture
Download-link	http://www.agriculture.gov.lb/
Date of acquirement	2017

B.6. Irrigated croplands

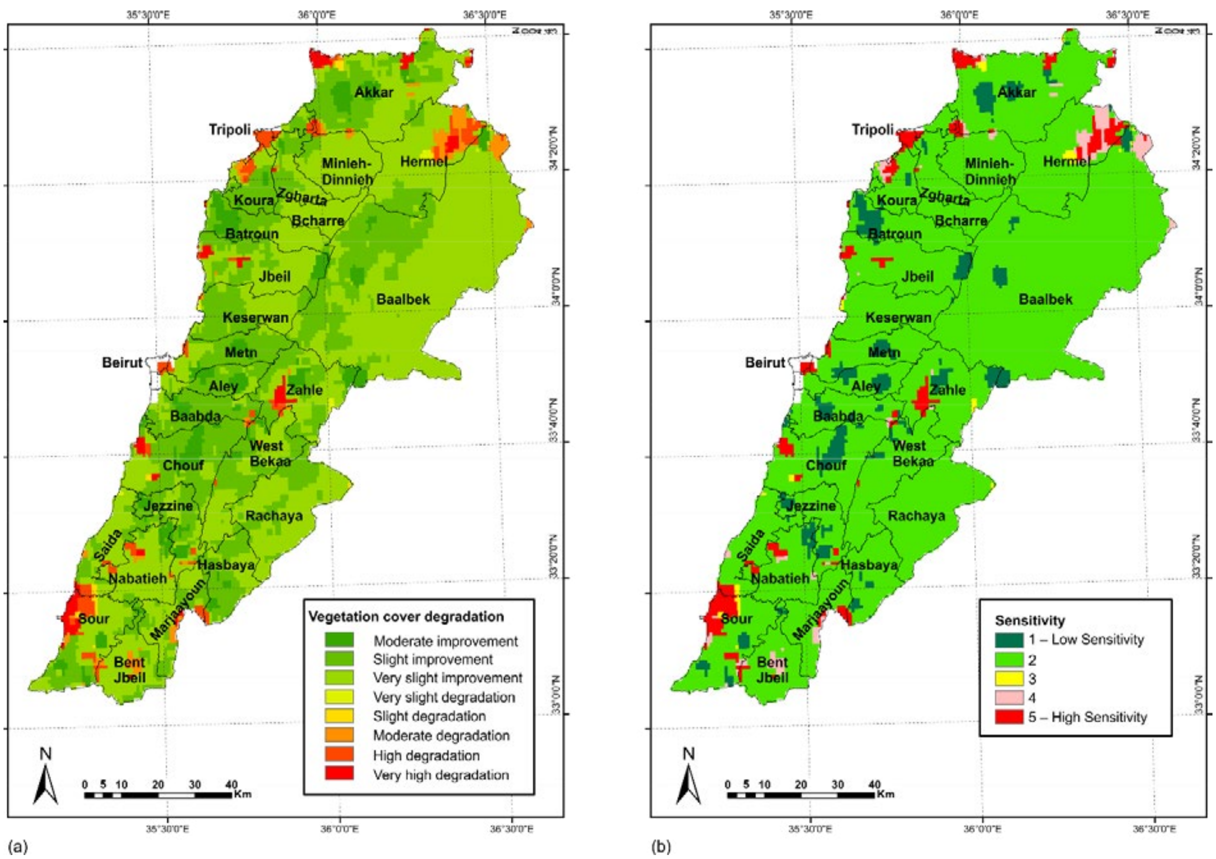
FIGURE B.6: Irrigated croplands (a) actual values and (b) classified values



Indicator fact sheet	
Indicator	**Irrigated croplands**
Vulnerability component	Sensitivity
Description	Percentage of irrigated areas from cultivated areas. The irrigated area is 113,000 ha (about 50%) of the cultivated area. About 65% of this area is fully irrigated while the remaining 35% is partially irrigated.
Classes and ranges	Sensitivity 1 = > 81 Sensitivity 2 = 61 – 80 Sensitivity 3 = 41 – 60 Sensitivity 4 = 21 – 40 Sensitivity 5 = < 20
Influence on vulnerability	Irrigated areas are less vulnerable because there is reduced dependence on precipitation.
Data source	Census of Lebanese Agricultural Ministry
Data information	
Type of Data	Tabular
Resolution	Caza level
Time Reference	2010
Unit of Measurement	Percentage (%)
Methodology for General Data Calculation	Data from the source
Methodology for classification and transformation of values	Equal interval
Input-indicators needed	None
Data supply and acquisition	
Date of processing and publication	2010
Availability and costs	Available from Ministry of Agriculture
Download-link	http://www.agriculture.gov.lb/
Date of acquirement	2017

B.7. Vegetation cover degradation

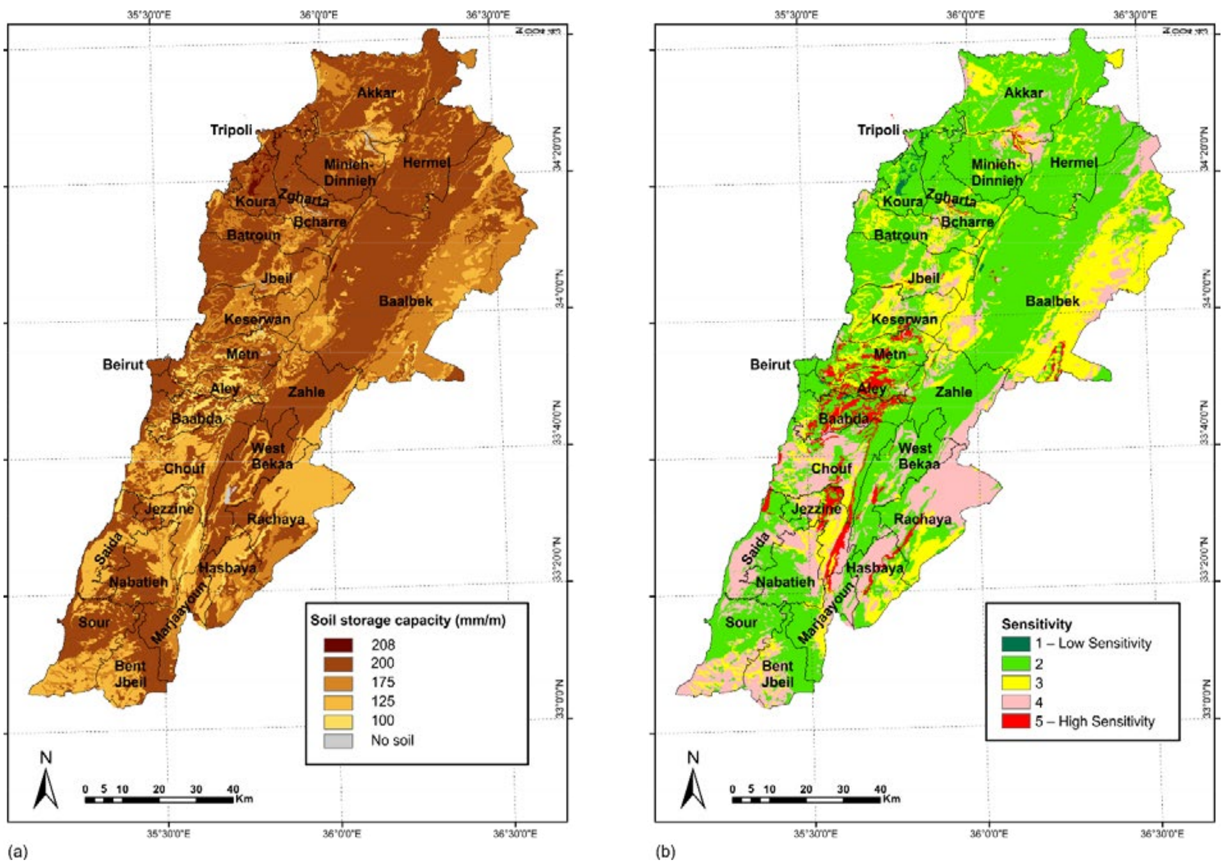
FIGURE B.7: Vegetation cover degradation (a) actual values and (b) classified values



Indicator fact sheet	
Indicator	**Vegetation cover degradation**
Vulnerability component	Sensitivity
Description	Change in vegetation cover between 2000 and 2011 as obtained from the Normalized Difference of Vegetation Index (NDVI).
Classes and ranges	Sensitivity 1 = Moderate improvement Sensitivity 2 = Very slight to slight improvement Sensitivity 3 = Very slight to slight degradation Sensitivity 4 = Moderate degradation Sensitivity 5 = High to very high degradation
Influence on vulnerability	Degraded land indicates a weakened ecosystem.
Data source	MODIS imagery; Data analyzed by ACSAD, GIZ, and Trior University (Germany)
Data information	
Type of Data	Raster
Resolution	1 km x 1 km
Time Reference	2000-2011
Unit of Measurement	Descriptive
Methodology for General Data Calculation	Archive of bi-monthly MODIS satellite images with 1km resolution cover the period 2000- 2011 was used to estimate monthly NDVI values using Maximum Value Composite method. Time State software was used to analyse the NDVI of the 10 years period.
Methodology for classification and transformation of values	The analysis methodology was based on calculation the trend line of the NDVI value according Mann-Kendall test. The results were divided into 5 classes.
Input-indicators needed	MODIS imagery https://modis.gsfc.nasa.gov/data/dataprod/mod13.php
Data supply and acquisition	
Date of processing and publication	2015
Availability and costs	Available from RICCAR
Download-link	www.riccar.org
Date of acquirement	2015

B.8. Soil storage capacity

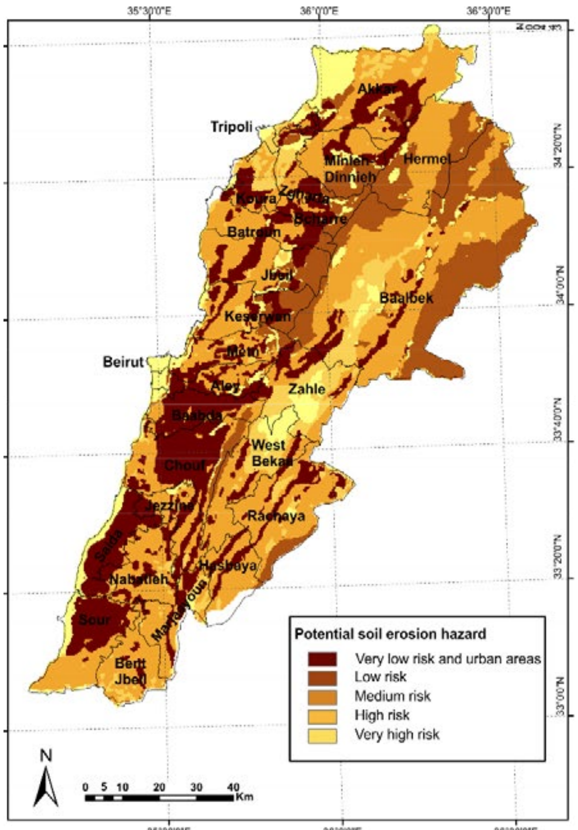
FIGURE B.8: Soil storage capacity (a) actual values and (b) classified values



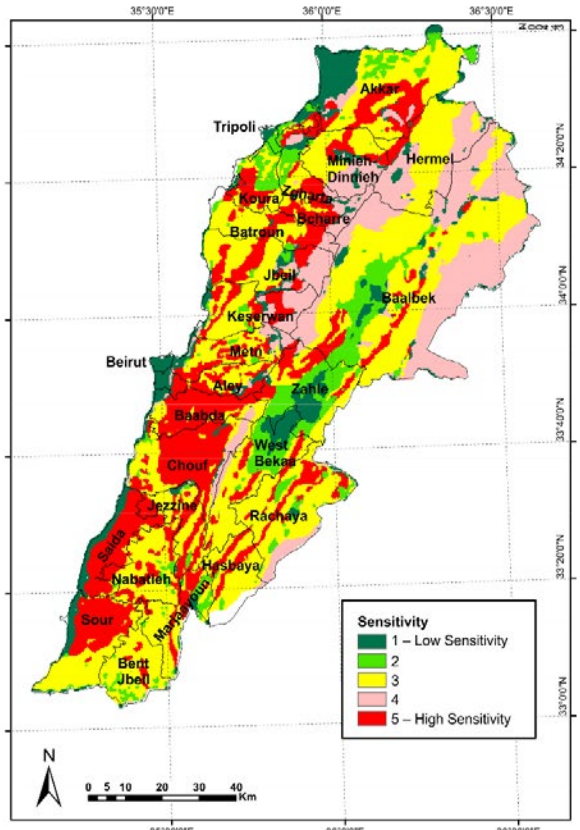
Indicator fact sheet	
Indicator	**Soil storage capacity**
Vulnerability component	Sensitivity
Description	Measure of available water storage capacity in mm/m of the soil unit
Classes and ranges	Sensitivity 1 = > 201 (Silty loam) Sensitivity 2 = 176 – 200 (Clay-clay; loam-sandy; clay-sandy; clay-loam-silty clay; silty-clay-loam) Sensitivity 3 = 126 – 175 (Loam) Sensitivity 4 = 101 – 125 (Sandy loam) Sensitivity 5 = < 100 (Loamy sand; no soil)
Influence on vulnerability	Areas with less capacity to store water have adverse impacts on crops.
Data source	Soil map of Lebanon (1:50,000); National Center for Scientific Research (CNRS) 2006
Data information	
Type of Data	Raster
Resolution	1:50,000
Time Reference	2006
Unit of Measurement	Descriptive
Methodology for General Data Calculation	Data from the source
Methodology for classification and transformation of values	Soil classification is provided according to three different taxonomies, namely, FAO-UNESCO legend, World Reference Base for soil resources (WRB) and keys to Soil Taxonomy (USDA).
Input-indicators needed	None
Data supply and acquisition	
Date of processing and publication	2006
Availability and costs	Available from CNRS
Download-link	Not applicable
Date of acquirement	2017

B.9. Potential soil erosion hazard

FIGURE B.9: Potential soil erosion hazard (a) actual values and (b) classified values



(a)

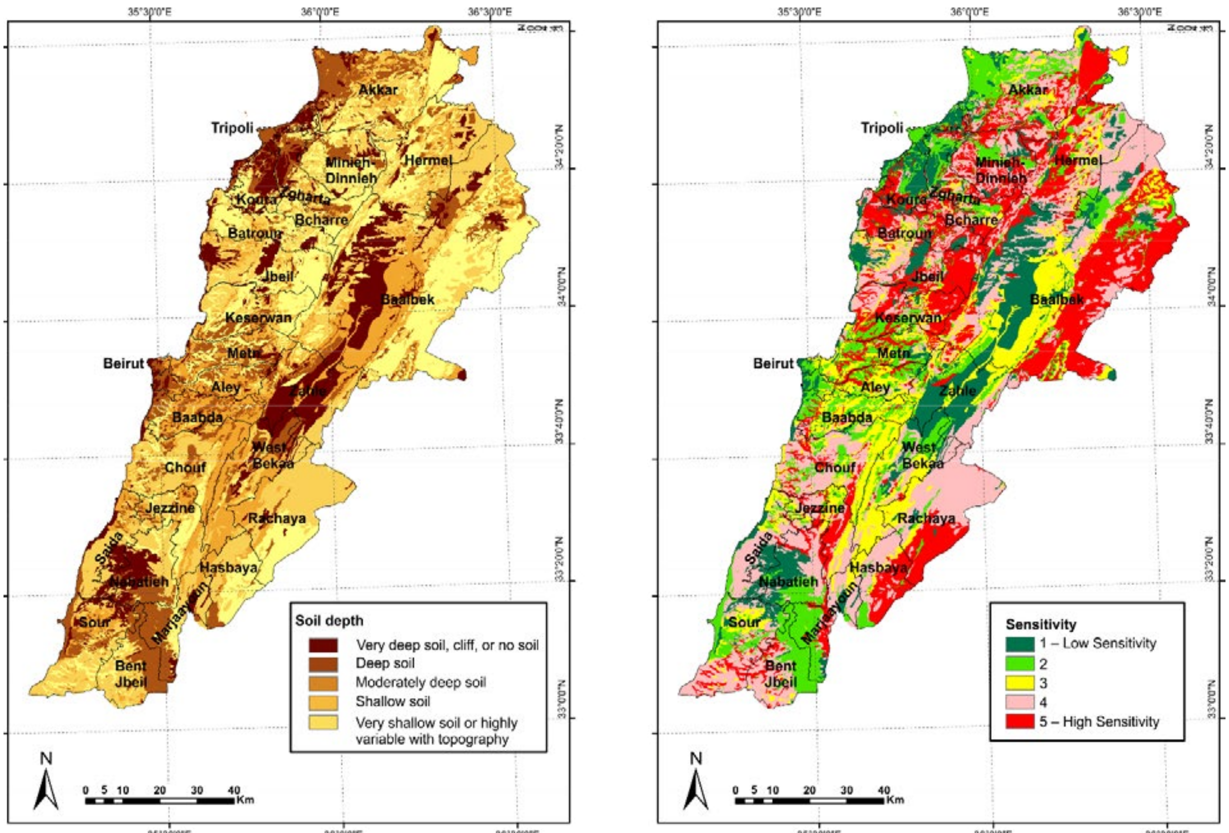


(b)

Indicator fact sheet	
Indicator	**Potential soil erosion hazard**
Vulnerability component	Sensitivity
Description	Risk for soil erosion by water
Classes and ranges	Sensitivity 1 = Very low risk and urban areas Sensitivity 2 = Low risk Sensitivity 3 = Medium risk Sensitivity 4 = High risk Sensitivity 5 = Very high risk
Influence on vulnerability	Areas that are prone to soil erosion can result in loss of crops
Data source	Soil vulnerability to erosion with GIS models (Bou Kheir et al., 2001)
Data information	
Type of Data	Raster
Resolution	1:1,000,000
Time Reference	2001
Unit of Measurement	Descriptive
Methodology for General Data Calculation	Potential soil erosion as a function of soil characteristics: soil depth, soil structure, soil texture, organic matter content, and structural stability in relation to geomorphology and climatic conditions
Methodology for classification and transformation of values	Expert opinion
Input-indicators needed	None
Data supply and acquisition	
Date of processing and publication	2001
Availability and costs	Available from National Center for Scientific Research (CNRS)
Download-link	Not available
Date of acquirement	2017

B.10. Soil depth

FIGURE B.10: Soil depth (a) actual values and (b) classified values

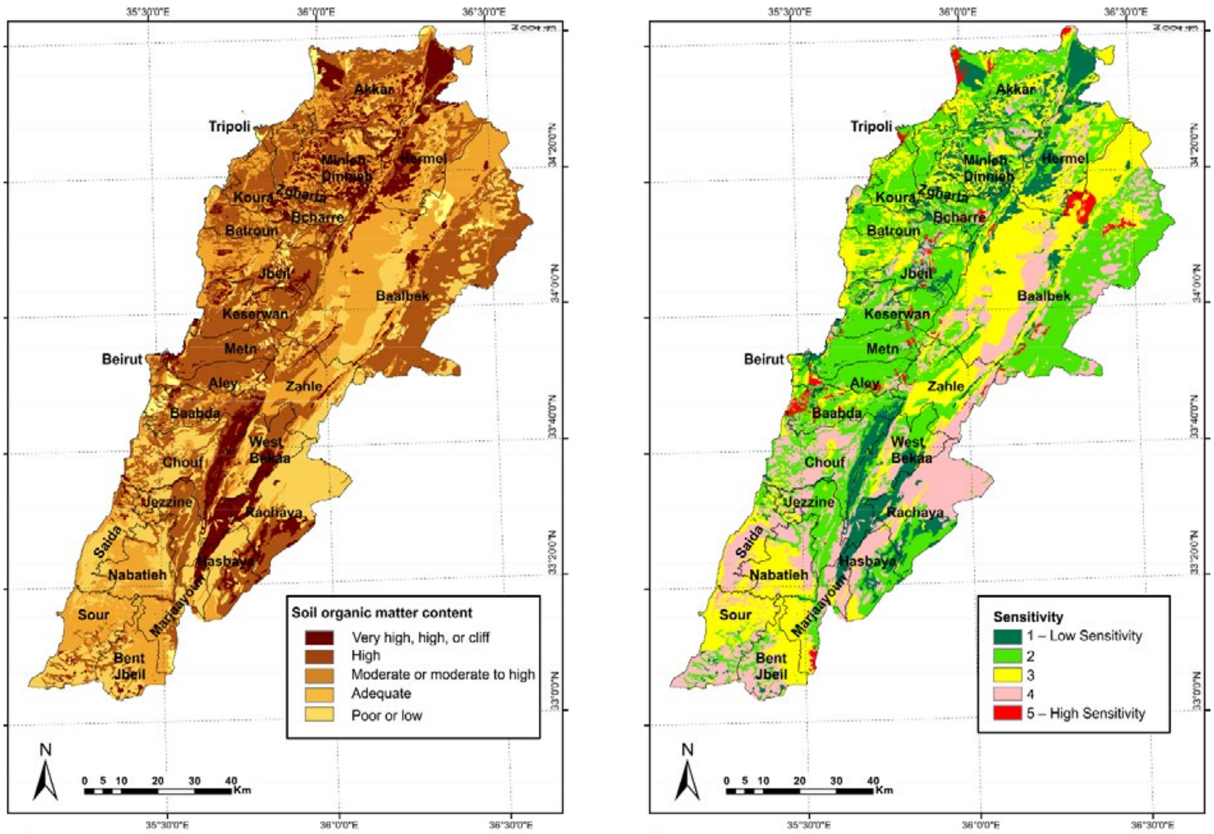


(a) (b)

Indicator fact sheet	
Indicator	**Soil depth**
Vulnerability component	Sensitivity
Description	Measure the depth of soil. In Lebanon, most soils are very shallow (especially mountain areas) and others are very deep (such as in the Bekaa Valley). They have mainly evolved from weathered rock and, to a lesser extent, volcanic material and accumulated plant residues. Many soils in Lebanon arise from transported materials deposited by water (forming so called alluvial soils), or by gravity (so called colluviums). The soils of Lebanon vary widely in quality and productivity and are typically Mediterranean in character.
Classes and ranges	Sensitivity 1 = Very deep soil, cliff, or no soil Sensitivity 2 = Deep soil Sensitivity 3 = Moderately deep soil Sensitivity 4 = Shallow soil Sensitivity 5 = Very shallow soil or highly variable with topography
Influence on vulnerability	Areas with very shallow soil can be unfavourable for crops and plant roots.
Data source	Soil map of Lebanon (1:50,000); National Center for Scientific Research (CNRS) 2006
Data information	
Type of Data	Raster
Resolution	1:50,000
Time Reference	2006
Unit of Measurement	Descriptive
Methodology for General Data Calculation	Detailed information on the soil type location, morphology, physical and chemical properties, geology, hydrology, climate, landcover/use and agricultural potential
Methodology for classification and transformation of values	Expert opinion
Input-indicators needed	None
Data supply and acquisition	
Date of processing and publication	2006
Availability and costs	Available from CNRS
Download-link	Not applicable
Date of acquirement	2017

B.11. Soil organic matter content

FIGURE B.11: Soil organic matter content (a) actual values and (b) classified values

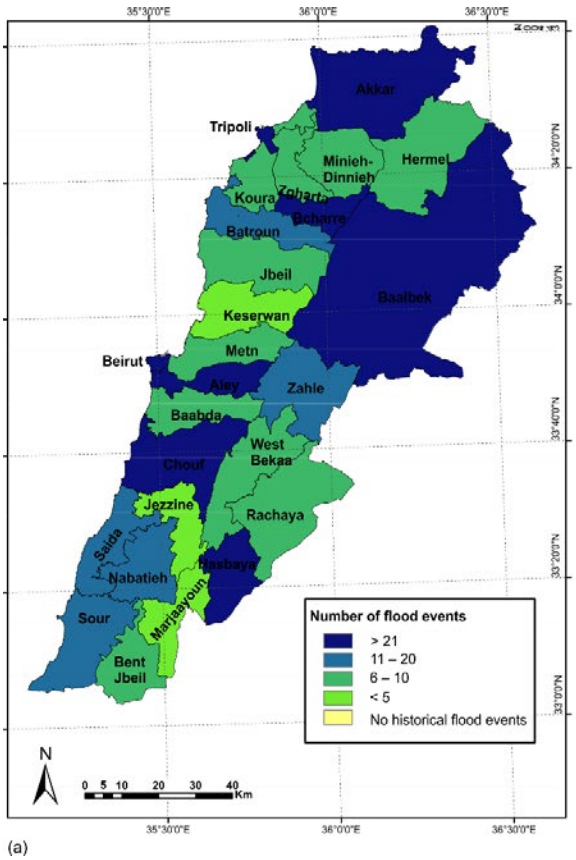


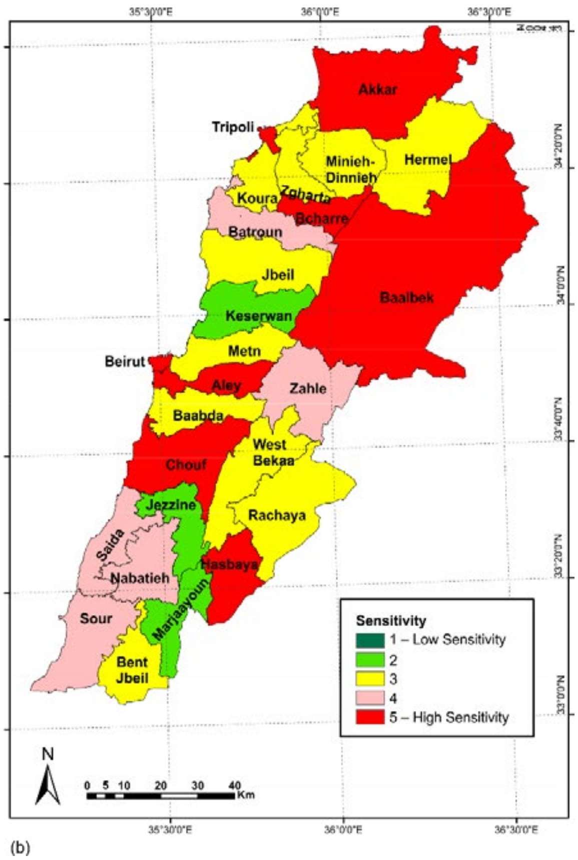
(a) (b)

Indicator fact sheet	
Indicator	**Soil organic matter content**
Vulnerability component	Sensitivity
Description	Measure the organic matter content in the soil. Soil disturbance affects carbon oxidation. Reduced carbon and soil organic matter implies increased carbon release into the atmosphere. CO2 is a leading greenhouse gas. Soil organic matter in greenhouses ranged from 1.23 to 4.10 percent, and from 1.37 to 5.81 percent in open agricultural fields.
Classes and ranges	Sensitivity 1 = Very high, high, or cliff Sensitivity 2 = High Sensitivity 3 = Moderate or moderate to high Sensitivity 4 = Adequate Sensitivity 5 = Poor or low
Influence on vulnerability	Soil organic matter and the soil organisms that live on it are critical to soil processes. It allows high crops yields and reduced input costs.
Data source	Soil map of Lebanon (1:50,000); National Center for Scientific Research (CNRS) 2006
Data information	
Type of Data	Raster
Resolution	1:50,000
Time Reference	2006
Unit of Measurement	Descriptive
Methodology for General Data Calculation	Data from the source
Methodology for classification and transformation of values	Expert opinion
Input-indicators needed	None
Data supply and acquisition	
Date of processing and publication	2006
Availability and costs	Available from CNRS
Download-link	Not applicable
Date of acquirement	2017

B.12. Flood hazard

FIGURE B.12: Flood hazard (a) actual values and (b) classified values

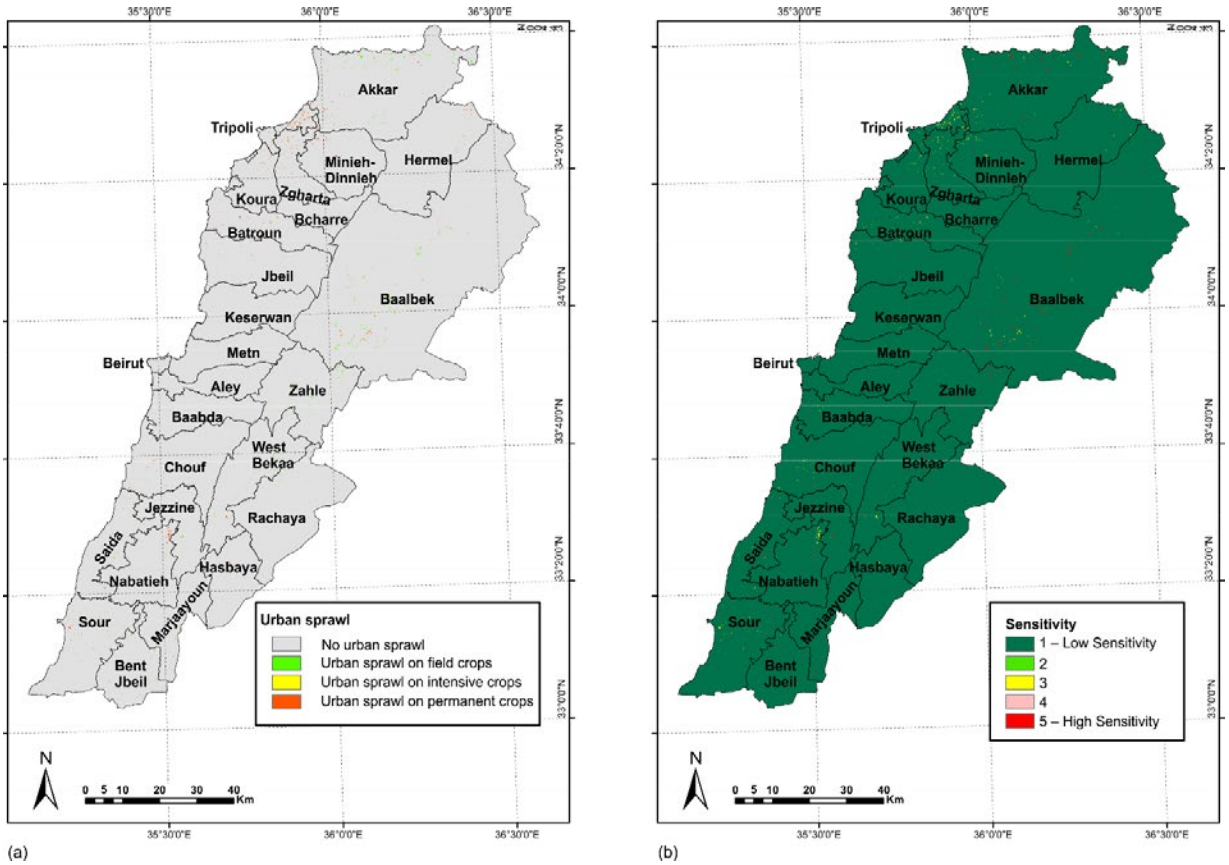




Indicator fact sheet	
Indicator	**Flood hazard**
Vulnerability component	Sensitivity
Description	Obtained from number of historical flood events between 1971 and 2012.
Classes and ranges	Sensitivity 1 = No historical flood events Sensitivity 2 = < 5 Sensitivity 3 = 6 – 10 Sensitivity 4 = 11 – 20 Sensitivity 5 = > 21
Influence on vulnerability	Flooding has an adverse impact on agriculture and livelihoods
Data source	Flood Risk Assessment and Mapping – Final Report; National Center for Scientific Research (CNRS) 2015
Data information	
Type of Data	Shapefile
Resolution	Caza level
Time Reference	1971-2012
Unit of Measurement	Number of flood events
Methodology for General Data Calculation	Data from the source
Methodology for classification and transformation of values	Expert opinion
Input-indicators needed	None
Data supply and acquisition	
Date of processing and publication	2015
Availability and costs	Available from CNRS
Download-link	Not applicable
Date of acquirement	2017

B.13. Urban sprawl

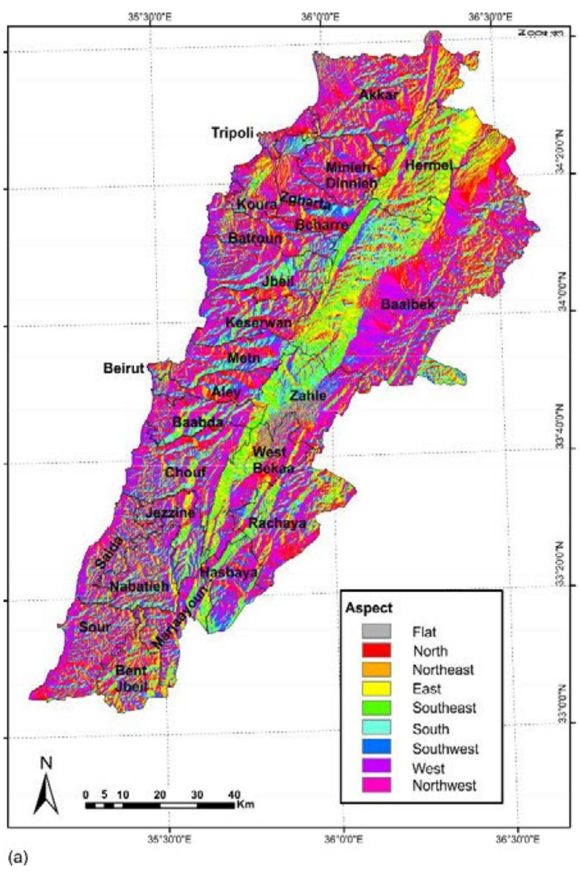
FIGURE B.13: Urban sprawl (a) actual values and (b) classified values

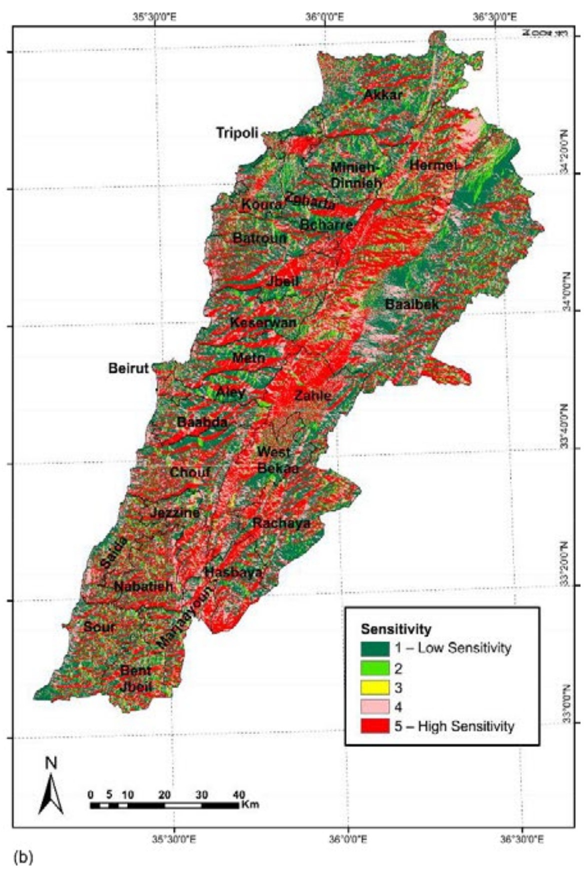


Indicator fact sheet	
Indicator	**Urban sprawl**
Vulnerability component	Sensitivity
Description	Presence of urban encroachments near agricultural areas where the total areas of urban structures do not exceed 30% of the total area
Classes and ranges	Sensitivity 1 = No urban sprawl Sensitivity 2 = (Not applicable) Sensitivity 3 = Urban sprawl on permanent crops Sensitivity 4 = Urban sprawl on intensive crops Sensitivity 5 = Urban sprawl on field crops
Influence on vulnerability	Agriculture areas are at risk due to urban sprawl
Data source	Land use/land cover map; National Center for Scientific Research (CNRS)
Data information	
Type of Data	Raster
Resolution	100 m x 100 m
Time Reference	2010
Unit of Measurement	Descriptive
Methodology for General Data Calculation	Remote sensing technique (SPOT and IRS-1C) was used in 2000 to produce the land cover map of Lebanon at 1:20.000 scale by visual interpretation due to small and fragmented land ownership. This updated map replaced the previous version produced by FAO in 1990 at 1;50.000 scale. Currently, an update of this map using Ikonos images is being developed for CNRS-CRS.
Methodology for classification and transformation of values	Classification was based on expert opinion
Input-indicators needed	None
Data supply and acquisition	
Date of processing and publication	2017
Availability and costs	Available from CNRS
Download-link	Not available
Date of acquirement	2017

B.14. Aspect/topography

FIGURE B.14: Aspect/topography (a) actual values and (b) classified values

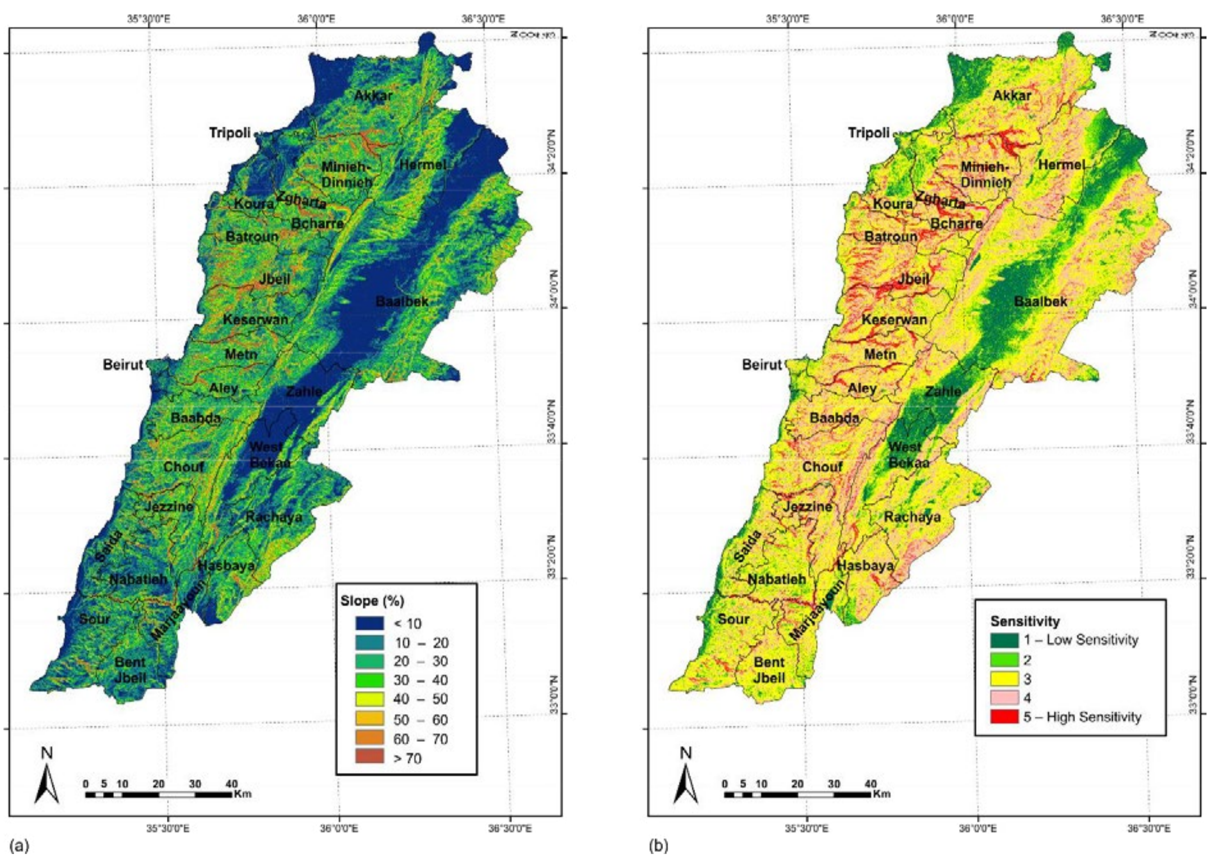




Indicator fact sheet	
Indicator	**Aspect/topography**
Vulnerability component	Sensitivity
Description	Aspect is the compass direction that a slope faces.
Classes and ranges	Sensitivity 1 = North Sensitivity 2 = Northeast or northwest Sensitivity 3 = Flat terrain Sensitivity 4 = East or west Sensitivity 5 = South, southwest, or southeast
Influence on vulnerability	Topography is a determining factor for potential crop types and agricultural techniques. Areas that receive more sunshine are more vulnerable due to increased evaporation rates.
Data source	ALOS Global Digital Surface Model (AW3D30 Version 2.1)
Data information	
Type of Data	Raster
Resolution	30 m x 30 m
Time Reference	2016
Unit of Measurement	Descriptive
Methodology for General Data Calculation	GIS transformation from compass direction
Methodology for classification and transformation of values	Expert opinion
Input-indicators needed	None
Data supply and acquisition	
Date of processing and publication	2016
Availability and costs	Available from ALOS World 3D - 30m (AW3D30)
Download-link	http://www.eorc.jaxa.jp/ALOS/en/aw3d30/
Date of acquirement	2017

B.15. Elevation slope

FIGURE B.15: Elevation slope (a) actual values and (b) classified values



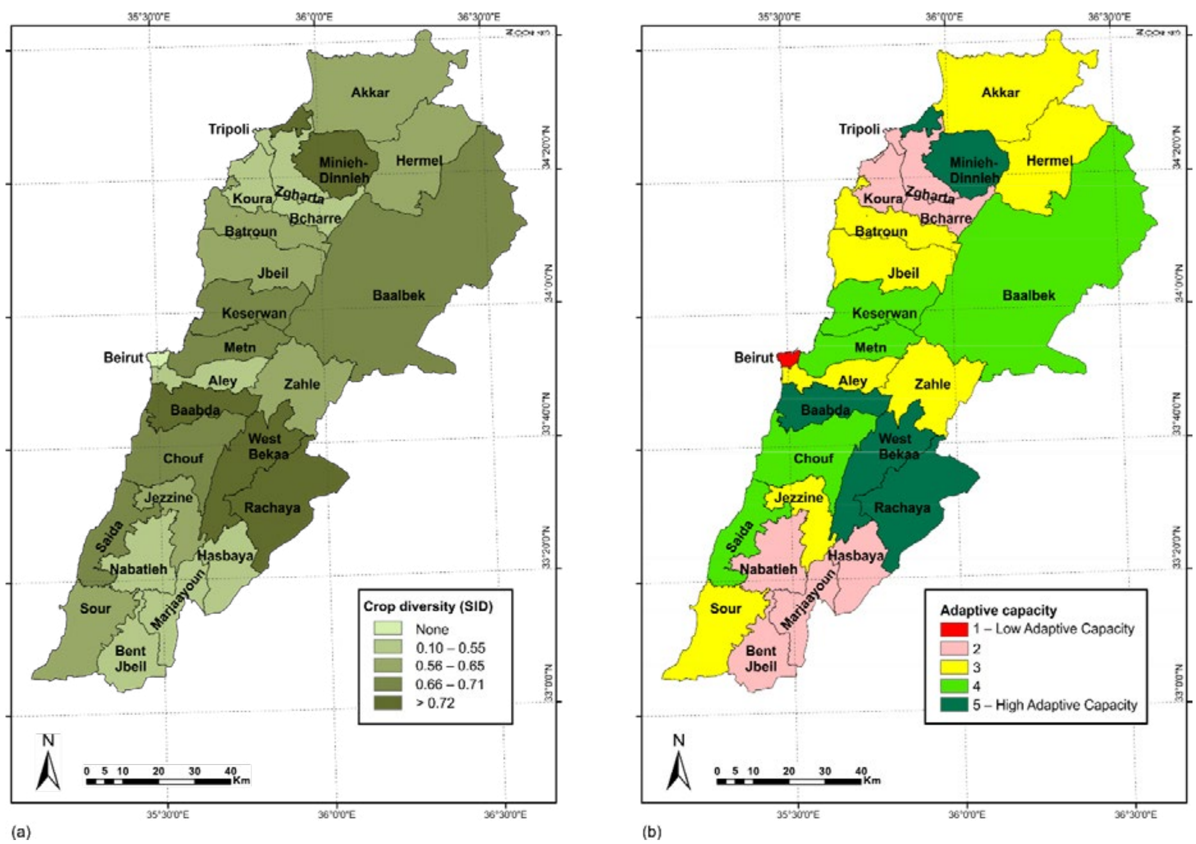
Indicator fact sheet	
Indicator	**Elevation slope**
Vulnerability component	Sensitivity
Description	Measure the slope by percent. The varied elevation of Lebanon offers the possibility of extending to diversified agricultural crops.
Classes and ranges	Sensitivity 1 = < 4.0 Sensitivity 2 = 4.1 – 7.0 Sensitivity 3 = 7.1 – 29.0 Sensitivity 4 = 29.1 – 59.0 Sensitivity 5 = > 59.0
Influence on vulnerability	Steep areas are more sensitive due to fast-draining soils and high risk of erosion.
Data source	ALOS Global Digital Surface Model (AW3D30 Version 2.1)
Data information	
Type of Data	Raster
Resolution	30 m x 30 m
Time Reference	2016
Unit of Measurement	Percent (%)
Methodology for General Data Calculation	GIS transformation from compass direction
Methodology for classification and transformation of values	Expert opinion
Input-indicators needed	None
Data supply and acquisition	
Date of processing and publication	2016
Availability and costs	Available from ALOS World 3D - 30m (AW3D30)
Download-link	http://www.eorc.jaxa.jp/ALOS/en/aw3d30/
Date of acquirement	2017

APPENDIX C: ADAPTIVE CAPACITY INDICATORS

Adaptive capacity indicators were selected based on factors relevant to agriculture in Lebanon which can help or hinder the ability to adapt to climate change impacts. For each indicator, maps showing actual values and the corresponding classified values are enclosed. In addition, a factsheet for each indicator is included which describes indicator details.

C.1. Crop diversity

FIGURE C.1: Crop diversity (a) actual values and (b) classified values



Indicator fact sheet	
Indicator	**Crop diversity**
Vulnerability component	Adaptive capacity
Description	The variance in genetic and phenotypic characteristics of plants used in agriculture
Classes and ranges	Adaptive capacity 1 = None Adaptive capacity 2 = 0.10 – 0.55 Adaptive capacity 3 = 0.56 – 0.65 Adaptive capacity 4 = 0.66 – 0.71 Adaptive capacity 5 = > 0.72
Influence on vulnerability	Crop diversity can help ensure food security, adapt to climate change, safeguard biodiversity, promote nutritional security, reduce poverty, and ensure sustainable agriculture
Data source	Census of Lebanese Agricultural Ministry
Data information	
Type of Data	Raster
Resolution	Caza level
Time Reference	2010
Unit of Measurement	Simpson Index (SID)
Methodology for General Data Calculation	Simpson Index (SID) was calculated to find the extent of diversification and was worked out using the following equation: $SID = 1 - \sum_{i=1}^{n} W_i^2$ where $W_i = \frac{xi}{\sum xi}$ *xi* : is the area of i[th] crop, and W_i is the proportionate area of the i[th] crop in the total crop.
Methodology for classification and transformation of values	Expert opinion
Input-indicators needed	None
Data supply and acquisition	
Date of processing and publication	2010
Availability and costs	Available from Ministry of Agriculture
Download-link	http://www.agriculture.gov.lb/
Date of acquirement	2017

C.2. Agricultural tenure obstacles

FIGURE C.2: Agricultural tenure obstacles (a) classified values and (b) actual values for agricultural infrastructure obstacles

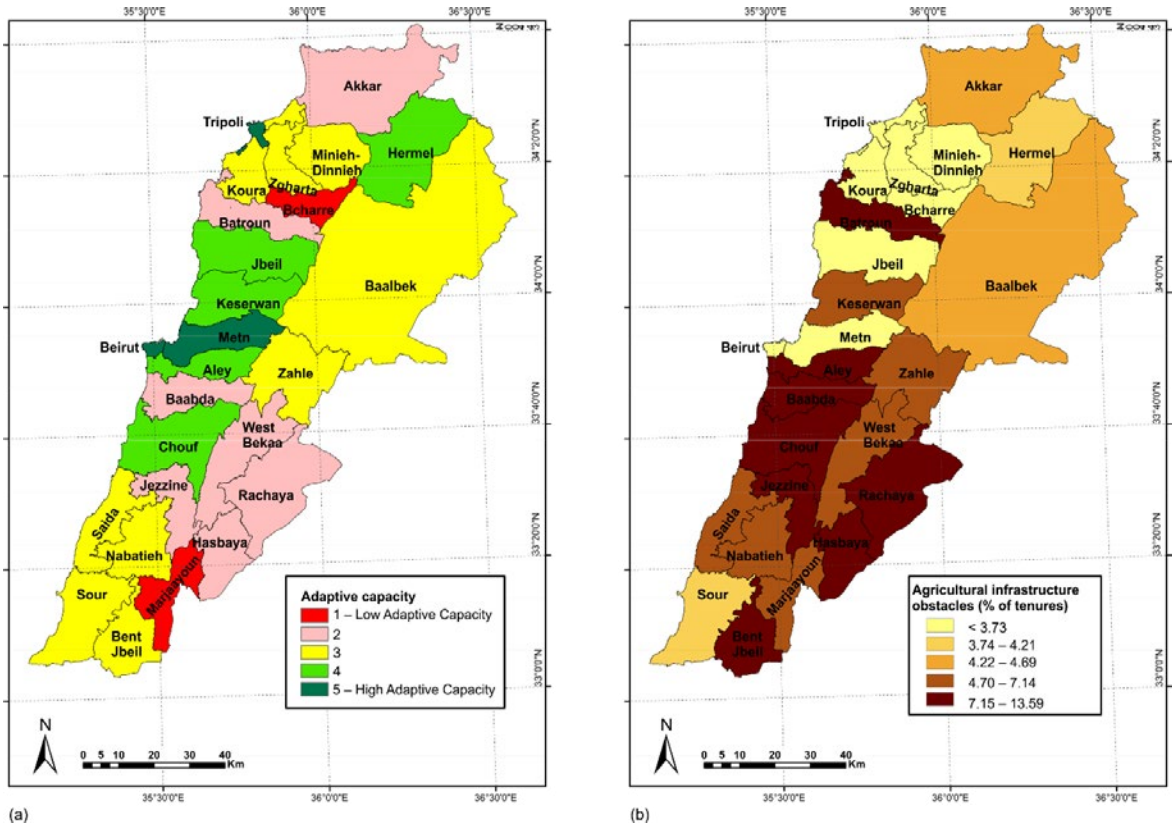


FIGURE C.3: Agricultural tenure obstacles (c) agricultural loan capacity and (d) land holding fragmentation obstacles

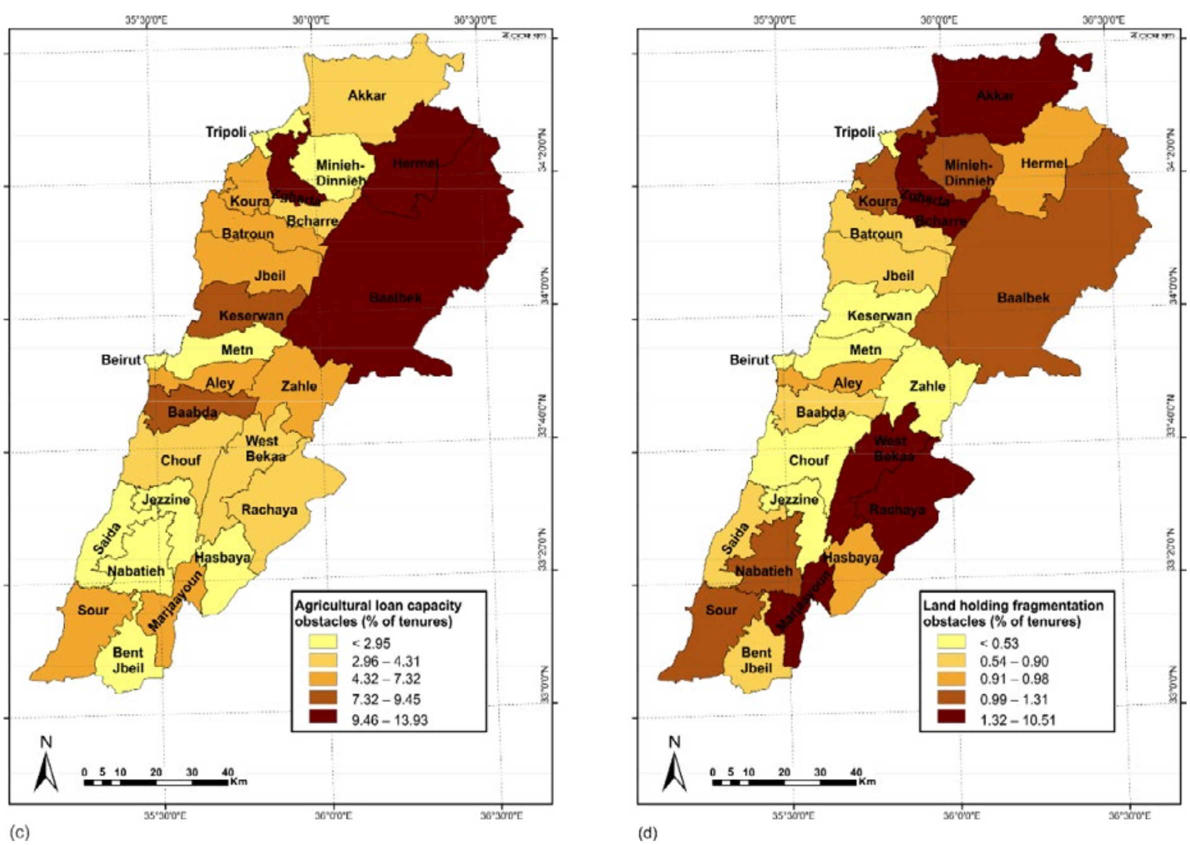


FIGURE C.4: Agricultural tenure obstacles (e) guidance and training and (f) marketing of agricultural production obstacles

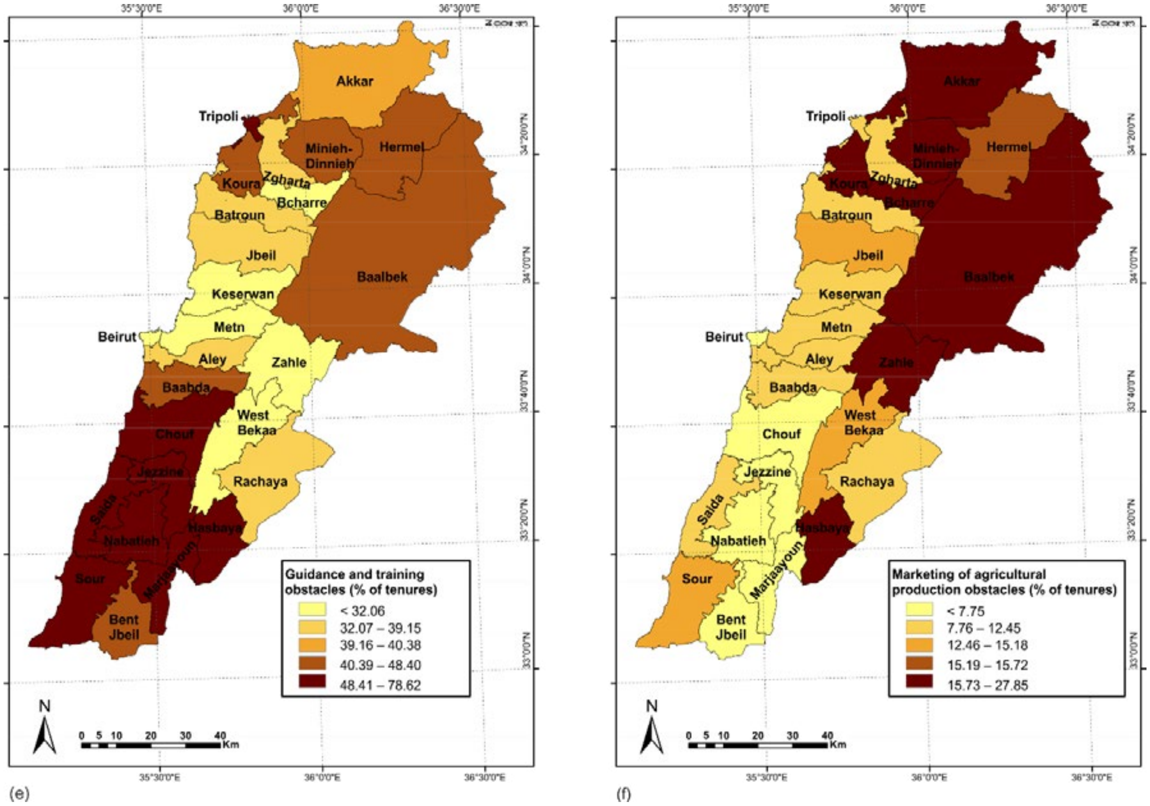
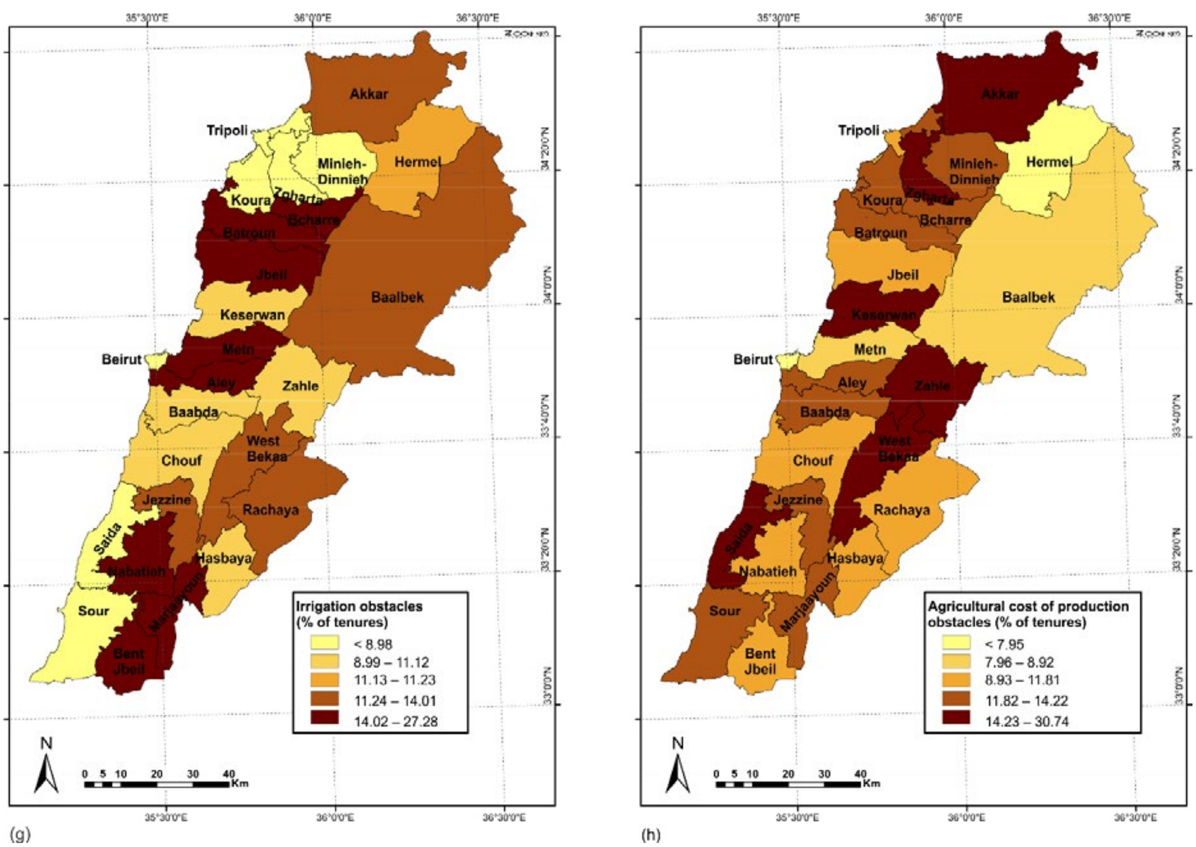


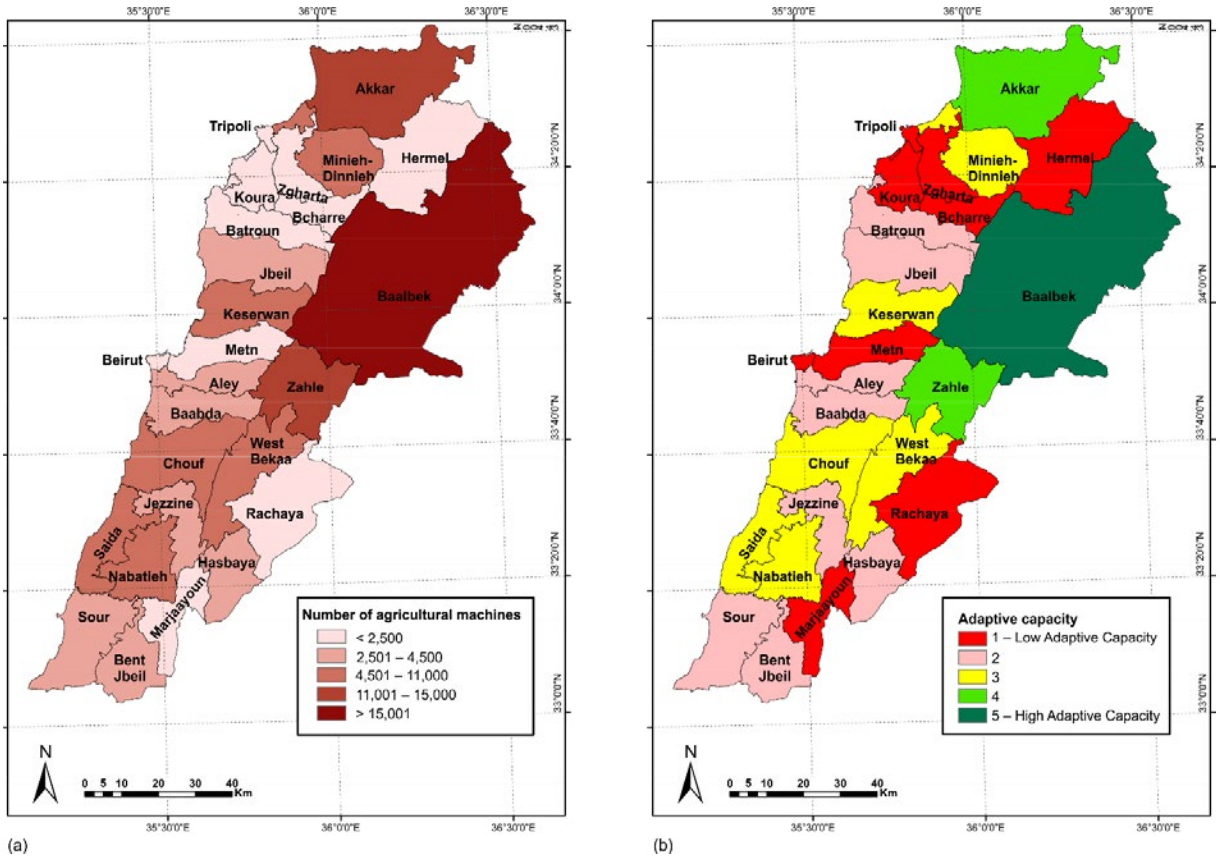
FIGURE C.5: Agricultural tenure obstacles (g) irrigation and (h) Agricultural cost of production obstacles



Indicator fact sheet		
Indicator	Agricultural tenure obstacles	
Vulnerability component	Adaptive capacity	
Description	Obstacles are defined as (a) agricultural infrastructure, (b) loaning, (c) land holding fragmentation, (d) guidance and training, (e) marketing of agricultural production, (f) irrigation, and (g) agricultural cost of production	
Classes and ranges		
Agricultural infrastructure Adaptive capacity 1 = 7.15 – 13.59 Adaptive capacity 2 = 4.70 – 7.14 Adaptive capacity 3 = 4.22 – 4.69 Adaptive capacity 4 = 3.74 – 4.21 Adaptive capacity 5 = < 3.73	Agricultural loan capacity Adaptive capacity 1 = 9.46 – 13.93 Adaptive capacity 2 = 7.32 – 9.45 Adaptive capacity 3 = 4.32 – 7.32 Adaptive capacity 4 = 2.96 – 4.31 Adaptive capacity 5 = < 2.95	Land holding fragmentation Adaptive capacity 1 = 1.32 – 10.51 Adaptive capacity 2 = 0.99 – 1.31 Adaptive capacity 3 = 0.91 – 0.98 Adaptive capacity 4 = 0.54 – 0.90 Adaptive capacity 5 = < 0.53
Guidance and training Adaptive capacity 1 = 48.41 – 78.62 Adaptive capacity 2 = 40.39 – 48.40 Adaptive capacity 3 = 39.16 – 40.38 Adaptive capacity 4 = 32.07 – 39.15 Adaptive capacity 5 = < 32.06	Marketing of agricultural production Adaptive capacity 1 = 15.73 – 27.85 Adaptive capacity 2 = 15.19 – 15.72 Adaptive capacity 3 = 12.46 – 15.18 Adaptive capacity 4 = 7.76 – 12.45 Adaptive capacity 5 = < 7.75	Irrigation Adaptive capacity 1 = 14.02 – 27.28 Adaptive capacity 2 = 11.24 – 14.01 Adaptive capacity 3 = 11.13 – 11.23 Adaptive capacity 4 = 8.99 – 11.12 Adaptive capacity 5 = < 8.98
Agricultural cost of production Adaptive capacity 1 = 14.23 – 30.74 Adaptive capacity 2 = 11.82 – 14.22 Adaptive capacity 3 = 8.93 – 11.81 Adaptive capacity 4 = 7.96 – 8.92 Adaptive capacity 5 = < 7.95		
Influence on vulnerability	Tenures facing less agricultural obstacles are more likely to adapt to climate change	
Data source	Census of Lebanese Agricultural Ministry	
Data information		
Type of data	Tabular	
Resolution	Caza level	
Time reference	2010	
Unit of measurement	% of tenures facing obstacles for each sub-indicator	
Methodology for general data calculation	Data from the source	
Methodology for classification and transformation of values	Quantile classification of sub-indicators; Geometrically aggregate all 7 indicators to obtain overall indicator and classify as follows:	
	Adaptive capacity 1 =	2.09 – 2.14
	Adaptive capacity 2 =	2.15 – 2.44
	Adaptive capacity 3 =	2.45 – 2.70
	Adaptive capacity 4 =	2.71 – 3.05
	Adaptive capacity 5 =	3.06 – 5.00
Input-indicators needed	All 7 described sub-indicators	
Data supply and acquisition		
Date of processing and publication	2010	
Availability and costs	Available from Ministry of Agriculture	
Download-link	http://www.agriculture.gov.lb/	
Date of acquirement	2017	

C.3. Number of agricultural machines

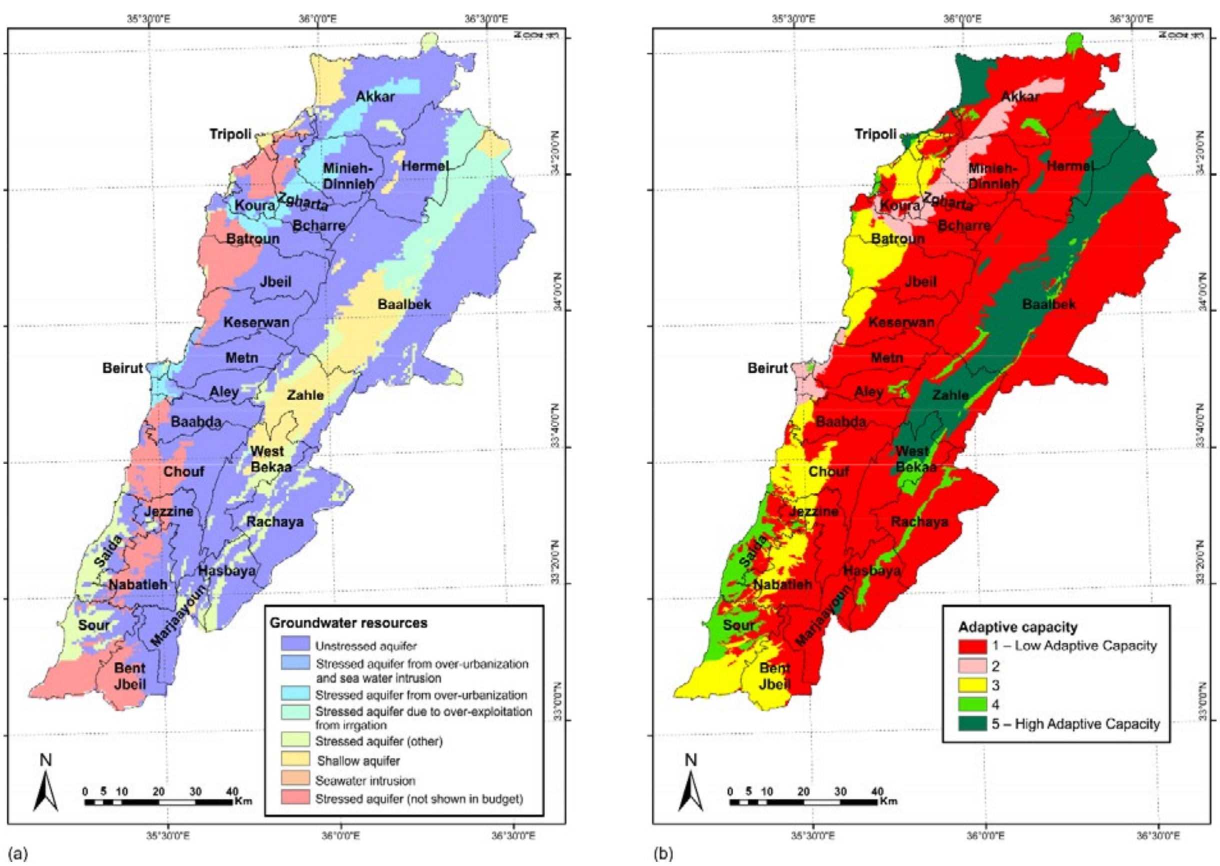
FIGURE C.6: Number of agricultural machines (a) actual values and (b) classified values



Indicator fact sheet	
Indicator	**Number of agricultural machines**
Vulnerability component	Adaptive capacity
Description	Machines include tractors, trucks, harvesters, milking machines, and spraying machines.
Classes and ranges	Adaptive capacity 1 = < 2,500 Adaptive capacity 2 = 2,501 – 4,500 Adaptive capacity 3 = 4,501 – 11,000 Adaptive capacity 4 = 11,001 – 15,000 Adaptive capacity 5 = > 15,001
Influence on vulnerability	More machinery indicates higher adaptive capacity
Data source	Census of Lebanese Agricultural Ministry
Data information	
Type of Data	Tabular
Resolution	Caza level
Time Reference	2010
Unit of Measurement	Number
Methodology for General Data Calculation	Data from the source
Methodology for classification and transformation of values	Expert opinion
Input-indicators needed	None
Data supply and acquisition	
Date of processing and publication	2010
Availability and costs	Available from Ministry of Agriculture
Download-link	http://www.agriculture.gov.lb/
Date of acquirement	2017

C.4. Groundwater resources

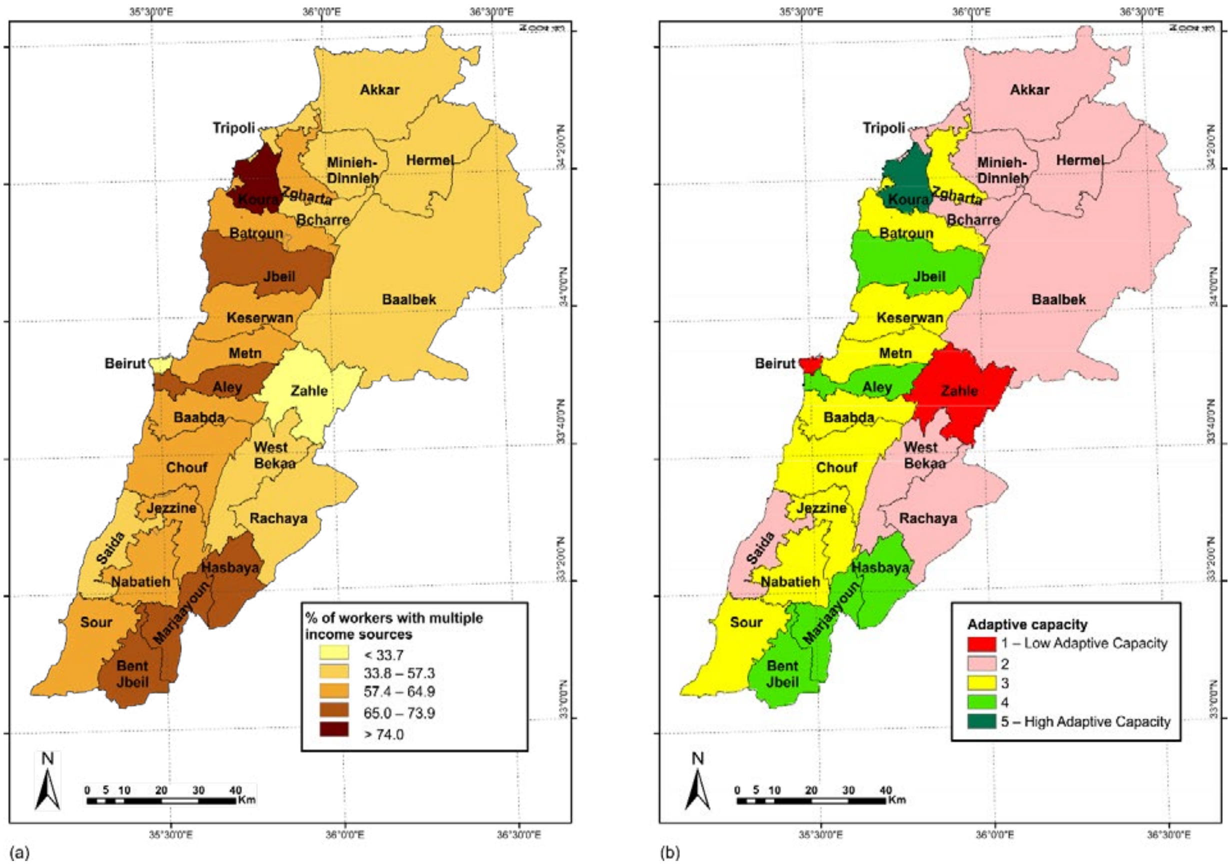
FIGURE C.7: Groundwater resources (a) actual values and (b) classified values



Indicator fact sheet	
Indicator	**Groundwater resources**
Vulnerability component	Adaptive capacity
Description	Shallow and stressed aquifers are potential irrigation water resources. Most coastal groundwater basins show severe deficiencies and are primarily used for domestic needs. In some basins (i.e. North Lebanon Cretaceous Basin), water shortages can reach > 150 MCM per year. Other key basins such as the Hadath-Hazmieh Cretaceous Basin and the Beirut Neogene Quaternary Basin reach deficiencies of 7.2 MCM and 38.4 MCM annually, respectively. Partly due to over-exploitation, deficiencies up to 45.7 MCM and 34.2 MCM have been detected in the South Beqaa Neogene-Quaternary Basin and the North Beqaa Neogene Quaternary Basins, respectively. Overall, groundwater in Lebanon contributes ~50% of irrigation water via wells as well as ~80% of drinking water from wells and springs.
Classes and ranges	Adaptive capacity 1 = Unstressed aquifers and stressed aquifers due to seawater intrusion Adaptive capacity 2 = Stressed aquifers due to over-exploitation and/or over-urbanization Adaptive capacity 3 = Stressed aquifers not included in water budget Adaptive capacity 4 = Stressed aquifers included in water budget Adaptive capacity 5 = Shallow aquifers and stressed aquifers due to over-exploitation from irrigation
Influence on vulnerability	Available of water resources for irrigation indicates higher adaptive capacity
Data source	MoEW and UNDP. Assessment of Groundwater Resources of Lebanon. 2014
Data information	
Type of Data	Raster
Resolution	By groundwater aquifer
Time Reference	2010
Unit of Measurement	Descriptive
Methodology for General Data Calculation	Data from the source
Methodology for classification and transformation of values	Expert opinion
Input-indicators needed	None
Data supply and acquisition	
Date of processing and publication	2014
Availability and costs	Available from MoEW and UNDP
Download-link	Not available
Date of acquirement	2017

C.5. Percentage of workers with multiple income sources

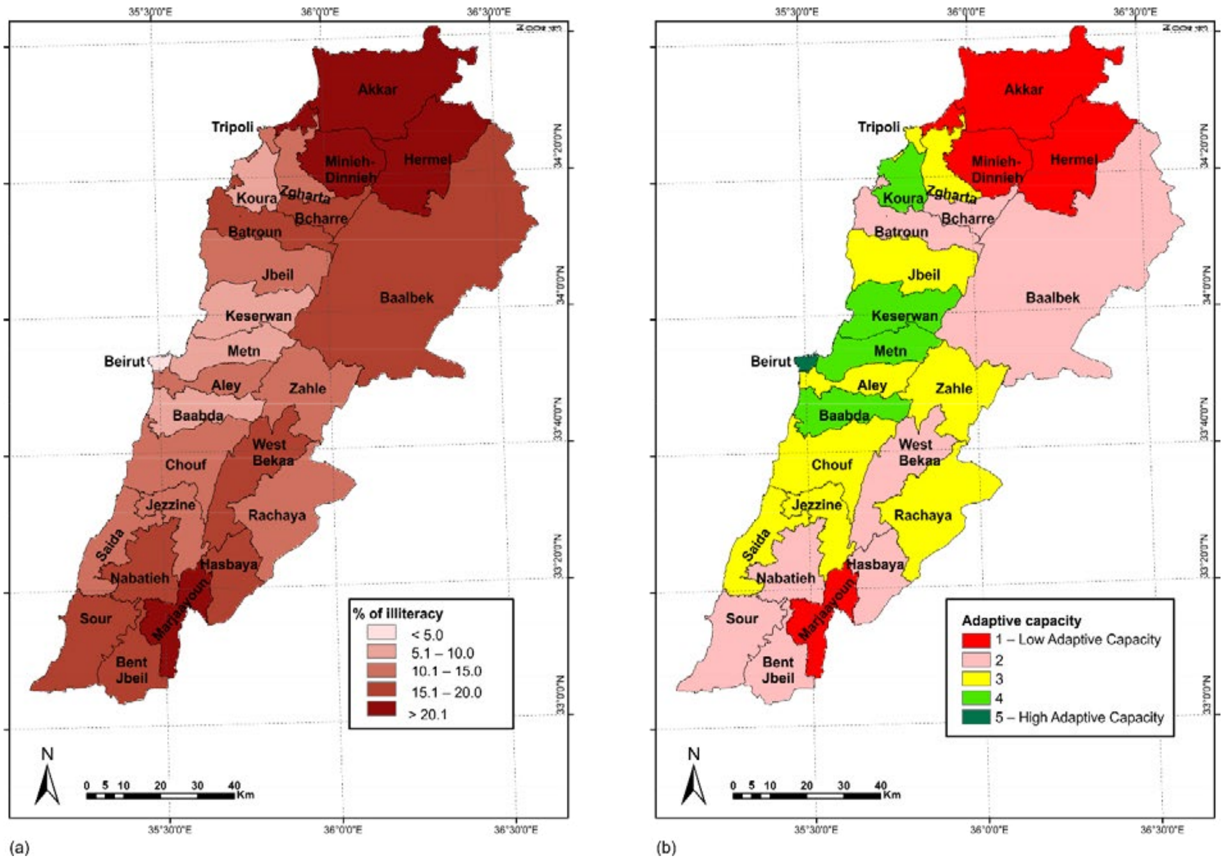
FIGURE C.8: Percentage of workers with multiple income sources (a) actual values and (b) classified values



Indicator fact sheet	
Indicator	**Percentage of workers with multiple income sources**
Vulnerability component	Adaptive capacity
Description	Workers with diversified income
Classes and ranges	Adaptive capacity 1 = < 33.7 Adaptive capacity 2 = 33.8 – 57.3 Adaptive capacity 3 = 57.4 – 64.9 Adaptive capacity 4 = 65.0 – 73.9 Adaptive capacity 5 = > 74.0
Influence on vulnerability	Workers with multiple incomes sources can diversify livelihoods and demonstrate higher adaptive capacity.
Data source	Verdeil, E. et al. 1999. Atlas du Liban
Data information	
Type of Data	Raster
Resolution	Caza level
Time Reference	1999
Unit of Measurement	Percentage (%)
Methodology for General Data Calculation	Data from the source
Methodology for classification and transformation of values	Expert opinion
Input-indicators needed	None
Data supply and acquisition	
Date of processing and publication	1999
Availability and costs	Available
Download-link	http://books.openedition.org/ifpo/420
Date of acquirement	2017

C.6. Illiteracy ratio

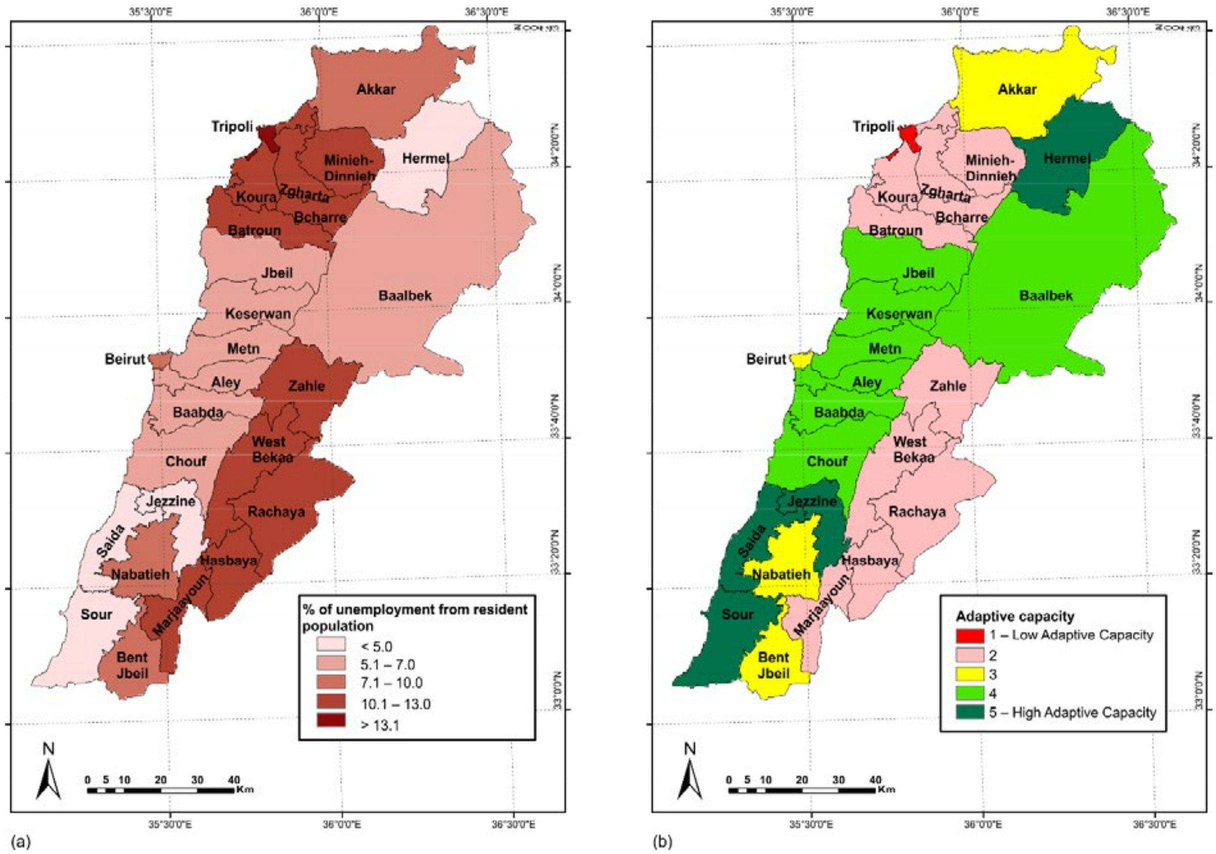
FIGURE C.9: Illiteracy ratio (a) actual values and (b) classified values



Indicator fact sheet	
Indicator	**Illiteracy ratio**
Vulnerability component	Adaptive capacity
Description	Average of illiteracy. High illiteracy rates can be partially explained by those over 45 years of age as well as high rates of emigration by young people of school age.
Classes and ranges	Adaptive capacity 1 = > 20.1 Adaptive capacity 2 = 15.1 – 20.0 Adaptive capacity 3 = 10.1 – 15.0 Adaptive capacity 4 = 5.1 – 10.0 Adaptive capacity 5 = < 5.0
Influence on vulnerability	High illiteracy rates are linked to low knowledge and awareness and thus less adaptive capacity.
Data source	MoSA/UNFPA. 2000. Analytical studies of results of surveying statistical indicators of population and households.
Data information	
Type of Data	Tabular
Resolution	Caza level
Time Reference	2000 (surveying statistical)
Unit of Measurement	Percentage (%)
Methodology for General Data Calculation	Data from the source
Methodology for classification and transformation of values	Expert opinion
Input-indicators needed	None
Data supply and acquisition	
Date of processing and publication	2017
Availability and costs	Available from MoSA/UNFPA
Download-link	Not available
Date of acquirement	2017

C.7. Percentage of unemployment from resident population

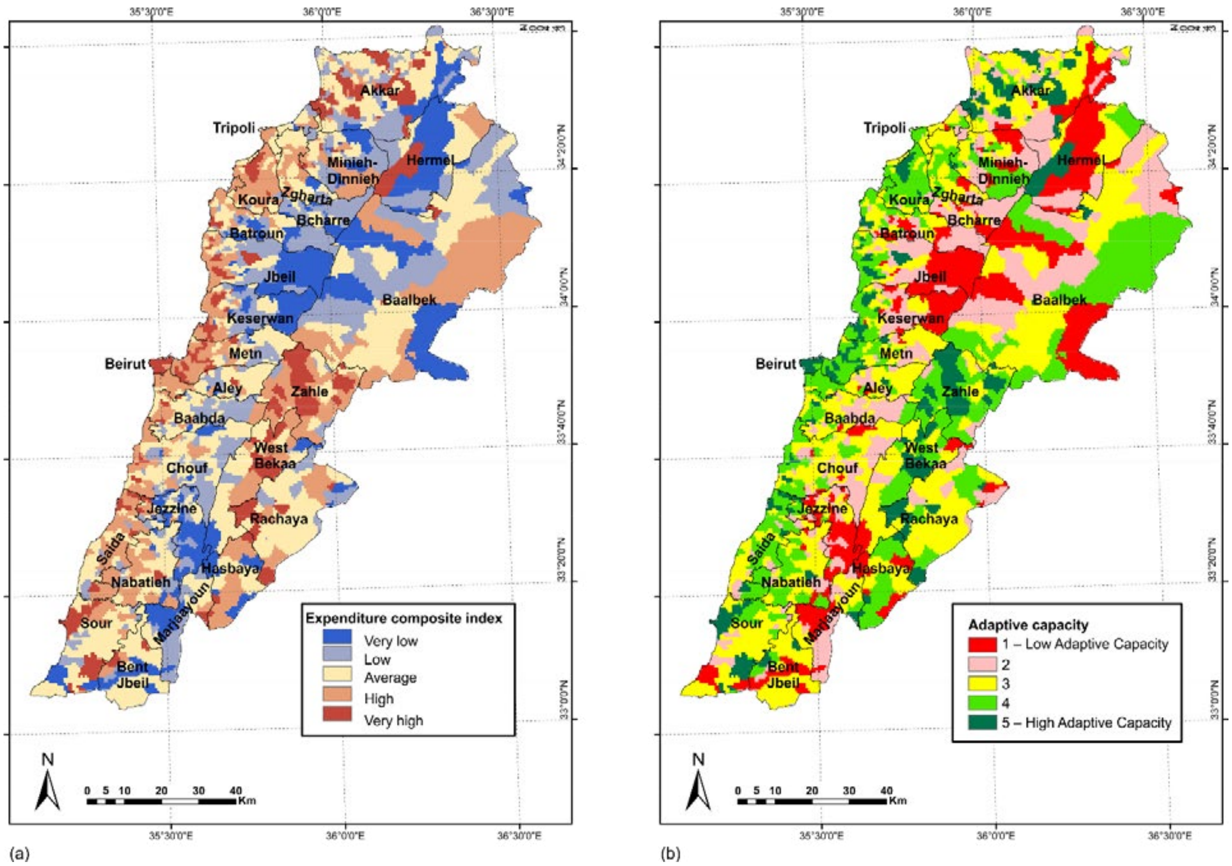
FIGURE C.10: Percentage of unemployment from resident population (a) actual values and (b) classified values



Indicator fact sheet	
Indicator	**Percentage of unemployment from resident population**
Vulnerability component	Adaptive capacity
Description	Unemployment is defined by ILO and is persons aged 15-64 that were unemployed during the reference period (week before survey).
Classes and ranges	Adaptive capacity 1 = > 13.1 Adaptive capacity 2 = 10.1 – 13.0 Adaptive capacity 3 = 7.1 – 10.0 Adaptive capacity 4 = 5.1 – 7.0 Adaptive capacity 5 = < 5.0
Influence on vulnerability	High unemployment has an impact upon livelihoods and thus lowers adaptive capacity.
Data source	Central Agency of Statistics (CAS) 1998
Data information	
Type of Data	Tabular
Resolution	Caza level
Time Reference	1998 (surveying statistical)
Unit of Measurement	Percentage (%)
Methodology for General Data Calculation	Data from the source
Methodology for classification and transformation of values	Expert opinion
Input-indicators needed	None
Data supply and acquisition	
Date of processing and publication	2017
Availability and costs	Available from CAS
Download-link	Not applicable
Date of acquirement	2017

C.8. Expenditure

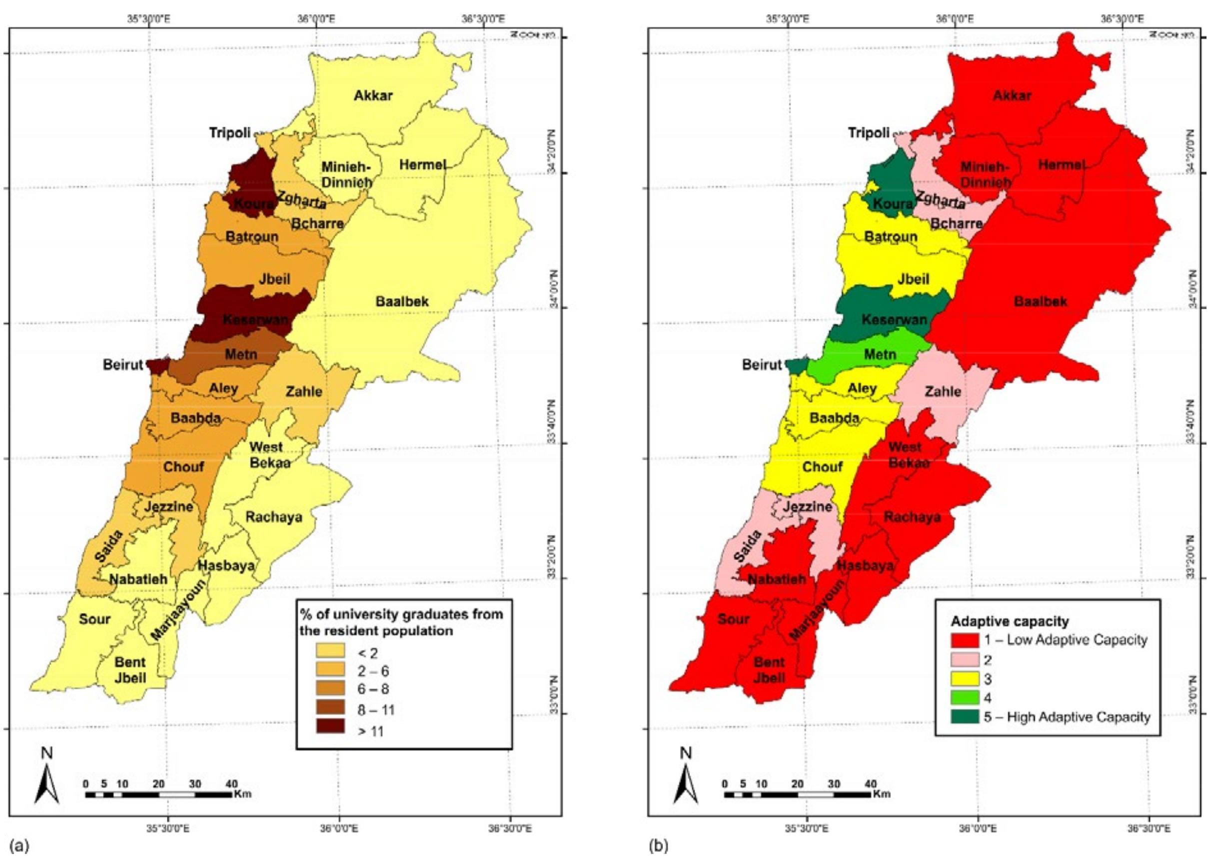
FIGURE C.11: Expenditure (a) actual values and (b) classified values



Indicator fact sheet	
Indicator	**Expenditure**
Vulnerability component	Adaptive capacity
Description	This is a composite index of residential telephone expenditure, commercial activity in terms of ratio of residences to shops, and construction rate.
Classes and ranges	Adaptive capacity 1 = Very low Adaptive capacity 2 = Low Adaptive capacity 3 = Moderate Adaptive capacity 4 = High Adaptive capacity 5 = Very high
Influence on vulnerability	Expenditure is indicative of economic resources of the population. Economic resources positively correlates with adaptive capacity.
Data source	SDATL and Ministry of Telecom
Data information	
Type of Data	Raster
Resolution	Village level; 1:375,000
Time Reference	2005
Unit of Measurement	Unitless index
Methodology for General Data Calculation	Composite index from the data source
Methodology for classification and transformation of values	Classification from the data source
Input-indicators needed	None
Data supply and acquisition	
Date of processing and publication	2017
Availability and costs	Available from SDATL and MoT
Download-link	http://www.localiban.org/IMG/pdf/composite_index.pdf
Date of acquirement	2017

C.9. Percentage of university graduates from the resident population

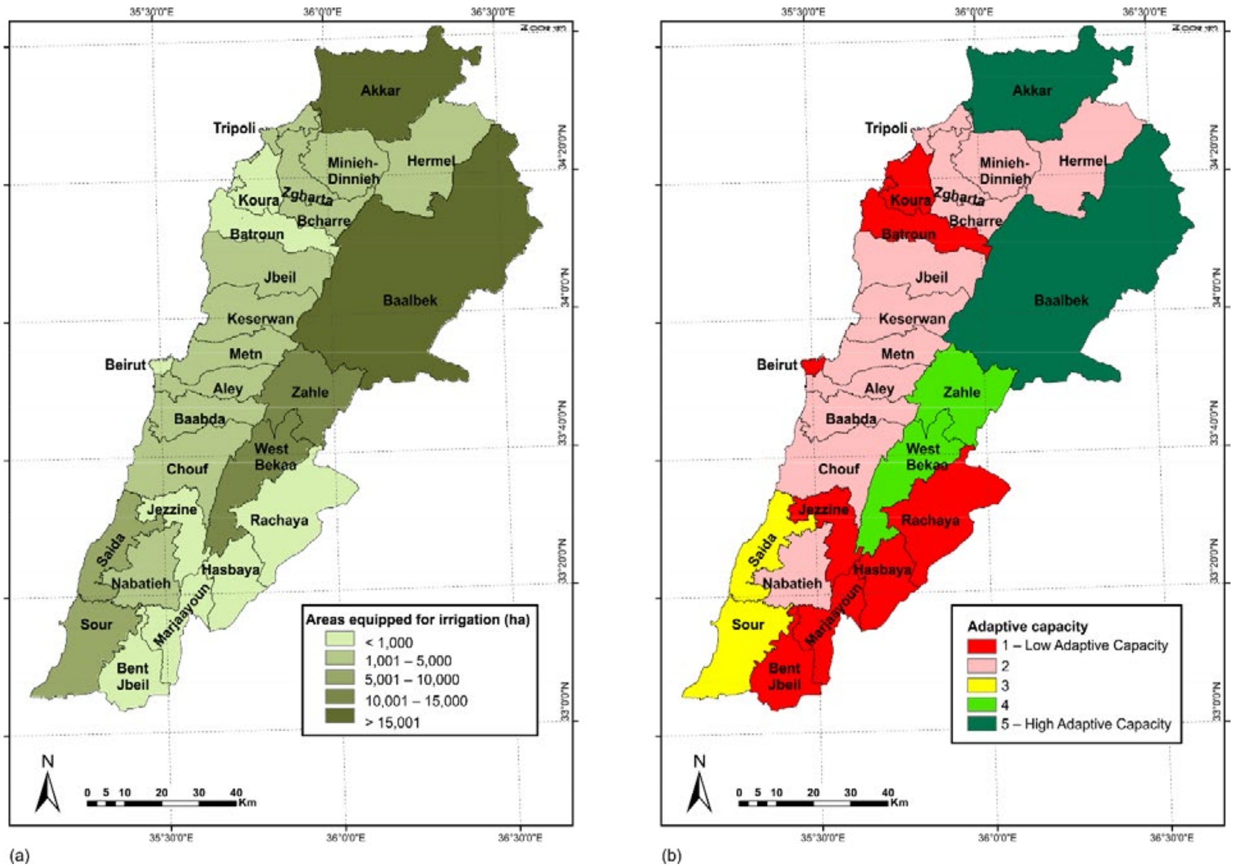
FIGURE C.12: Percentage of university graduates from the resident population (a) actual values and (b) classified values



Indicator fact sheet	
Indicator	**Percentage of university graduates from the resident population**
Vulnerability component	Adaptive capacity
Description	Percentage of university graduates from the resident population
Classes and ranges	Adaptive capacity 1 = < 2 Adaptive capacity 2 = 2 – 6 Adaptive capacity 3 = 6 – 8 Adaptive capacity 4 = 8 – 11 Adaptive capacity 5 = > 11
Influence on vulnerability	High percentage implies a high level of knowledge and awareness and thus high adaptive capacity
Data source	Ministry of Social Affairs (1996)
Data information	
Type of Data	Tabular
Resolution	Governorate level
Time Reference	1996
Unit of Measurement	Percentage (%)
Methodology for General Data Calculation	Data from the source
Methodology for classification and transformation of values	Expert opinion
Input-indicators needed	None
Data supply and acquisition	
Date of processing and publication	2017
Availability and costs	Available from Ministry of Social Affairs
Download-link	Not available
Date of acquirement	2017

C.10. Areas equipped for irrigation

FIGURE C.13: Areas equipped for irrigation (a) actual values and (b) classified values



Indicator fact sheet	
Indicator	**Areas equipped for irrigation**
Vulnerability component	Adaptive capacity
Description	Areas irrigated with surface and/or groundwater
Classes and ranges	Adaptive capacity 1 = < 1,000 Adaptive capacity 2 = 1,001 – 5,000 Adaptive capacity 3 = 5,001 – 10,000 Adaptive capacity 4 = 10,001 – 15,000 Adaptive capacity 5 = > 15,001
Influence on vulnerability	Areas equipped for irrigation have better ability to adapt to climate change.
Data source	Area equipped for irrigation per district was derived from the Agricultural Atlas of Lebanon that is based on the results of an agricultural census undertaken in year 1998. Total AEI according to this inventory was 104,009 ha.
Data information	
Type of Data	Tabular
Resolution	Caza level
Time Reference	2004
Unit of Measurement	Hectare (ha)
Methodology for General Data Calculation	Irrigated areas were digitized from a land-use map and from satellite imagery. In several cazas, the extent of the areas digitized that way was smaller than the AEI reported by the statistics. Therefore, the remaining AEI was assigned in these cazas to areas classified in the regional Globcover landcover classification for North Africa as rainfed cropland and, if required, to areas classified as mosaics of rainfed cropland with other land uses. The resulting pattern of irrigated land was quite like a map showing irrigation schemes in Lebanon in year 2004.
Methodology for classification and transformation of values	Expert opinion
Input-indicators needed	None
Data supply and acquisition	
Date of processing and publication	2017
Availability and costs	Available from data source
Download-link	Not applicable
Date of acquirement	2017