PART II

INTEGRATED VULNERABILITY ASSESSMENT

CHAPTER 8

BACKGROUND AND METHODOLOGY

Based on the impact assessment findings, the vulnerability assessment was conducted across the Arab region in targeted sectors and sub-sectors identified through a consultative process, and based on the classification and weighting of region specific geospatial indicators that characterize each sector's exposure, sensitivity and adaptive capacity with respect to climate change. This chapter introduces the conceptual framework of the vulnerability assessment used in RICCAR, and provides background information on the methodology followed, including the different steps applied through the integrated mapping process.

8.1 CONCEPTUAL FRAMEWORK

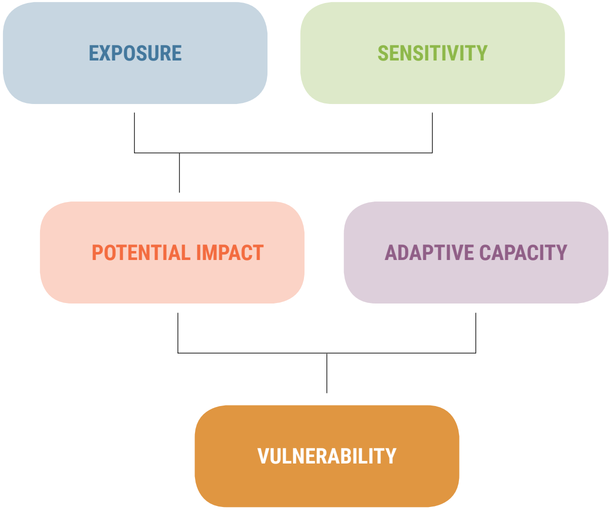
Vulnerability is a concept used to express the complex interaction of climate change effects and the susceptibility of a system to its impacts, with several existing definitions and approaches to characterize this concept. The integrated vulnerability assessment methodology applied in RICCAR is based on an understanding of vulnerability as a function of a system's climate change exposure, sensitivity and adaptive capacity to cope with climate change effects, consistent with the approach put forward by IPCC in its Fourth Assessment Report (AR4) and as illustrated in Figure 105.

Within this conceptual framework:

- **Exposure** refers to changes in climate parameters that might affect socio-ecological systems. Such parameters are, for example, temperature and precipitation, which climate change alters in terms of quantity and quality, as well as spatial and temporal distribution.
- **Sensitivity** provides information about the status quo of the physical and natural environment that makes the affected systems particularly susceptible to climate change. For example, a sensitivity factor could be topography, land use, land cover, distribution and density of population, built environment, proximity to the coast, etc.
- **Potential impact** is determined by combining the exposure and sensitivity to climate change on a system.
- **Adaptive capacity** refers to "the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences" as defined in IPCC AR4.[1]

Combining indicators related to exposure, sensitivity and adaptive capacity through an integrated mapping methodology allows for assessing the vulnerability of a system to climate change.

FIGURE 105: Components of vulnerability based on the IPCC AR4 approach



Source: Based on IPCC, 2007

8.2 TARGET SECTORS AND IMPACTS

With the aim of attaining a comprehensive assessment that can serve as a basis for dialogue and consultation on climate change issues across the Arab region and among its member States, the integrated vulnerability assessment combines a series of individual vulnerability assessments for several water-related climate change impacts on different sectors in the region. This type of assessment provides an integrated and cross-sectoral understanding of the region's vulnerability to potential climate change impacts. As such, the overall Arab region's vulnerability comprises the different sectoral vulnerabilities towards the various key climate change impacts identified, which are comprised of one or more subsectors.

Based on the outcomes of consultations conducted as part of RICCAR, the Vulnerability Assessment Working Group (VA-WG) was established in 2013 and identified five key sectors for examination along with associated subsectors, as illustrated in Figure 106. These were subsequently endorsed at the RICCAR Expert Group Meetings and by the Arab Ministerial Water Council. They consist of: (1) Water, focused on water availability; (2) Biodiversity and ecosystems, including (a) Forests, and (b) Wetlands; (3) Agriculture, including (a) Water available for crops, and (b) Water available for livestock; (4) Infrastructure and human settlements, focused on inland flooding; and (5) People, including (a) Water available for drinking, (b) Health conditions due to heat stress, and (c) Employment rate for the agricultural sector.

FIGURE 106: Sectors and subsectors selected for the Arab region vulnerability assessment

SECTORS	SUBSECTORS
Water	Water availability
Biodiversity and Ecosystems	Area covered by forests Area covered by wetlands
Agriculture	Water available for crops Water available for livestock
Infrastructure and Human Settlements	Inland flooding area
People	Water available for drinking Health conditions due to heat stress Employment rate for the agricultural sector

8.3 METHODOLOGY DEVELOPMENT PROCESS

The vulnerability assessment methodology was developed through a consultative and participatory process with experts from the Arab region. It was elaborated based on discussions during annual Expert Group Meetings (EGMs) and through the establishment of the VA-WG, comprising representatives of Arab Governments, as well as the League of Arab States, the United Nations and expert organizations serving the Arab region. The VA-WG was also assisted by a technical advisory team supported by GIZ. Two task forces were additionally formed to support the vetting and review of regionally appropriate vulnerability indicators related to sensitivity and adaptive capacity in the Arab region. Moreover, expert knowledge was sought from regional stakeholders that contributed to the selection of indicators through a questionnaire in which they were asked to select and assign the values or categories an indicator could have to a pre-defined scale, taking into consideration how the indicator value relates to the vulnerability component it is part of.

The development of the methodology progressed through a set of meetings of the VA-WG and task forces that were held regularly over the course of the project to refine its key components and associated processes, as elaborated in the RICCAR technical note *Integrated Vulnerability Assessment: Arab Regional Application (2017)*.[2] Adjustments to the indicator framework were made during the testing of the methodology in order to overcome data gaps or concerns about data quality.

Experts, as well as members of regional research centres with expertise in the area of climate change assessment and geographic information system (GIS) applications, were invited to review, test and comment on the draft vulnerability assessment methodology during a regional workshop (Beirut, May 2014) and its progress was presented for consideration by Arab Governments, regional organizations and the RICCAR partners at the Fifth RICCAR Expert Group Meeting (Amman, December 2013) and the Sixth RICCAR Expert Group Meeting (Cairo, December 2014), respectively. The methodology was finalized in May 2015, and an expert group review was subsequently organized in 2016 to fully review and vet the application of the methodology with regard to the final set of indicators, as well as the weights and normalization scheme applied during the preparation of the assessment (Beirut, April 2016). Finally, the results and findings of the integrated VA were peer-reviewed during an expert peer review meeting (Beirut, December 2016) to examine the aggregated results for the nine subsectors, namely the maps related to exposure, sensitivity, potential impact, adaptive capacity and overall vulnerability in view of identifying the potential vulnerability hotspots in the region.

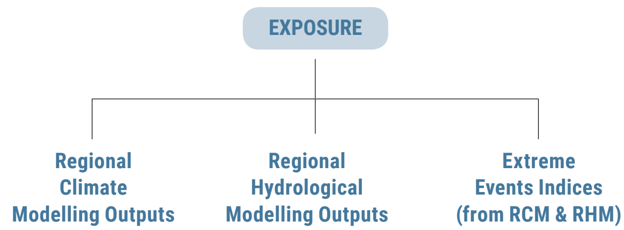
8.4 INTEGRATED MAPPING METHODOLOGY

Integrated mapping methodology for the integrated vulnerability assessment combines indicators that contribute to the characterization of the sensitivity, exposure, potential impact and adaptive capacity components and dimensions of vulnerability with respect to climate change as represented in an impact chain. The methodology applied in RICCAR for the Arab region draws upon regionally appropriate and available indicators, applies weights to each indicator (derived from statistical analysis, existing literature, stakeholder information, expert opinion) as developed by regional consultations and expert opinions. These weighted dimensions were then reflected in a geometric aggregation method used to combine these components to determine climate change vulnerability. 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 through a multi-step process. Detailed guidance on the methodology with precisions on each step is presented in the RICCAR technical note *Integrated Vulnerability Assessment: Arab Regional Application (2017)*.[3] Additional information is provided in the *Training Manual on the Integrated Vulnerability Assessment Methodology (2017)* prepared within the framework of the ACCWaM programme support to RICCAR.[4] The applied methodology is briefly summarized below:

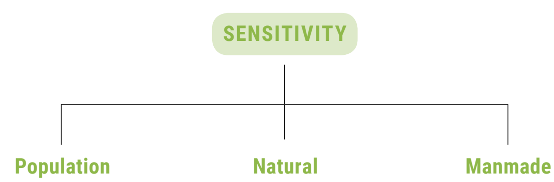
Step 1: Developing impact chains.
A long list of exposure, sensitivity and adaptive capacity indicators that could characterize the effects of climate change on the selected sector and subsectors was undertaken. For each climate change impact, indicators were identified with the help of an impact chain. These are analytical tools that illustrate the cause-effect relationships between indicators, dimensions, components and the relevant impact.

Step 2: Identifying and selecting indicators.
Indicators were selected based on their relevance, homogeneity, validity, reliability and coverage for the entire Arab Domain. They were assigned for each component as deemed relevant and classified under different dimensions.

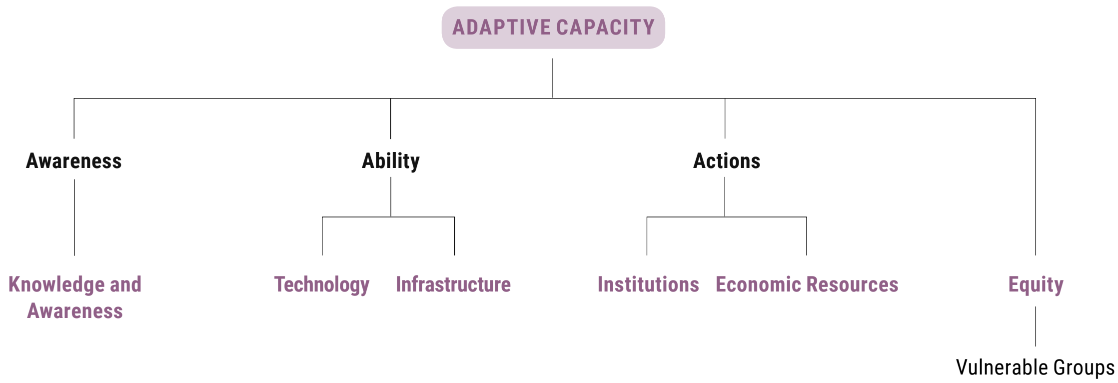
- **Exposure** indicators were derived from the regional climate modelling and regional hydrological modelling outputs and are the sole dynamic datasets applied in the assessment. They were developed for five differing time periods and climate scenarios: reference period; future mid-century based on a moderate scenario (RCP 4.5); future mid-century based on an extreme scenario (RCP 8.5); future end century based on a moderate scenario; and future end-century based on an extreme scenario.



- The **sensitivity** component includes 25 indicators classified in three dimensions: population, natural and man-made. The population dimension is comprised of societal factors which place pressure on the physical system due to population growth, including human migration and resource depletion. The natural dimension considers environmental and ecological elements such as soil type and land cover[5] which may be subject to degradation. Lastly, the man-made dimension incorporates anthropogenic factors which may be exacerbated due to climate change. While many elements which can be evaluated as part of sensitivity are dynamic (population growth), because of data-availability limitations, all indicators used for RICCAR are static, based on the most recent available information for all future climate scenarios.



- **Adaptive capacity** comprises 27 indicators categorized into six dimensions: knowledge and awareness, technology, infrastructure, institutions, economic resources, and equity. The first dimension reflects general education and cognizance regarding climate change. These transition into technology and infrastructure, which support the ability to adapt. At a macro level, adaptation is promoted further via institutions and economic resources. Lastly, equity factors in gender, age structure and access for people with disabilities. Infrastructure indicators were selected based on five pillars: energy, transportation, health, water and sanitation, and environment. Like the sensitivity indicators, the adaptive capacity indicators are static.



Step 3: Data acquisition.
Data pertaining to each indicator were acquired from a wide variety of sources. Exposure indicator datasets were based on outputs from RCMs and RHMs which comprise projected changes in temperature, precipitation and other hydrological parameters for different emission scenarios and time periods. Data corresponding to exposure from RHMs were based on the outputs from the VIC hydrological model only. In quantifying sensitivity and adaptive capacity indicators, data were mainly extracted from statistical databases and international organizations providing maps and datasets covering the selected 21 countries in the Arab region.

The assessment drew extensively on data at the national and subnational scale when available. An overview of the main data sources used such as demographics, economic resources or equity-related databases are briefly described in the introduction to this report. Detailed information on the data source for each indicator including date, resolution, scale, how the data was developed, etc., is provided on an indicator factsheet to be made available on the regional knowledge hub.

Step 4: Normalization and classification of indicator data.
As indicators are characterized by varying magnitudes and units of measurement, they were normalized and classified based on a common scale from 1 to 10 prior to aggregation. For exposure and sensitivity indicators, 1 represents a positive condition (low exposure) and 10 suggests a negative condition. For adaptive capacity, the scale is reversed (1 represents low adaptive capacity) and, therefore, prior to aggregation, values must be inverted to correlate positive and negative conditions together. Indicators were generally classified in accordance with water-availability vulnerability.

It is important to point out that this concept was not applicable for some subsectors and indicators were reclassified for applicable subsectors. In addition, indicators were classified based on relative vulnerability within the Arab region, not globally.

Step 5: Weighing and aggregation of indicators.
Indicators were assigned weights to measure their relative importance for a given climate change impact and were determined using a multi-step process based on the results obtained from an expert survey. Experts were solicited from differing fields related to the vulnerability assessment from around the Arab region who evaluated the relative importance of differing indicators. Results were then vetted by an expert panel to ensure validity. Finally, the most relevant sensitivity indicator was selected for each climate change impact and assigned a heavier weight to help highlight the specific impact. In turn, the most relevant adaptive capacity indicator was also an equally heavy weight to balance the physical and natural impacts with mankind's ability to overcome. Indicators were aggregated through geometric aggregation using their respective weights. Geometric aggregation is a non-linear approach which is preferred to other methods because it is multiplicative and synergetic.[6] Individual indicators were aggregated by pillar, then by dimension, if applicable, to obtain a composite indicator for each component.

Step 6: Aggregation of vulnerability components.
The exposure and sensitivity composite indicators were subsequently aggregated to obtain the potential impact described for each time period and climate scenario. Finally, the potential impact and adaptive capacity composite indicators were aggregated to obtain the overall vulnerability for each climate change impact subsector. In cases where there were two or more climate change impacts identified for a sector, the impacts were then aggregated to obtain overall vulnerability for the sector.

Step 7: Presenting outcomes as vulnerability maps.
Vulnerability assessment results were ultimately presented as maps describing precise locations where people, the environment or natural resources are at high risk. Visualization of vulnerable areas and hotspots on maps facilitates communication and provides entry points for a regional dialogue on joint adaptation efforts to cope with the challenges of climate change in the Arab region.

8.5 PRESENTATION OF RESULTS

Integrated vulnerability assessment outputs are presented in maps for five sectors and nine subsectors. The presentation of findings in this report related to each sector and subsector includes the impact chain and results generated for the reference period, future periods (mid-century, end-century) for two RCPs and the identification of sector-specific hotspots (Figure 107). Additional outputs are available in the Technical Annex of this report.

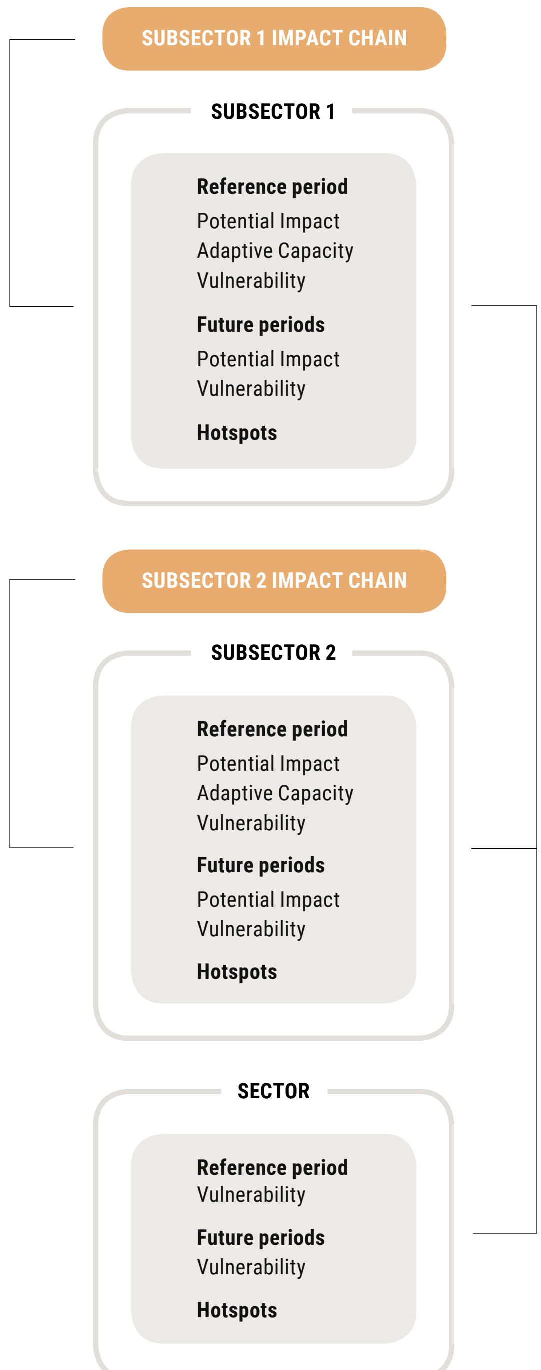
It is important to note that rather than reveal results obtained for the entire region, maps solely highlight the specific area of interest for a given sector or subsector. Areas of interest were based on one or more indicators. For example, for the Area covered by forests subsector, maps only show results obtained in areas with forest cover and all climate change impacts studied under the People sector show populated areas only. This approach helps to focus discussions on the relevant area of interest and allows for a cohesive presentation of the Arab region. Areas outside the specific area of interest but part of the Arab region are shaded in light grey.

It is also essential to point out that due to data limitations, many of the same adaptive capacity indicators have been used for all climate change impacts. Results are therefore largely similar. Higher adaptive capacity is generally found in the northern Maghreb and the Levant, while lower adaptive capacity is revealed in the southern Maghreb and areas near the Gulf of Aden. Other areas suggest moderate adaptive capacity. Although the indicators themselves are not necessarily applicable for a given climate change impact, they can be considered as proxies for the dimensions they represent.

Vulnerability hotspots identify areas that are especially vulnerable to climate change impacts. Such areas are intended to highlight high instances of vulnerability in a particular sector or subsector at the Arab regional level. Conceptual and methodological methods to define hotspots are varied among studies conducted elsewhere and are affected by spatial scale and uncertainties in data and outputs. For RICCAR, hotspots were identified based on the top percentage of overall vulnerability among the two time periods and two scenarios for each climate change impact. In terms of spatial scale, the scale – or pixel size – of the different input datasets varies significantly and these datasets are overlaid in the integrated mapping in order to create maps on vulnerability, as well as its respective components. The different spatial resolution of the data therefore poses a limit to the spatial accuracy of the maps, e.g. in regard to the location of climate change hotspots. Hence the results of the mapping roughly indicate areas at risk to climate change impacts on a subnational level.

This serves the purpose of a regional vulnerability assessment designed to highlight shared challenges from climate change. Such an assessment, however, does not provide a suitable basis for the concrete planning of adaptation measures on the local level. We recommend taking the hotspots identified on the regional level as an entry point to conduct further and more in-depth studies on a national or subnational level in order to identify locations for adaptation interventions. Such applications are already being carried out.

FIGURE 107: Presentation of results



ENDNOTES

1. IPCC, 2007
2. ESCWA et al., 2017
3. See ESCWA et al., 2017
4. See ACSAD et al., 2017
5. Fritzsche et al., 2014
6. El-Zein and Tonmoy, 2015
7. De Sherbinin, 2014

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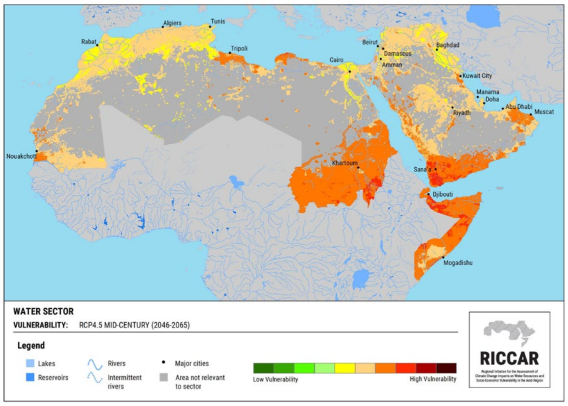
WATER SECTOR

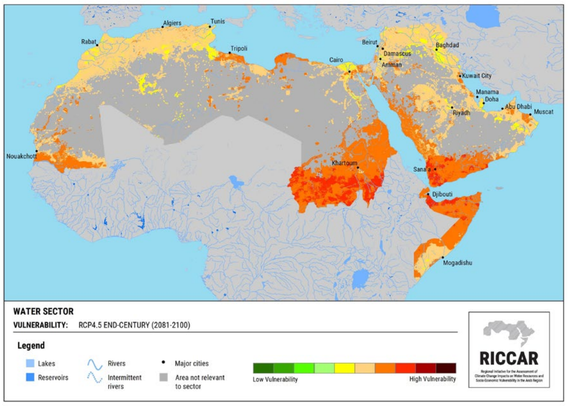
OVERALL VULNERABILITY

RCP 4.5

2046-2065

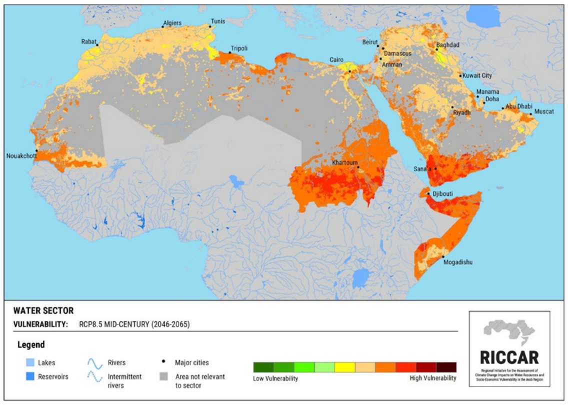


2081-2100

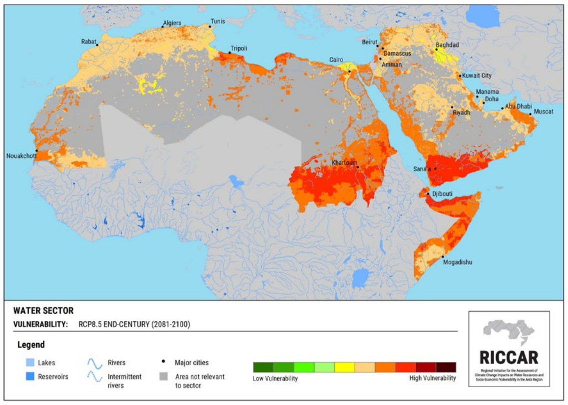


RCP 8.5

2046-2065



2081-2100



CHAPTER 9

WATER SECTOR – VULNERABILITY

Water demand is ubiquitous, essential for food supply, the human population, livestock, ecosystems and industries. Although a renewable resource, its availability is constrained. According to the Falkenmark Water Stress Indicator,[1] a country is water-stressed once annual water supplies drop below 1,700 m^3 per person per year. Freshwater shortages are expected when levels range between 1,000 m^3 to 1,700 m^3 per person per year and, once it drops below 1,000 m^3 per person per year, the country is water-scarce. The Arab region is thus considered water-scarce, with an estimated 610 m^3 per person per year of total available renewable water resources, and as low as 5 m^3 per person per year in some countries.[2]

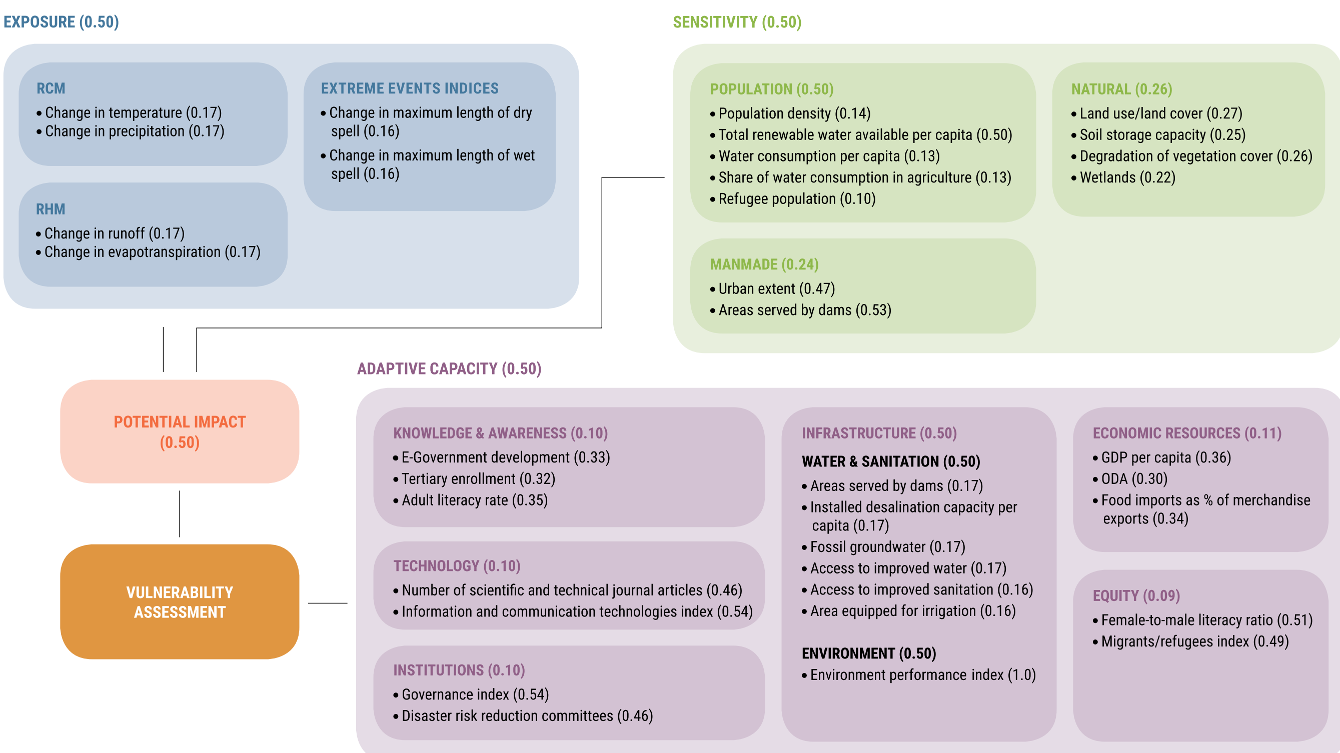
Given the central role of freshwater in the region and its importance in daily life and all economic sectors, the *Water* sector was selected as the starting point when preparing the vulnerability assessment of the Arab region, focusing on the potential impact of *Change in water availability*. It is commonly understood by regional stakeholders to be an overarching, cross-cutting issue that directly influences the vulnerability of the other targeted sectors to climate change. Results from the vulnerability assessment pertaining to this sector are presented in the sections below.

The water-availability study area represents 49% of the Arab region and is defined by selected indicators and water users, as reflected by the areas drawing upon freshwater resources: Forested areas; Wetland areas; Rainfed cropland areas; Irrigated cropland areas; Livestock areas (greater than 10 heads per square kilometre); Populated areas (greater than 2 inhabitants per square kilometre). Because the *Water* sector comprises only one subsector, resultant maps and discussion are assumed to be identical and are thus not included herein at the sector level.

9.1 WATER AVAILABILITY

The different indicators used under each component for this sector and their corresponding weights are presented in the impact chain (Figure 108).

FIGURE 108: Impact chain and weights for water availability



9.1.1 Reference period

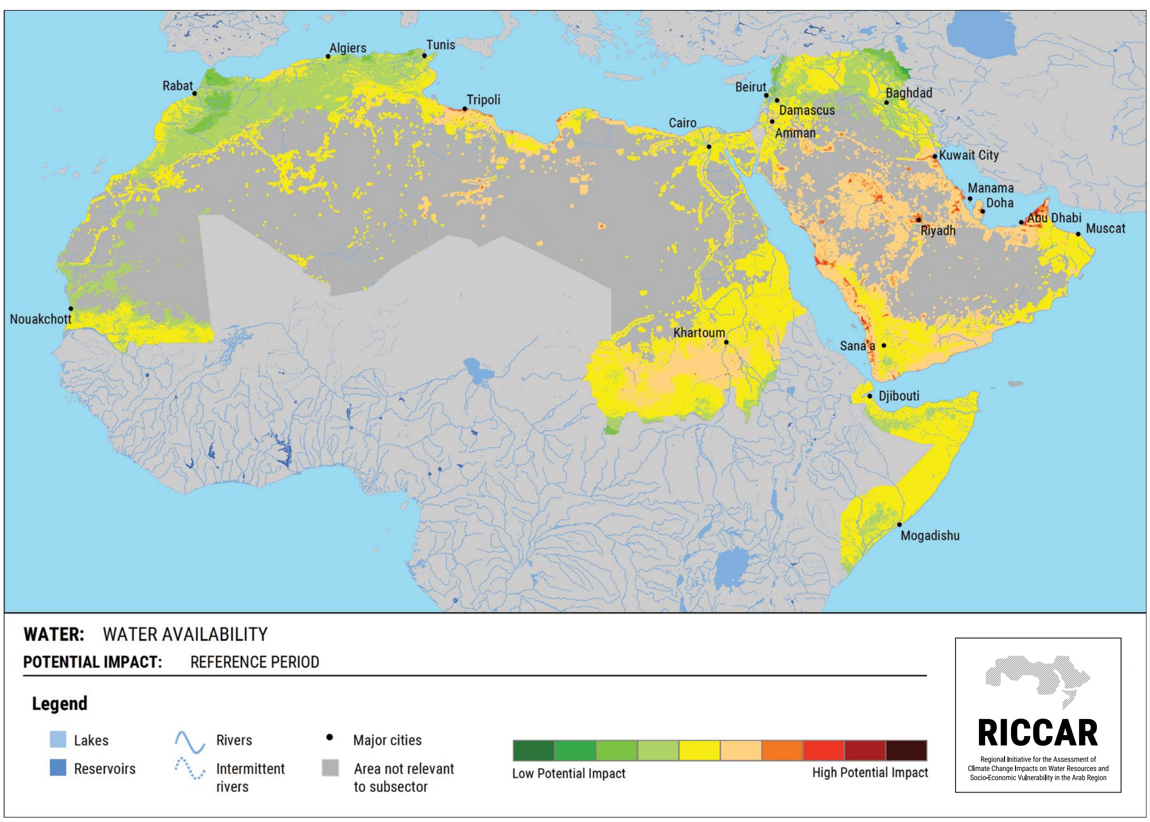
9.1.1.1 Potential impact

Potential impact is the aggregated result of both exposure and sensitivity. Selected exposure indicators focus on those parameters which are related to hydrology, as well as wet- and dry-spell durations, all of which can have a dramatic impact on water availability. Because much of the Arab region is considered water-scarce, expected exposure for the reference period is high in most of the study area (74%). Nearly a quarter of the study area (24%) is regarded as moderate exposure with remaining areas considered as low exposure. Areas of low exposure are contained in the Atlas Mountains and adjacent coastal areas, the coastal Levant, the Zagros Mountains, the Asir Mountains and the south-eastern Sahel. These areas of low exposure transition to moderate and eventually to high exposure.

Available water is expected to meet the needs of differing competing water users. Agriculture warrants the largest demand, using an average 73% of total available water in the Arab region and often exceeds 90%.[3] Water is also needed for industrial, municipal and domestic use. Selected sensitivity indicators reflect the various water users. The study area suggests a nearly equal division between low (48%) and moderate (51%) sensitivity, with isolated areas of high sensitivity. Areas with moderate-to-high sensitivity include the Tell Atlas region, the Jafara Plain basin and the Green Mountains in North Africa, the Asir Mountains and the central Arabian Desert. Sensitivity tends to be highest in areas where total available renewable water per capita is lowest, and in population centres.

Nearly the entire region (96%) has indicated moderate potential impact, with remaining areas divided between low and moderate potential impact. Potential impact correlates with total available renewable water. Areas with moderate-to-high potential impact include the central Arabian Desert and the Asir Mountains, whereas areas with low potential impact include the Atlas Mountains, the coastal Levant and much of the Tigris–Euphrates basin (Figure 109).

FIGURE 109: Water availability – Reference Period – Potential Impact

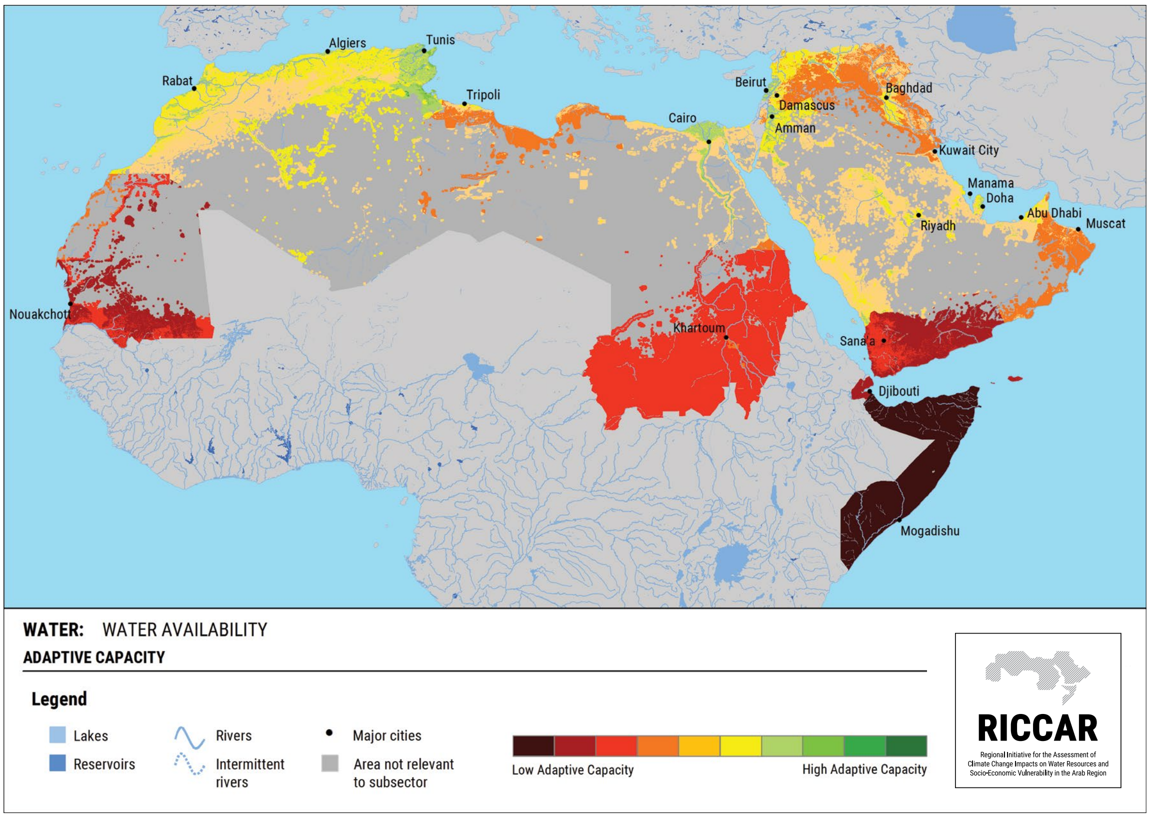


9.1.1.2 Adaptive capacity

The ability to cope is dependent upon several interrelated variables. For example, geopolitical factors consider shared water basins, which can impact regional stability, socio-economic development, environmental protection and security in areas downstream. Infrastructure and management are linked by water usage and efficiency. Gender plays a role because, in some areas, women must devote time every day to fetching water, potentially risking health and safety.

Nearly half (43%) of the study area has indicated low adaptive capacity and includes the Horn of Africa, the southern Tindouf basin and the south-western Arabian Peninsula due to weak infrastructure and other variables. Conversely, areas of high adaptive capacity represent 4% of the study area and include the lower Nile Valley, areas of the coastal Levant and the eastern Atlas Mountains. Remaining areas indicate moderate adaptive capacity (Figure 110).

FIGURE 110: Water availability – Adaptive capacity

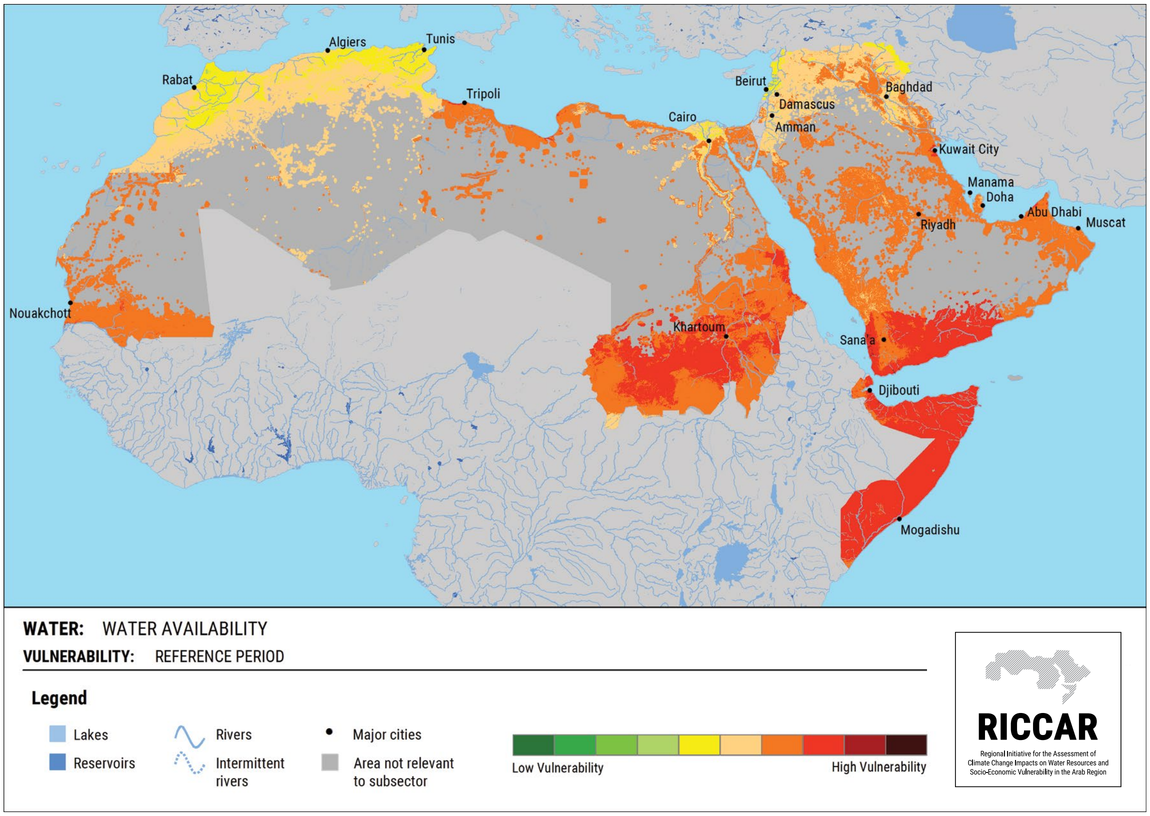


9.1.1.3 Vulnerability

For the reference period, a majority of the study area (70%) signifies high vulnerability for water availability, with remaining areas indicating moderate vulnerability (Figure 111). Areas with the highest vulnerability are clustered around the Marra Mountains in Sudan, the upper Nile Valley, Wadi Hadramaut in the southern Arabian Peninsula and the Horn of Africa. The Atlas Mountains and adjacent coastal areas, the Levantine coast and upper Mesopotamia represent lowest vulnerability compared to the rest of the Arab region. Due to adaptive capacity, areas that have the least total available renewable water resources are not necessarily the most vulnerable. Such areas include countries of the Gulf Cooperation Council, which benefit from economic wealth, facilitating water infrastructure projects like desalinization.

A comparison of different sectors reveals livestock was most vulnerable for water availability. Contributing factors include marginalization of pastoralists and deterioration of rangeland areas. Conversely, the least vulnerable user was croplands. Even so, cropland areas signified moderate vulnerability in general and should not be neglected.

FIGURE 111: Water availability – Reference Period – Vulnerability



9.1.2 Future periods

9.1.2.1 Potential impact

Future potential impact is influenced by both projected dynamic exposure and static sensitivity. Exposure is largely moderate at mid-century, representing 64% (RCP 8.5) to 88% (RCP 4.5) of the study area; areas of high exposure include 7% (RCP 4.5) to 33% (RCP 8.5) of the study area. Such areas include Dinder National Park in Sudan and the Dhamar Montane Plains. At end-century, moderate exposure signifies 39% (RCP 8.5) to 68% (RCP 4.5) of the study area while 27% (RCP 4.5) to 58% (RCP 8.5) is of high exposure.

Affected areas include those included at mid-century, as well as the coastal Levant and east of the Jebel Marra massif. In terms of trends from mid- to end-century, areas with the largest increases in exposure include the lower Nile Valley, the Jebel Marra massif and the central Senegal River Valley for RCP 4.5 and the eastern Murzuk basin and the eastern Red Hamada basin for RCP 8.5.

Assuming static sensitivity, forecast potential impact is largely moderate for both mid- and end-century for both scenarios, representing > 88% of the study area (Figure 112 to Figure 115). Areas of high potential impact are up to 2% at end-century (RCP 8.5). Remaining areas suggest low potential impact. As a result, the current status of the natural and physical environment counterbalance climate change effects. Should these sensitivity parameters change, however, potential impact will suffer.

Potential impact is highest near the Asir Mountains, the Green Mountains and the eastern Jafara Plain basin. Though moderate, potential impact is expected to follow similar trends as exposure with increasing areas noted above. Areas with decreasing potential impact include the southern Horn of Africa and the central Tigris–Euphrates basin for both scenarios.

FIGURE 112: Water availability – Mid-century RCP 4.5 – Potential impact

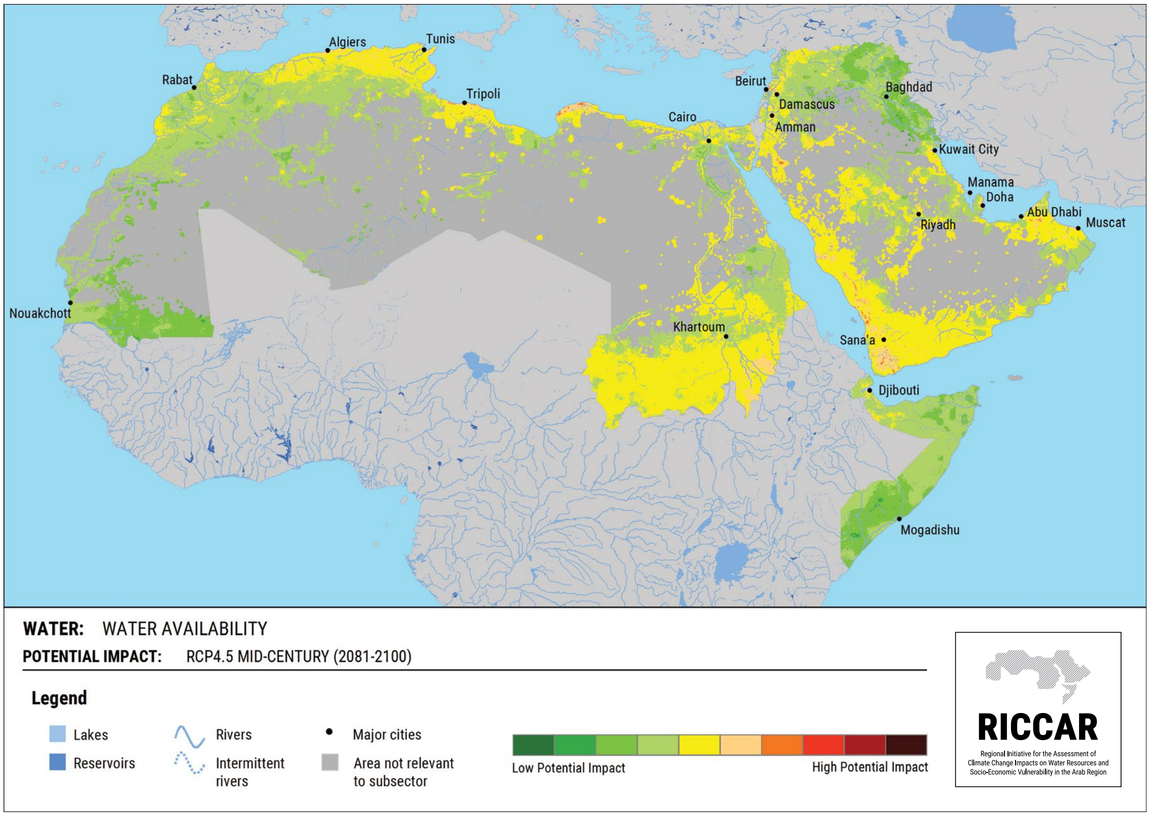


FIGURE 113: Water availability – Mid-century RCP 8.5 – Potential impact

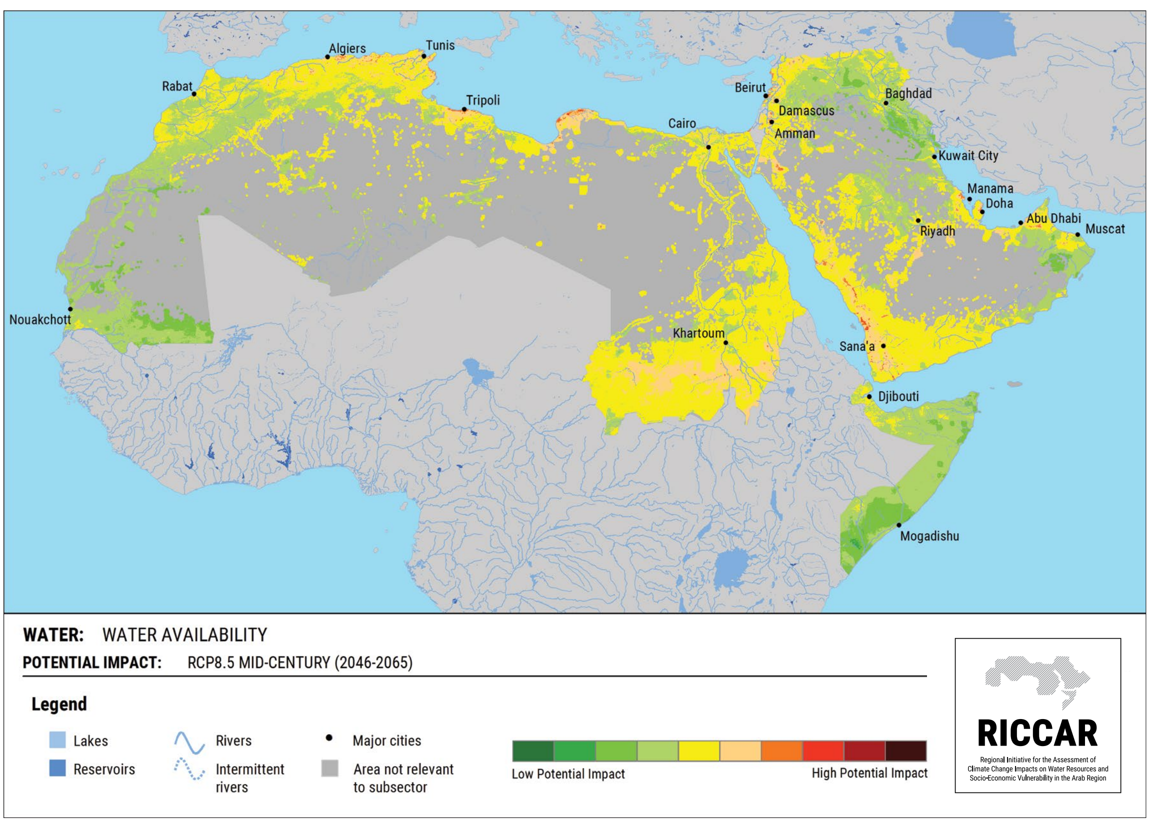


FIGURE 114: Water availability – End-century RCP 4.5 – Potential impact

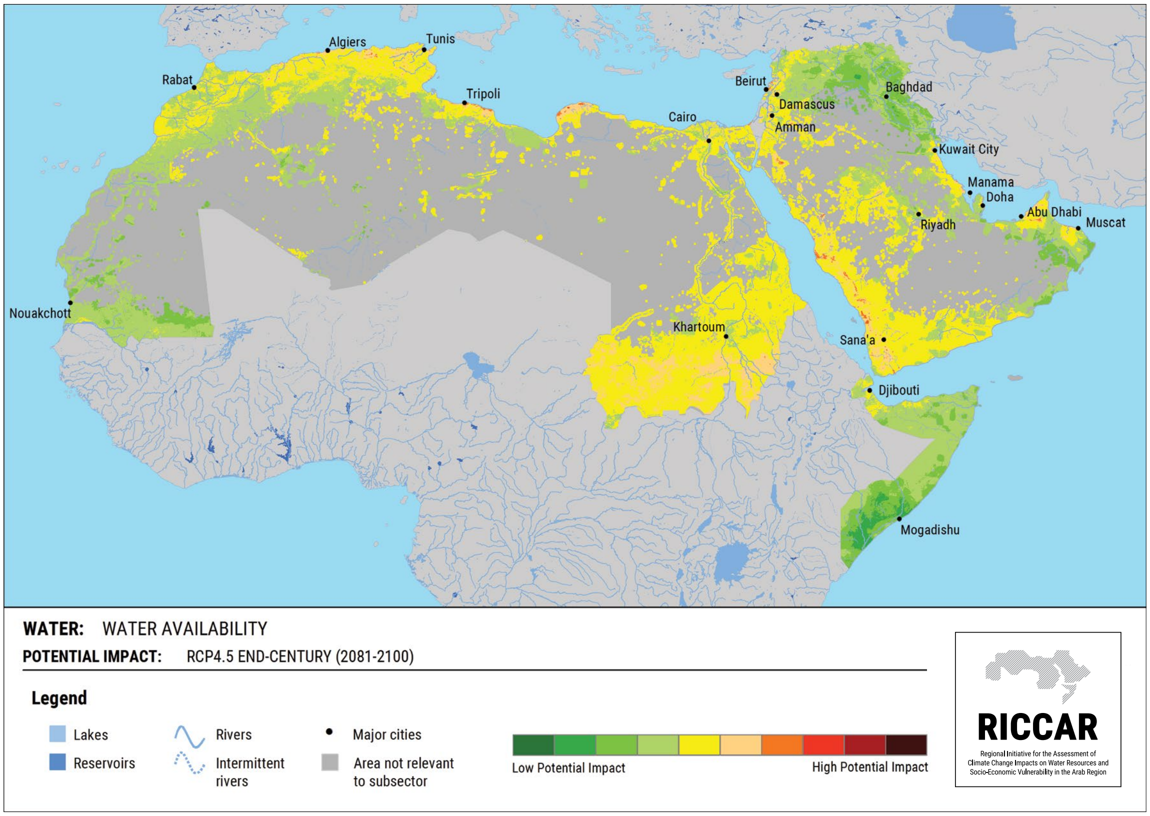
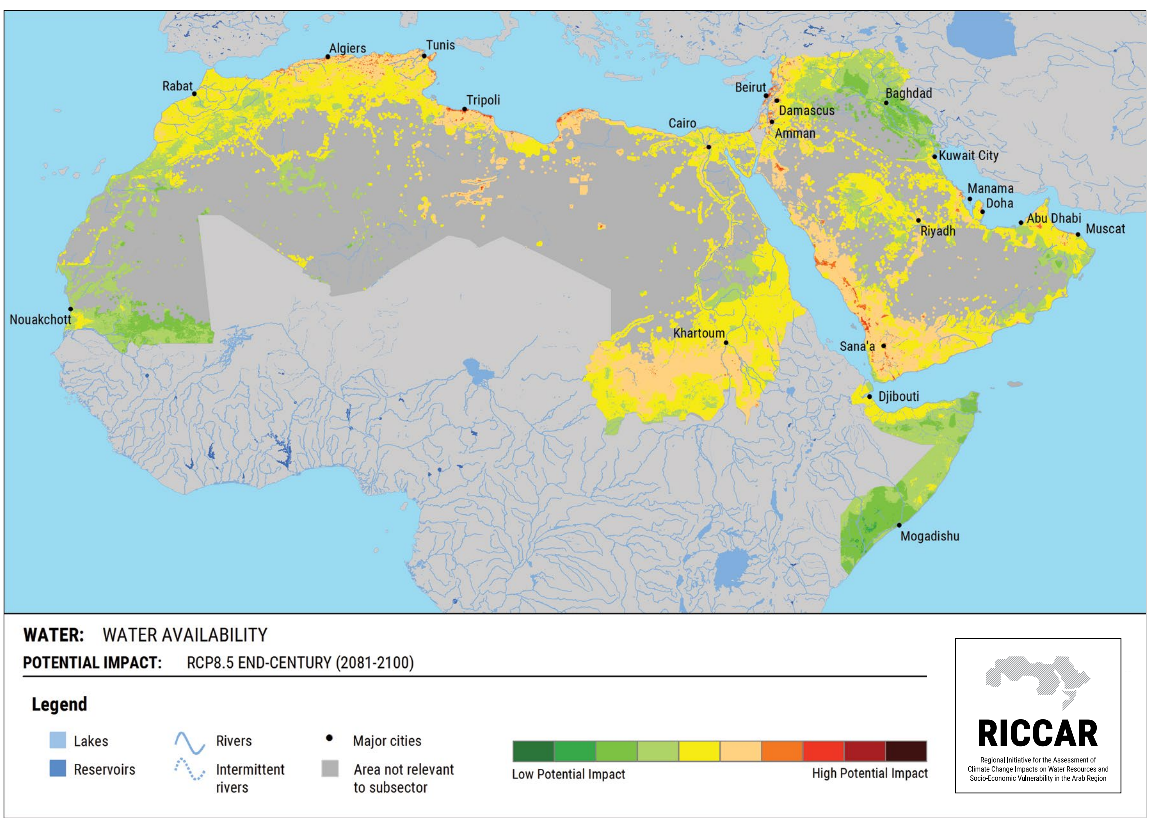


FIGURE 115: Water availability – End-century RCP 8.5 – Potential impact



9.1.2.2 Vulnerability

Vulnerability for both mid- and end-century is nearly equally divided between areas of moderate and high vulnerability. At mid-century, 43% (RCP 4.5) to 52% (RCP 8.5) of the study area predicts high vulnerability.

Areas of high vulnerability increase slightly at end-century, representing 48% (RCP 4.5) to 57% (RCP 8.5) of the study area (Table 21). Such areas include the upper Nile Valley, the south-western Arabian Peninsula and the northern Horn of Africa, due to low adaptive capacity. Remaining areas suggest moderate vulnerability. Areas with relatively low vulnerability include the Tigris–Euphrates basin and the lower Nile Valley, including the Nile Delta (Figure 116 to Figure 119).

Trend analysis indicates the largest increases in vulnerability along the coast in the Red Hamada basin and the eastern Murzuk basin from mid- to end-century, due partly to a surge in maximum length of dry spell. Conversely, the largest decreases are located in the Horn of Africa, due partly to rising precipitation and runoff. Like the reference period, the most vulnerable water users are projected as pastoralists and livestock. Livestock require large quantities of water to produce feed, allow grazing and for direct water usage. Populated areas are, comparatively, the least vulnerable. Nevertheless, aspects not considered as part of this study, including population growth, projected environmental degradation and water quality, give rise to concerns regarding water availability.

TABLE 21: Percentage of study area by vulnerability classification for water availability

Scenario	Vulnerability (% of study area)		
	Low	**Moderate**	**High**
Mid-Century RCP 4.5	0%	57%	43%
Mid-Century RCP 8.5	0%	48%	52%
End-Century RCP 4.5	0%	52%	48%
End-Century RCP 8.5	0%	43%	57%

FIGURE 116: Water availability – Mid-century RCP 4.5 – Vulnerability

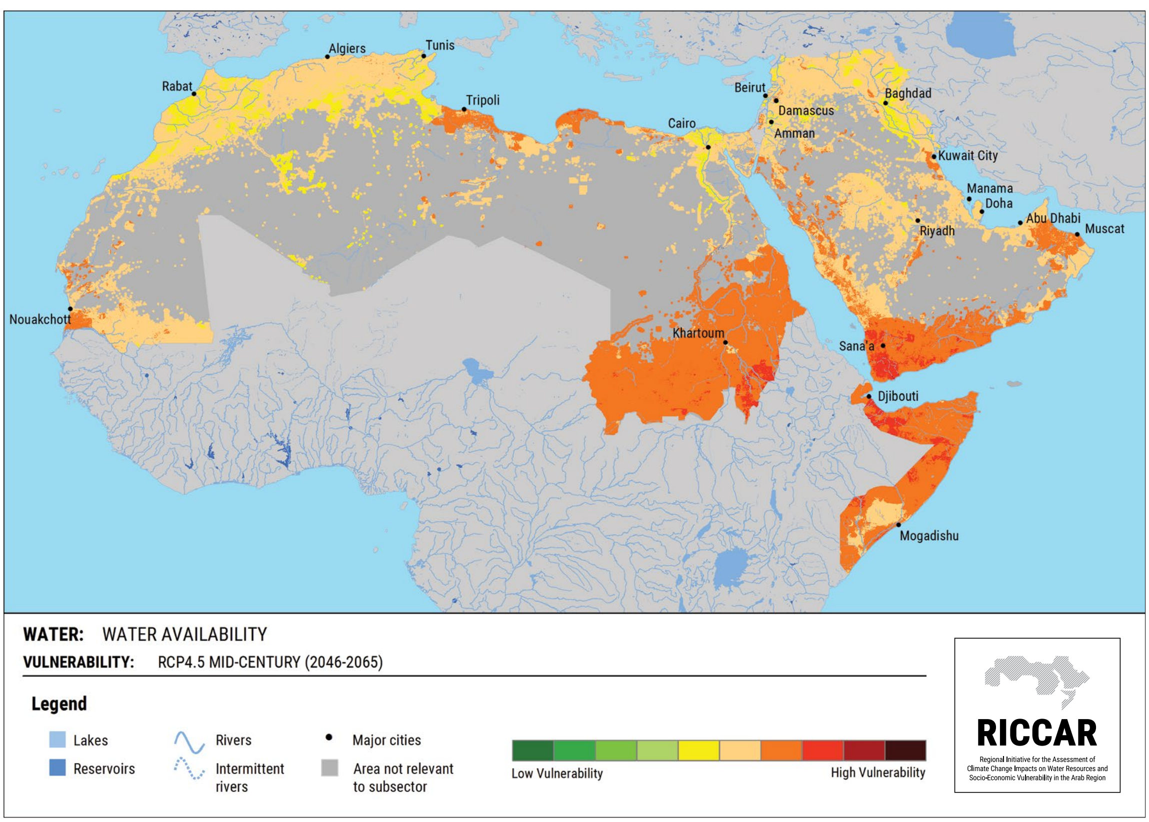


FIGURE 117: Water availability – Mid-century RCP 8.5 – Vulnerability

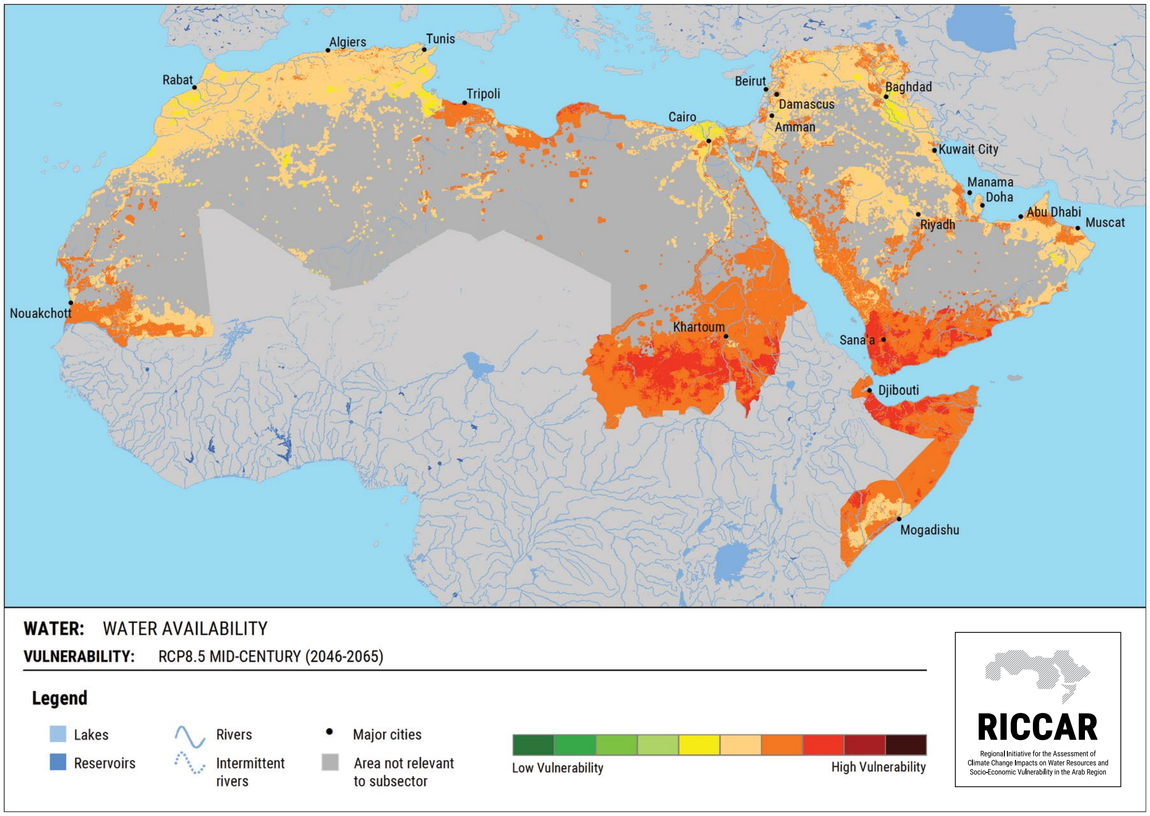


FIGURE 118: Water availability – End-century RCP 4.5 – Vulnerability

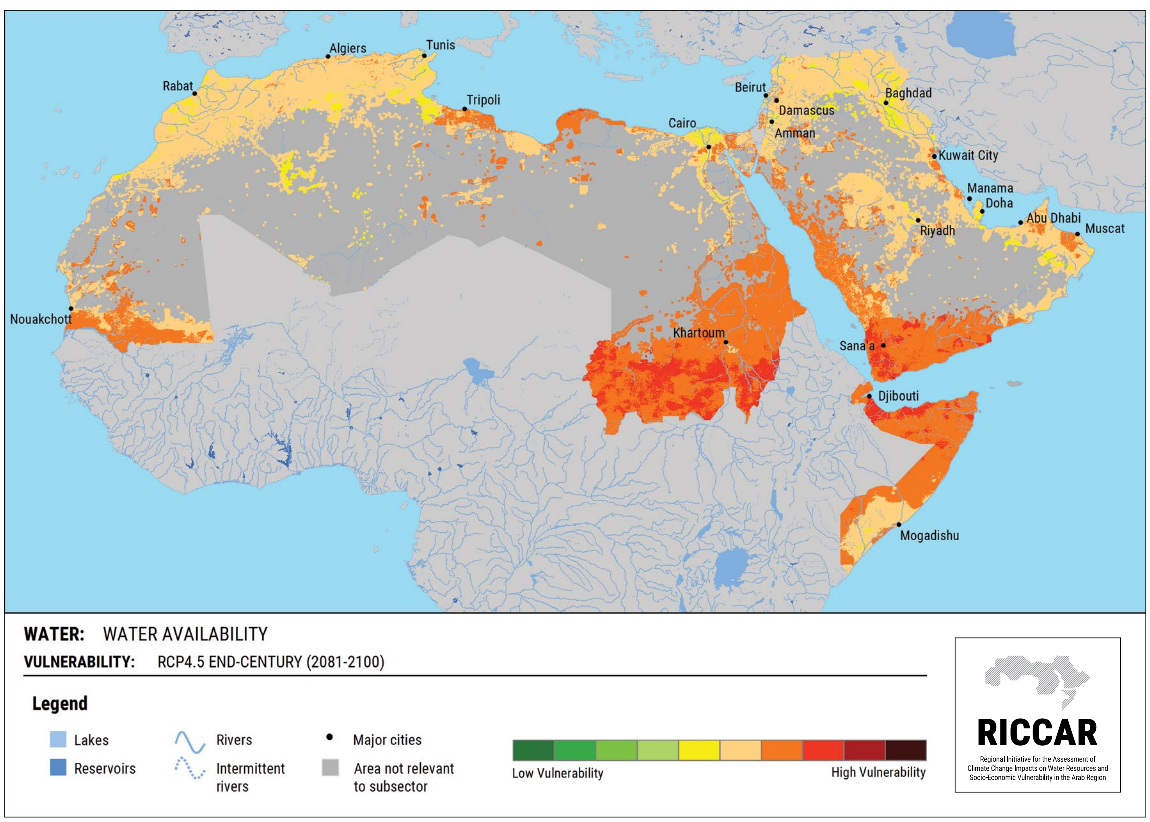
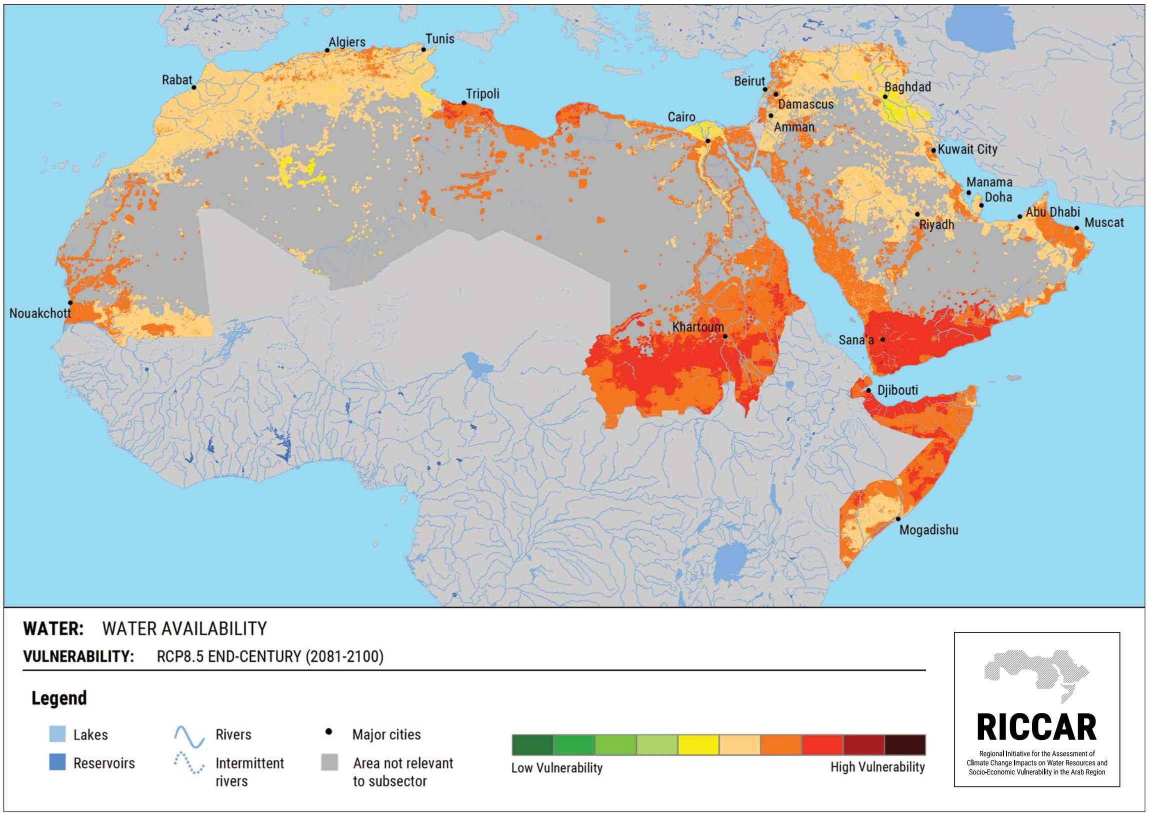


FIGURE 119: Water availability – End-century RCP 8.5 – Vulnerability



9.1.3 Hotspots

Hotspots represent the areas with the highest projected vulnerability and up to 14% of the study area. They constitute a call to action where decision-makers and aid agencies should focus efforts. Hotspots include selected areas south of the Jebel Abyad Plateau and the Nubian Desert, the south-western Arabian Peninsula and the northern Horn of Africa. These areas are primarily influenced by low adaptive capacity because projected potential impact is low to moderate. An exception is the Dhamar Montane Plains area, located in the south-western Arabian Peninsula, which indicates relatively high potential impact, partly due to high population density and low total available renewable water resources.

All the hotspots are located in areas which reveal a livestock population. A moderately high cattle population is located near the White Nile and Blue Nile rivers south of Khartoum. A dense goat population is also indicated south of Khartoum and at certain locations within the Dhamar Montane Plains area. Lastly, the camel population is relatively high in the Horn of Africa. A fairly low incidence of sheep is revealed in all hotspot areas.

Most of the hotspot areas within areas south of the Jebel Abyad Plateau and the Nubian Desert and the Dhamar Montane Plains area include croplands. Most areas are rainfed and sorghum, cereals and other crops are cultivated. Irrigated areas are also reflected in hotspots to a limited extent. Drought and rainfall variability will reduce crop yields, impacting food security, already known to affect these areas.

Nyala region, Sudan, 2006. Source: UN Photo/Fred Noy.

ENDNOTES

1. Falkenmark, 1989
2. FAO, 2017
3. Ibid.

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Falkenmark, M. 1989. The Massive Water Scarcity Now Threatening Africa: Why Isn't It Being Addressed? *AMBIO: A Journal of the Human Environment*, 18(2): p. 112-118.

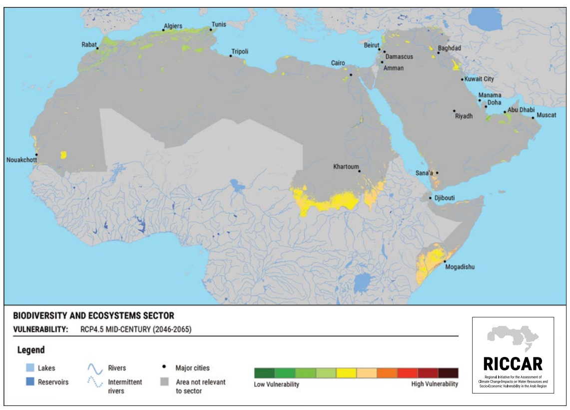
FAO (Food and Agriculture Organization of the United Nations). 2017. AQUASTAT Main Database 2017. Available at: http://www.fao.org/nr/water/aquastat/main/index.stm.

BIODIVERSITY AND ECOSYSTEMS SECTOR

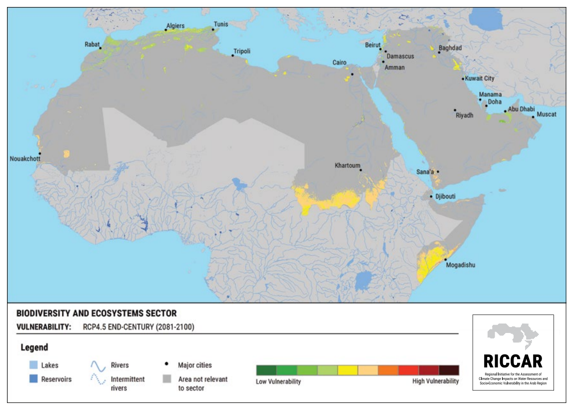
OVERALL VULNERABILITY

RCP 4.5

2046-2065

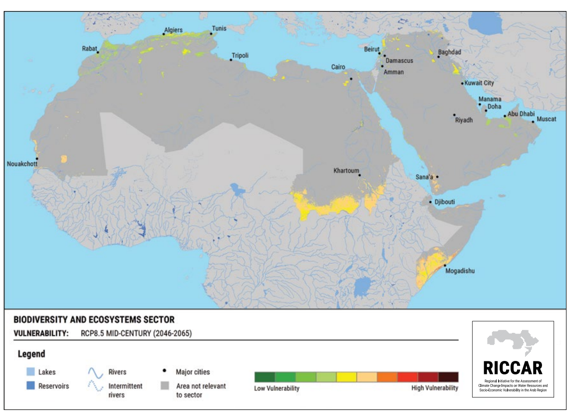


2081-2100

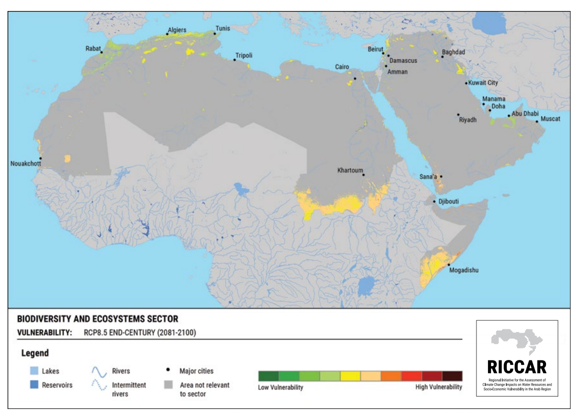


RCP 8.5

2046-2065



2081-2100



CHAPTER 10

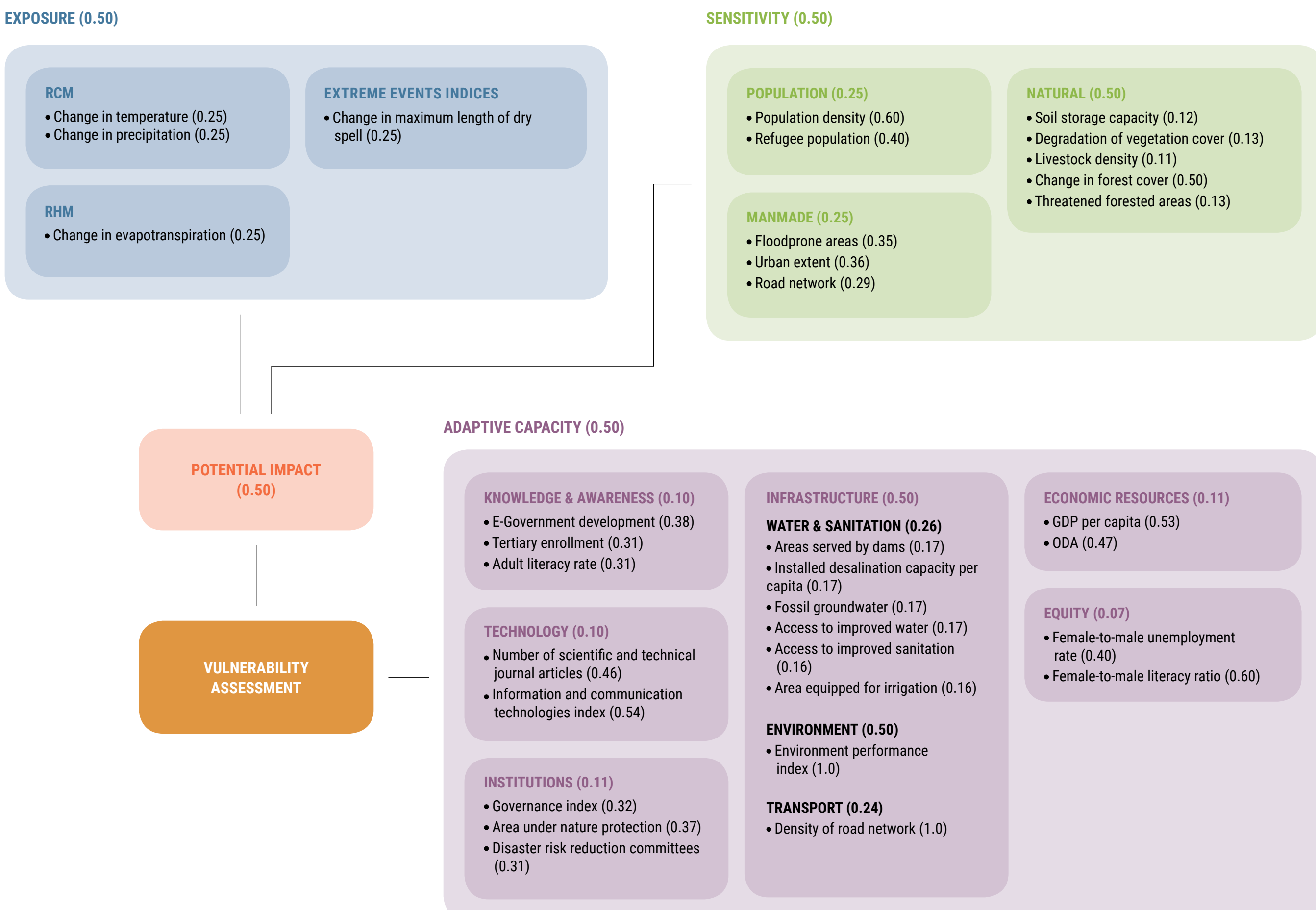
BIODIVERSITY AND ECOSYSTEMS SECTOR – VULNERABILITY

Ecosystems provide valuable services, regulate chemical and physical processes and supply food and water. Biodiversity is essential to ecosystem health, but also provides a basis for human economic activity, health and recreation. High population growth, urbanization and industrialization converging with unsustainable management of land and water resources have led to a decline in biodiversity and a destruction of valuable habitats and ecosystems all over the Arab region.[1] In this context, forests and wetlands are among the ecosystems considered to be highly vulnerable regarding changing temperatures and a reduction in water availability in a context of climate change. The VA-WG thus selected the *Biodiversity and ecosystems sector* to be included in the vulnerability assessment with particular focus on climate change effects upon the *change in the area covered by forests* and the *change in the area covered by wetlands*. Outcomes from the vulnerability assessment for this sector and associated subsectors are presented in this chapter.
Both forested and wetland areas represent a small fraction of the Arab region (5% and 2%, respectively). The respective study areas are defined by indicators and include forested areas from 2000 to 2014 for the *Area covered by forests* subsector. The *Area covered by wetlands* subsector includes Ramsar sites and their buffers, coastal wetlands, riverine wetlands, sabkhas and saltpans. For the sector, the combined area evaluated represents 7% of the Arab region.

10.1 AREA COVERED BY FORESTS

The impact chain highlighting the different indicators and weights for this subsector is presented in Figure 120.

FIGURE 120: Impact chain and weights for area covered by forests



10.1.1 Reference period

10.1.1.1 Potential impact

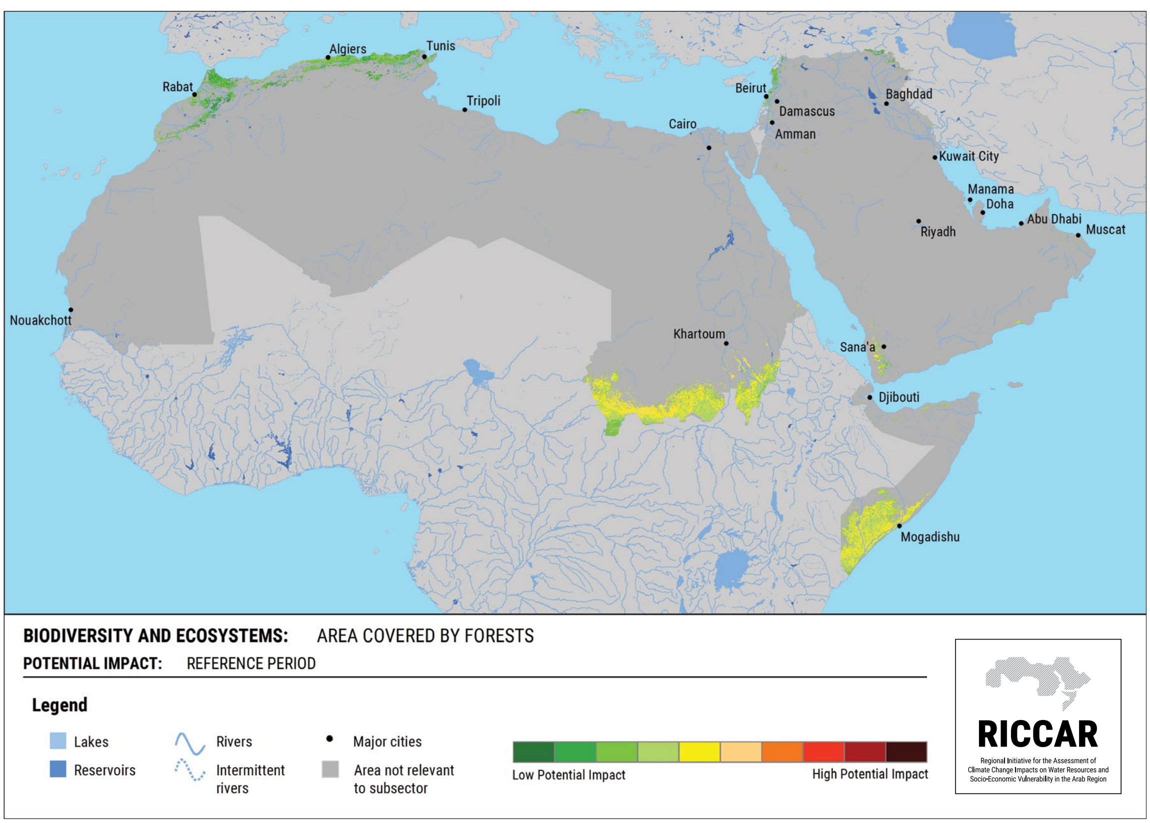
Forest areas represent a small percentage of the Arab landscape but play a significant role in natural resource and environmental conservation which, in turn, influences rural development. Forests contribute toward watershed management through soil conservation, erosion control and flood mitigation. They also benefit rural livelihoods by generating fuelwood, charcoal and other commodities.

Potential impact reflects both exposure and sensitivity. Four exposure indicators were selected to assess areas most prone to drought: temperature, precipitation, evapotranspiration and maximum length of dry spell (CDD). Drought can induce tree mortality as well as physiological stresses such as insect outbreaks and wildfires. For the reference period, 21% of forests are identified by low exposure, 72% moderate exposure, and 6% high exposure. Areas with high exposure include tropical shrublands located in a belt south of Khartoum. Forests in the Atlas Mountains and the Levant represent the lowest exposure for the reference period.

Forests in the region have faced other threats: population growth, urbanization, agricultural encroachment, deforestation and inadequate social and economic conditions. Population growth and urbanization are reflected in four selected sensitivity indicators: population density, refugee population, urban extent and road network. Threatened forest areas and livestock density are both factors in agricultural encroachment. Lastly, degradation of vegetation cover, change in forest cover, threatened forested areas and floodprone areas are all considered as part of deforestation. A majority of the region's forests (54%) are indicative of low sensitivity, while moderate sensitivity areas represent 46% of the study area. Areas of moderate to high sensitivity are interspersed throughout the region and are not confined to a particular area, although sensitivity tends to be higher in areas with higher population density.

The resultant potential impact for the reference period (Figure 121) is primarily moderate, representing 68% of the region's forests. The remaining study area indicates low potential impact. Areas of moderate impact include the woodland savannah in the eastern Sahel, the Jabal Bura Valley forest in the south-western Arabian Peninsula and the riverine forests of the Jubba River Valley in the Horn of Africa.

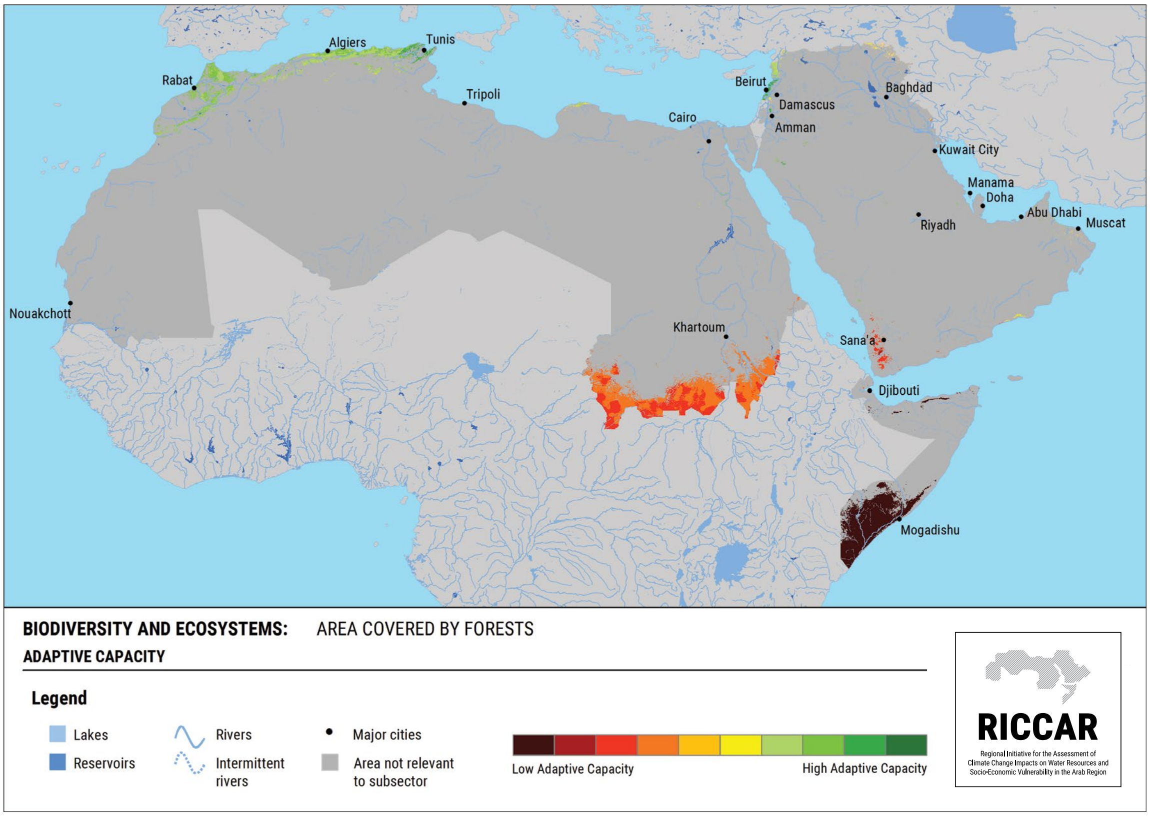
FIGURE 121: Area covered by forests – Reference period – Potential impact



10.1.1.2 Adaptive capacity

Adaptive capacity was based on 20 differing indicators, with emphasis placed upon environmental infrastructure. In this context, environmental infrastructure includes environmental regulations, establishment of effectively managed protected area networks and corridors, areas/ecosystems implementing Ecosystem-Based Management (EBM), sustainable forest management, social markets, product certification, and land acquisition. Nearly half the region's forests (46%) indicate low adaptive capacity. These areas include the selected savannah woodlands in the eastern Sahel, the Jabal Bura Valley forest and the riverine forests of the Jubba River Valley. Other savannah woodlands in the eastern Sahel represent moderate adaptive capacity (Figure 122). About a quarter of the study area (23%) represents high adaptive capacity relative to the region and includes forests in the Atlas Mountains and the Levant.

FIGURE 122: Area covered by forests – Adaptive capacity



10.1.1.3 Vulnerability

Over half the study area (55%) indicates high vulnerability for the reference period, largely stemming from low adaptive capacity, and include the eastern Sahel, the Jubal Bura Valley forest and the Jubba riverine forests (Figure 123). These forests are threatened by overgrazing, overcultivation and deforestation. For example, in the eastern Sahel, gum trees – which produce a lucrative cash crop called gum arabic – have largely been destroyed and thus the economy has been harmed. Degradation of forests has affected formerly abundant wildlife species such as oryx, gazelle, ostrich, ibex and Barbary sheep. Those that remain are endangered owing to loss of habitat and uncontrolled hunting.

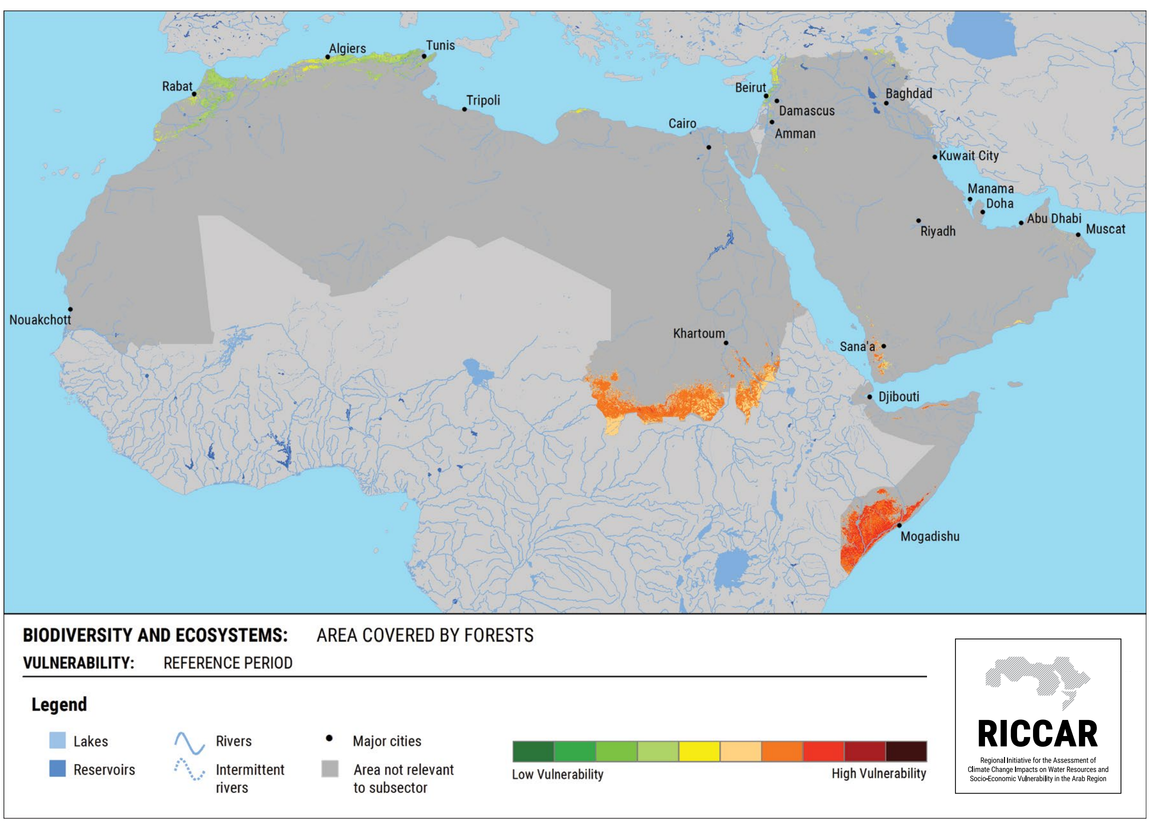
Forests in south-western Arabia include small patches in valleys near Jabal Raymah, Jabal Melhan, and Jabal Bura, the latter being the largest. The habitat is unique in the Arabian Peninsula and is home to certain endemic plant and animal species. Successful lobbying resulted in declaring Jubal Bura a protected area. In addition, until recently, the region was relatively underdeveloped and thus conserved. Recent roadway construction through the forest, however, has contributed to deforestation, among other threats.

Forests in the Horn of Africa, particularly in the Juba River Valley, are at risk from deforestation, agricultural expansion and erosion from flooding. The forest is home to birds and animals such as storks, pelicans, squirrels and duikers. In addition to habitat loss, these birds and animals are threatened by hunting, despite its being illegal. Local livelihoods depend upon the forest for commodities such as timber, coppiced canes, charcoal, edible fruits and dyestuffs. Apiculture is profitable, but dependent on a sustainable ecosystem.

Most other areas indicate moderate vulnerability for the reference period (41% of the study area) and includes subtropical dry forest of the Tell Atlas region, which underwent up to 30% deforestation from 2000 to 2014.[2] Another area indicating moderate vulnerability is forested land in the Levant, which has actually experienced gains in extent[3], possibly reducing its inherent vulnerability.

Forest in Aseer Mountains, Saudi Arabia, 2010. Source: Ihab Jnad.

FIGURE 123: Area covered by forests – Reference period – Vulnerability



10.1.2 Future periods

10.1.2.1 Potential impact

Climate change impacts can be detrimental to forests. Although species can theoretically relocate to more favourable climatic areas, they do so at a slower rate than predicted climate change. Moreover, suitable areas may be fragmented and movement is restricted. Tree growth is affected by water balance stemming from precipitation and evapotranspiration. Extreme events can be detrimental to tree survival and climate phenomena can also impact tree phenology. Lastly, responses to climate change can vary according to the different plants and animals in forest ecosystems.

Forecast exposure is expected to be largely moderate: at mid-century (Figure 124 and Figure 125), it ranges from 81% (RCP 4.5) to 84% (RCP 8.5); at end-century (Figure 126 and Figure 127), moderate exposure is predicted at 53% (RCP 8.5) to 78% (RCP 4.5) of the study area. A small percentage of the study area indicates high exposure at mid-century to be 1% (RCP 4.5) and 8% (RCP 8.5) but, at end-century, this increases to 3% (RCP 4.5) and 44% (RCP 8.5) of the study area. Areas with the highest exposure include the Barzan area and the Gali Balnda Nature Reserve in the Zagros Mountains, the Jabal Bura Valley forest in the south-western Arabian Peninsula and forests in the Levant, including the Al Shouf Cedars Nature Reserve. Conversely, low exposure is forecast in the forests of the Golis Mountains and deciduous bushland of the Lag Badana ecosystem, both in the Horn of Africa. Assuming static sensitivity, potential impact is also largely moderate, ranging from 65% (RCP 4.5) to 74% (RCP 8.5) at mid-century and 67% (RCP 4.5) to 81% (RCP 8.5) at end-century. Remaining areas suggest low potential impact. The current state of the natural and physical environment helps compensate for projected climate change impacts. Sensitivity, however, can vary, according to factors such as increased deforestation and urbanization and parameters not considered as part of this study, such as forest fires and disease. Areas with the highest potential impact include forests of the Levant, Acacia nilotica plantations along the banks of the Blue Nile south of Khartoum and the Taza Biosphere Reserve in the Tell Atlas region.

In terms of trends, most forests exhibit steady-to-increasing potential impact from mid- to end century. In particular, forecasts for forests in the Levant, including the Al Shouf Cedars Nature Reserve, indicate a sharp increase in potential impact, particularly under the RCP 8.5 scenario, as a result of exposure. The sole region to anticipate a decline in potential impact are the forests of the southern Horn of Africa, owing to a predicted increase in precipitation.

FIGURE 124: Area covered by forests – Mid-century RCP 4.5 – Potential impact

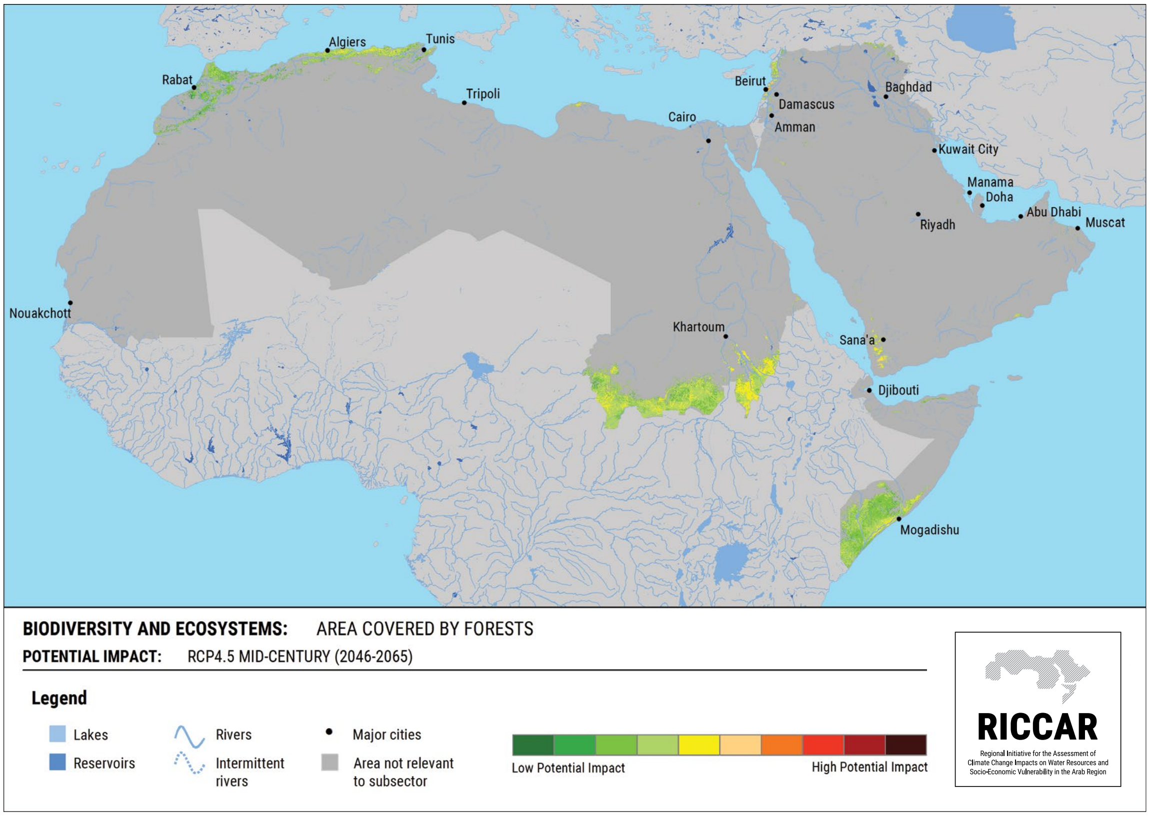


FIGURE 125: Area covered by forests – Mid-century RCP 8.5 – Potential impact

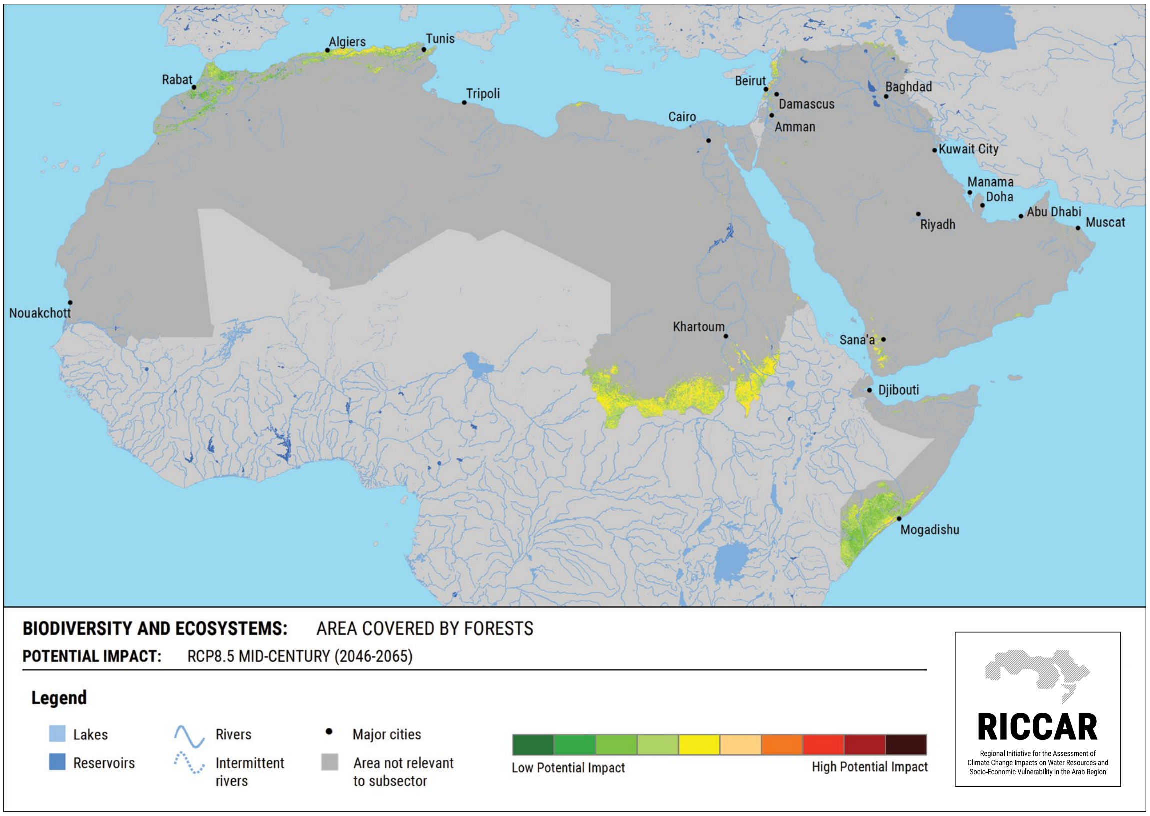


FIGURE 126: Area covered by forests – End-century RCP 4.5 – Potential impact

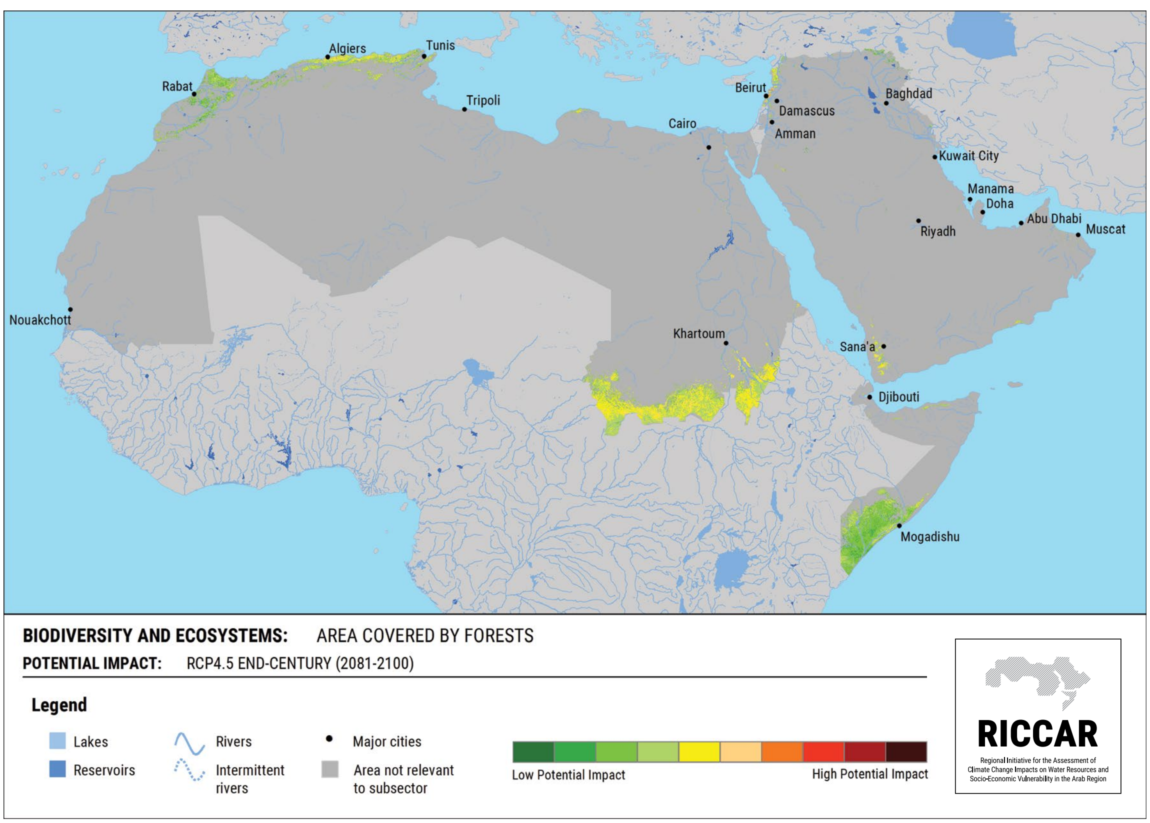
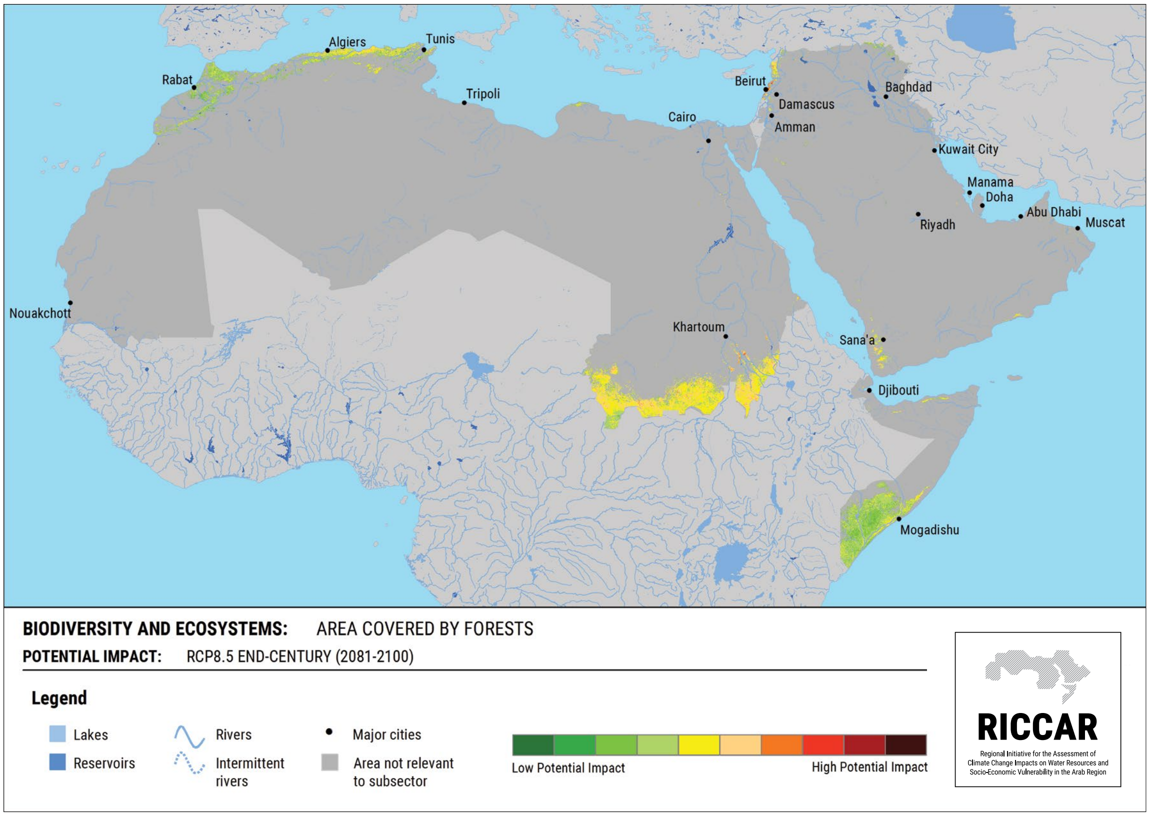


FIGURE 127: Area covered by forests – End-century RCP 8.5 – Potential impact



10.1.2.2 Vulnerability

The varying threats facing forests in the Arab region can be summarized as three primary issues: environmental degradation, declining quality and quantity of forests, and loss of biodiversity.

These threats are exacerbated by climate change impacts. Coping mechanisms to combat deforestation have been set forth by Arab institutions, including reforestation strategies, sustainable forest management and the declaration of forest reserves.

The net difference between threats and adaptive measures is reflected in the projected vulnerability for forests. Based on the indicators described herein, vulnerability is nearly evenly divided between moderate and high for the study area, with no evidence of low vulnerability (Figure 128 to Figure 131).

Areas of high vulnerability range from 41% (RCP 4.5) to 58% (RCP 8.5) at mid-century and 50% (RCP 4.5) to 64% (RCP 8.5) at end-century (Table 22).

Forests with the highest vulnerability include tropical dry forest and tropical shrubland in sub-Saharan Africa and the tropical mountain system forests in the south-western Arabian Peninsula. Areas with relatively lower vulnerability include subtropical dry forest in the Rif region of North-West Africa and forests in and around Ichkeul National Park near the central North African coastline.

Trend analysis from mid- to end-century reveals many forests in the Arab region are generally exhibiting increasing vulnerability for RCP 4.5, particularly in the woodland savannah forests in and around Radom National Park, which has been designated as a biosphere reserve by UNESCO.

Forests in the southern Horn of Africa, however, reveal decreasing vulnerability due to changes in exposure. For RCP 8.5, vulnerability is largely constant from mid- to end-century in all forests.

Al Shouf Cedar Nature Reserve, Lebanon, 2005. Source: Wikimedia Commons/Habbouche.

TABLE 22: Percentage of study area by vulnerability classification for area covered by forests

Scenario	Vulnerability (% of study area)		
	Low	**Moderate**	**High**
Mid-Century RCP 4.5	0%	59%	41%
Mid-Century RCP 8.5	0%	42%	58%
End-Century RCP 4.5	0%	50%	50%
End-Century RCP 8.5	0%	36%	64%

FIGURE 128: Area covered by forests – Mid-century RCP 4.5 – Vulnerability

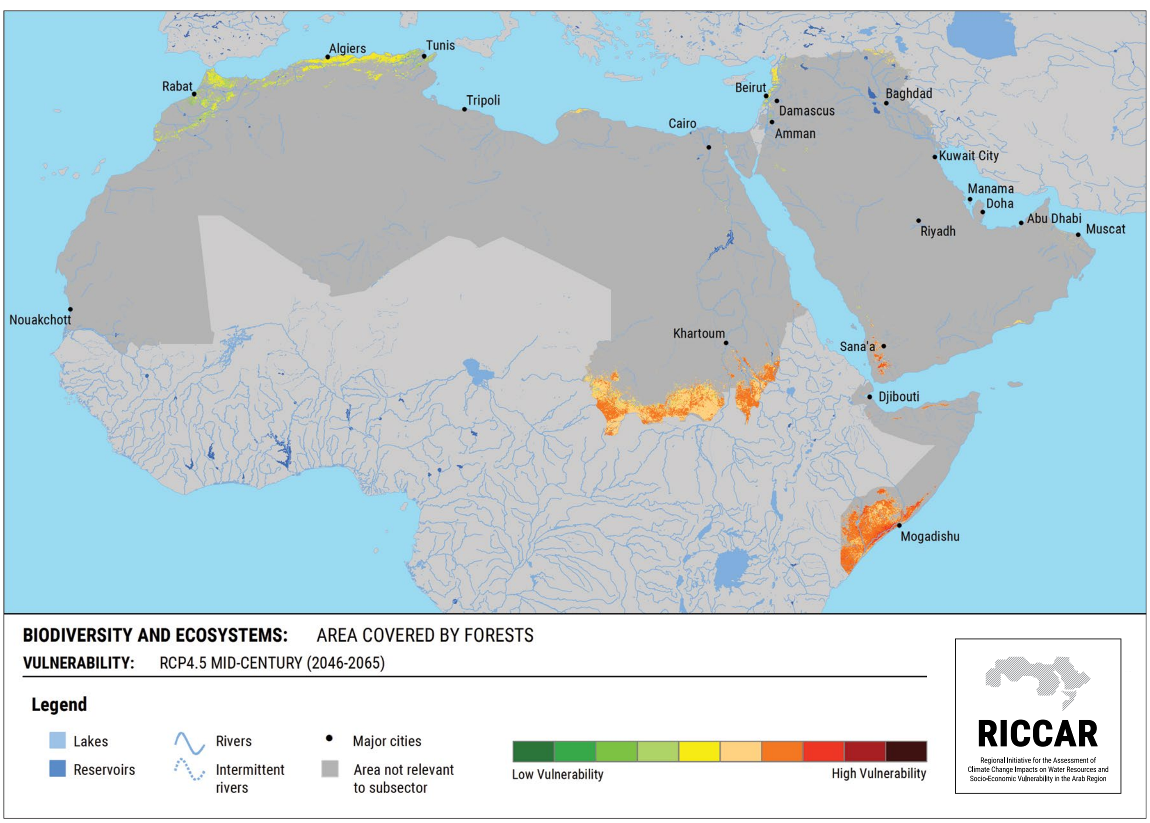


FIGURE 129: Area covered by forests – Mid-century RCP 8.5 – Vulnerability

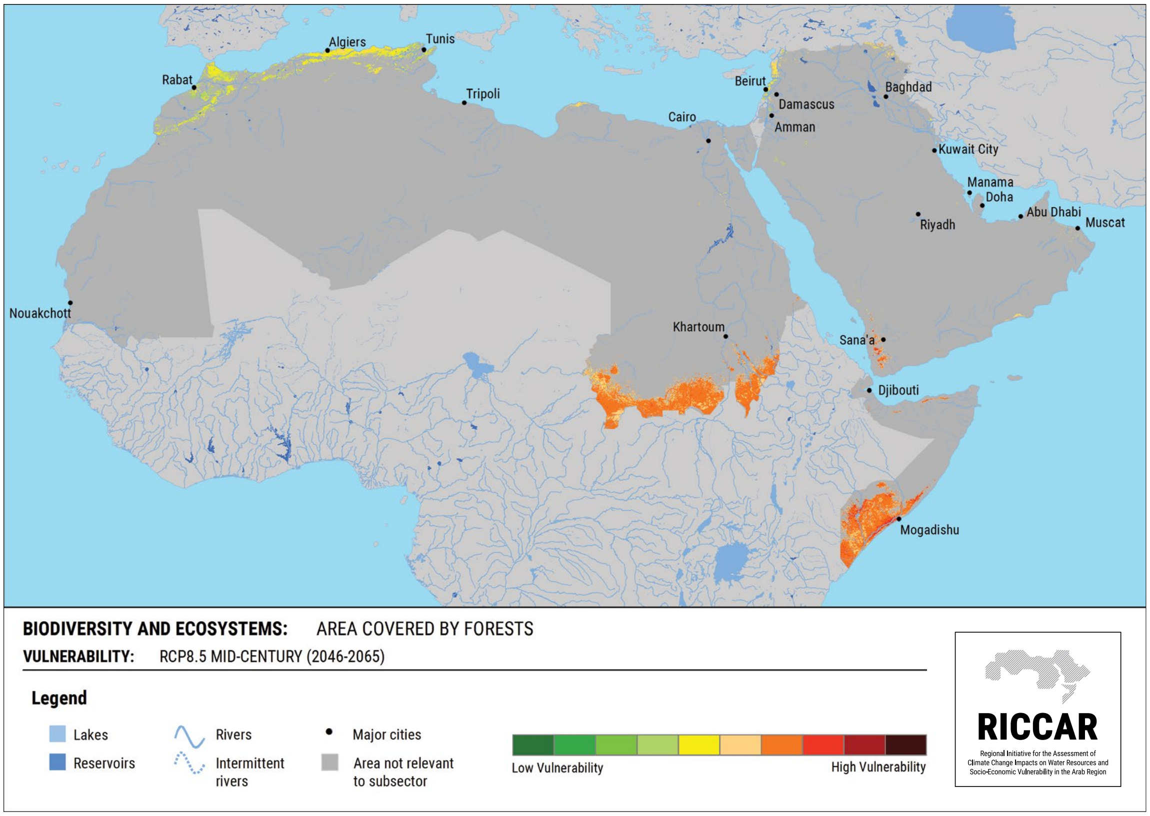


FIGURE 130: Area covered by forests – End-century RCP 4.5 – Vulnerability

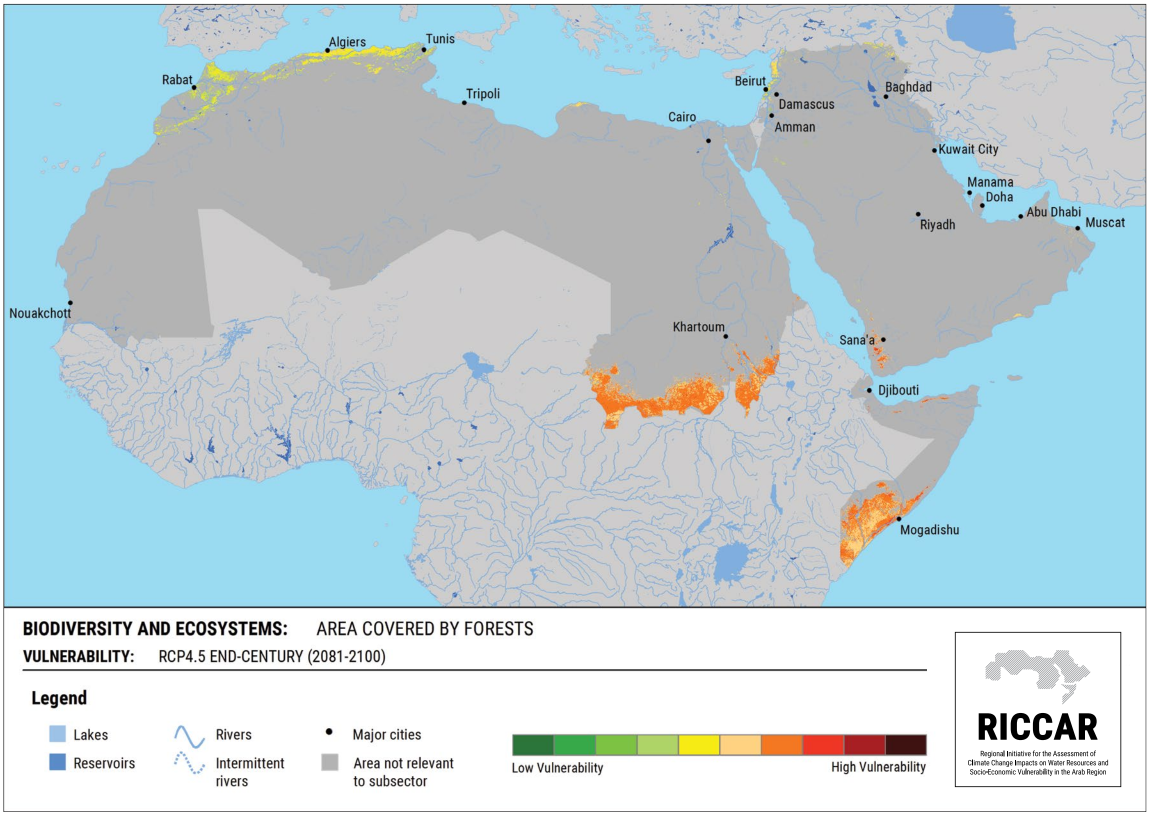
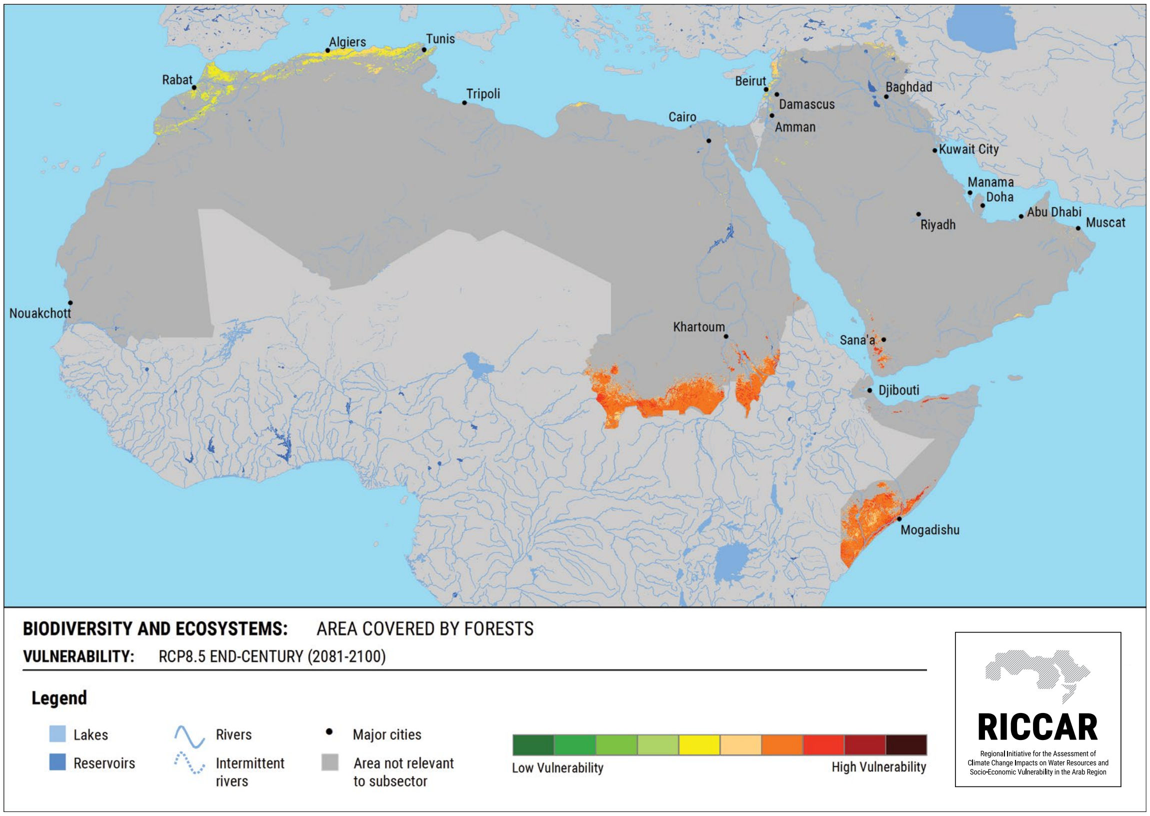


FIGURE 131: Area covered by forests – End-century RCP 8.5 – Vulnerability



10.1.3 Hotspots

Hotspots are areas with the highest projected vulnerability: up to 11% (RCP 8.5 end-century) of the study area signify forest-area hotspots.

Forests of the Horn of Africa, such as evergreen stands in the Golis mountain range, for example, have been subjected to increased exploitation pressure from human settlements directly in the forest, deciduous bushland of *Acacia spp*. in the south and Lag Badana National Park – the first national park in Somalia. After a temporary halt, development there has resumed, aimed at local youth to strengthen environmental preservation and ecotourism.

Other areas are located in the eastern Sahel, which include the El-Rawashda and Wad Kabo natural forest reserves and *Acacia nilotica* riparian forests along the White and Blue Nile rivers such as Khartoum Sunt Forest.

The former sites have long been subjected to overgrazing, lopping of trees for animal feed, and deforestation. Community initiatives to restore the forest have been introduced, which recognize the benefits of natural resources and encourage community participation though volunteerism.

The final forest hotspot region is located in the south-western Arabian Peninsula and includes the Jabal Bura Valley forest, which contains acacia (*A. asak*) and myrrh trees.

The forest has been decimated due to several factors, notably recent roadway construction, which destroyed 20%–30% of the area. Associated impacts include clogging of wells and streams from roadwork waste.

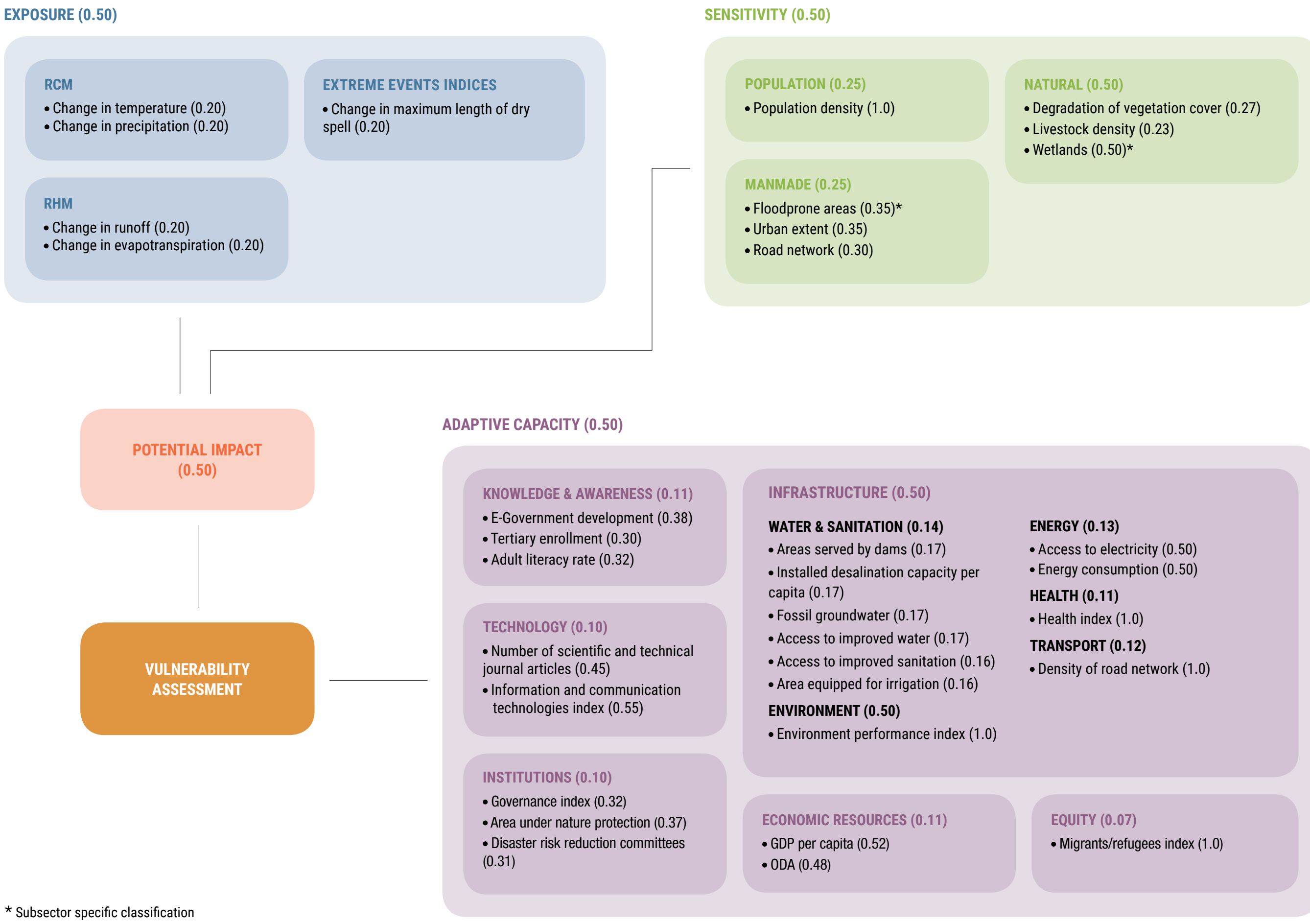
In addition, easier access to the forest permitted increased logging, while the prickly pear, an invasive species, was introduced, threatening native plants.

Nonetheless, the region is recognized for its biodiversity and was added to the UNESCO World Network of Biosphere Reserves in 2011. Community initiatives have been introduced to promote forestry management and ecotourism.

10.2 AREA COVERED BY WETLANDS

The impact chain presented in Figure 132 presents the indicators used under each component and its associated weights for this subsector. Methodology related to asterisked indicators is available in ESCWA et al., 2017.

FIGURE 132: Impact chain and weights for area covered by wetlands



* Subsector specific classification

10.2.1 Reference period

10.2.1.1 Potential impact

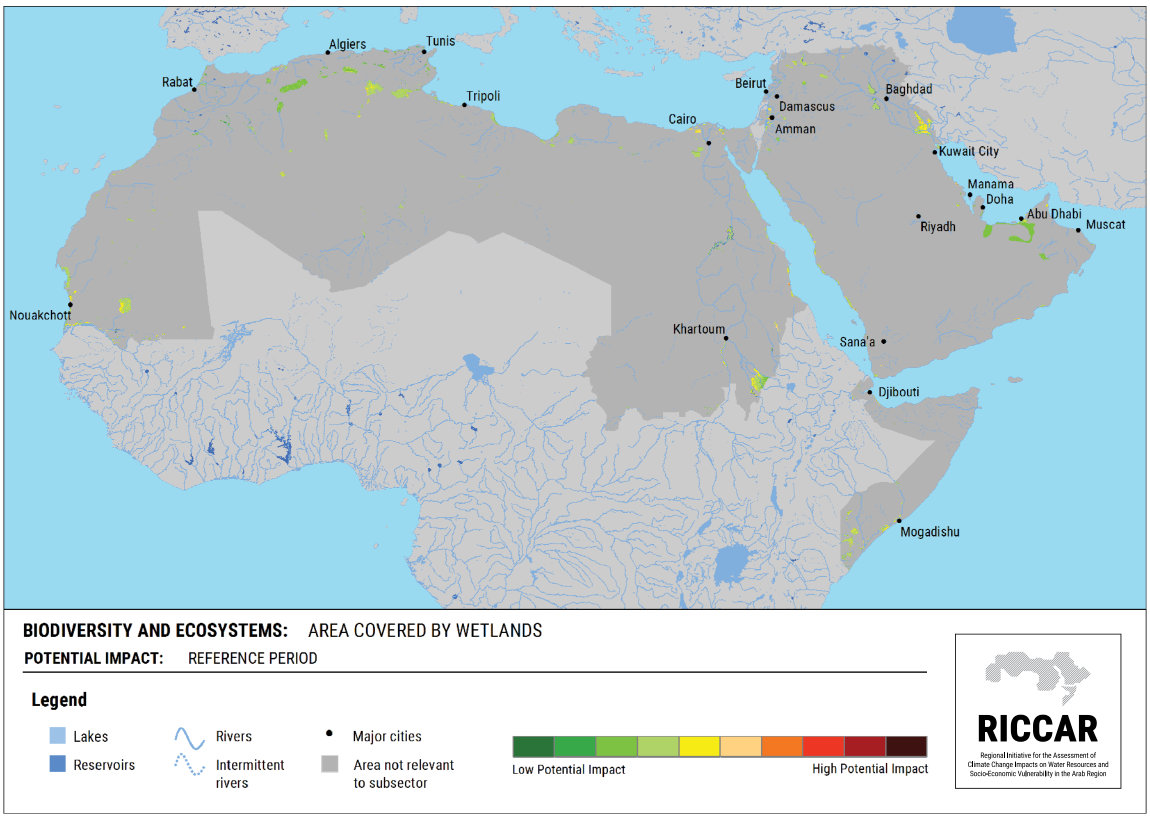
For RICCAR, the wetlands study area includes sabkhas, saltpans and oases in addition to coastal and riverine wetlands. Ramsar sites, the international entity for the protection of wetlands, are also included.

Potential impact reflects the aggregated result of exposure and sensitivity. For exposure, meteorological phenomena such as precipitation, runoff and evaporation can affect flow into wetlands and inundation. Temperature and dry spells can impact wetland ecosystems. For these reasons, temperature, precipitation, runoff, evapotranspiration and the maximum length of dry spell (CDD) were selected as exposure indicators. A majority of the area (71%) is indicative of moderate exposure for the reference period. Less than a quarter (20%) suggests high exposure and includes wetlands near the Senegal River, as well as nearby Lac Gabou and the Parc National du Banc d'Arguin, and wetlands near the Gulf, including Sabkha Matti. Remaining areas suggest low exposure.

Wetlands can be threatened by elements such as urbanization, land-use changes and other factors. Land-use changes are reflected in the following selected sensitivity indicators: population density, degradation of vegetation cover, livestock density, urban extent and road network. The wetlands indicator, which has the heaviest sensitivity weighting, was classified according to freshwater demand. Lastly, the floodprone areas indicator was selected and classified in accordance with water availability as floods benefit wetland areas. A majority of the wetlands study area (80%) suggests low sensitivity. Most of the remaining areas (19%) are of moderate sensitivity and include isolated areas within wetlands throughout the region, including the Iraqi Marshes, riverine wetlands of the Euphrates and estuarine wetlands of the Nile Delta.

Resultant potential impact for the reference period (Figure 133) is indicated as moderate for most of the study area (69%), including riverine wetlands of the Senegal, Jubba, Shabelle, White Nile and Blue Nile rivers. In addition, coastal wetlands near the Gulf of Aden, as well as nearby Lake Abb, indicate moderate-to-high potential impact. Remaining wetlands suggest low potential impact as there are no wetlands exhibiting high potential impact.

FIGURE 133: Area covered by wetlands – Reference period – Potential impact



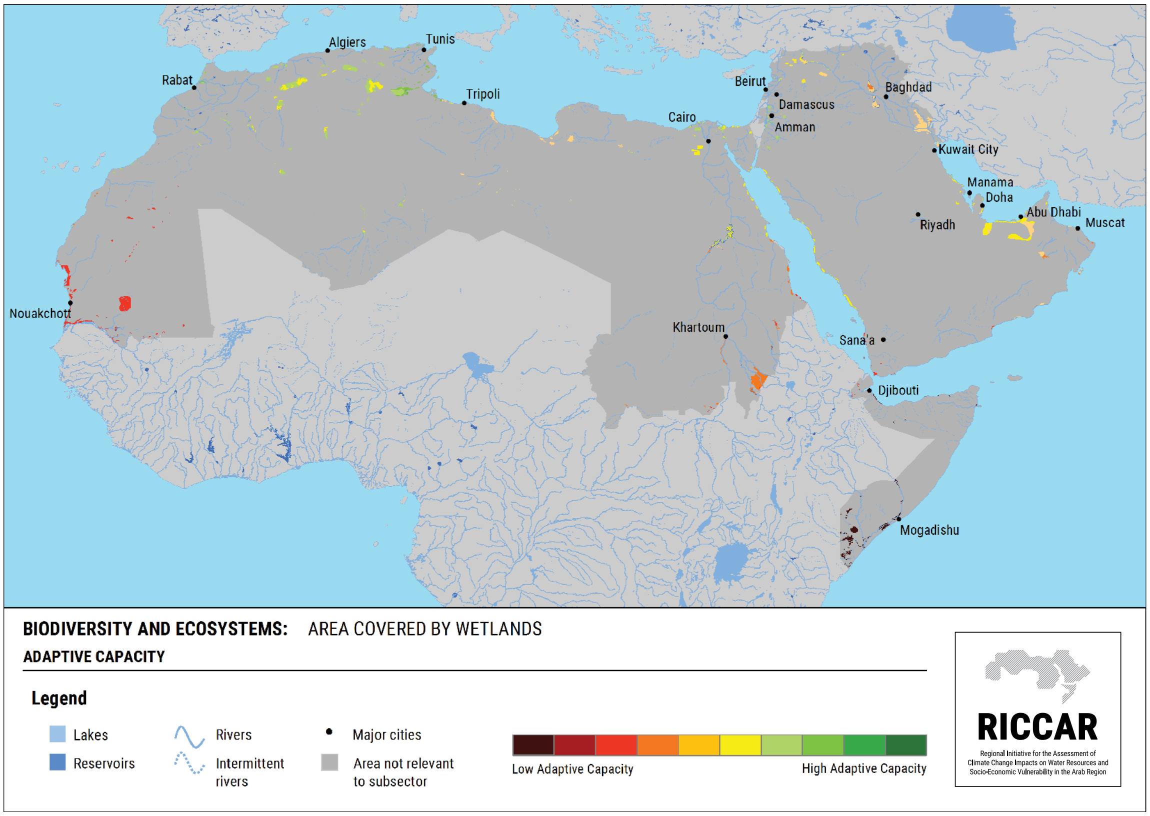
10.2.1.2 Adaptive capacity

According to Ramsar, a framework for the wise use of wetlands must consider several adaptive measures, including human well-being and poverty reduction in addition to ecosystem services. The former considers health, environmental, economic and cultural security, as well as equity. Ecosystem services include the provision of natural resources, wetland regulation, cultural significance and support of the ecosystem as a whole.[4]

The adaptive capacity indicators selected reflect the recommendations of Ramsar. The environmental pillar under infrastructure is weighted most heavily and represents a proxy for ecosystem services. Over half the study area (53%) indicates moderate potential impact with remaining areas divided between low and high potential impact (21% and 26%, respectively). Even though all indicators denote a weak correlation with composite adaptive capacity, the environmental pillar is the strongest.

The aggregated result indicates low adaptive capacity for wetlands in sub-Saharan Africa. Higher adaptive capacity is evident, progressing northwards towards the Mediterranean Sea (Figure 134).

FIGURE 134: Area covered by wetlands – Adaptive capacity



10.2.1.3 Vulnerability

Resultant vulnerability for the reference period (Figure 135) reveals moderate vulnerability for most of the study area (90%) with high vulnerability in isolated areas (7%). Remaining areas suggest low vulnerability.

Wetlands with the highest vulnerability are located in the Horn of Africa with some tidal wetlands along the Gulf of Aden, swamps and floodplains near the Shabelle and Jubba rivers (*desheks*), mangroves and lagoons. High vulnerability in the region is primarily attributed to low adaptive capacity.

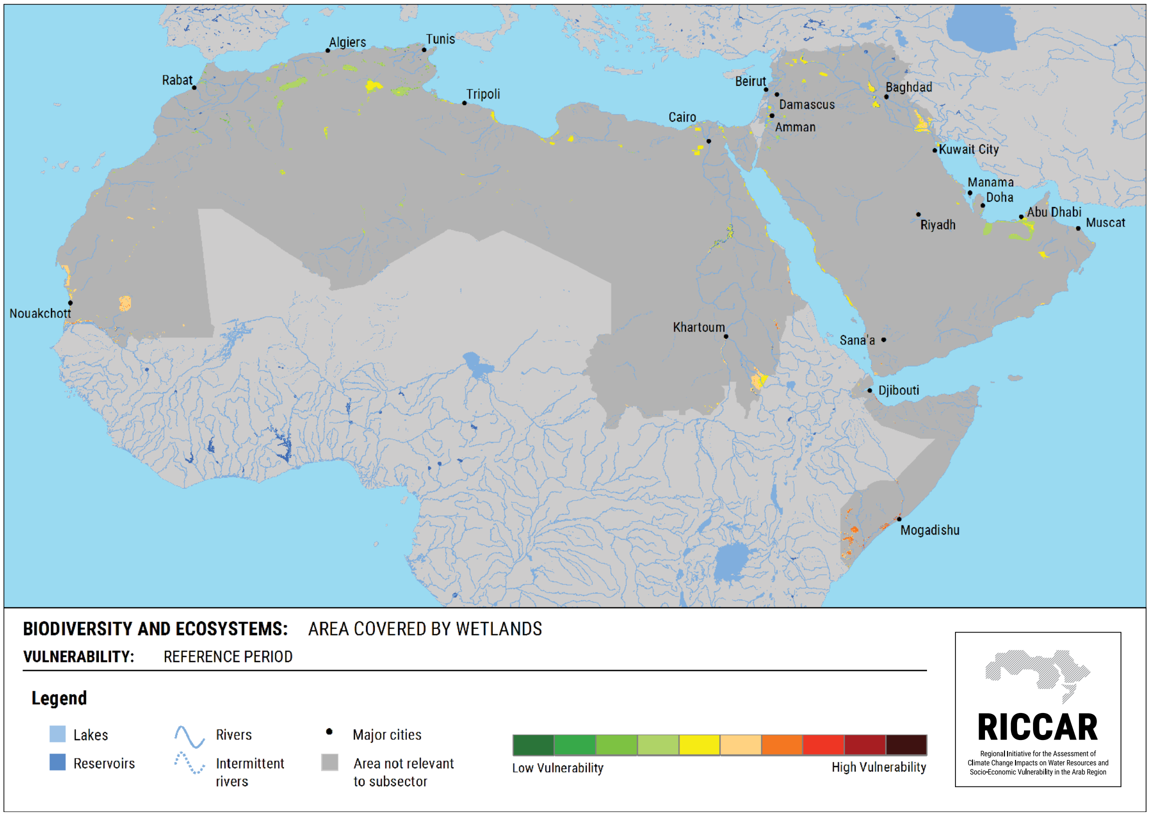
An area of moderate-to-high vulnerability includes wetlands located within the Tindouf basin. One area is the Banc d'Arguin, which was established as a national park in 1976. It is recognized as the most significant waterbird site in western Africa. Wetlands located farther inland are also waterbird migration sites, serving avifauna like the black stork. Conservation of these wetlands has been minimalized due to other priorities, such as agricultural development.

The Iraqi Marshes (Al-Ahwar) suggest moderate potential impact and were once the largest wetlands in the Middle East, serving as a habitat for migrating birds. This region has suffered from water resource development, including the Southeastern Anatolian Project, the Tabqa Dam, and the Karkheh River Dam adversely affecting food and livelihood for inhabitants. Users located downstream of these projects have exacerbated problems by depending on the remaining flows for water resources.

A final area of moderate-to-high potential impact includes the wetlands of Dinder National Park in Sudan. Known locally as *mayas*, these floodplain wetlands serve as the primary food and water source for wildlife, particularly during the dry season extending from November to June.

Like other wetlands in the Arab region, these *mayas* are also habitats for migrating birds. Human migration, however, has resulted in development and agricultural expansion. New livestock has competed with indigenous wildlife for resources and have introduced diseases. A grant was provided in the early 2000s aiming to increase wildlife capacity and improve park management, but funding has since ceased.

FIGURE 135: Area covered by wetlands – Reference period – Vulnerability



10.2.2 Future periods

10.2.2.1 Potential impact

Climate change impacts on wetlands include changes in hydrology and temperature. Hydrological parameters include precipitation, runoff and evaporation, which induce flood threat, reduction in flows and increased soil erosion. Temperature can alter evaporation rates and affect other aspects of wetland ecosystems such as increased heat stress to wildlife and water-quality degradation.

At mid-century, most wetlands project moderate exposure, ranging from 86% (RCP 4.5) to 88% (RCP 8.5). At end-century, 63% (RCP 8.5) to 82% (RCP 4.5) of wetlands reveal moderate exposure with areas of high exposure indicated in 28% of the study area under RCP 8.5 only. Wetlands with the highest exposure include Lake Nasser, coastal wetlands on the western shore of the Red Sea and Ammiq Wetland and Buhayrat al-Laha in the Levant. Other locations in the study area indicate low exposure.

The resultant potential impact, assuming static sensitivity, suggests mostly moderate potential impact at mid-century, ranging from 53% (RCP 4.5) to 70% (RCP 8.5) of the study area (Figure 136 and Figure 137). At end-century, moderate potential impact is forecast in 65% (RCP 4.5) to 70% (RCP 8.5) of the region's wetlands (Figure 138 and Figure 139). Most remaining areas predict low exposure other than a trace (1% of the study area) at end-century under RCP 8.5. Areas of moderate-to-high potential impact include wetlands of the Levant, Nile Delta region and wetlands in the northern Maghreb.

Note that potential impact does not take sea-level rise – one of the primary threats against coastal wetlands – into consideration, due to data limitations. Although wetlands can adapt to minimal changes through landward migration (provided there are no other limiting factors), larger changes in sea level can result in ecosystem collapse.

Some research has projected that a 1-m increase in sea level would result in the loss of over 96% of coastal wetlands in the Arab region.[5] UN Environment rapid economic assessments of wetlands have also predicted impacts over the coming 50 years.

FIGURE 136: Area covered by wetlands – Mid-century RCP 4.5 – Potential impact

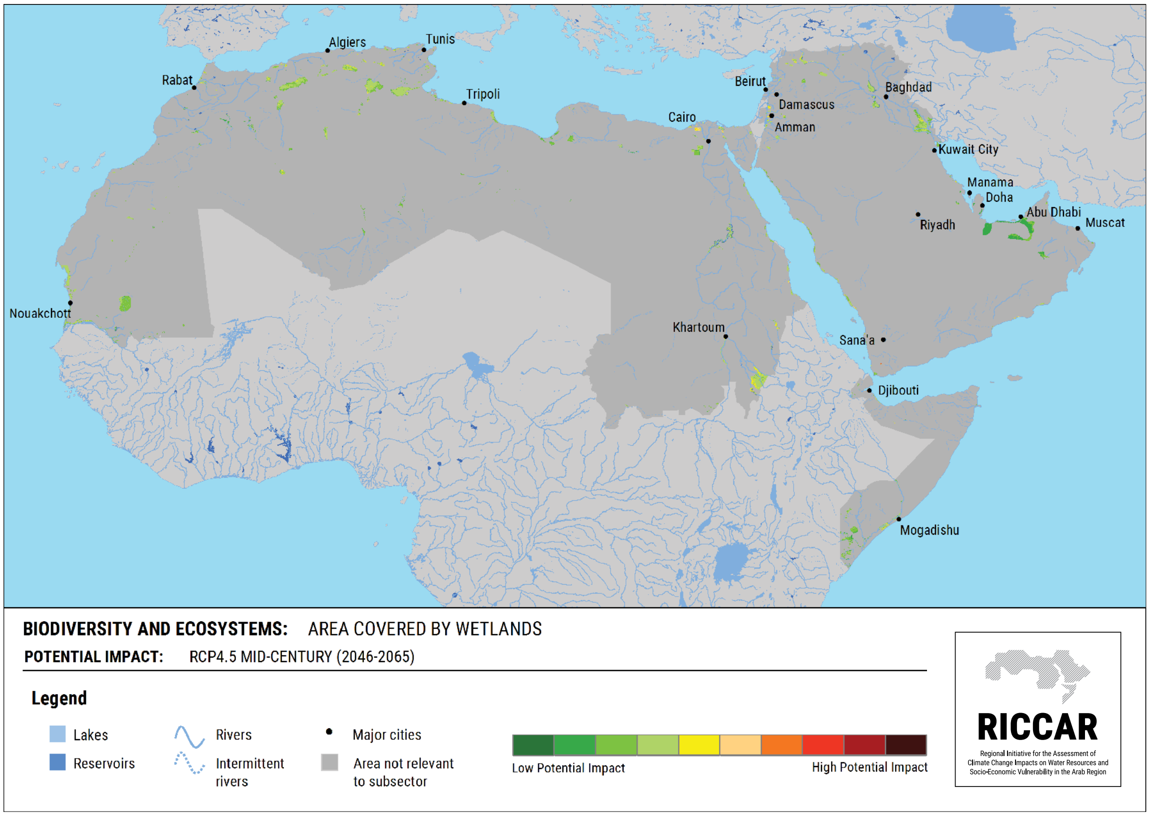


FIGURE 137: Area covered by wetlands – Mid-century RCP 8.5 – Potential impact

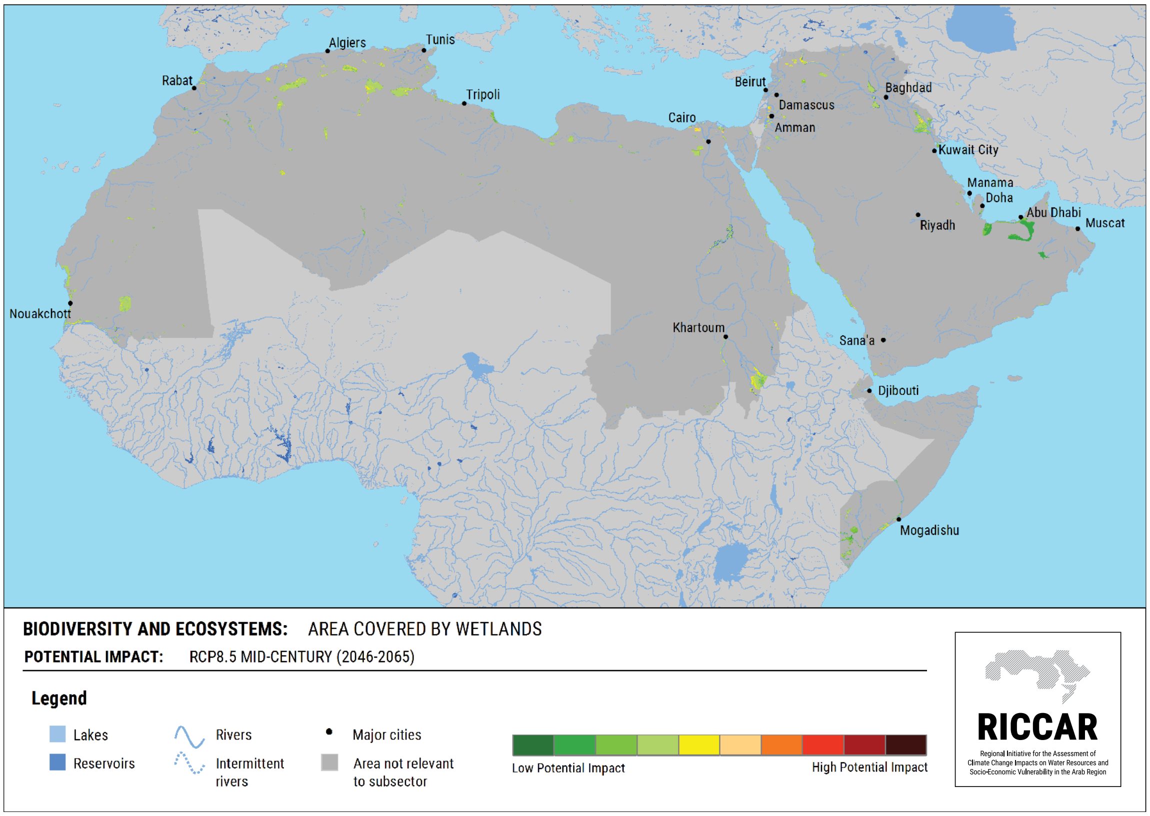


FIGURE 138: Area covered by wetlands – End-century RCP 4.5 – Potential impact

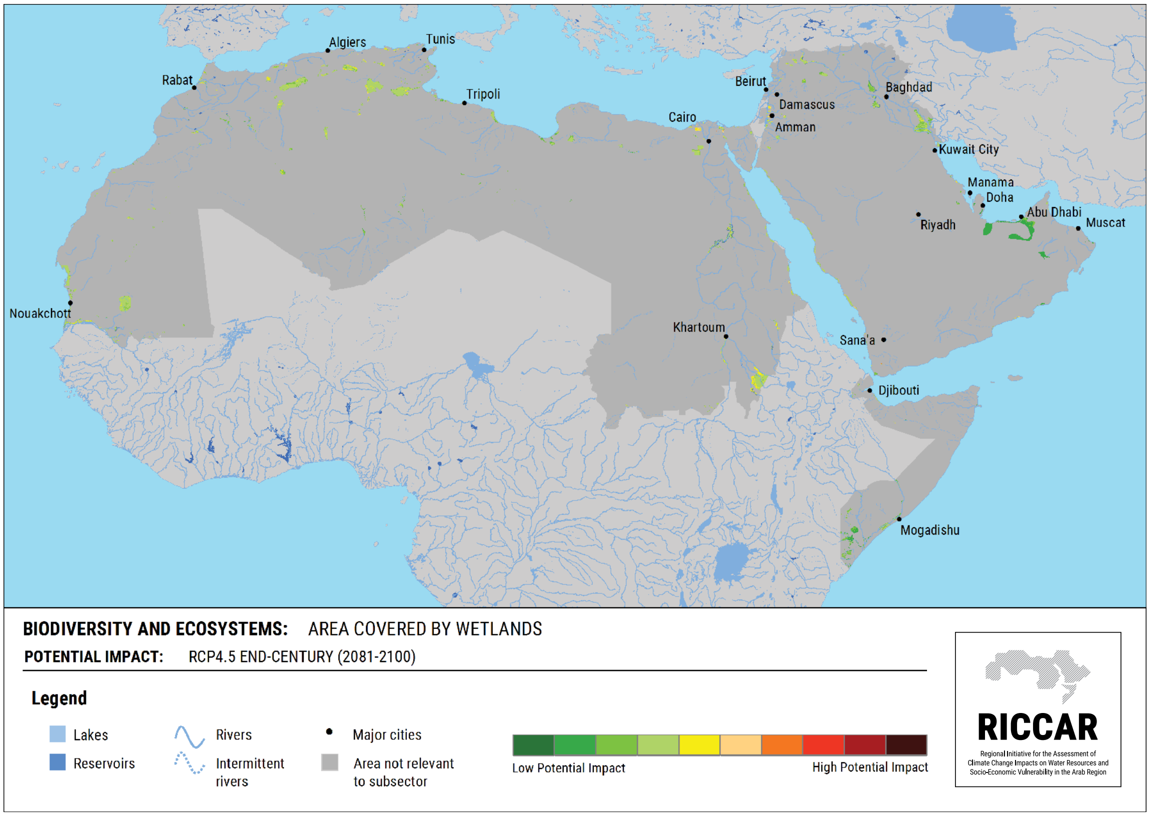
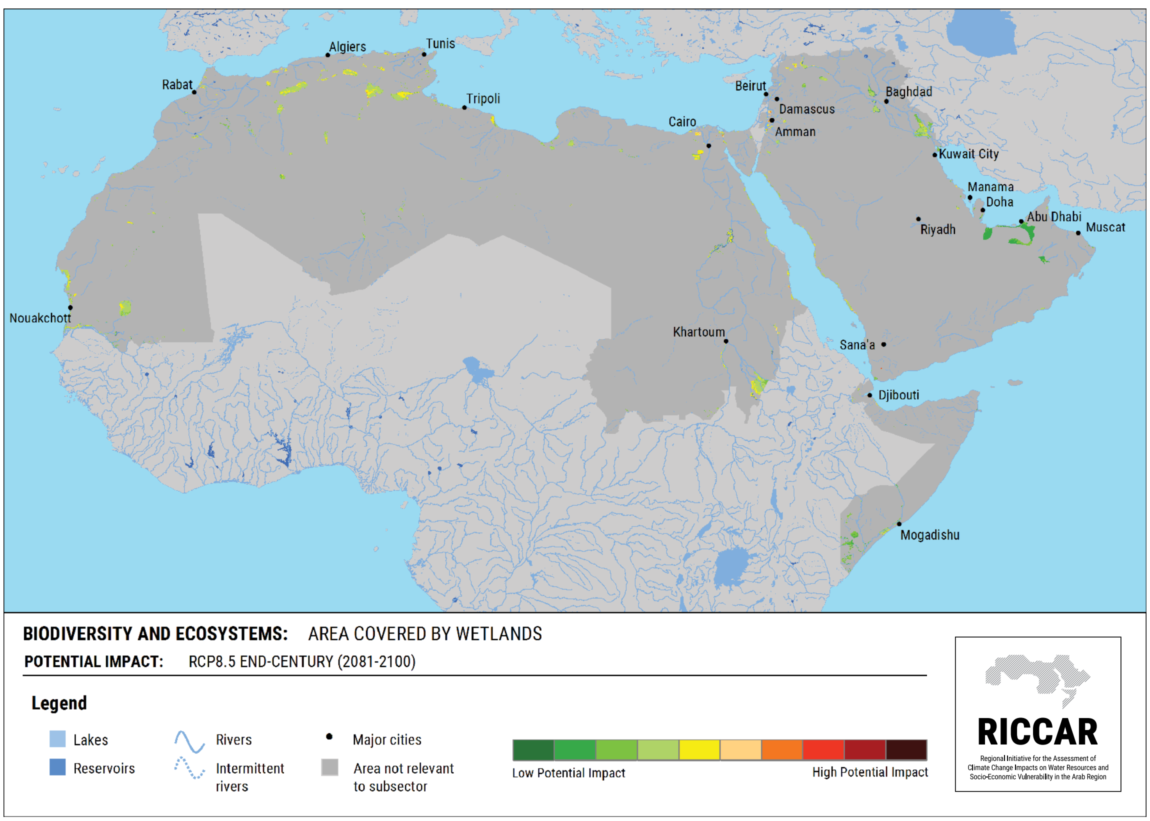


FIGURE 139: Area covered by wetlands – End-century RCP 8.5 – Potential impact



10.2.2.2 Vulnerability

Nearly all wetlands in the region (over 93%) project moderate vulnerability for both mid- and end century. Remaining areas are split between low and high vulnerability (Table 23). Vulnerability exhibits a strong correlation with both sensitivity and adaptive capacity and thus any changes in either component will considerably affect vulnerability. Areas with the lowest vulnerability relative to the Arab region include several wetlands in the eastern Atlas region, such as the Shott el Djerid/Shott el Fedjadj Complex, Sebkhet Sidi el Hani and Sebkhet el Melah, wetlands in the southern Maghreb, including Oasis de Tamantit et Sid Ahmed Timmi, and some wetlands near the Gulf such as Sabkha Matti (Figure 140 to Figure 143).

There are several mechanisms to reduce wetland vulnerability: protection, mitigation, rehabilitation and management. One of the avenues to achieving these goals is through the Ramsar Convention. To date, most countries within the Arab Region have become contracting parties and 108 designated Wetlands of International Importance cover over 75,000 km^2. By participating in the Ramsar Convention, shareholders agree to work towards the wise use of wetlands via policy, education and management and international cooperation on transboundary wetlands.

TABLE 23: Percentage of study area by vulnerability classification for area covered by wetlands

Scenario	Vulnerability (% of study area)		
	Low	Moderate	High
Mid-Century RCP 4.5	5%	94%	1%
Mid-Century RCP 8.5	1%	97%	2%
End-Century RCP 4.5	6%	93%	1%
End-Century RCP 8.5	1%	97%	2%

FIGURE 140: Area covered by wetlands – Mid-century RCP 4.5 – Vulnerability

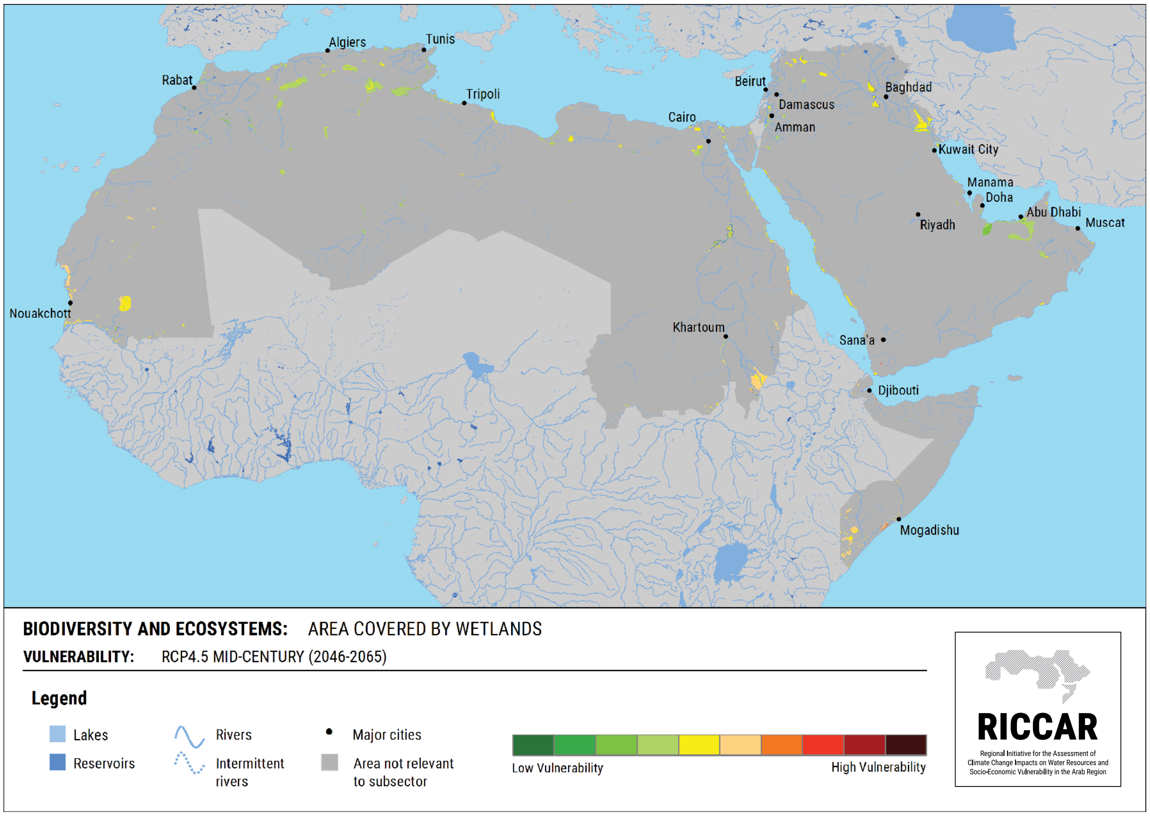


FIGURE 141: Area covered by wetlands – Mid-century RCP 8.5 – Vulnerability

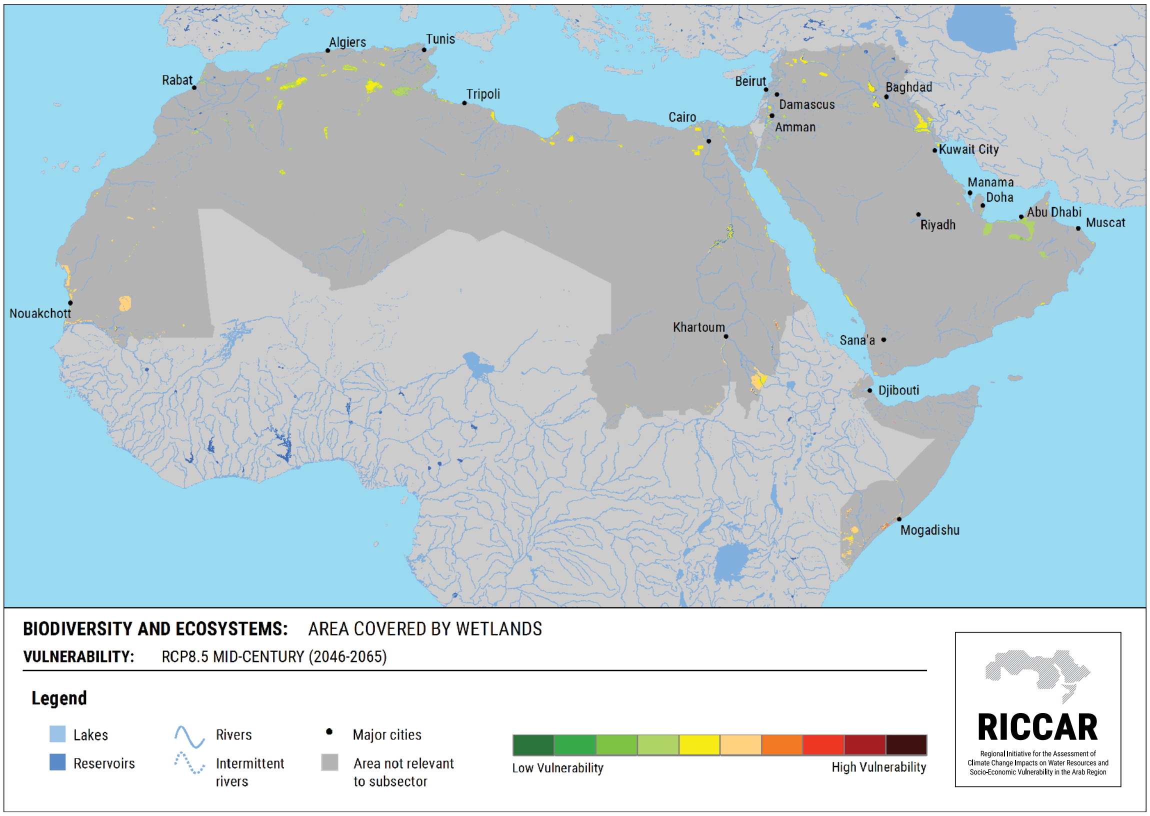


FIGURE 142: Area covered by wetlands – End-century RCP 4.5 – Vulnerability

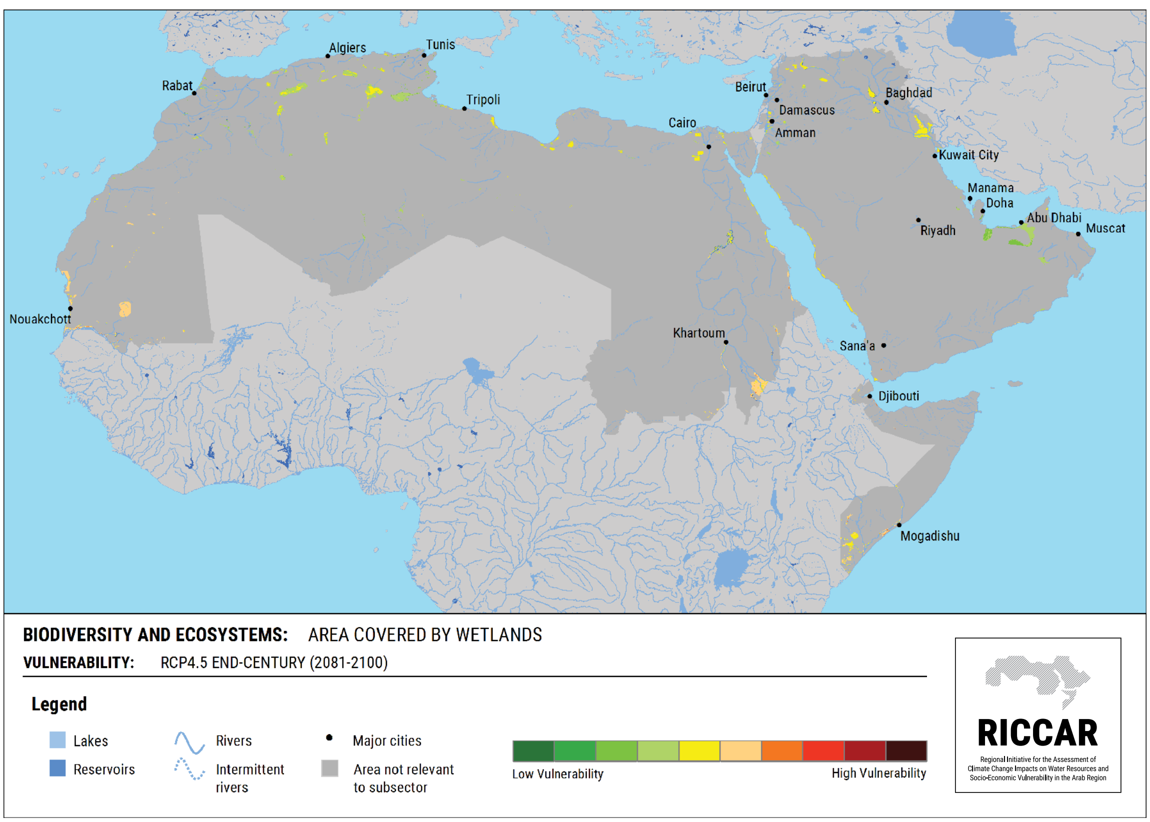
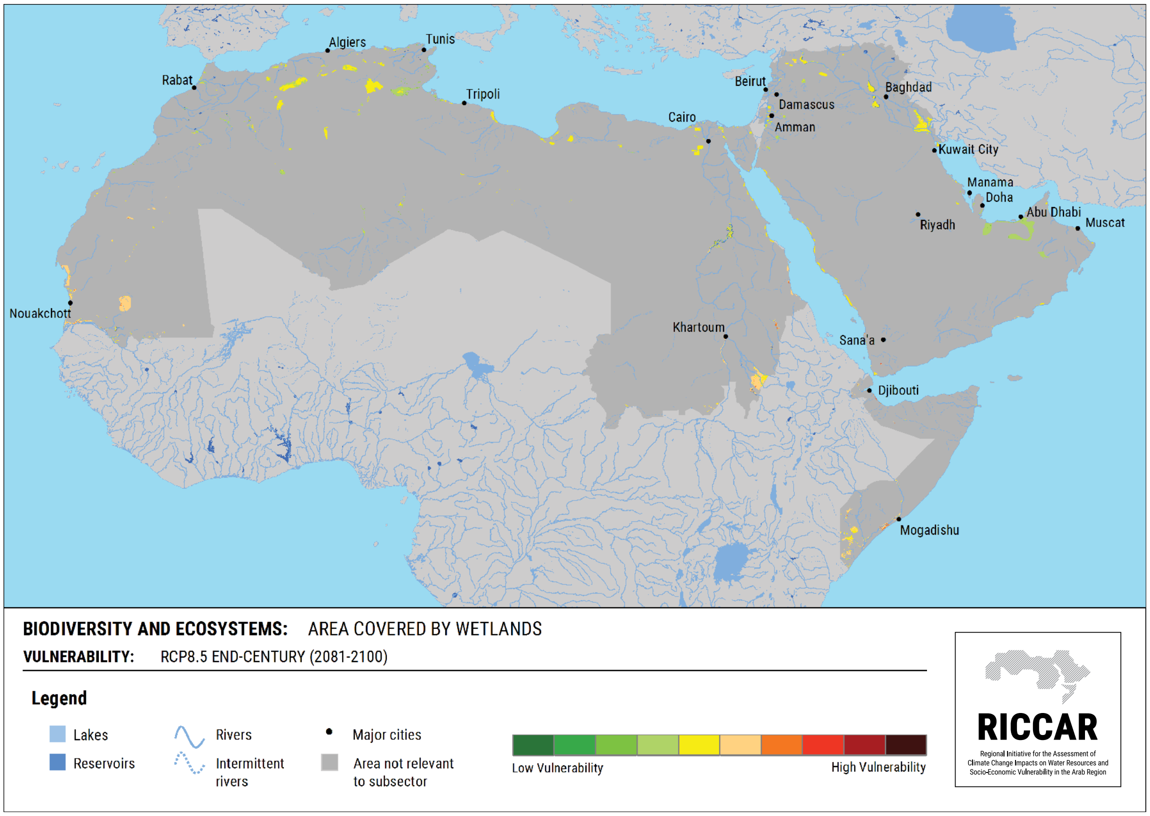


FIGURE 143: Area covered by wetlands – End-century RCP 8.5 – Vulnerability



10.2.3 Hotspots

Hotspot areas reflect those wetlands with the highest projected vulnerability. Only about 1% of wetlands in the Arab region are hotspots. Nevertheless, they include several wetlands in sub-Saharan Africa and some wetlands near the southern Red Sea and Gulf of Aden. Wetland hotspots in the Tindouf basin include Aftout es Saheli along the Atlantic Ocean shoreline, freshwater marshes in the Senegal River Valley, Lac Gabou and the hydrographic network of the Tagant Plateau.

The latter was designated a Ramsar site in 2009 and has a network of rivers which flow from the mountains to form Lac Gabou, temporary lagoons and ponds, freshwater springs and oases. Like other wetlands in the area, it supports significant flora and fauna and is a migratory bird site. Nevertheless, these wetlands have been subjected to poor agricultural management, water resources development and other threats.

Wetland hotspots located in the eastern Sahel include freshwater marshland along the White Nile River, Er Rosieres Reservoir on the Blue Nile River, Khawr Abu Muhhar (a tributary of the Blue Nile), intermittent lakes fed by the Qash River, and coastal wetlands of the Red Sea. Wetlands such as the Blue Nile *mayas* have suffered from severe degradation stemming from water resources development and siltation, felling of riverine forests, overgrazing and other factors. The Red Sea mangroves are badly degraded and shrinking in extent: they may also be subject to loss from sea-level rise, but this was not evaluated as part of RICCAR.

In the Horn of Africa, wetland hotspots include tidal wetlands adjacent to the Gulf of Aden, freshwater marshes of the Shabelle River and freshwater marshes of the Jubba River. Mangrove stands located in tidal wetlands have been plundered for firewood and timber such that little vegetation remains and the wetlands are now salt marshes.

The riverine wetlands are important for local wildlife but have deteriorated due to cultivation, water demand and migration. Lastly, wetlands located in the south-western Arabian Peninsula such as the Ta'izz wetlands and the Gulf of Aden mudflats have been designated hotspots. These wetlands are also bird habitats, supporting avifauna like the bald ibis. Similar to other wetland hotspots, these areas have been subject to increased development and other threats.

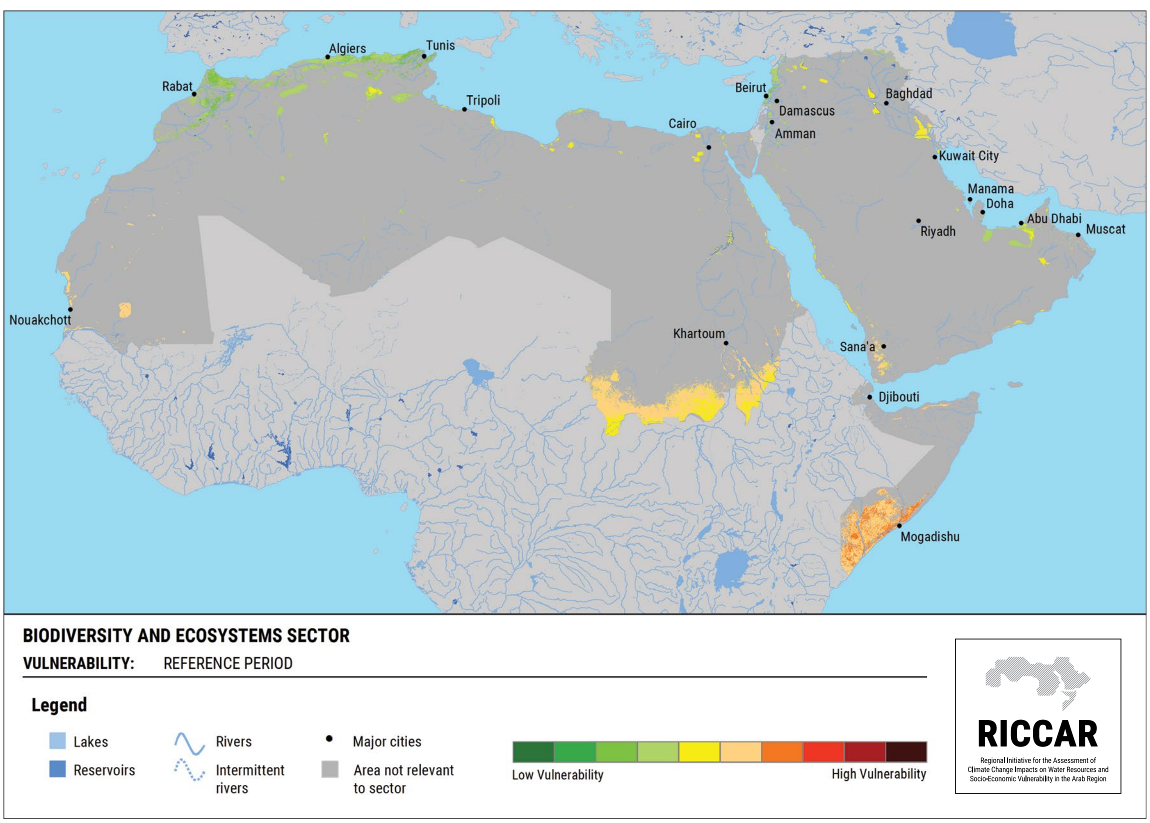
10.3 BIODIVERSITY AND ECOSYSTEMS SECTOR: OVERALL VULNERABILITY

10.3.1 Reference period

Vulnerability for the *Biodiversity and ecosystems* sector is the aggregation of vulnerability of both the forests and wetlands subsectors. A majority of the study area (86%) indicates moderate vulnerability, whereas 7% suggests high vulnerability. Areas of high vulnerability are confined to the southern Horn of Africa and include tropical shrubland, as well as tropical desert. Conversely, areas of low vulnerability are located in the northern Maghreb, in a subtropical dry forest ecosystem and subtropical mountain system, as well as the Levantine subtropical dry forest ecosystem. Wetland systems are contained within these areas (Figure 144). Although both subsectors contribute equally towards sector vulnerability, the subsector *Area covered by forests* has a stronger correlation.

Jebel Tammun Nature Reserve, State of Palestine, 2017. Source: Alaa Kanan.

FIGURE 144: Biodiversity and ecosystems sector – Vulnerability – Reference period



10.3.2 Future periods

10.3.2.1 Vulnerability

Ecosystems are at risk of terrestrial change or extinction due to climate change impacts. Nearly the entire region (at least 98%) projects moderate vulnerability for both mid- and end-century for the two climate scenarios (Table 24). Nevertheless, like the trends described for the subsectors *Area covered by forests* and *Area covered by wetlands*, most ecosystems within the study area exhibit a constant-to-increasing vulnerability under RCP 4.5 from mid- to end-century. Exceptions are the south-western corner of the Arabian Peninsula and the southern Horn of Africa, which suggest a constant-to-decreasing vulnerability.

Similar trends are revealed for RCP 8.5, although some areas within the eastern Sahel indicate constant-to-decreasing vulnerability and some areas, such as the Shabelle–Jubba Delta, project constant-to-increasing vulnerability (Figure 145 to Figure 148).

Like the reference period, the future scenarios have a strong correlation with the subsector *Area covered by forests*. Improvements in reforestation/afforestation efforts are expected to increase biodiversity and ecosystems in the region as a whole.

TABLE 24: Percentage of study area by vulnerability classification for biodiversity and ecosystems sector

Scenario	Vulnerability (% of study area)		
	Low	Moderate	High
Mid-Century RCP 4.5	1%	98%	1%
Mid-Century RCP 8.5	0%	99%	1%
End-Century RCP 4.5	1%	99%	0%
End-Century RCP 8.5	0%	98%	2%

FIGURE 145: Biodiversity and ecosystems sector – Vulnerability – Mid-century RCP 4.5

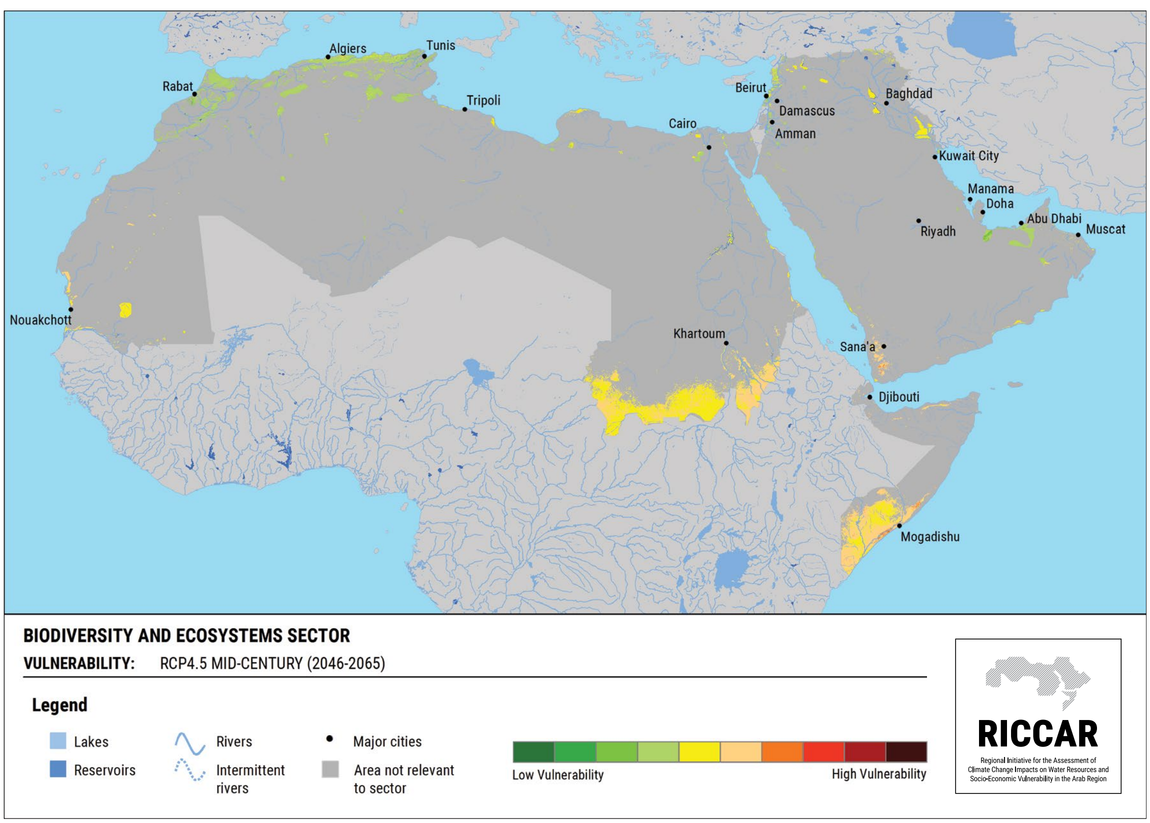


FIGURE 146: Biodiversity and ecosystems sector – Vulnerability – Mid-century RCP 8.5

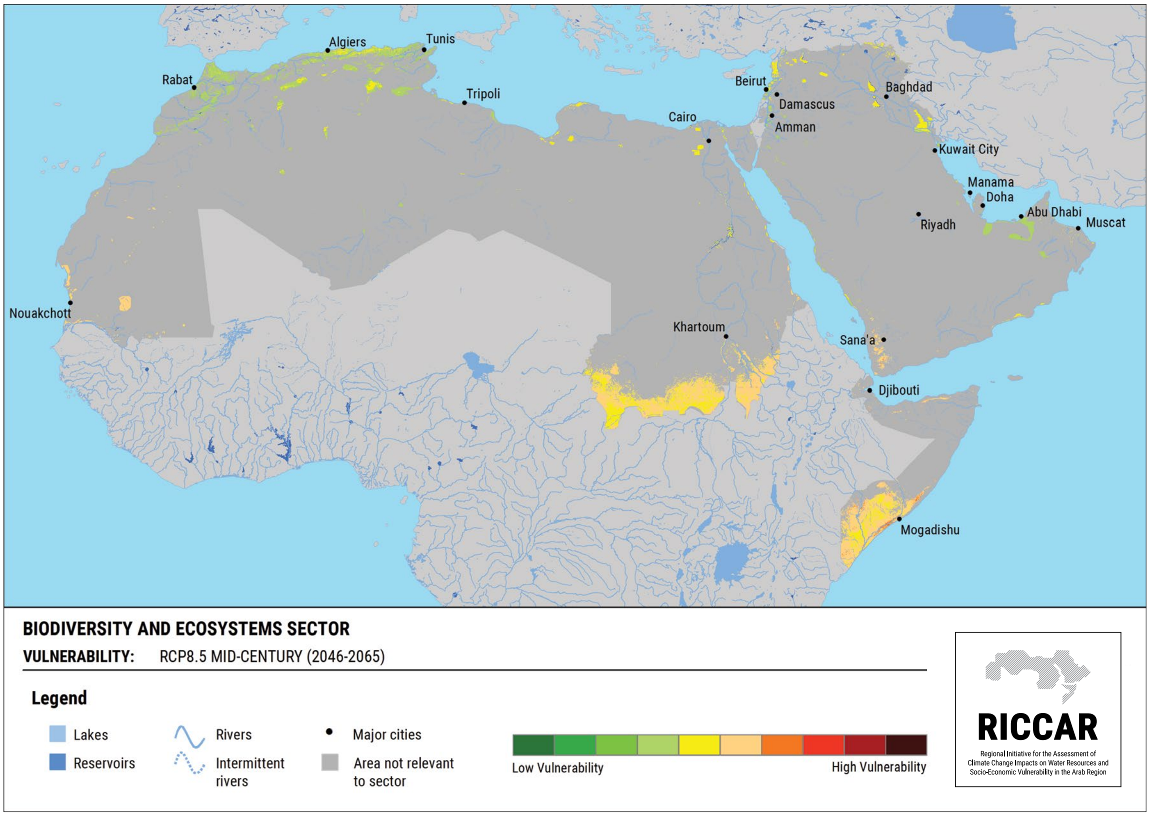


FIGURE 147: Biodiversity and ecosystems sector – Vulnerability – End-century RCP 4.5

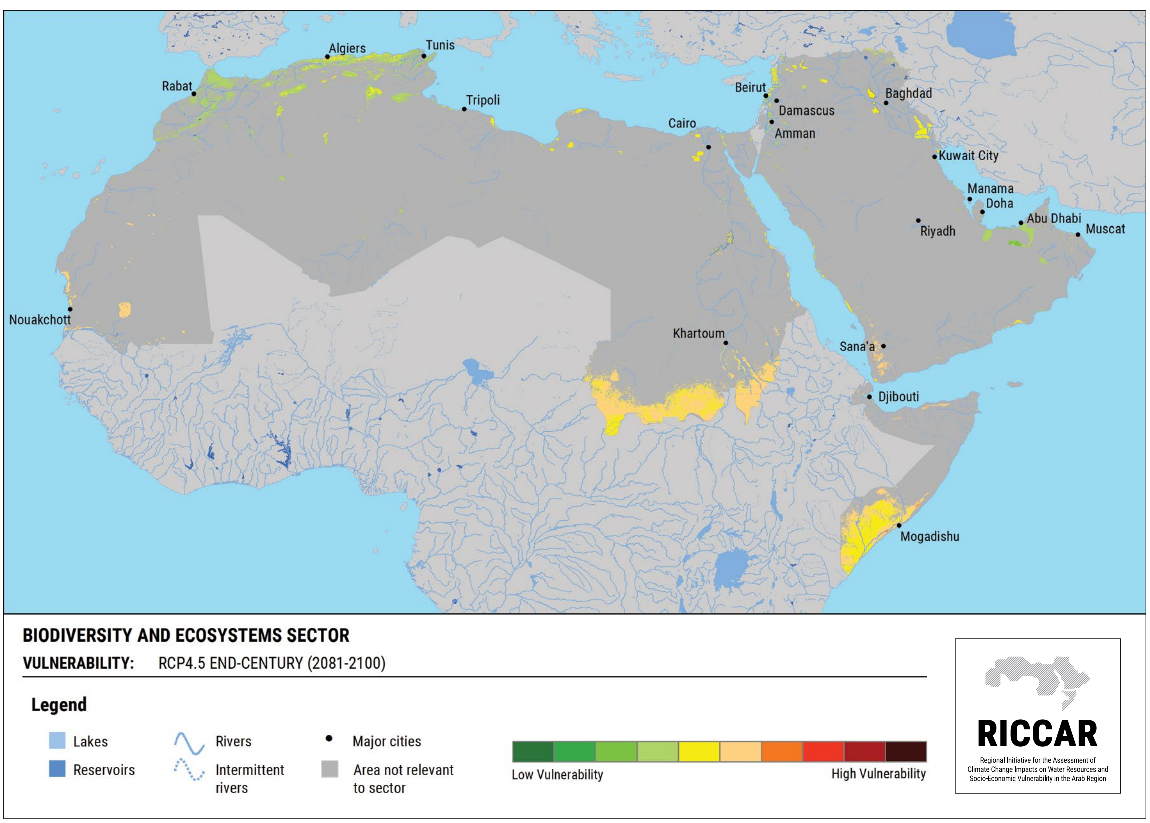
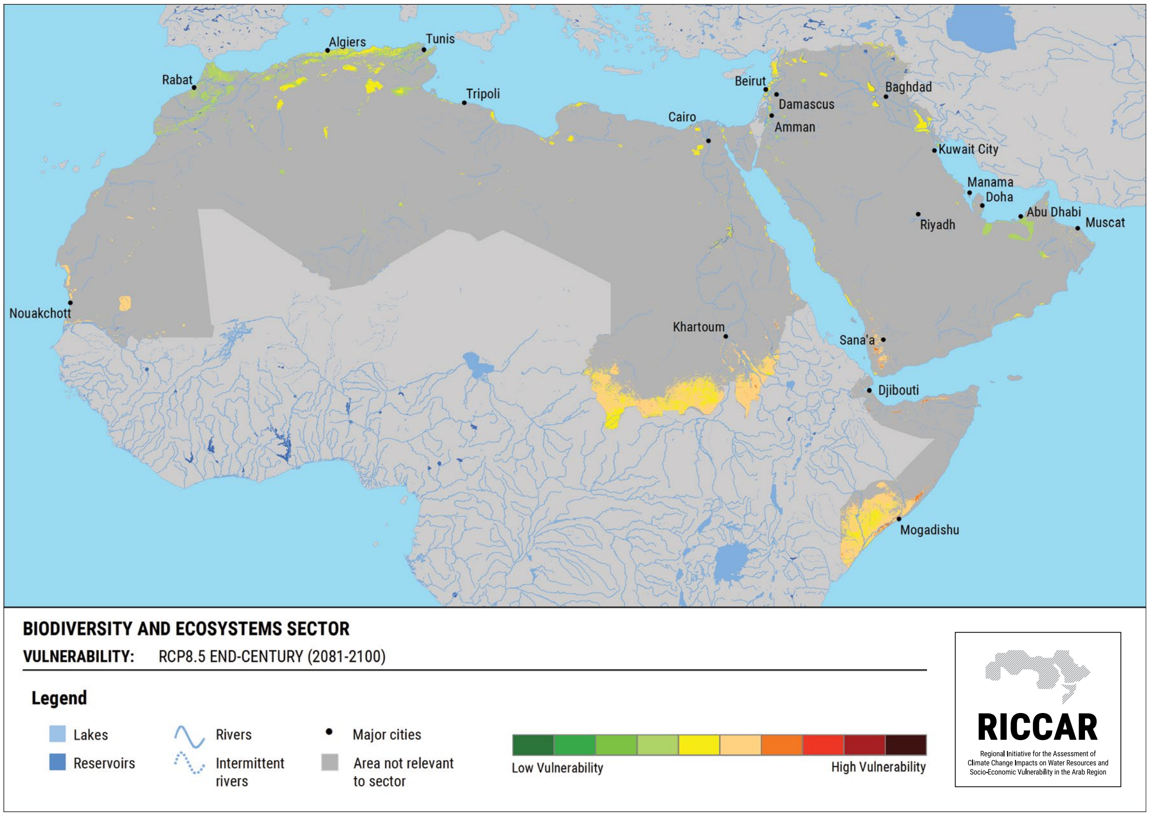


FIGURE 148: Biodiversity and ecosystems sector – Vulnerability – End-century RCP 8.5



10.3.3 Hotspots

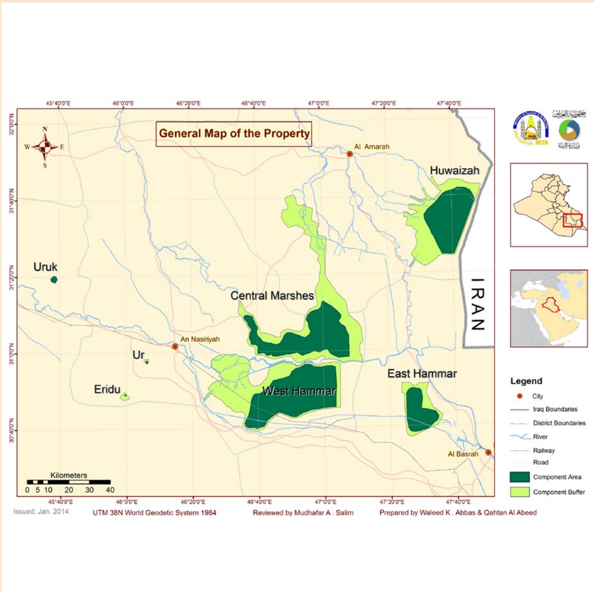
Identified hotspots represent the most vulnerable forests and wetlands in the Arab region and comprise 2% of the study area, including forest and wetland ecosystems in sub-Saharan Africa and the south-western Arabian Peninsula. In particular, the Ta'izz wetlands, tidal wetlands along the southern Gulf of Aden coastline, forests of the Golis Mountains and selected freshwater marshes in the Jubba and Shabelle riparian areas exhibit the absolute highest vulnerability in the region.

BOX 7: Implications of climate change for the Iraqi Marshlands

The Iraqi Marshlands, considered to be the largest wetland ecosystem in the West Asia region of environmental, historical and socio-cultural significance extend over more than 20,000 km^2 and are located in the areas surrounding the confluence of the Euphrates and Tigris rivers (Figure 149). They represent an ecosystem of fundamental importance to natural and human life in the region, providing local communities with an essential habitat and source of livelihood. Hosting an extraordinary biodiversity and cultural richness, the Marshlands used to provide a permanent settlement and a migratory flyway point for numerous bird species, as well as a central habitat for the Gulf's freshwater fish.[6] Historically, the Marshes filtered out the waste and other pollutants from the Tigris and Euphrates rivers, preserving a pristine ecosystem and preventing the degradation of the Gulf coast.

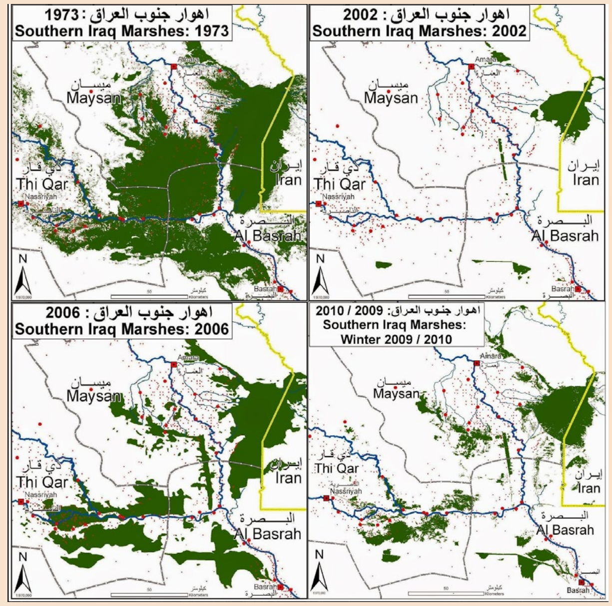
Since the 1970s, over 90% of the original Marshlands area has been desiccated through the combined actions of upstream damming, systematic draining, and oil excavation. As a result, by the year 2000, the only remaining marsh was a portion of Al-Hawizeh on the southern border with the Islamic Republic of Iran, leaving the area extremely vulnerable to drought, climate change and sand- and dust storms. Since 2003, some efforts have been made by a number of organizations to rehabilitate the Marshlands.

FIGURE 149: Map of the Iraqi Marshlands highlighting the four key areas



Source: Ministry of Environment, Republic of Iraq, in UNESCO, 2016a

FIGURE 150: Change in the size of the southern Marshes from 1973 to 2010



Source: CIMI, 2010 in Harhash et al., 2015

The upper reaches of the Euphrates and Tigris rivers are located at high altitudes and receive significant amounts of precipitation in winter months in the form of snow, which provides about 88% of runoff as it melts in the spring, flowing downstream all the way to the Gulf through the rivers and their tributaries.[7] Recently, the water input into the Marshes has been severely affected by changes in climate patterns, as well as human intervention.

Climate change is one of the major challenges currently facing the Iraqi Marshlands. Regional climate modelling outputs by RICCAR indicate a consistent projected increase of temperature in this region by end-century. Several studies also project decreases in precipitation levels in the upper Euphrates and Tigris rivers which will ultimately affect river flow towards the Marshlands.[8] It is expected that, by 2025, water flow will decrease by more than 50% in the Euphrates and 25% in the Tigris.[9] There is also evidence of the rapid expansion of desertification, increasingly frequent and intense duststorms, prolonged drought conditions and unprecedented heatwaves with temperatures exceeding 50 °C in the summer months.[10]

These combined phenomena are having substantial effects on water availability, as well as water quality, and are causing additional stress for biodiversity, particularly in the Marshlands. For example, a mass reduction and loss of key populations of mammals, such as wild boars and water buffaloes have been reported. Species of great ecological, economic and cultural importance could be lost forever, including 18 globally threatened species of fish, mammals and insects found in the Marshlands.[11]

The impacts of climate change are further magnified by human intervention. A series of major dams, diversion schemes and oil-related activities on the Euphrates and Tigris rivers in neighbouring countries (Islamic Republic of Iran, Syrian Arab Republic and Turkey) have significantly altered the hydrological cycle by restricting the amount of water entering the Marshes, as well as interfering with the seasonal pattern of water during the rainy season.[12] The development of these dams has also resulted in the resettlement or displacement of local people impacted by the change in water flow.

Iraqi Marshlands, 2017. Source: Qahtan Abid.

Iraqi Marshlands, 2017. Source: Qahtan Abid.

Along with the draining of the marshes, extensive ecological damage was observed, furthering the deterioration of the Marshlands and significantly affecting their biodiversity and people's livelihoods.

As part of the rehabilitation and restoration efforts, several water-diversion projects into the Marshlands have been implemented as examples of interventions trying to influence positive change.[13] In 2003, the Iraqi government identified the need and importance to rehabilitate the Marshlands with the support of a number of national and international organizations, leading to the restoration of about 45% of the original Marshlands (Figure 150).[14]

In 2009, UN Environment and UNESCO launched the joint project Natural and Cultural Management of the Iraqi Marshlands to establish and implement a longer-term sustainable management framework leading to the inclusion of the Iraqi Marshlands in the UNESCO World Heritage List at the 40th session of the World Heritage Committee in July 2016.[15]

A successive nomination of three Sumerian Mesopotamian cities (Ur, Uruk and Tel-Erido) and four marshland areas on the World Heritage List followed. This recognition highlights the historical and ecological importance of the site and the necessity to establish a consolidated management plan for the area combining its cultural, historical and natural characteristics. The UN Environment and UNESCO initiative aimed to provide guidance and support to the Iraqi stakeholders in implementing a sustainable preservation and management plan to mitigate the complex effects of climate change on biodiversity and water resources, the overexploitation of natural resources, as well as pollution, drought, sand and dust storms and dam construction upstream.

The management plan sought also to build capacity and raise awareness among the local population to ensure their livelihoods and encourage their participation in the management of the Marshlands and the sustainable use of its ecosystem services and traditional knowledge, which is 5,000 years old.

ENDNOTES

1. UNEP, 2013
2. Hansen et al., 2013
3. Ibid.
4. Ramsar Convention Secretariat, 2010
5. Blankespoor et al., 2014
6. United Nations Integrated Water Task Force for Iraq, 2011
7. Ministry of Health and Environment in Iraq, 2014
8. Ibid.
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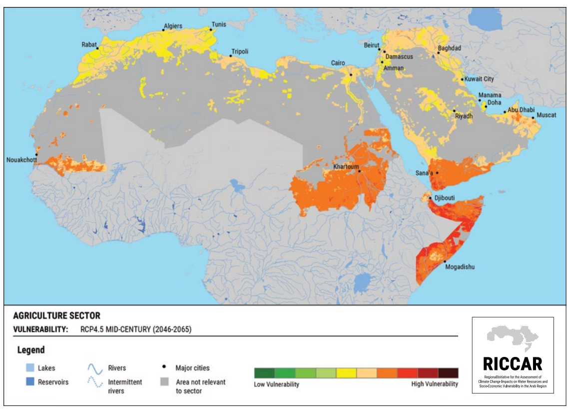
AGRICULTURE SECTOR

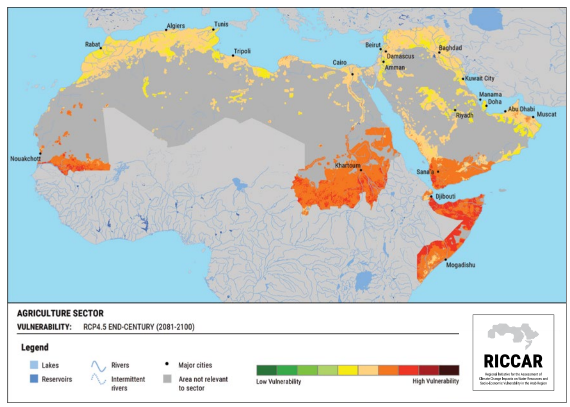
OVERALL VULNERABILITY

RCP 4.5

2046-2065

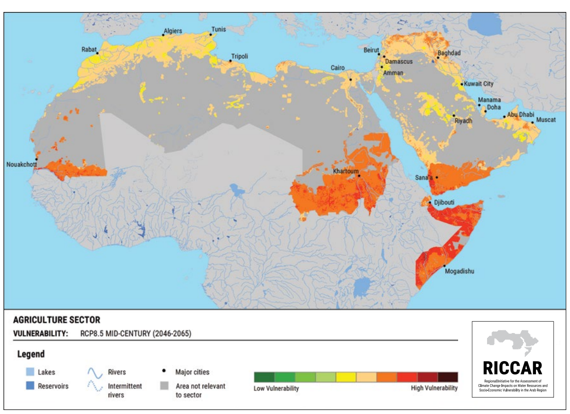


2081-2100

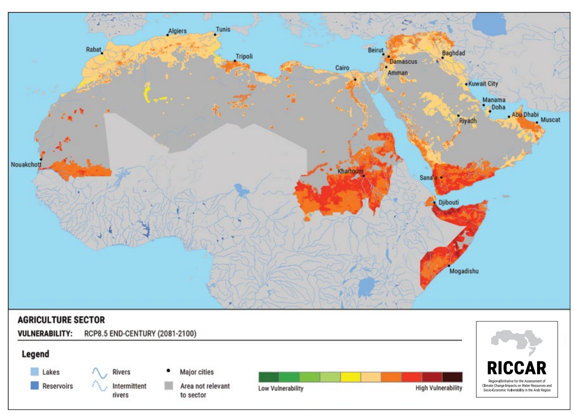


RCP 8.5

2046-2065



2081-2100



CHAPTER 11

AGRICULTURE SECTOR – VULNERABILITY

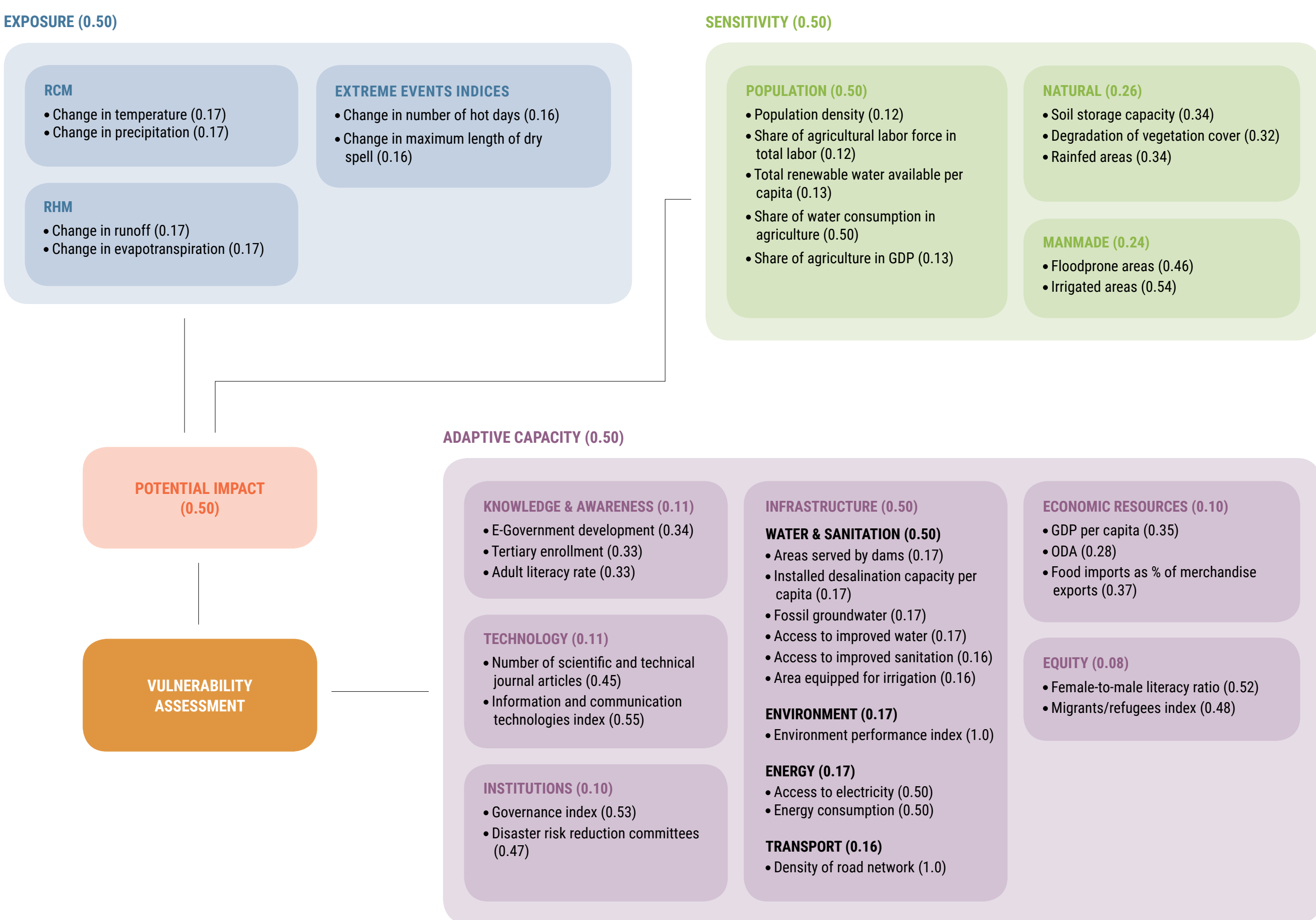
The agricultural sector plays an important role in most economies of the Arab region and is also the largest consumer of freshwater, constituting more than 80% of total water use. Crops such as wheat, barley and sorghum require an estimated 1,000 to 3,800 m^3 of water per tonne of harvested produce.[1] Research has shown that livestock require substantially more due to feed, grazing and direct water demand; dairy cows require the most water: an estimated 89,000 to 160,000 m^3/t over an animal's lifespan.[2] Being highly dependent on water and fertile soils – both scarce natural resources in the region – the agricultural sector is particularly prone to adverse climate change impacts. It was thus selected for inclusion in vulnerability, with particular focus on the potential impacts of *Change in the water available for crops* and *Change in the water available for livestock*, of which the outcomes are presented in the following sections.

The study areas for both subsectors have been defined by selected indicators. In the case of water available for crops, both rainfed and irrigated cropland areas were included. In this context, if at least a portion of a given grid cell represents cropland, the entire cell was considered part of the study area. For the *Water available for livestock* subsector, the study area was based on livestock density over 10 heads per square kilometre. The managed water available for crops and water available for livestock represents 22% and 33% of the Arab region, respectively. The study area for the *Agriculture* sector represents the combined study areas of the subsectors, which often overlap, and includes 37% of the Arab region.

11.1 WATER AVAILABLE FOR CROPS

Figure 151 highlights the impact chain for this subsector, showing the set of indicators considered for analysis and its assigned weights.

FIGURE 151: Impact chain and weights for water available for crops



11.1.1 Reference period

11.1.1.1 Potential impact

Potential impact represents the aggregated result of both exposure and sensitivity. In terms of exposure, a change in water availability for crops is related to drought, most commonly attributed to meteorological phenomena, specifically changes in precipitation patterns. Six differing exposure indicators were selected, including precipitation (see Figure 151).

For the reference period, the exposure composite indicator is primarily influenced by temperature and the annual number of hot days (SU35). High temperatures can accelerate soil-water evaporation, particularly in arid and semi-arid environments, where crops do not completely cover the ground. For the reference period, 19% of the study area is considered to have low exposure, 38% moderate exposure and 43% high exposure. Areas with the highest exposure include the southern Tindouf basin, the Nile Valley near Khartoum, selected locations near the Red Sea coastline and selected locations near the Gulf coastline.

Sensitivity, in this context, is typically defined by other water surfaces, soil type, land use and irrigation practices. Under RICCAR, 10 different sensitivity indicators were selected, of which the share of water consumption in agriculture – an indicator based on population statistics – was given the highest weight. Agriculture is the largest consumer of water, using 84% of total water available in the Arab region and over 90% in certain countries.[3] Neither crop yield nor harvested losses were considered part of this study due to region-wide data unavailability.

The results suggest that a majority of the study area (84%) indicates moderate sensitivity, while 9% suggests high sensitivity. The area with the highest sensitivity is that of the lower Nile Valley and Nile Delta. Other areas of moderate-to-high sensitivity are dispersed throughout the study area. Sensitivity exhibits the strongest correlation with the floodprone areas indicator; minor floods can be beneficial to crops in terms of water availability. Sensitivity is also reasonably correlated with irrigated areas and population density.

However, despite the heavy weight assigned to the share of water consumption in agriculture indicator, it reveals a weak correlation with sensitivity, partly because the indicator is solely available at a national scale and the composite sensitivity is subnational.

Potential impact implies the effect upon a system assuming no implementation of adaptation measures. In this case, it suggests areas which are most likely to be subject to a decline in water availability for crops. A majority of the study area (86%) signifies moderate potential impact, while 9% shows high potential impact (Figure 152).

The entire Nile Valley denotes high potential impact for the reference period, as well as much of the Sahel, the eastern Red Sea coastline, the Jubba and Shabelle rivers in the Horn of Africa, certain areas in the Arabian Desert and the lower Tigris–Euphrates basin.

11.1.1.2 Adaptive capacity

Adaptive capacity reflects the current ability of a system to adjust to climate change (both variability and extremes), lessen potential damage and exploit potential solutions. Selection of relevant indicators was based on all six dimensions, focusing on water infrastructure.

The Arab region has long been subject to deteriorating water infrastructure due to deferred maintenance and the inability to dedicate financial resources for new investments. Facets from the other adaptive capacity dimensions also matter. Current science and technology methods practised in the region include plant cultivation and animal breeding, biotechnology, mineral fertilizers and water-efficient irrigation. Economic resources include production of goods for trade, alternative means of income generation, cooperation with industry and financial aid. However, these techniques are utilized on a limited scale only.

Approximately 28% of the study area can be considered to have low adaptive capacity and are located in the croplands of the Horn of Africa, the Sahel, and the south-western Arabian Peninsula. Most of the study area (66%) reveals moderate adaptive capacity. High adaptive capacity is limited to 7% of the study area and is generally confined to the lower Nile Valley and Delta, areas of the Levant and the eastern Tell Atlas region (Figure 153).

FIGURE 152: Water available for crops – Reference period – Potential impact

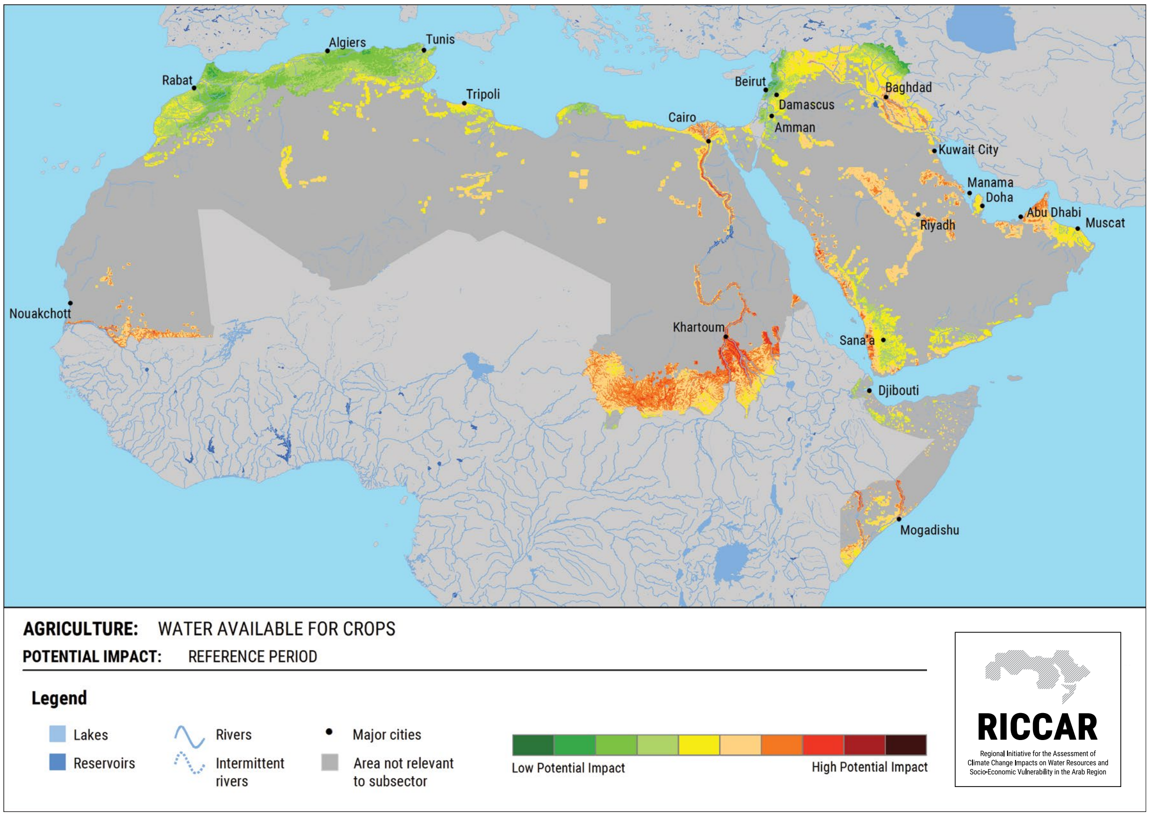
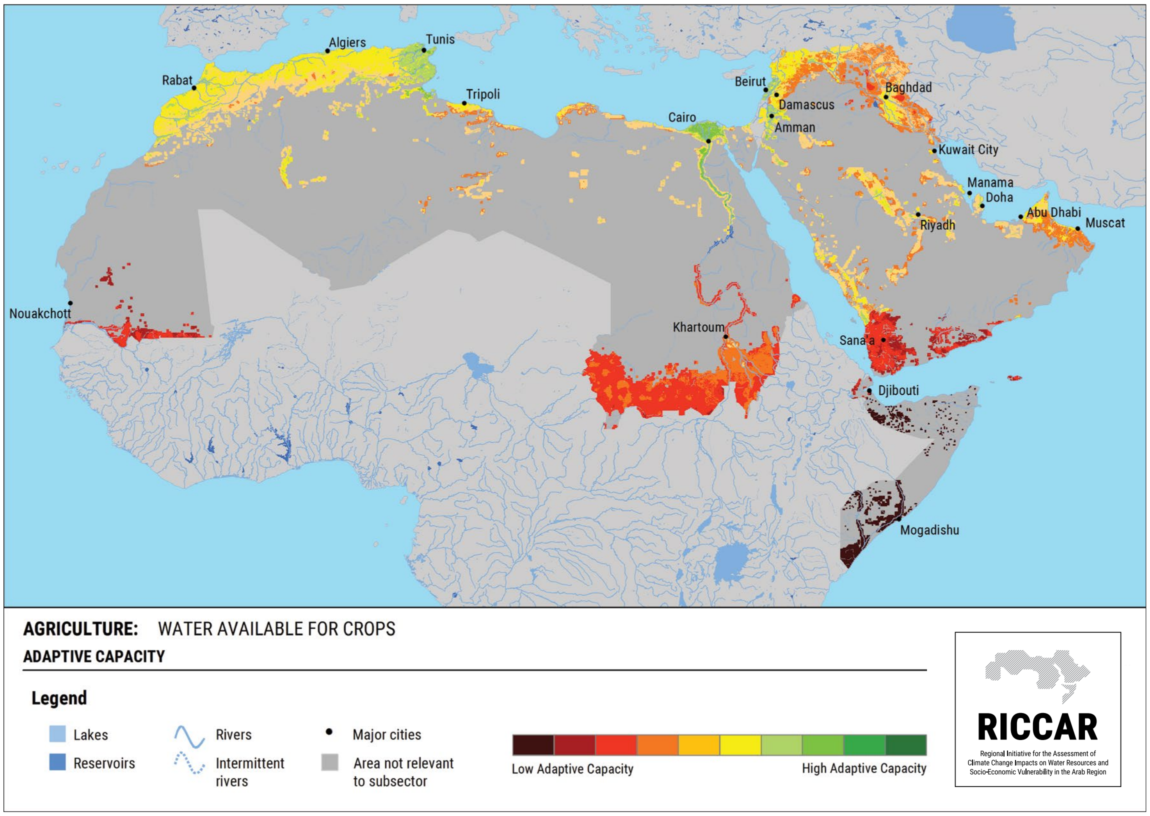


FIGURE 153: Water available for crops – Adaptive capacity

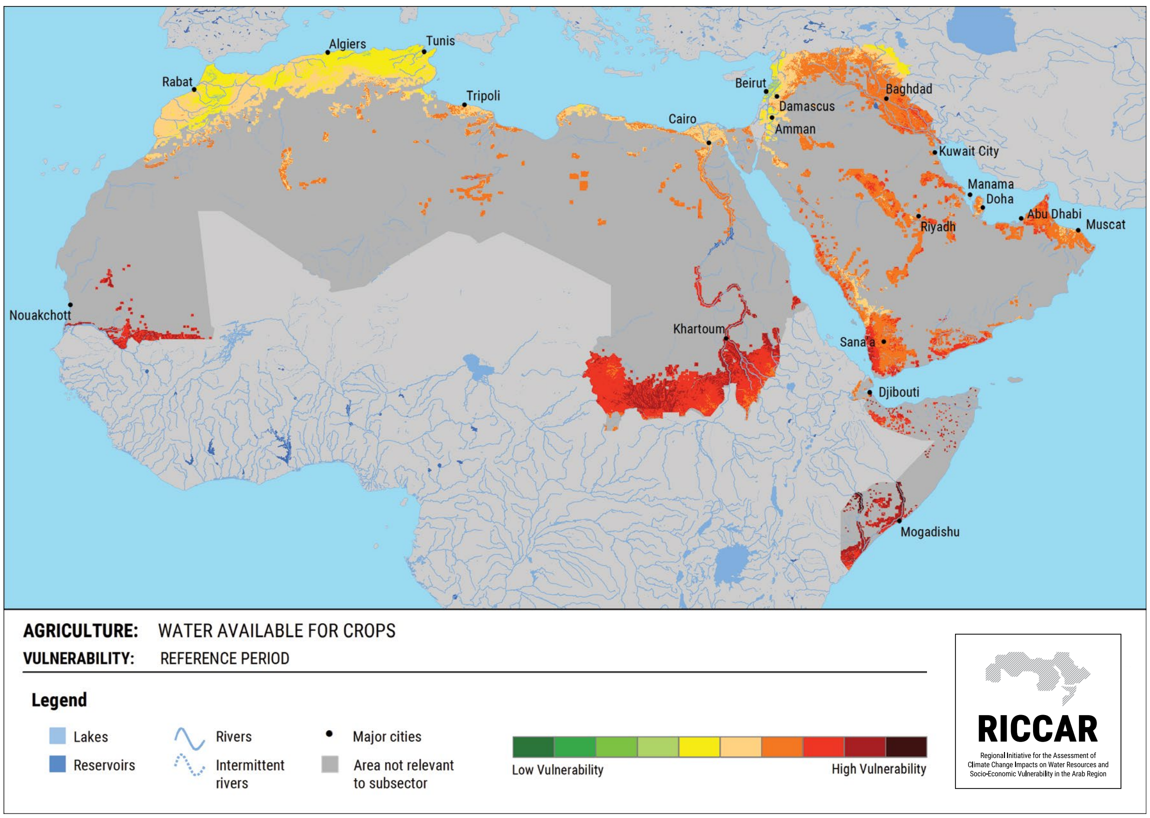


11.1.1.3 Vulnerability

Vulnerability reflects the balance between climate, the natural and physical environment and the ability to cope. Assessing the vulnerability related to water availability for crops stems from several interrelated issues, including limited water resources. Much of the study area (63%) signifies high vulnerability for the reference period, with remaining areas indicating moderate vulnerability. Areas with the highest vulnerability include the Sahel, the Jubba and Shabelle river valleys, and croplands south of the Asir Mountains. Vulnerability to water availability adversely impacts crops, but affects numerous other sectors, too, often in conjunction with high population growth, urbanization and industrialization. Results are for instance: overexploitation of ecosystems and loss of habitats, especially coastal and wetland habitats, followed by a decline in biodiversity and a deterioration of forests and grasslands all over the Arab region. Forests and wetlands are amongst the ecosystems most affected by current degradation processes.

Areas with moderately low vulnerability relative to the region include lands in the northern Maghreb, the Levant and the Zagros Mountains due to reduced potential impact and relatively high adaptive capacity (Figure 154).

FIGURE 154: Water available for crops – Reference period – Vulnerability



11.1.2 Future periods

11.1.2.1 Potential impact

Climate change can affect water availability, crop yield, crop–water productivity, soil–water balance, and ultimately food security. Water availability in this context considers how much water can be diverted toward the *Agriculture* sector, when it can be obtained and how much can be stored for future use. Water productivity differs as it reflects economics and management and similar issues. An increase in water productivity enables farmers to produce the same crop yield using fewer water resources.

Exposure is largely moderate for most of the study area at mid-century, signifying 67% (RCP 8.5) to 86% (RCP 4.5) of the study area. High exposure is predicted in 7% (RCP 4.5) to 32% (RCP 8.5) of the study area. At end-century, exposure increases and 26% (RCP 4.5) to 64% (RCP 8.5) of the study area is denoted high exposure with 35% (RCP 8.5) to 68% (RCP 4.5) as moderate exposure.

Areas of high exposure include the Blue Nile–White Nile basin, the south-western Arabian Peninsula and croplands near the Gulf of Oman. High-exposure areas expand dramatically for end-century RCP 8.5 to include the entire Mediterranean coast and the Nile River.

Sensitivity is assumed unchanged from the reference period due to data unavailability. However, sensitivity can change greatly over time if values from one or more indicators evolve greatly. For example, land subsidence due to over-pumping caused by expansion of urban areas in river deltas can provoke saltwater intrusion and hence increased competition for available freshwater resources. In addition, parameters not considered for RICCAR due to data limitations such as soil salinization and water quality degradation can increase sensitivity.

In the absence of available adaptation measures, potential impact is expected to increase under both RCP 4.5 and RCP 8.5 from mid- to end-of-century. For all scenarios, the majority of the area can anticipate moderate potential impact, affecting 90% (RCP 8.5) to 94% (RCP 4.5) of the study area at mid-century (Figure 155 and Figure 156) and 79% (RCP 8.5) to 89% (RCP 4.5) of the study area at end-century (Figure 157 and Figure 158). Areas of high potential impact reflect 4% (RCP 4.5) to 10% (RCP 8.5) of the study area at mid-century, and 9% (RCP 4.5) to 21% (RCP 8.5) at end-century. Areas with high projected potential impact tend to be the same as those with high projected exposure.

With respect to trends from mid- to end-century, areas that generally exhibit increasing potential impact under RCP 4.5 are the western Sahel and the lower Nile River Valley. Croplands revealing declining potential impact for RCP 4.5 include the Tigris–Euphrates basin and the Jubba–Shabelle river valleys. For RCP 8.5, the entire Sahel indicates decreasing potential impact, as well as the Tigris–Euphrates basin. Crop areas located in the central Sahara Desert exhibit increasing potential impact under RCP 8.5.

FIGURE 155: Water available for crops – Mid-century RCP 4.5 – Potential impact

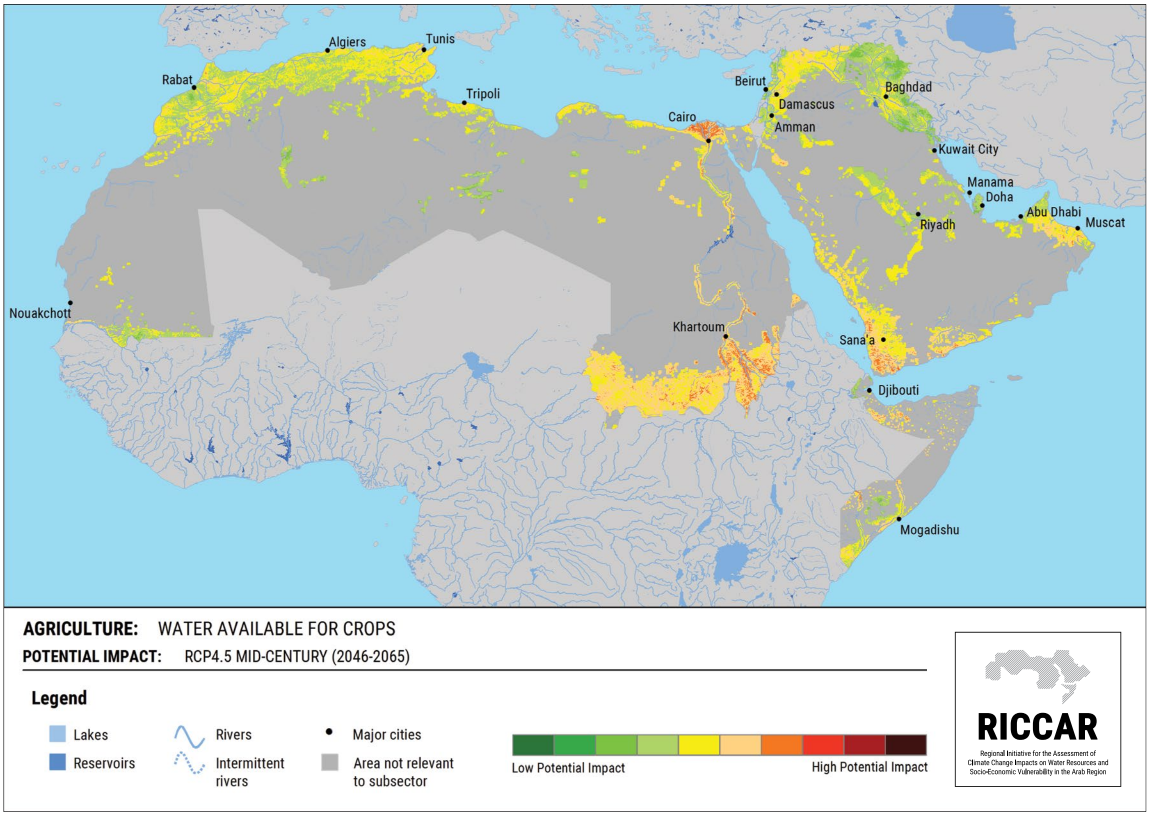


FIGURE 156: Water available for crops – Mid-century RCP 8.5 – Potential impact

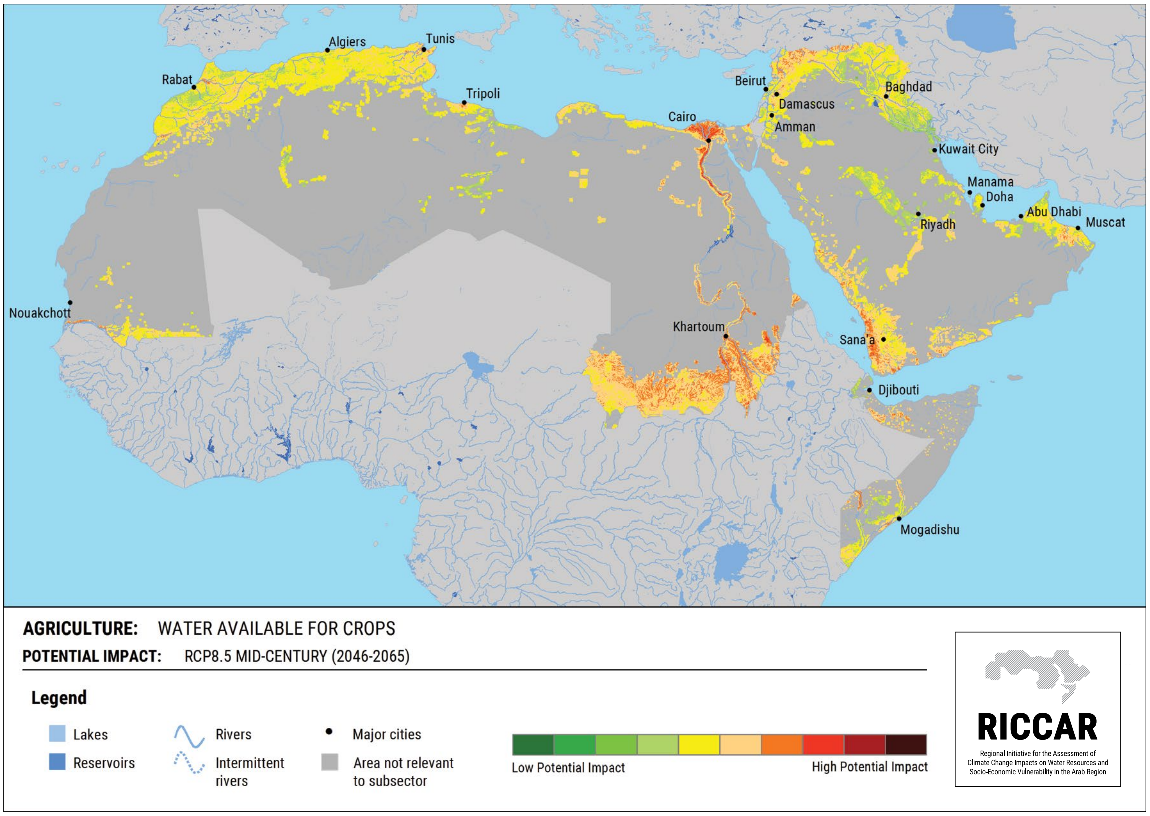


FIGURE 157: Water available for crops – End-century RCP 4.5 – Potential impact

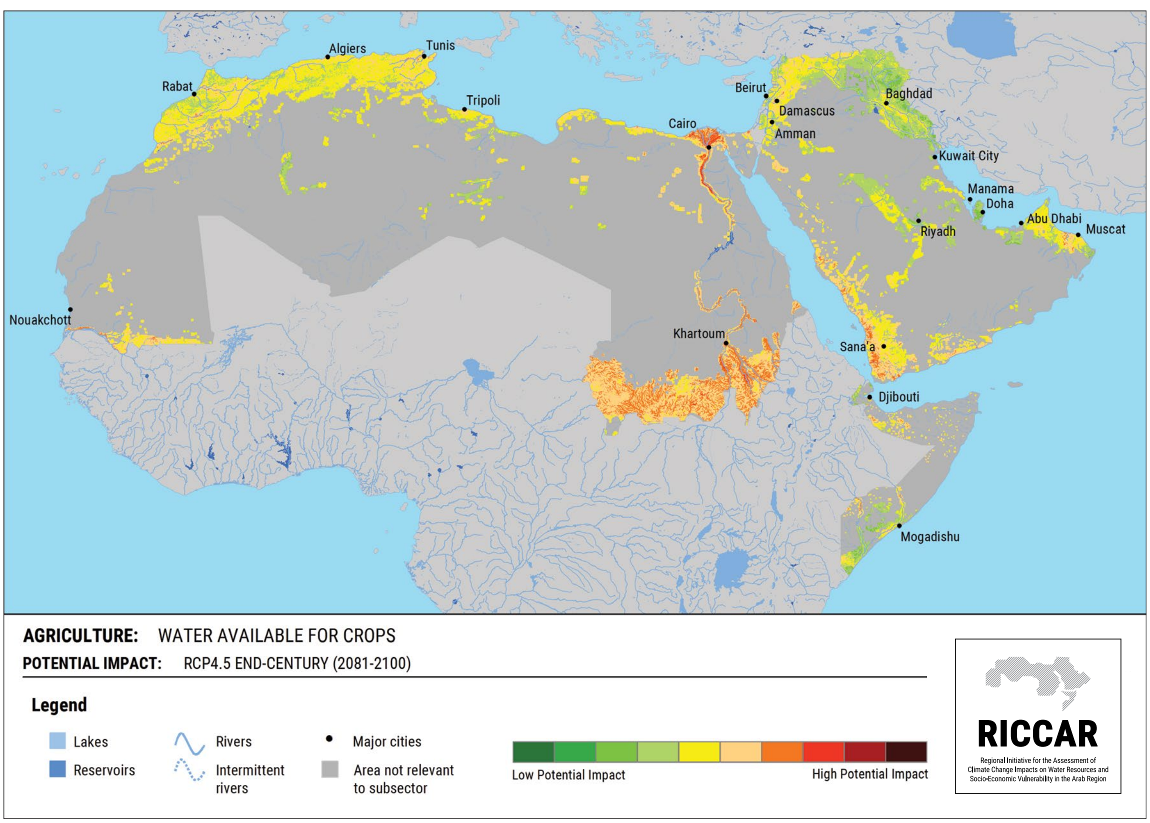
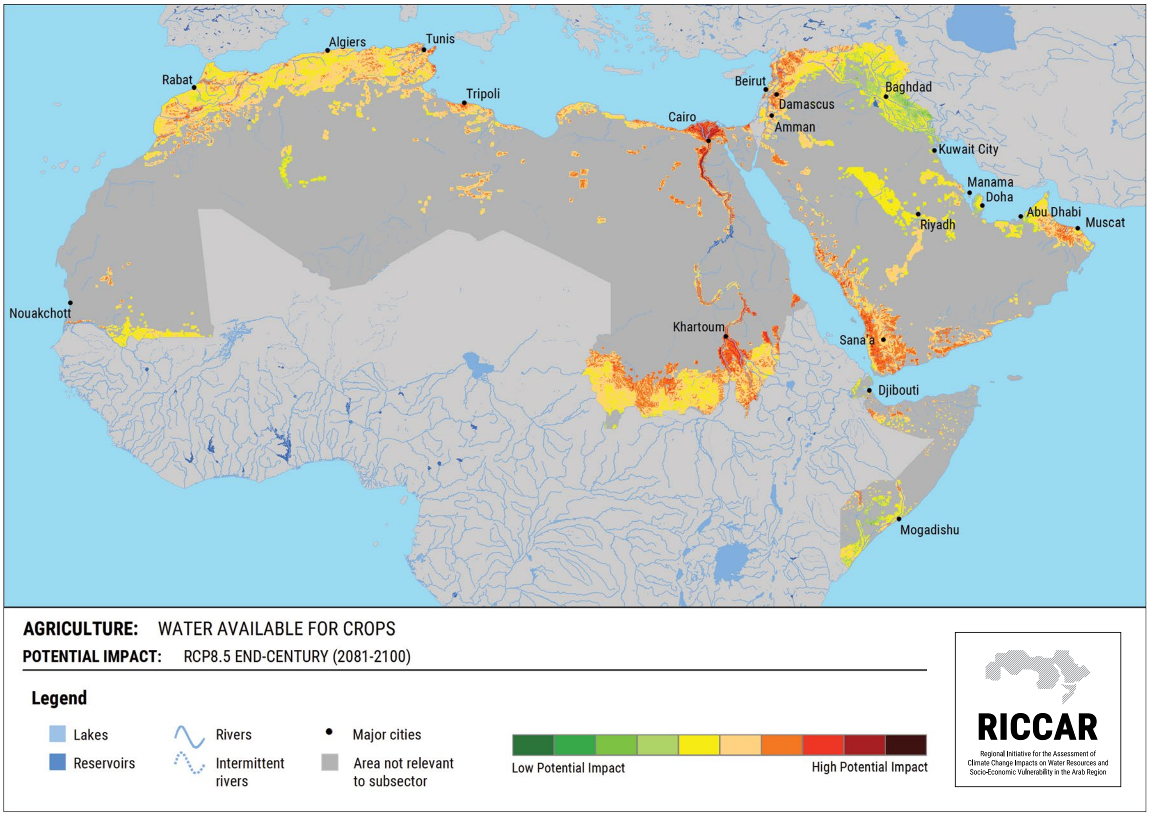


FIGURE 158: Water available for crops – End-century RCP 8.5 – Potential impact



11.1.2.2 Vulnerability

Croplands throughout the Arab region can be expected to endure moderate-to-high future vulnerability. At mid-century, 50% (RCP 4.5) to 67% (RCP 8.5) of the study area project high vulnerability and 57% (RCP 4.5) to 84% (RCP 8.5) signify high vulnerability at end-century (Table 25). Water demand for selected crops in the Arab region are presented in Table 26. Croplands which project relatively lower vulnerability include the Mediterranean coast of the Maghreb, the southern Grand Erg Oriental, parts of the Levant, the Tigris–Euphrates basin and the central eastern Arabian Desert (Figure 159 to Figure 162).

Vulnerability exhibits a strong correlation with adaptive capacity and a modest correlation with sensitivity. Correlation with exposure is relatively weak. Thus, improvements in adaptive capacity will have the greatest impact upon reducing vulnerability.
These measures can include improvement in water infrastructure and irrigation efficiency, as well as the use of non-conventional water resources such as wastewater re-use. An example of a success story in this regard is the Gezira Scheme.

TABLE 25: Percentage of study area by vulnerability classification for water availability for crops

Scenario	Vulnerability (% of study area)		
	Low	Moderate	High
Mid-Century RCP 4.5	0%	50%	50%
Mid-Century RCP 8.5	0%	33%	67%
End-Century RCP 4.5	0%	43%	57%
End-Century RCP 8.5	0%	16%	84%

TABLE 26: Water demand for selected crops in the Arab region

Crop	Virtual water demand (m^3 per ton)
Bananas	200–2,300
Millet	2,000–18,000
Palm	1,200–14,000
Potato	100–1,800
Sorghum	800–23,000
Tomato	100–600

Source: Hoekstra and Hung, 2002

FIGURE 159: Water available for crops – Mid-century RCP 4.5 – Vulnerability

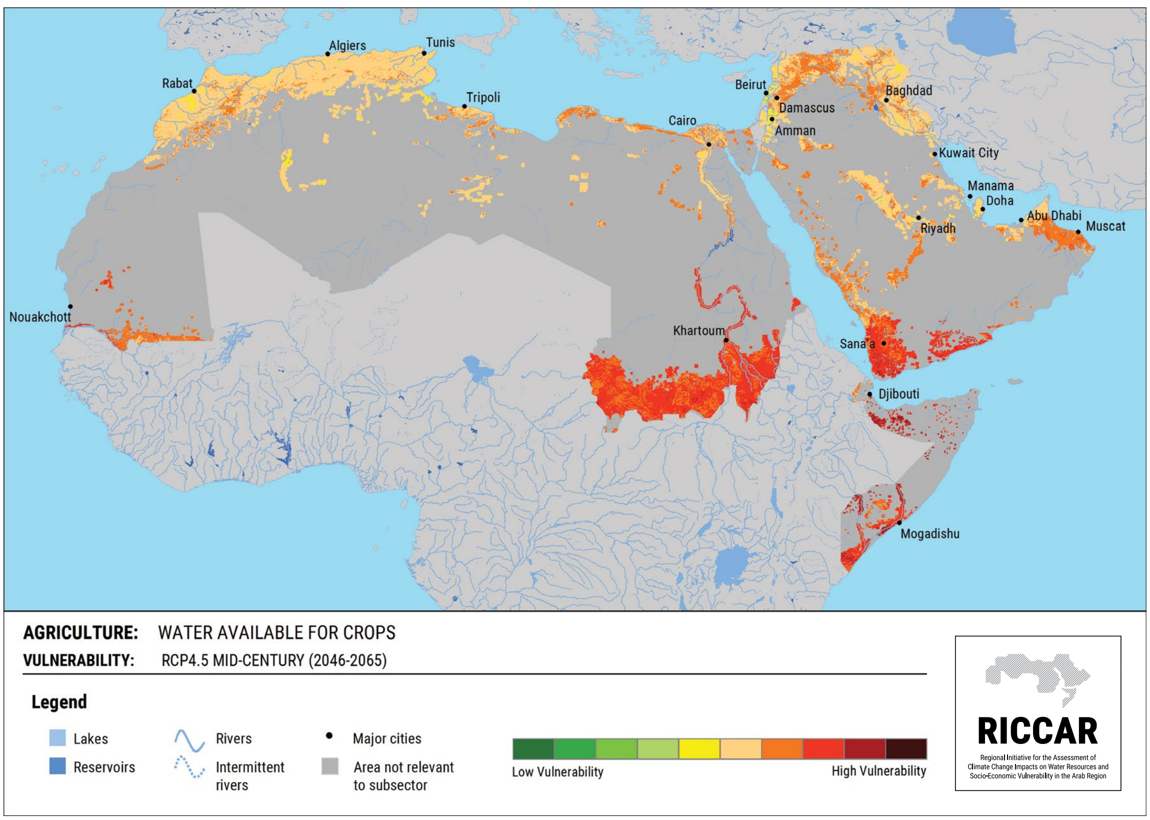


FIGURE 160: Water available for crops – Mid-century RCP 8.5 – Vulnerability

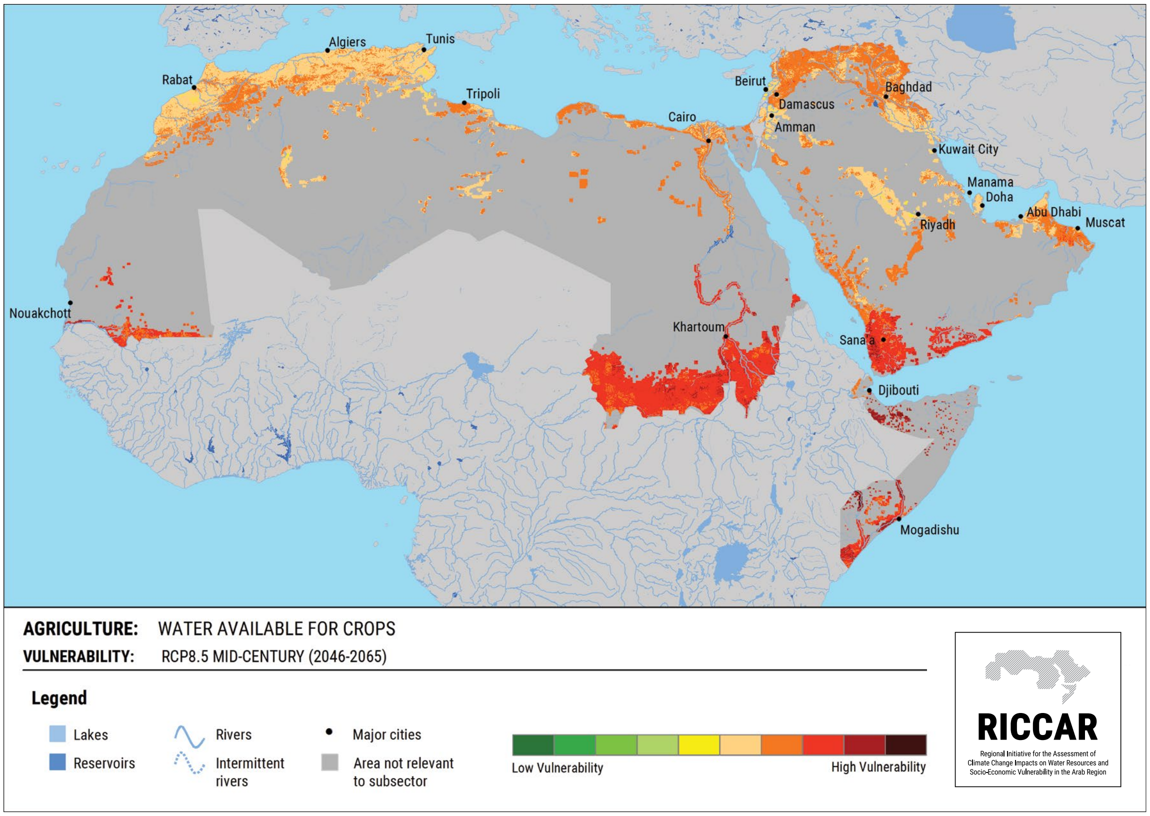


FIGURE 161: Water available for crops – End-century RCP 4.5 – Vulnerability

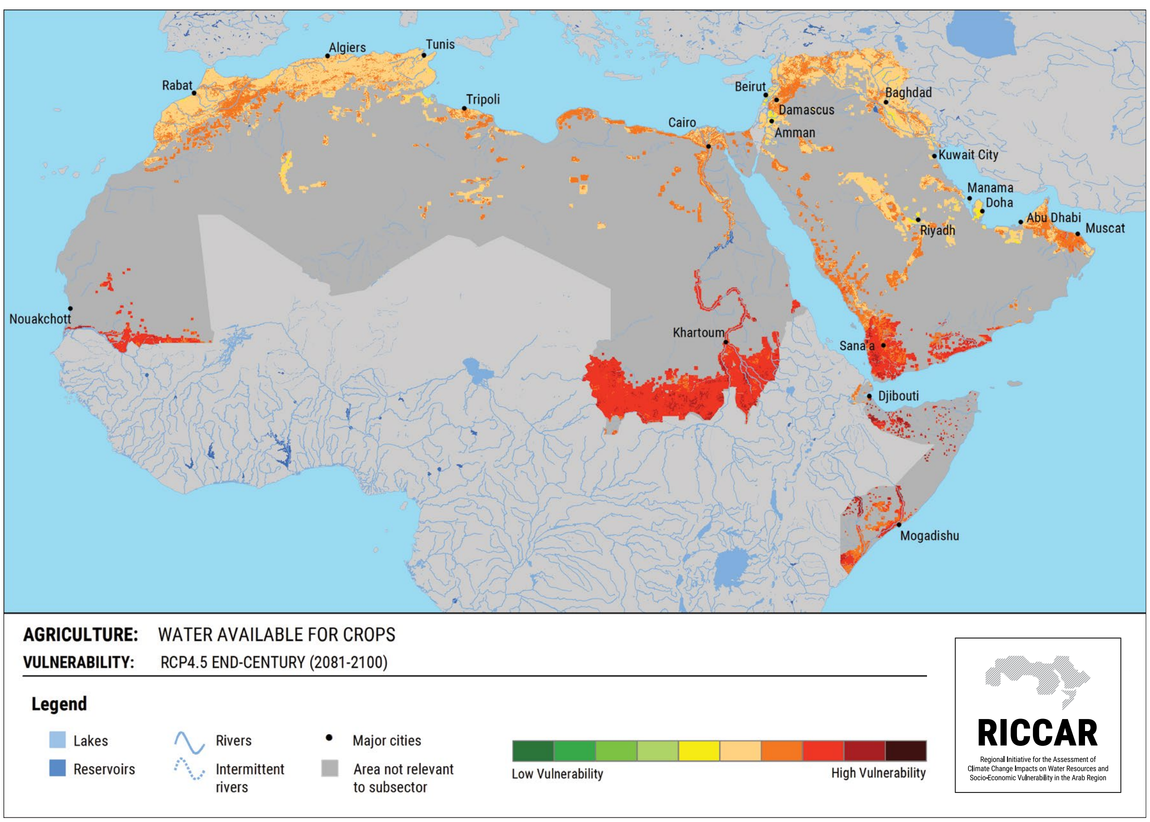
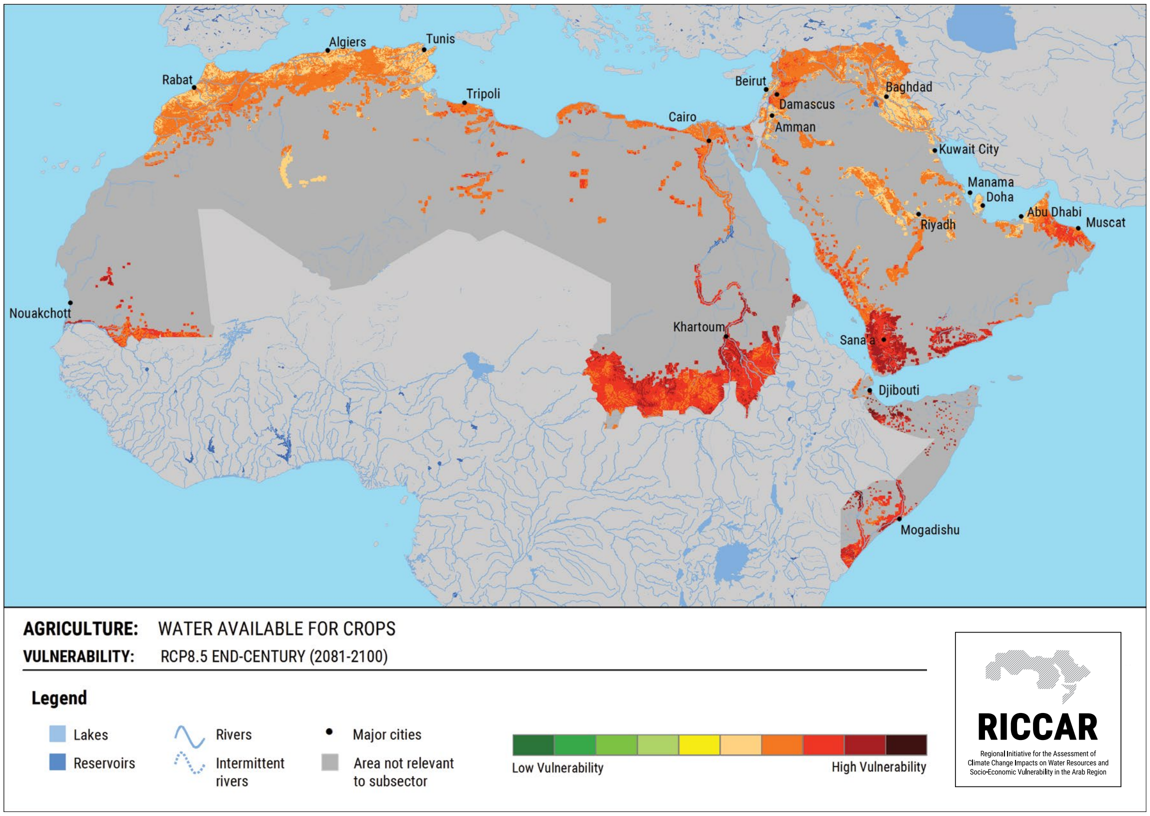


FIGURE 162: Water available for crops – End-century RCP 8.5 – Vulnerability



11.1.3 Hotspots

Hotspots are the most critical areas of high vulnerability, where resources are ideally allocated to relieve water scarcity. Up to 6% of the study area represents cropland hotspots. They include croplands of sub-Saharan Africa, the Horn of Africa and the south-western Arabian Peninsula. Among the crops grown in these locations are sorghum, sugarcane, millet, sesame, potatoes and mangoes, many of which need large quantities of water.

Croplands in these areas are largely rainfed and thus subject to projected decreases and variability in precipitation. The Horn of Africa projects increasing rainfall, so crops will benefit, but it also has the lowest adaptive capacity.

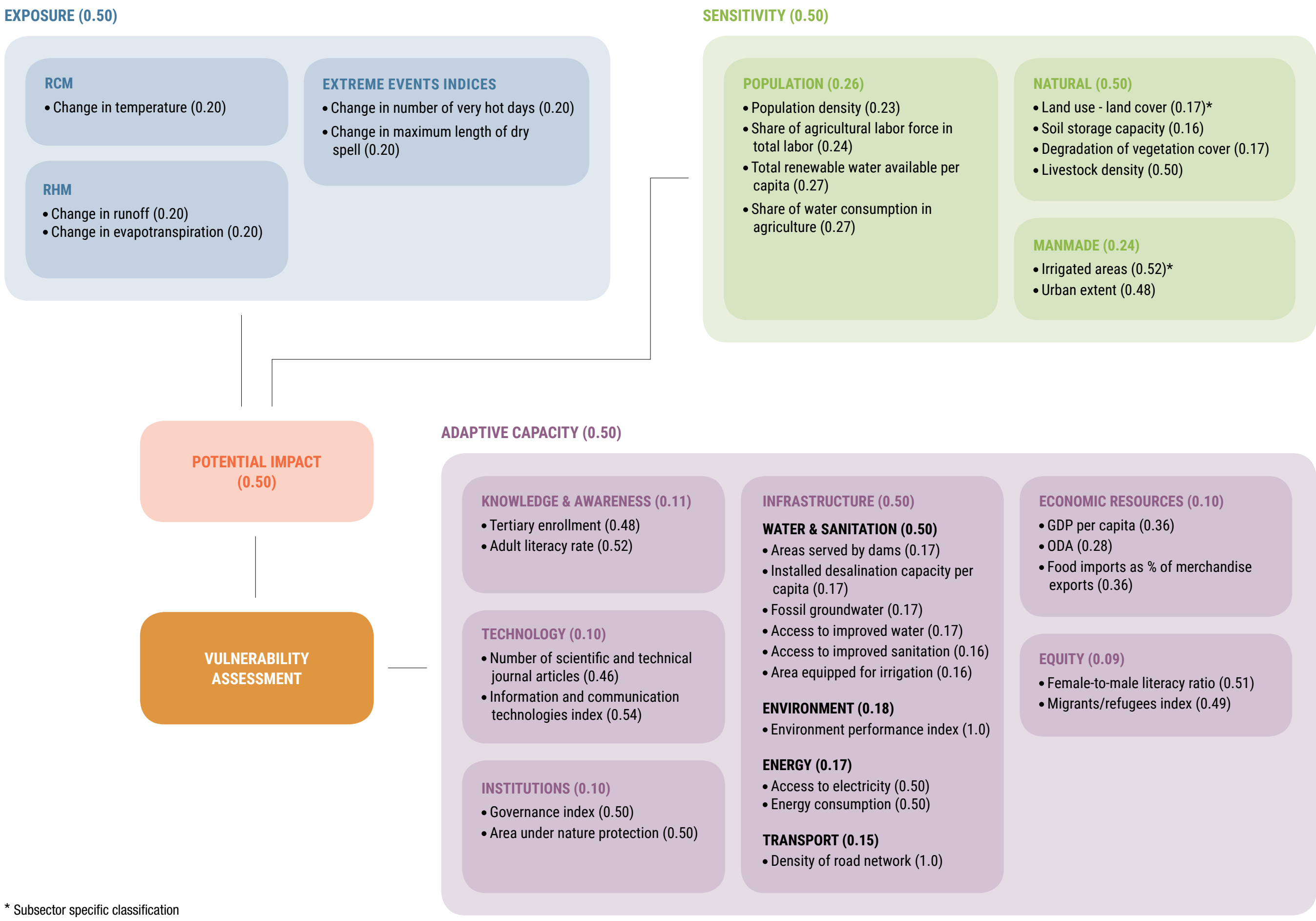
Some cropland hotspots are irrigated and will benefit the most from improvements in infrastructure.

Wasi El Masad, Iraq, 2013. Source: Sadeq Oleiwi Sulaiman.

11.2 WATER AVAILABLE FOR LIVESTOCK

The different indicators used under each component for this subsector and their corresponding weights are presented in the impact chain (Figure 163).

FIGURE 163: Impact chain and weights for water available for livestock



* Subsector specific classification

11.2.1 Reference period

11.2.1.1 Potential impact

Potential impact reveals the composite of exposure and sensitivity. In the Arab region, the recent estimated livestock population (2013) comprised 136 million sheep, 66 million goats, 23 million cattle and 6 million camels.[4] Livestock water demand is very high when considering all virtual water, which includes water for drinking, servicing and feed (Table 27). This water demand depends on several meteorological factors. Hydrologically, runoff contributes toward direct water demand and evapotranspiration rates control feed production and grazing capabilities. High temperatures and dry spells can induce heat stress, thereby increasing water demand and causing rangeland mortality.

For these reasons, temperature, runoff, evapotranspiration, the number of very hot days (SU40), and maximum length of dry spell (CDD) were selected as exposure indicators. The study area is divided fairly equally between low, moderate and high aggregated exposure (26%, 42%, and 31%, respectively) for the reference period. Areas of high exposure include the southern Tindouf basin, the White and Blue Nile rivers near Khartoum, livestock areas in the central and eastern Arabian Desert near the Gulf coastline, and the lower Tigris–Euphrates basin.

Several factors can induce stress in livestock and their corresponding water demand, including competing sectors and rangeland degradation. These elements are reflected in the selected sensitivity indicators. A majority (66%) of the study area is indicative of low sensitivity. However, almost one third of the area suggests moderate sensitivity with isolated areas of high sensitivity.

Sensitivity signals the strongest correlation with population density, due to competition for water resources, followed by irrigated areas, urban extent and livestock density.

Areas of moderate-to-high sensitivity include the lower Nile River and Delta, as well as some isolated areas in the Levant and the Asir Mountains.

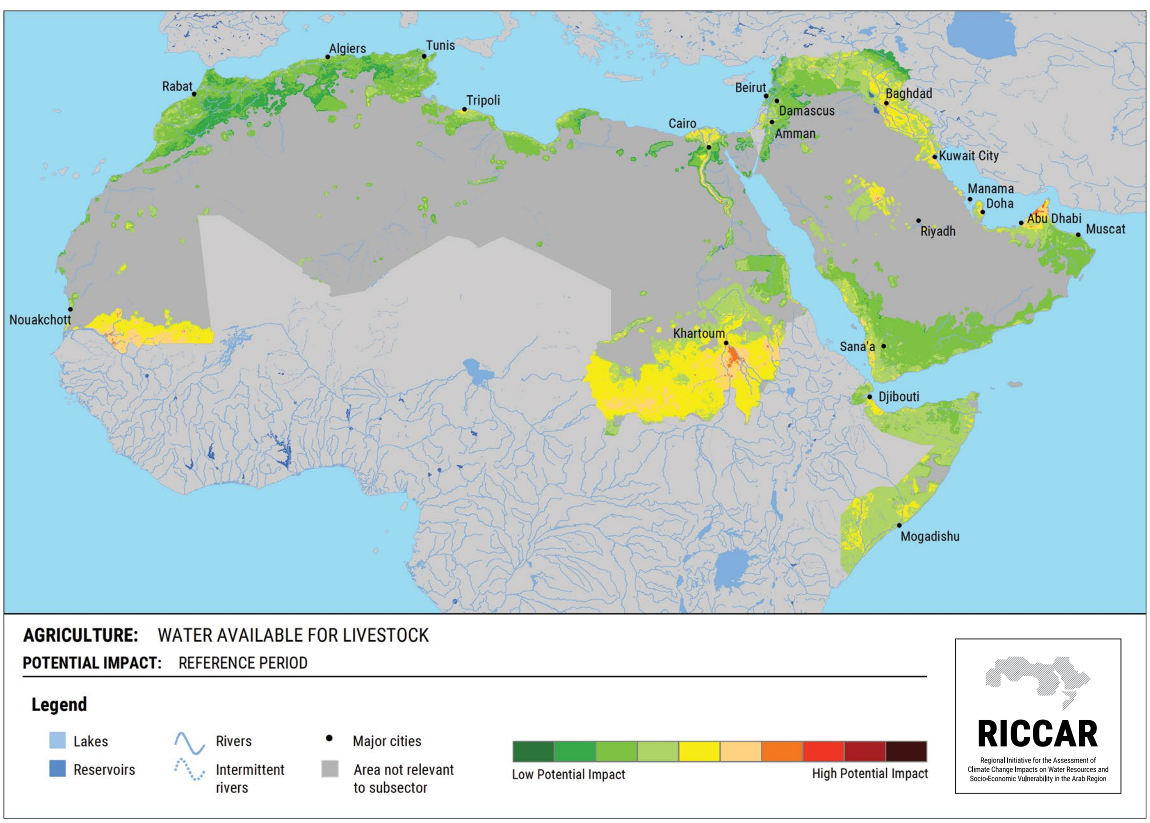
Over half (59%) of the study area has revealed moderate potential impact for the reference period. Less than 1% of the region suggests high potential impact and remaining areas indicate low potential impact. Areas of moderate-to-high potential impact include the Blue Nile valley just south of Khartoum and the lower Gulf near the Strait of Hormuz (Figure 164).

TABLE 27: Virtual water content of selected livestock in the Arab region

Animal	Total virtual water (m^3/t over life span)
Beef cattle	9,400–40,100
Dairy cows	89,000–330,000
Sheep	5,600–10,400
Goats	2,800–9,000

Source: Chapagain and Hoekstra, 2003

FIGURE 164: Water available for livestock – Reference Period – Potential impact

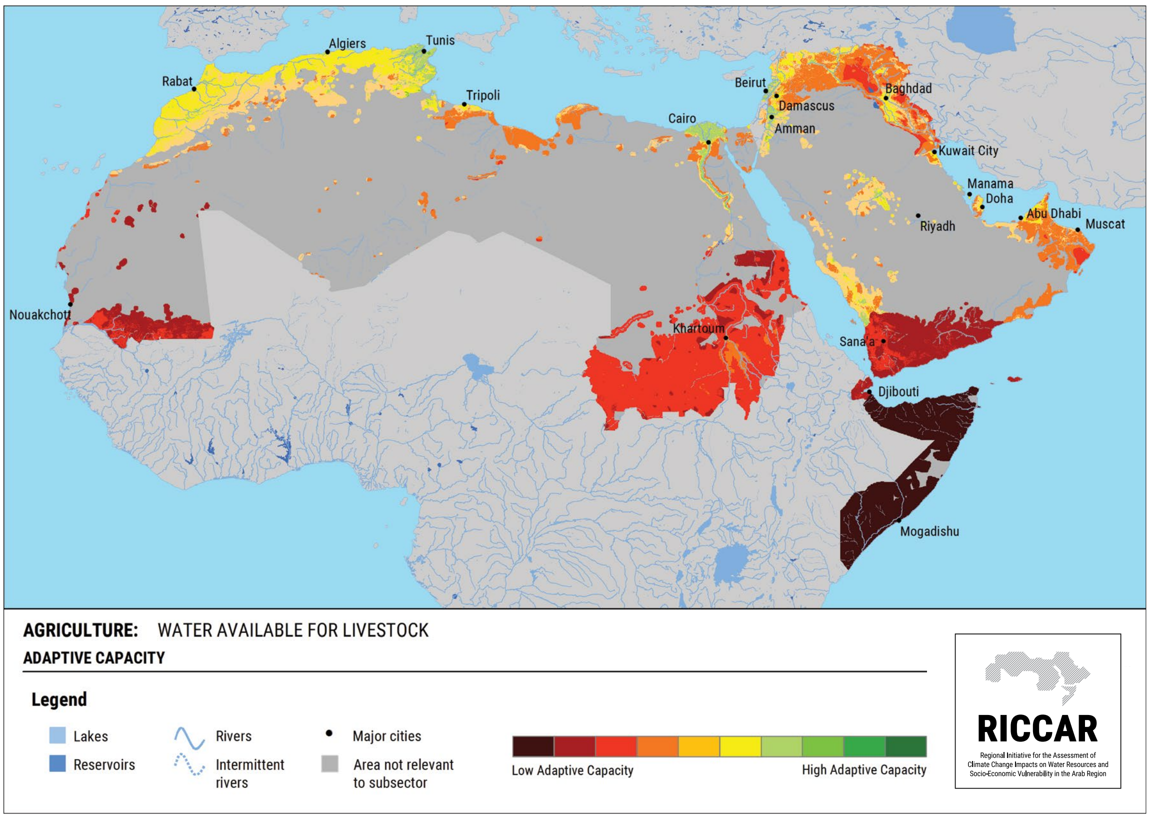


11.2.1.2 Adaptive capacity

In the Arab region, pastoralists have adopted some of their own adaptation measures to mitigate water scarcity for livestock through various government approaches.[5] Practices include investment in water infrastructure, which has been weighted most in the impact chain, by utilizing wells, cisterns and water harvesting. Another practice is to encourage reduction of land degradation by implementing nomadic grazing, which minimizes foraging in a particular location.

Despite these efforts, much of the study area (53%) signals low adaptive capacity often due to factors beyond pastoralists' control. Coping mechanisms must consider different facets. For example, policies with regard to livestock are generally lacking. Loose regulations based on self-sufficiency have resulted in limited trade and weak inter-Arab investments in agriculture, restricting economic development. Emphasis has been placed on increasing livestock production to meet demand, which entails cheaper food options for the urban population, but neglects those in rural areas. Gender also plays a role as women often do not own livestock but take care of them. Areas of low adaptive capacity include livestock areas in sub-Saharan Africa, the south-western Arabian Peninsula and areas within the Tigris–Euphrates basin. Most of the remaining area (44%) indicates moderate adaptive capacity (Figure 165).

FIGURE 165: Water available for livestock – Adaptive capacity



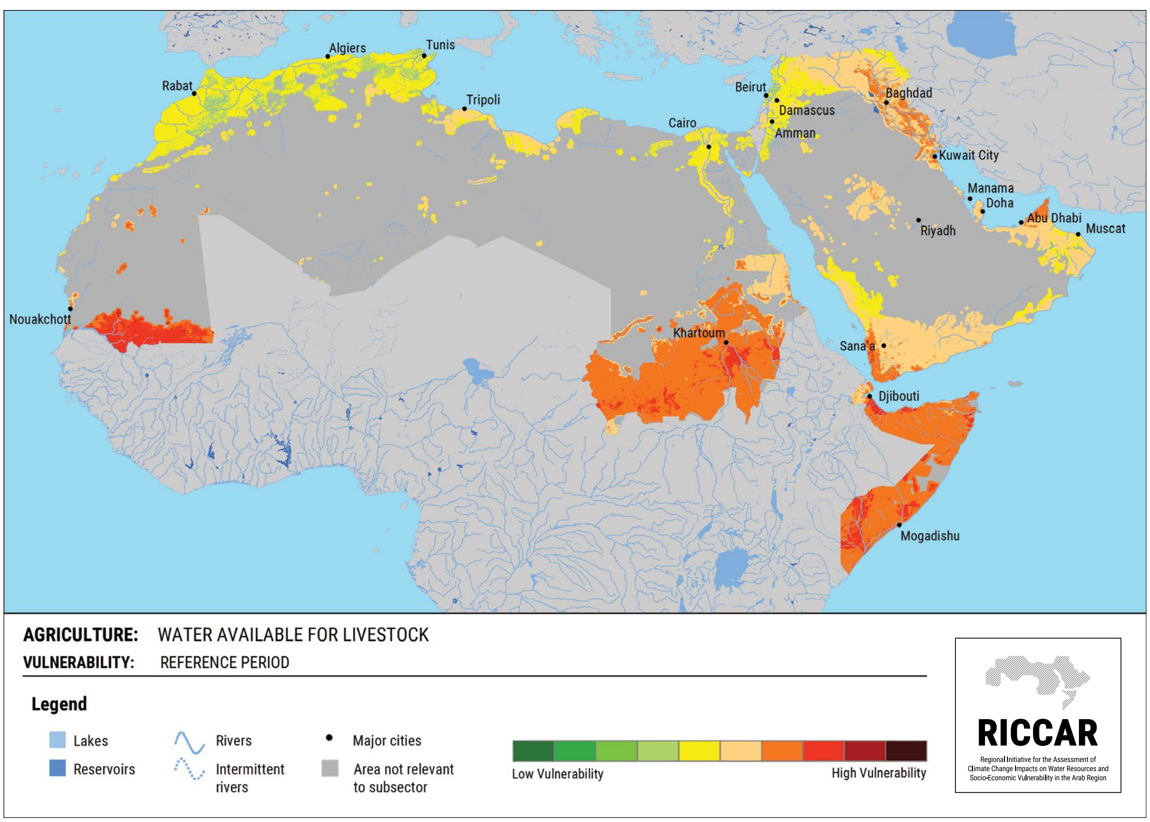
11.2.1.3 Vulnerability

The reference period signifies high vulnerability for 43% of the study area and remaining areas represent moderate vulnerability. Areas with the highest vulnerability include sections of the western Sahel, the Blue Nile River Valley just south of Khartoum, areas along the south Gulf of Aden coastline and areas within the Jubba River basin (Figure 166). Primarily, camels are impacted in the western Sahel and the Jubba River region. Goats, sheep, and cattle are raised in the Blue Nile River Valley and goats and sheep near the Gulf of Aden.

In the eastern Sahel, including the Blue Nile River Valley, livestock have long been faced with water scarcity. The region is characterized by high interannual precipitation variability. A wet phase during the 1950s and 1960s was followed by a dry phase extending into the reference period, including a drought in 1984/1985, which killed a considerable number of livestock. Resultant adaptation to climate variability has included a decreasing number of grazing cattle but an increase in sedentary draught and fattened cattle; expanding herd mobility and grazing/feeding patterns; income diversification; an increasing number of camels; and a movement of herds southwards towards more humid areas. In the Horn of Africa, which includes the southern Gulf of Aden coastline and the Jubba River region, the sector *Water available for livestock* is the largest contributor to local livelihoods. In Somalia, livestock and their products represent about 80% of all exports.[6] However, pastoralists in the region have faced many challenges such as fluctuating rainfall and drought. Drought leads to a decline in commodity prices which adversely impacts the livelihoods of pastoralists.

Livestock in Qadarf, Sudan, 2007. Source: Ihab Jnad.

FIGURE 166: Water available for livestock – Reference period – Vulnerability



11.2.2 Future periods

11.2.2.1 Potential impact

Livestock are subject to adverse impacts due to climate change, including increasing temperatures and declining water resources. Ruminants need increased water uptake in warmer weather. Rangeland areas can also perish. Lastly, disease vectors can multiply in warmer climates affecting animals' health. Changes in climatic variables reveal generally moderate future exposure, signalling 69% (RCP 8.5) to 76% (RCP 4.5) of the study area at mid-century and 53% (RCP 8.5) to 67% (RCP 4.5) at end-century. High exposure is revealed in 3% (RCP 4.5) to 23% (RCP 8.5) of the study area at mid-century and 18% (RCP 4.5) to 47% (RCP 8.5) at end-century. Remaining areas suggest low exposure. Areas with the highest exposure include the upper eastern Sahel, livestock areas in the Sahara Desert and coastal areas near the Gulf of Aden. Conversely, areas with the lowest projected exposure include the coastal Atlas Plains and the Rif region, the lower Tigris–Euphrates basin and the Green Mountains in Libya.

Assuming static sensitivity, a majority of the region signals moderate potential impact for the future. Specifically, at mid-century (Figure 167 and Figure 168), 58% (RCP 4.5) to 74% (RCP 8.5) of the study area reveals moderate potential impact and this increases to 66% (RCP 4.5) to 89% (RCP 8.5) at end-century (Figure 169 and Figure 170). Most other areas suggest low potential impact, although at end-century (RCP 8.5), a trace (1% of the study area) of high potential impact is revealed. Areas with the highest potential impact include the lower Nile River and Delta, the Blue Nile Valley just south of Khartoum and the Asir Mountains. Trend analysis indicates the largest increases in potential impact from mid- to end-century (RCP 4.5) in the western Sahel and the lower Nile Valley. The largest decreases in potential impact under RCP 4.5 include the Tigris–Euphrates basin, Al Hajar Mountains in Oman/UAE and the Shabelle River Valley in the Horn of Africa. For RCP 8.5, the Tigris–Euphrates basin exhibits a decreasing trend in potential impact and the lower Nile Valley shows an increasing trend, but the other areas described (western Sahel, Al Hajar Mountains and the Shabelle River Valley) signal an opposite trend from RCP 4.5.

Potential impact can be significantly impacted by changes in sensitivity to include population growth, differing livestock population and distribution and land degradation. Potential impact can also vary due to factors not evaluated. These include livestock diseases such as Rift valley fever, which have harmed livestock trade between the Horn of Africa and the Arabian Peninsula, which was exacerbated by lack of access to veterinary service.

FIGURE 167: Water available for livestock – Mid-century RCP 4.5 – Potential impact

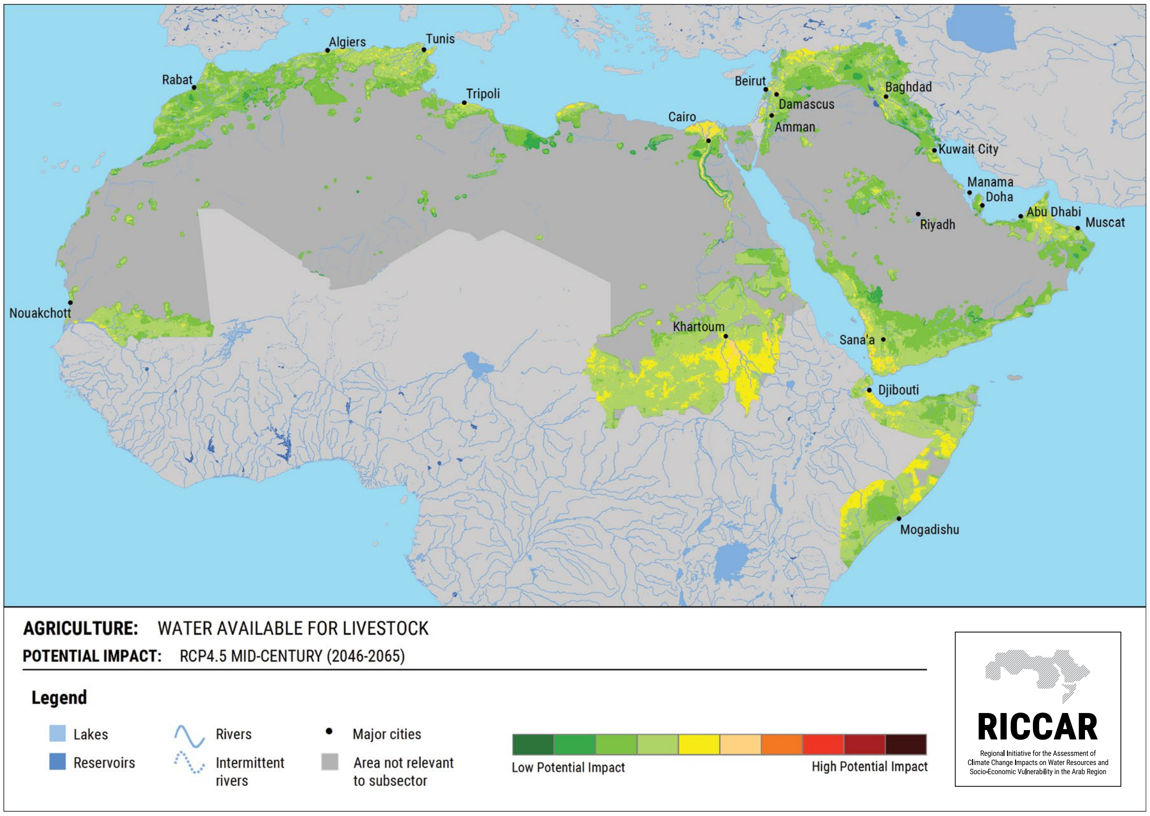


FIGURE 168: Water available for livestock – Mid-century RCP 8.5 – Potential impact

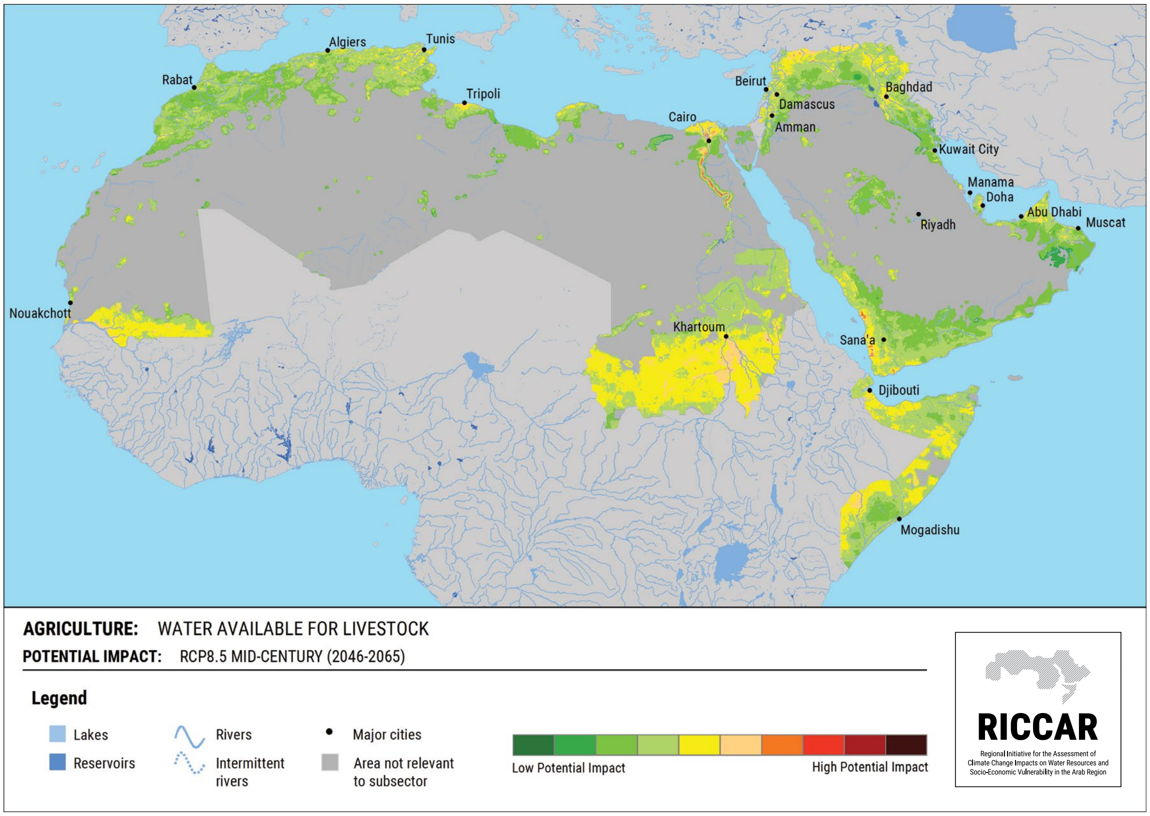


FIGURE 169: Water available for livestock – End-century RCP 4.5 – Potential impact

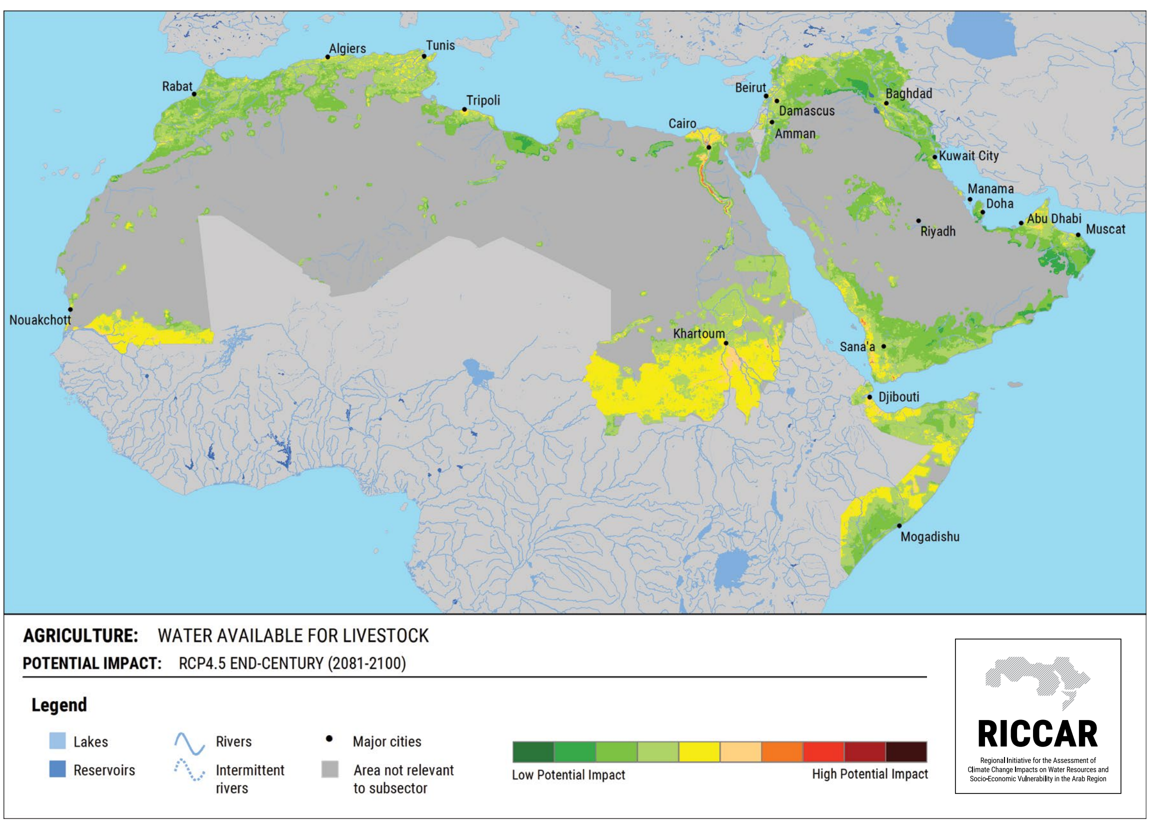
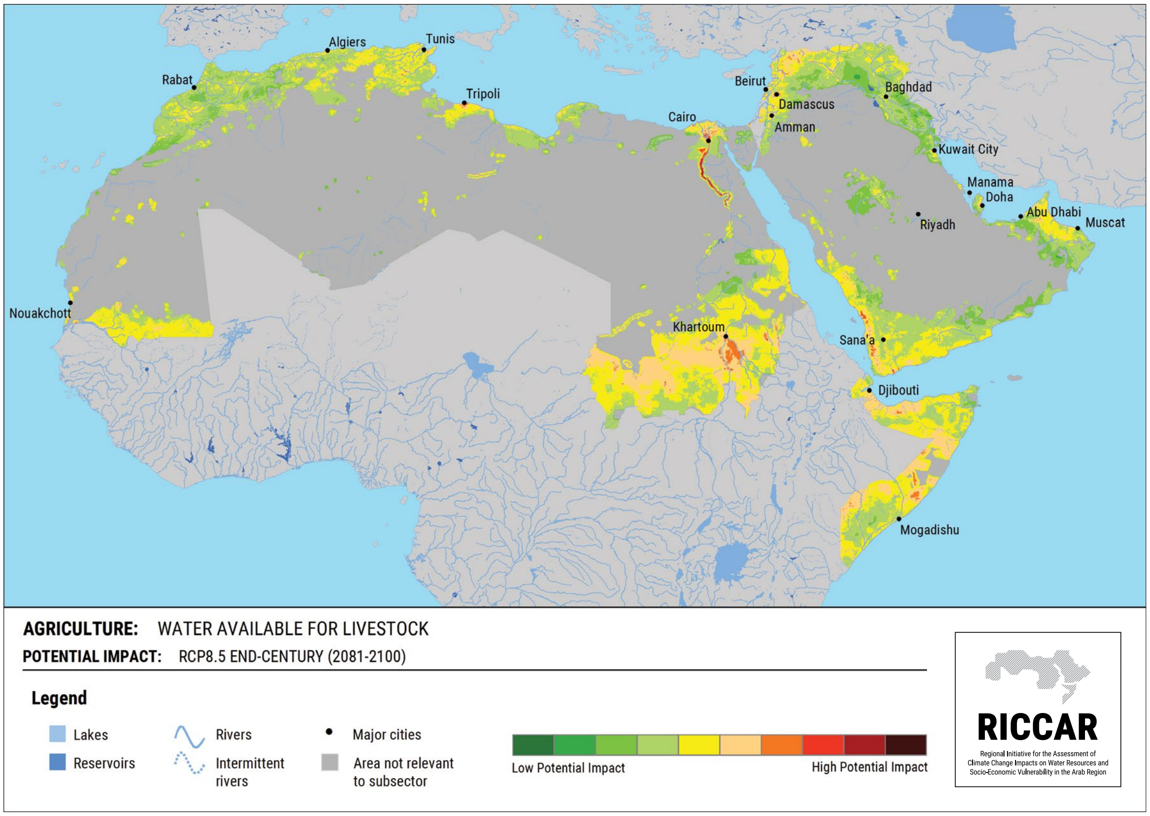


FIGURE 170: Water available for livestock – End-century RCP 8.5 – Potential impact



11.2.2.2 Vulnerability

Projected vulnerability rerated to water availability for livestock is either moderate or high. At mid-century, 33% (RCP 4.5) to 45% (RCP 8.5) of the study area shows high vulnerability and increases to 42% (RCP 4.5) to 54% (RCP 8.5) at end-century (Table 28).

Areas with relatively lower vulnerability tend to be in the Atlas Mountains and Plains and the central Arabian Desert; both exhibit comparatively higher adaptive capacity and lower potential impact. Areas with high vulnerability are located in sub-Saharan Africa, the Levant, the upper Tigris–Euphrates basin and the Al Hajar Mountains (Figure 171 to Figure 174).

Due to dynamic exposure and static sensitivity and adaptive capacity, increasing and decreasing trends in vulnerability tend to be parallel to potential impact trends. Nonetheless, for RCP 4.5, differences between mid- and end-century vulnerability tend to be relatively small, but changes under RCP 8.5 are more pronounced, revealing increasing vulnerability.

Up to 86% of the camel population (Table 29) is located in areas of high vulnerability. Luckily, camels are able to withstand changes in body temperature and water consumption to a much greater extent than other animals; even if they are located in highly vulnerable areas, the resulting impact on camels may be low.

The cattle and goat populations are also to a large extent located in areas of high vulnerability (up to 77% and 72%, respectively) and may be strongly impacted by changes in water availability. Sheep, however, are mostly located in areas of moderate vulnerability (up to 67%).

Vulnerability can be reduced by adopting adaptive capacity measures, often based on applied agricultural research. These can include methods to enhance knowledge and awareness. Integrated crop livestock systems, agroforestry systems and crop–aquaculture systems can help to promote agricultural diversification. Finally, improved water infrastructure can benefit intensive livestock farming.

TABLE 28: Percentage of study area by vulnerability classification for water availability for livestock

Scenario	Vulnerability (% of study area)		
	Low	Moderate	High
Mid-Century RCP 4.5	0%	67%	33%
Mid-Century RCP 8.5	0%	55%	45%
End-Century RCP 4.5	0%	58%	42%
End-Century RCP 8.5	0%	46%	54%

TABLE 29: Percentage of ruminant population by vulnerability classification for each projected scenario

Ruminant	Climate scenario	Percentage of population by vulnerability classification	
		Moderate	High
Camels	Mid-Century RCP 4.5	35%	65%
	Mid-Century RCP 8.5	21%	79%
	End-Century RCP 4.5	25%	75%
	End-Century RCP 8.5	14%	86%
Cattle	Mid-Century RCP 4.5	34%	66%
	Mid-Century RCP 8.5	27%	73%
	End-Century RCP 4.5	29%	71%
	End-Century RCP 8.5	23%	77%
Goats	Mid-Century RCP 4.5	44%	56%
	Mid-Century RCP 8.5	37%	63%
	End-Century RCP 4.5	39%	61%
	End-Century RCP 8.5	28%	72%
Sheep	Mid-Century RCP 4.5	67%	33%
	Mid-Century RCP 8.5	61%	39%
	End-Century RCP 4.5	64%	36%
	End-Century RCP 8.5	52%	48%

FIGURE 171: Water available for livestock – Mid-century RCP 4.5 – Vulnerability

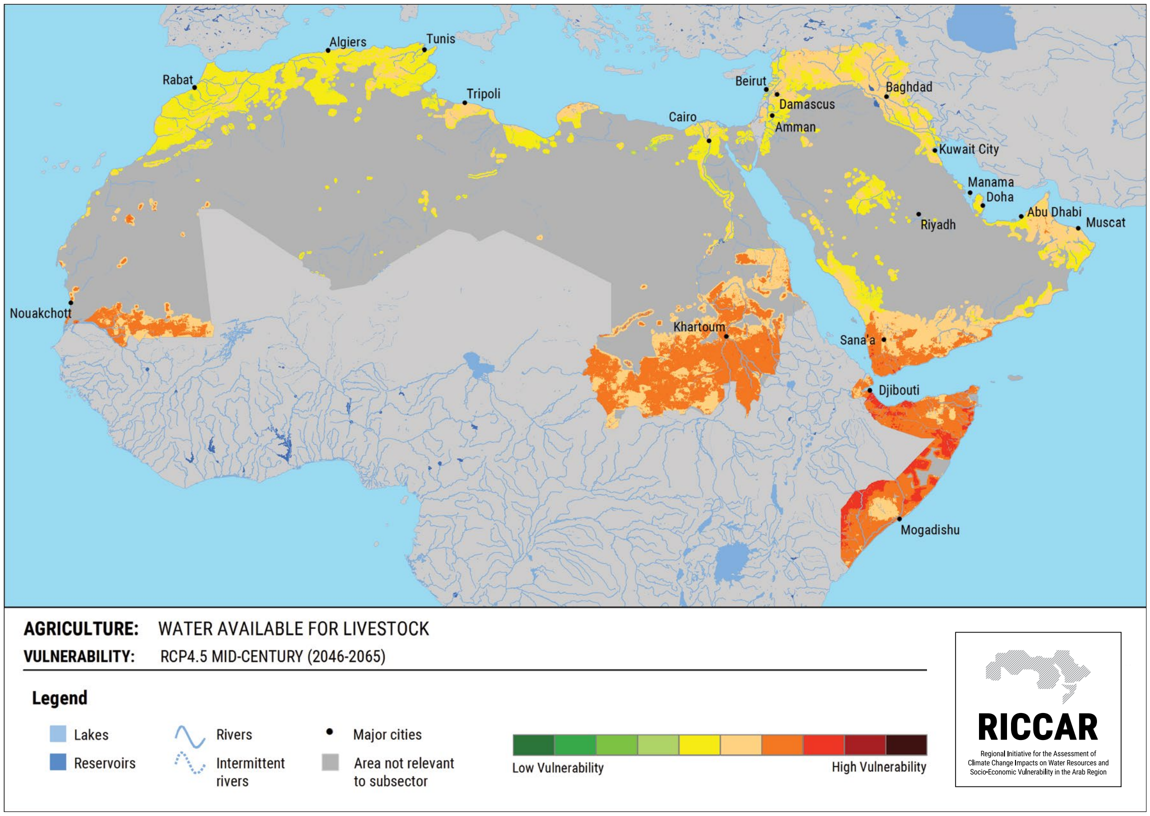


FIGURE 172: Water available for livestock – Mid-century RCP 8.5 – Vulnerability

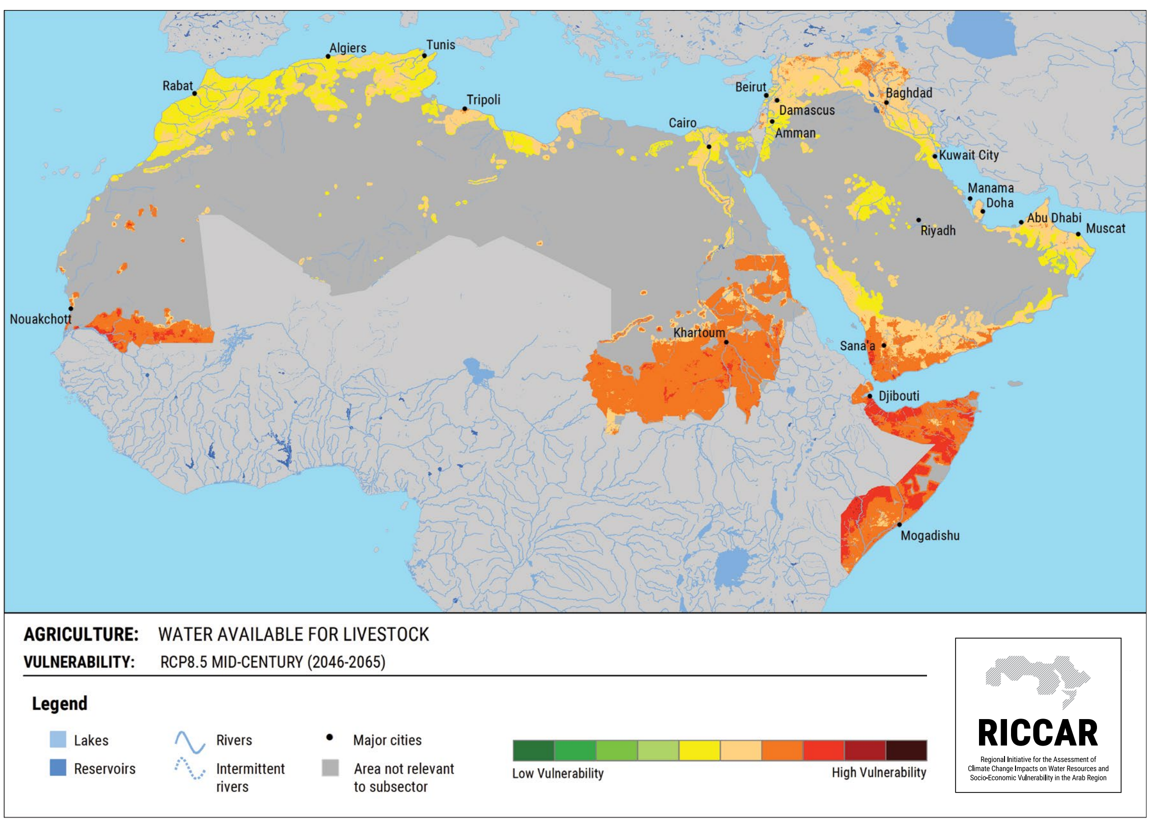


FIGURE 173: Water available for livestock – End-century RCP 4.5 – Vulnerability

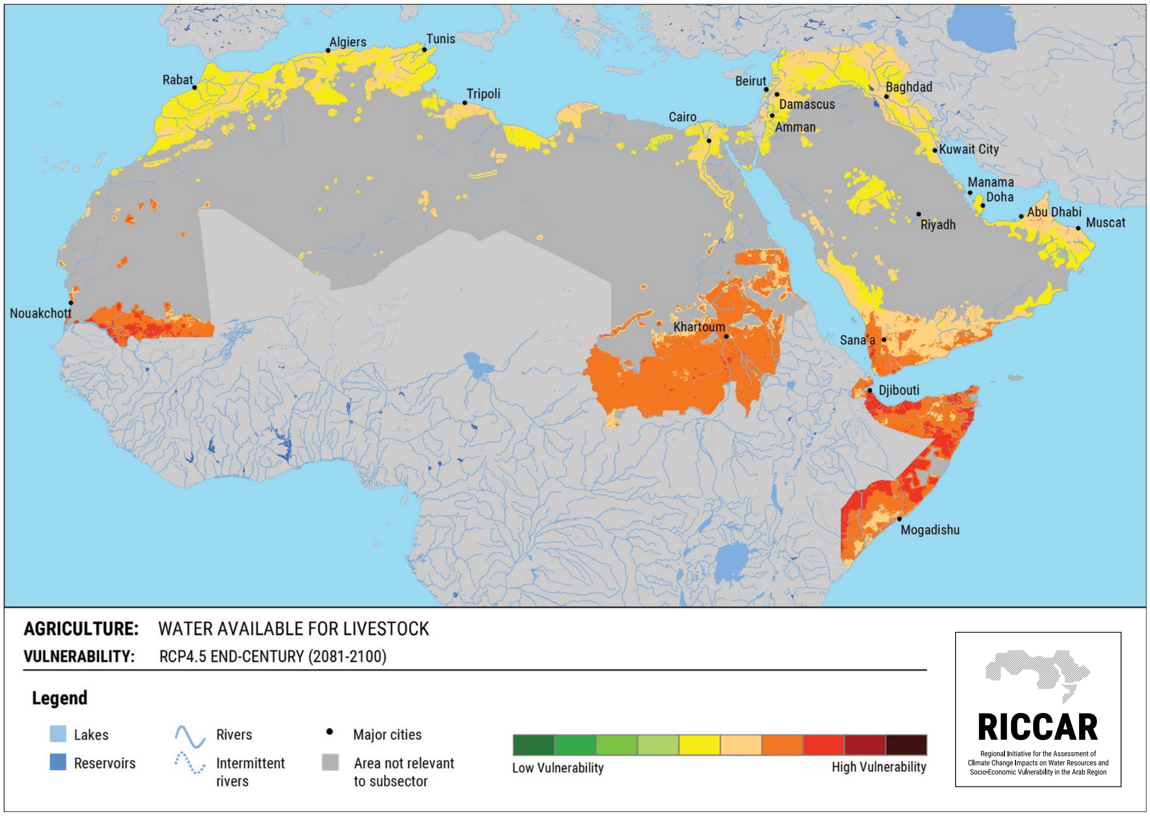
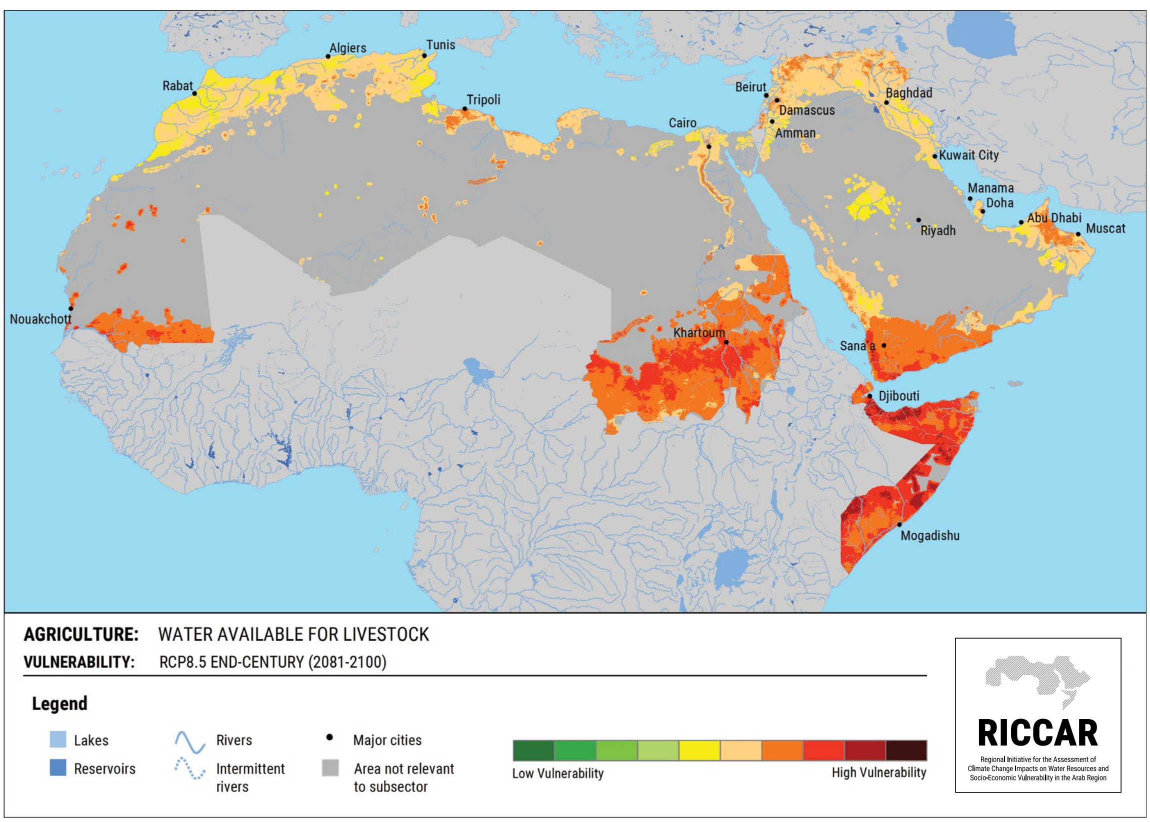


FIGURE 174: Water available for livestock – End-century RCP 8.5 – Vulnerability



11.2.3 Hotspots

Hotspots are those livestock areas subject to the highest projected vulnerability in terms of water availability. Up to 12% of the study area has been designated as hotspots, some of which are the Sahel, the south western Arabian Peninsula and the Horn of Africa.

All include a high camel population at present. Cattle and sheep tend to be confined to the eastern Sahel and the south-western Arabian Peninsula and goats are prevalent in all hotspots other than the western Sahel.

Severe vulnerability with regard to water availability for livestock can have detrimental impacts. During periods of drought, farmers are often forced to sell animals; in extreme cases, this means selling breeding stock, which constitute rural household wealth.

Insufficient fodder compels pastoralists to move to other rangelands, which can exacerbate land degradation in those areas. An option for sedentary herds is to buy hay or straw from irrigated farms or commercial traders.

11.3 AGRICULTURE SECTOR: OVERALL VULNERABILITY

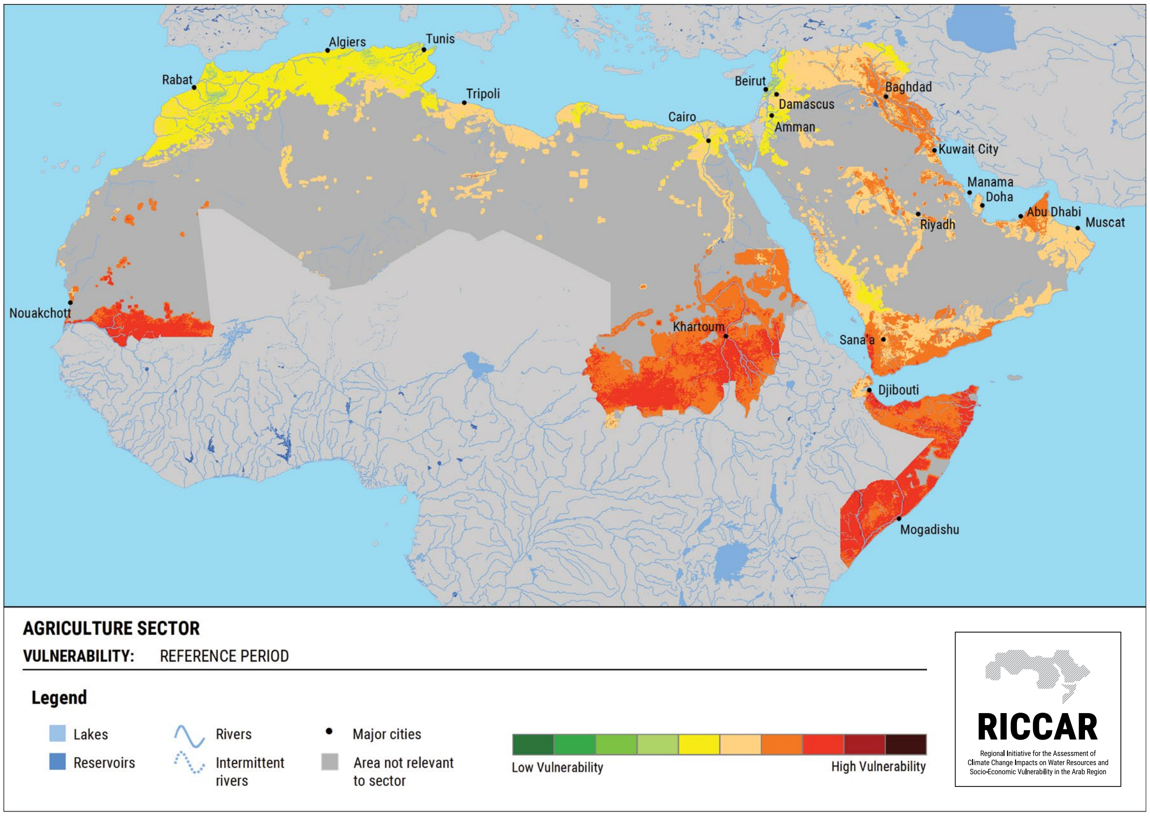
11.3.1 Reference period

Vulnerability for the *Agriculture* sector represents the equal aggregation of vulnerability obtained from the *Water available for crops* and *Water available for livestock* subsectors.

For the reference period, areas of moderate and high vulnerability represent 51% and 49% of the study area, respectively. Agricultural areas representing the highest relative vulnerability are the southern Horn of Africa and the Sahel, which includes both cropland and livestock areas (Figure 175).

Agriculture vulnerability signals a strong correlation with both subsectors but, of the two, the relationship is greater with water available for livestock. Thus, the threats on livestock have a greater impact on overall threats on agriculture.

FIGURE 175: Agriculture sector – Vulnerability – Reference period



11.3.2 Future periods

11.3.2.1 Vulnerability

As for the reference period, future vulnerability is fairly evenly divided between moderate and high vulnerability. For mid-century, 43% (RCP 4.5) to 49% (RCP 8.5) of the study area will experience high vulnerability and this will increase slightly to 46% (RCP 4.5) to 58% (RCP 8.5) of the study area at end-century (Table 30). No part of the study area denotes low vulnerability. Areas with relatively lower vulnerability include coastal areas of the Maghreb, agricultural areas in the Grand Erg Occidental Region, the central Arabian Desert, areas east of the Dead Sea and the lower Tigris–Euphrates basin.

Although vulnerability trends from mid- to end-century area are somewhat constant, some areas reveal differences as shown in Figure 176 to Figure 179. For RCP 4.5, increasing vulnerability is more evident in the Maghreb due to decreasing rainfall and runoff and in the western Sahel due to an increasing number of hot days and very hot days. Decreasing vulnerability is indicated for the Al Hajar Mountains.

The Maghreb also exhibits increasing vulnerability under RCP 8.5 but to a lesser extent. However, a reverse trend is noted for both the western Sahel and the Al Hajar Mountains under RCP 8.5. Lastly, agricultural areas in the upper eastern Sahel, central Sahara Desert, and south-western Arabian Peninsula reveal a generally increasing vulnerability under RCP 8.5.

TABLE 30: Percentage of study area by vulnerability classification for the agriculture sector

Scenario	Vulnerability (% of study area)		
	Low	Moderate	High
Mid-Century RCP 4.5	0%	57%	43%
Mid-Century RCP 8.5	0%	51%	49%
End-Century RCP 4.5	0%	54%	46%
End-Century RCP 8.5	0%	42%	58%

FIGURE 176: Agriculture sector – Vulnerability – Mid-century RCP 4.5

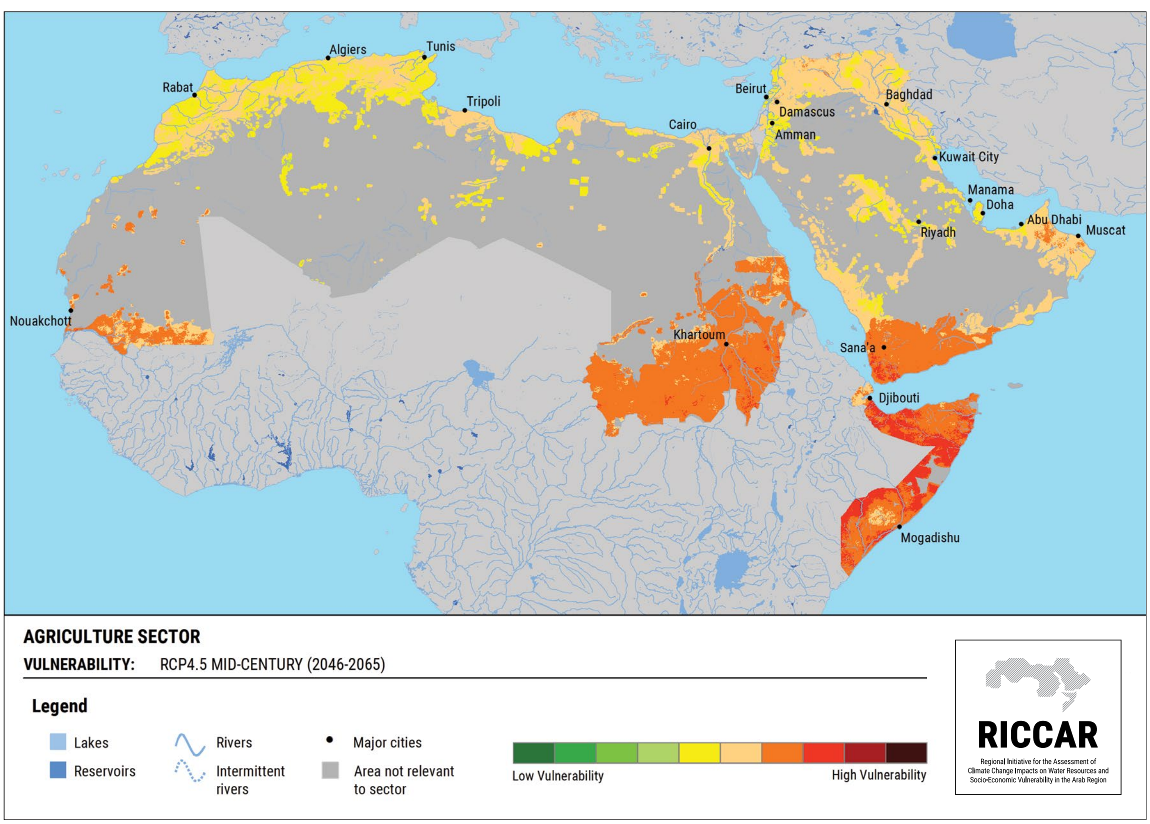


FIGURE 177: Agriculture sector – Vulnerability – Mid-century RCP 8.5

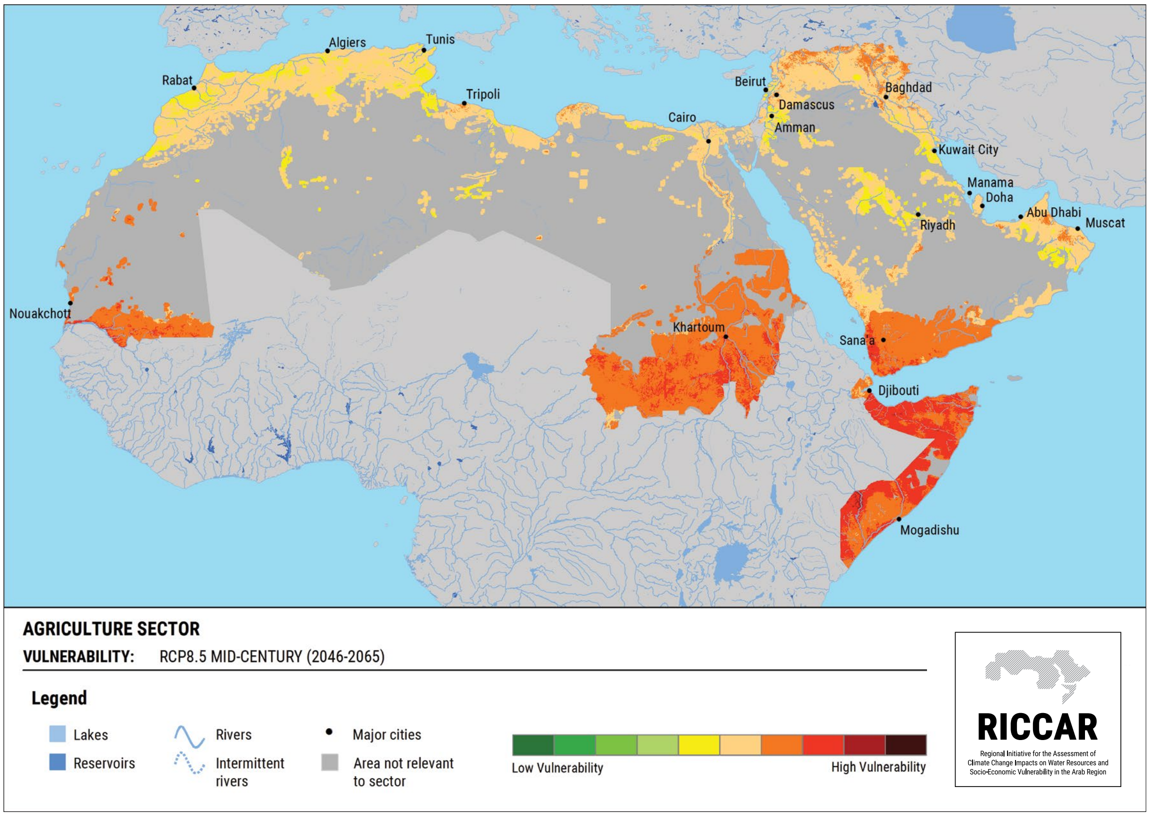


FIGURE 178: Agriculture sector – Vulnerability – End-century RCP 4.5

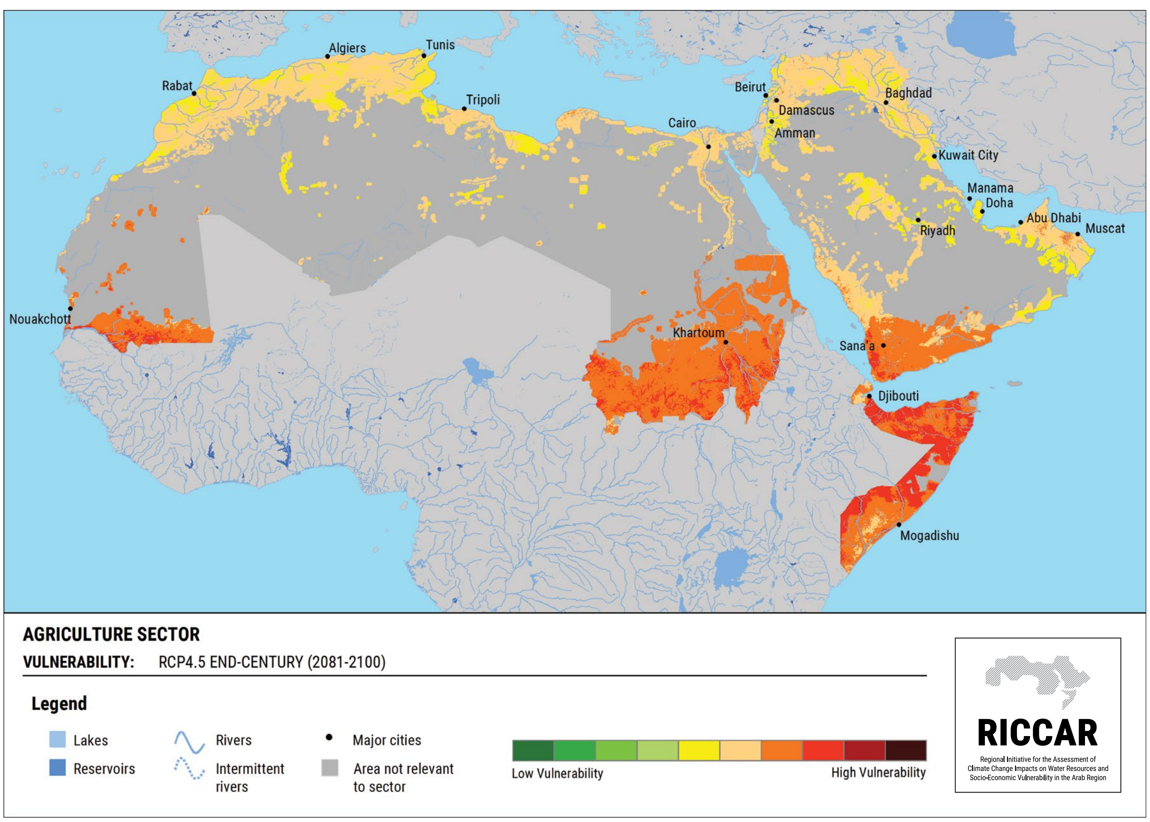
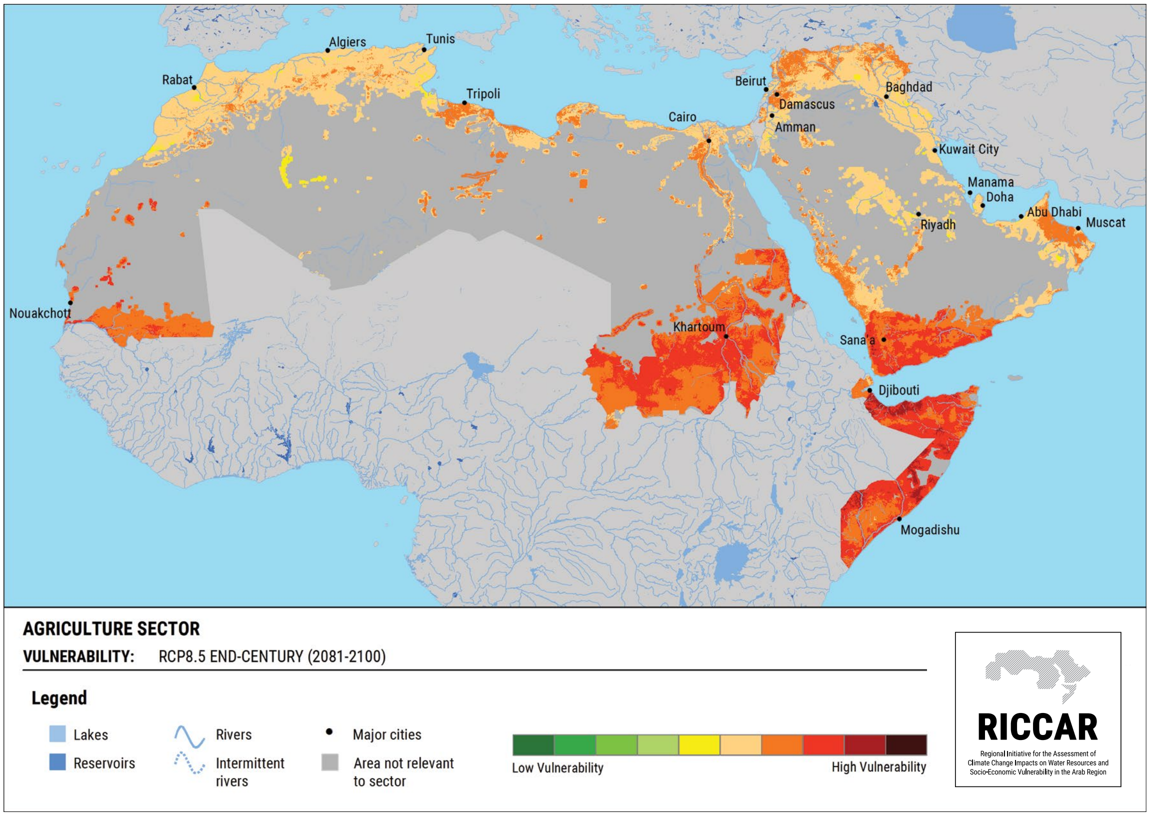


FIGURE 179: Agriculture sector – Vulnerability – End-century RCP 8.5



11.3.3 Hotspots

Hotspots represent those agricultural areas that are most likely to exhibit high vulnerability stemming from water availability for the sector and represent up to 9% of the study area. Hotspots are dispersed throughout the Tindouf basin, eastern sub-Saharan Africa, and the south-western Arabian Peninsula. These areas indicate an estimated 94% of available water used for agriculture.[7] Very high vulnerability with regard to agricultural water availability could mean the collapse of the sector unless strong adaptive capacity measures are taken for its survival.

ENDNOTES

1. Hoekstra and Hung, 2002
2. Chapagain and Hoekstra, 2003
3. FAO, 2017b
4. Ibid.
5. For example, see GEF and UNEP, 2016
6. FAO, 2017c
7. FAO, 2017a

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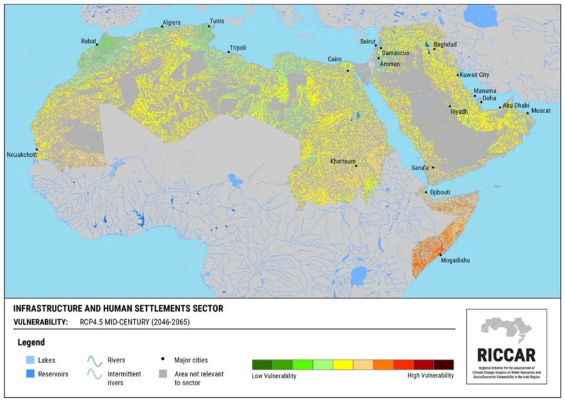
INFRASTRUCTURE AND HUMAN SETTLEMENTS SECTOR

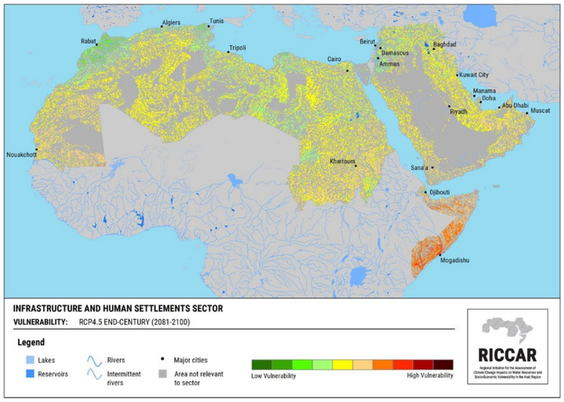
OVERALL VULNERABILITY

RCP 4.5

2046-2065

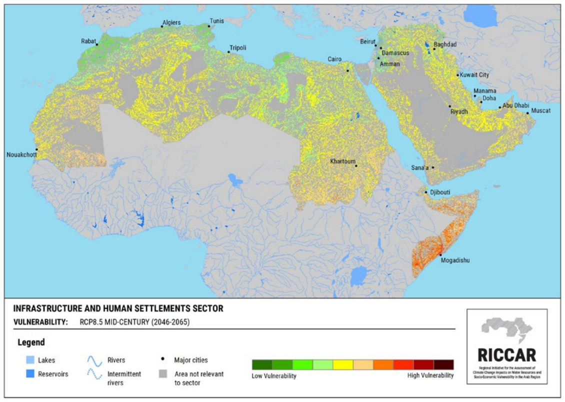


2081-2100

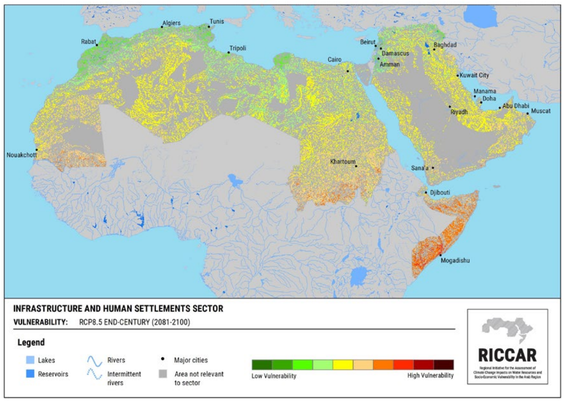


RCP 8.5

2046-2065



2081-2100



CHAPTER 12

INFRASTRUCTURE AND HUMAN SETTLEMENTS SECTOR – VULNERABILITY

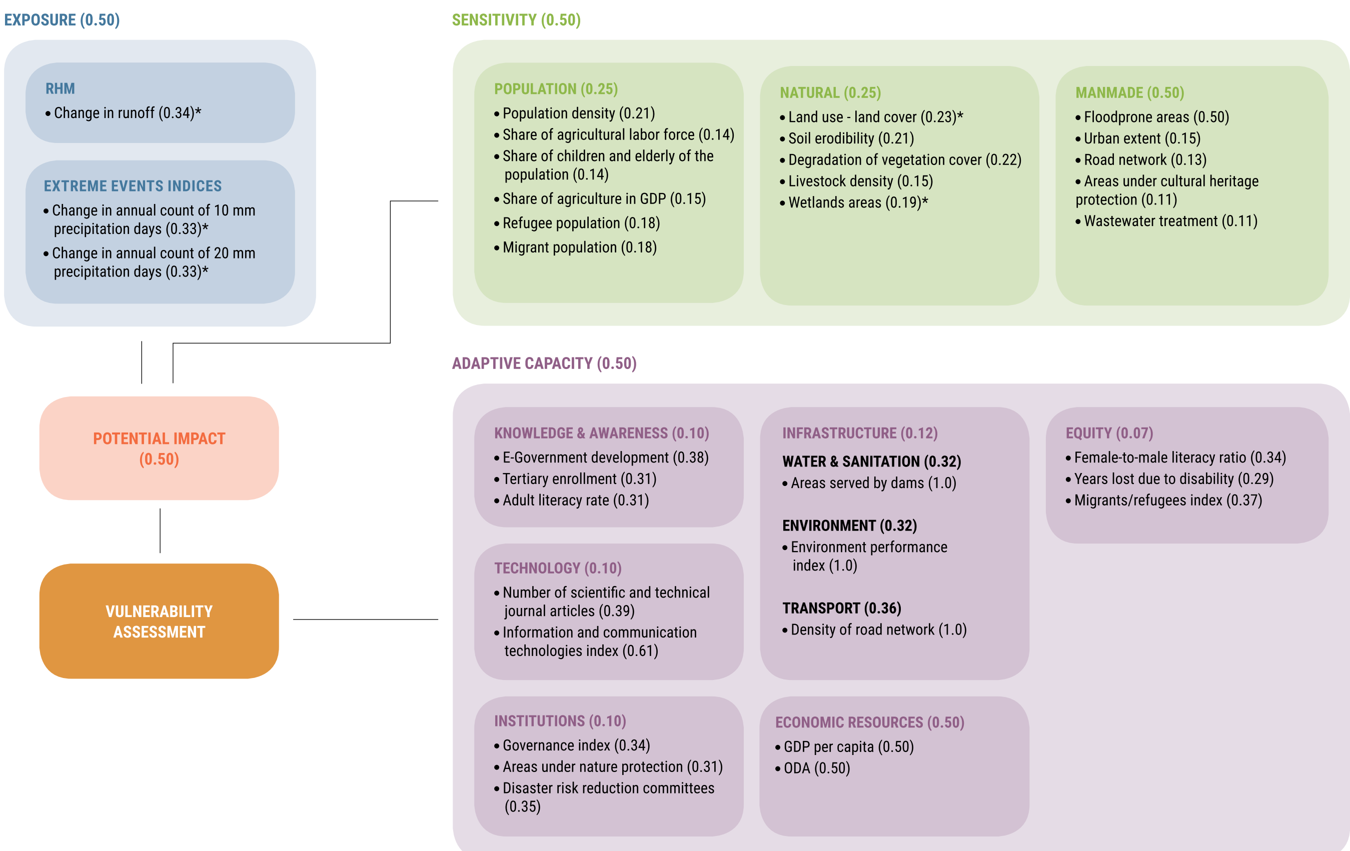
The Arab region has experienced unprecedented population growth over recent decades, with over half of the population now residing in urban areas.[1] Many of the urban centres are located along the coastline or along riverbanks, such as those of the Nile and Euphrates. Given the extent of the urban environment and the underdevelopment of stormwater networks in what is predominately an arid and semi-arid region, a particular challenge for these highly populated areas is to cope with the effects of flood events, including flash floods, due to extreme weather events. Low-lying coastal areas, deltas and artificial lands extending beyond the natural coastline are also sensitive to sea-level rise. The *Change in inland flooding area* was thus selected as a key climate change impact in the integrated assessment for the region. It should be noted that the outputs of regional climate models do not model sea-level rise and thus projections generated from GCMs would be necessary to assess the potential impacts of sea-level rise on coastal zones. Moreover, high-resolution digital elevation models (DEMs) are needed to conduct such analysis based on the climate change scenarios currently adopted by the IPCC and the required DEMs are not available at present. Vulnerability assessment results and findings for this sector are presented hereafter.

Because there is only one subsector included in the *Infrastructure and human settlements* sector, vulnerability assessment maps are assumed to be identical and are thus not included at the sector level. The study area is based upon the floodprone areas indicator, selecting all areas with low or greater flood potential and includes 32% of the Arab region. Areas with very low flood potential are not considered as part of the study area.

12.1 INLAND FLOODING AREA

The impact chain highlighting the different indicators and weights for this subsector is presented in Figure 180.

FIGURE 180: Impact chain and weights for inland flooding area



12.1.1 Reference period

12.1.1.1 Potential impact

Potential impact reflects the flood threats stemming from exposure and sensitivity. Arid and semi arid territories such as the Arab region are subject to inland flooding events which can threaten life, property and infrastructure. Yet, precipitation and runoff from larger events can be beneficial to replenish groundwater aquifers and other water resources. Flood risk is exacerbated once the water balance is upset by ongoing water scarcity coupled with extreme runoff. Heavy rainfall events can also jeopardize the water balance and pose a flood threat. For these reasons, runoff and the number of both heavy and very heavy precipitation days (R10 and R20, respectively) were selected as exposure indicators, which have been classified such that greater rainfall signifies higher exposure.

Most of the study area (89%) signals low exposure for the reference period. Only 9% indicates moderate exposure and remaining areas suggest high exposure. Areas with the highest exposure include the Rif region, the coastal Levant and the Zagros Mountains. Note that exposure is based on annual average parameters and can vary widely if seasonal effects are considered. Flooding is largely a function of precipitation duration and intensity. One extreme event can result in disaster, even if the average rainfall throughout the year is relatively low.

Sensitivity to inland flooding vulnerability is multi-faceted. The most important indicator evaluated, based on its respective weight, is floodprone areas, defined by a modelling study and historical flood events. Other indicators classified under the man-made dimension are also relevant: urban extent, road network, cultural heritage areas and wastewater treatment. Urban areas are more sensitive to flooding due to impervious areas and adequacy of stormwater drainage. Road networks are affected by flood risk because planned trips and evacuation routes may be flooded or available routes may be congested from traffic diversion. Damage to cultural heritage sites, such as UNESCO World Heritage Sites, induces adverse impacts upon local and national communities due to their significance and socio-economic value. Lastly, faulty wastewater treatment systems can increase pollution risks stemming from floods.

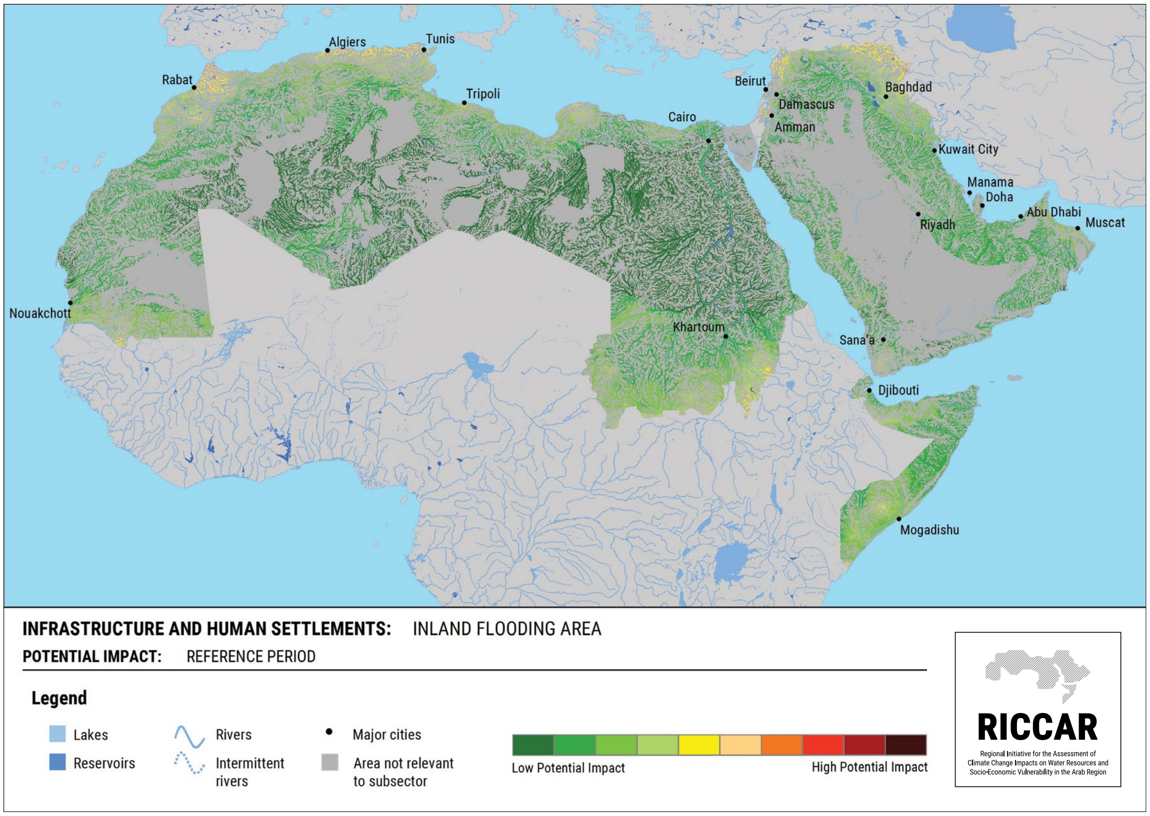
Inland flooding is also sensitive to population and natural elements. While the general population and structure are vulnerable to flooding, certain demographics are particularly susceptible to impacts such as children, the elderly and migrants and refugees who may reside in substandard housing. In terms of natural indicators, certain landscapes and soils are more prone to flood damage. Flooding of agricultural and rangeland areas can inflict economic losses but wetland areas, also considered, can benefit from floods.

A majority of the study area (89%) is indicative of low sensitivity to inland flooding for the reference period. Most remaining areas are classified with moderate sensitivity and include major river valleys throughout the Arab region. High-sensitivity areas are negligible. Sensitivity was limited by data availability and can vary widely if other parameters are considered, including distribution of wealth, design and quality of construction, household demographics and terrain elevation and slope.

Resultant potential impact for the reference period is low overall, covering 91% of the study area (Figure 181). Moderate areas represent most of the remaining region, while high potential impact is negligible. Areas with greater potential impact include coastal areas near the Mediterranean, such as the Rif region. This area has been afflicted by several flood events: one in May 2003 resulted in over 20 deaths.[2] Another coastal area with increased potential impact is the Levant, west of Mount Lebanon, which was subjected to at least 77 flood and flash-flood events during the reference period, including one in December 1987, which necessitated evacuation.[3] Lastly, the Nahr Diyala watershed in the Zagros Mountains is an area of higher potential impact.

Damages in Muscat after the passage of Cyclone Gonu, Oman, 2007.
Source: Wikimedia Commons.

FIGURE 181: Inland flooding area – Reference period – Potential impact



12.1.1.2 Adaptive capacity

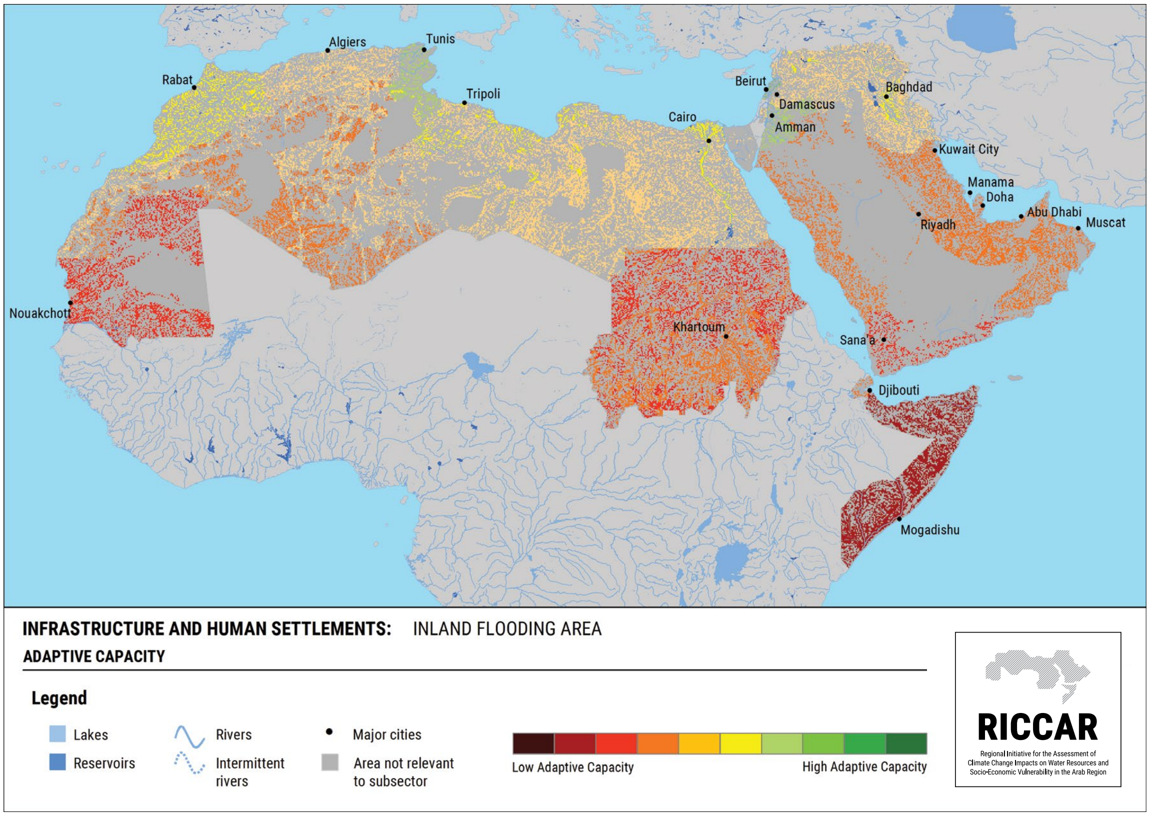
Sixteen different adaptive capacity indicators were selected, many of which can be considered proxies for typical structural and non-structural flood mitigation measures. Structural measures, including dams, channels, levees and improved construction, are considered part of the infrastructure dimension.

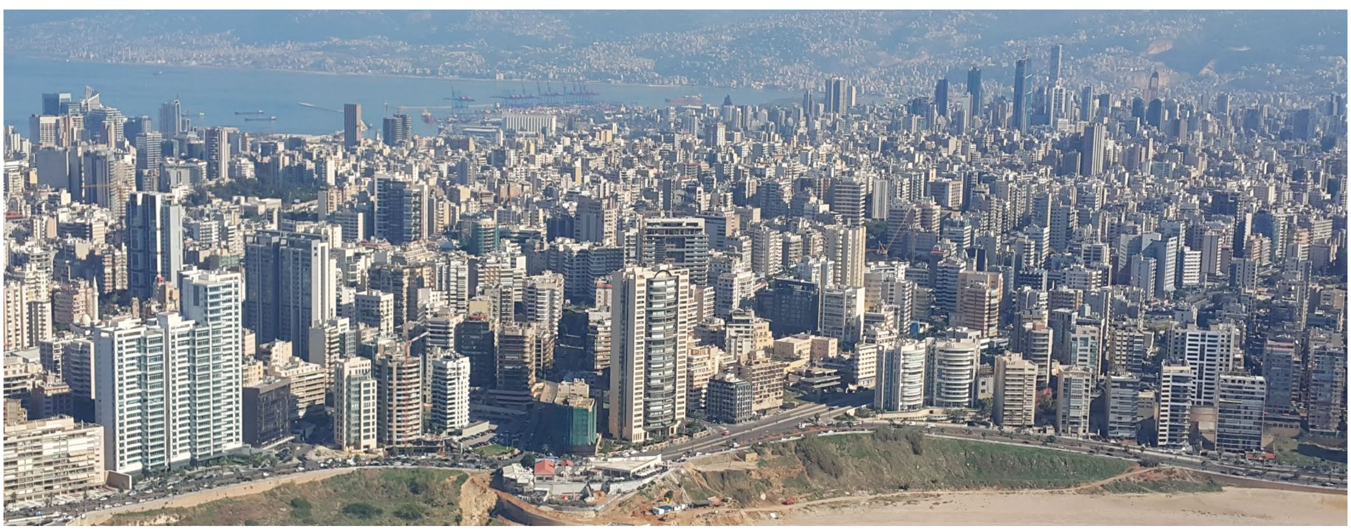
Non-structural measures, such as hazard forecasting, emergency plans, land-use planning and risk mapping, are incorporated under knowledge and awareness, technology, institutions and equity. Both types are dependent on economic resources; this dimension and its respective indicators have the largest weight for this component (see Figure 180).

A majority of the study area (73%) suggests moderate adaptive capacity for inland flooding, while a quarter (25%) indicates low adaptive capacity. Remaining areas reveal high adaptive capacity relative to the region. Areas with lower adaptive capacity include wadis and streams in sub-Saharan Africa and the south-western Arabian Peninsula (Figure 182).

Merowe Dam, Sudan, 2009. Source: Ihab Jnad.

FIGURE 182: Inland flooding area – Adaptive capacity





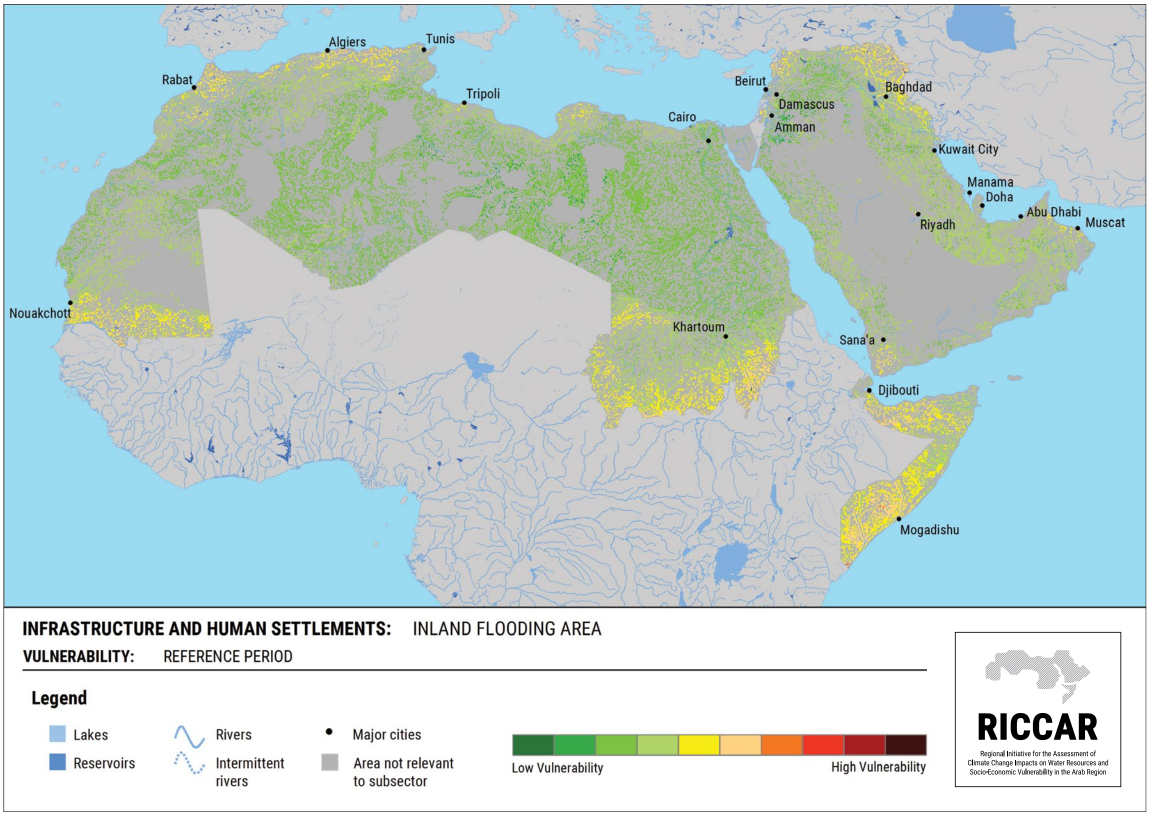
Beirut, Lebanon, 2015. Source: Carol Chouchani Cherfane.

12.1.1.3 Vulnerability

Vulnerability in this context indicates a combination of flood threat and the capability to cope therewith. Vulnerability for the reference period indicates a nearly even split between low and moderate vulnerability (48% and 52% of the study area, respectively).

Areas of high vulnerability are negligible. Locations with the highest vulnerability include the Senegal River middle valley, the Blue Nile watershed, and Bahr al Arab floodplains in the Sahel, the lower Orontes River floodplain in the Levant, tributary floodplains of the Tigris River, Red Sea coastal drainage in the south-western Arabian Peninsula, coastal drainage in the northern Horn of Africa, the Jubba and Shabelle river floodplains, the Rif region, and the Tell Atlas region (Figure 183).

FIGURE 183: Inland flooding area – Reference period – Vulnerability



12.1.2 Future periods

12.1.2.1 Potential impact

Projected flood risk is uncertain but various factors signal an increase in the Arab region, despite declining rainfall in some areas. Areas of low exposure, which is based on precipitation and number of heavy and very heavy precipitation days, generally reflect areas with decreasing precipitation at 5% of the study area at mid-century (RCP 4.5 and RCP 8.5) and 4% (RCP 4.5) to 7% (RCP 8.5) at end-century. Moderate exposure tends to indicate areas where precipitation is nearly unchanging from the reference period and includes 75% (RCP 8.5) to 79% (RCP 4.5) of the study area at mid-century and 60% (RCP 8.5) to 71% (RCP 4.5) at end-century. Lastly, areas of high exposure are those where precipitation is increasing and represent 16% (RCP 4.5) to 20% (RCP 8.5) of the study area at mid-century and 25% (RCP 4.5) to 34% (RCP 8.5) at end-century. Areas with the highest exposure vary by climate scenario but consistently include the floodplains of the Jubba and Shabelle rivers and the lower Tindouf basin.

Potential impact, the combination of exposure and sensitivity, is largely moderate. For mid-century, 73% (RCP 8.5) to 83% (RCP 4.5) of the study area indicates moderate potential impact (Figure 184 and Figure 185). Similarly, at end-century, 76% (RCP 8.5) to 79% (RCP 4.5) of the study area suggests moderate potential impact (Figure 186 and Figure 187). Remaining areas point towards low potential impact. Areas of high potential impact are negligible. Those with the highest potential impact are the middle valley of the Senegal River, the Jubba–Shabelle river floodplains, and the Bahr el Arab floodplain in the eastern Sahel. Conversely, areas with the lowest potential impact relative to the region include the Atlas Mountains and coastal plain, the Jafara Plain, the Green Mountains, the coastal Levant and the Zagros Mountains.

Changes in sensitivity can substantially transform projected potential impact. These include changes in the watershed, such as increased urbanization, which results in an increase in impervious area. Increased urbanization and migration can contribute to a rise in substandard housing which may be constructed on floodplains. Lastly, a rise in certain population groups such as children, women, the elderly and the disabled, will need differing needs to be considered concerning evacuation, shelter, relief distribution and flood recovery.

FIGURE 184: Inland flooding area – Mid-century RCP 4.5 – Potential impact

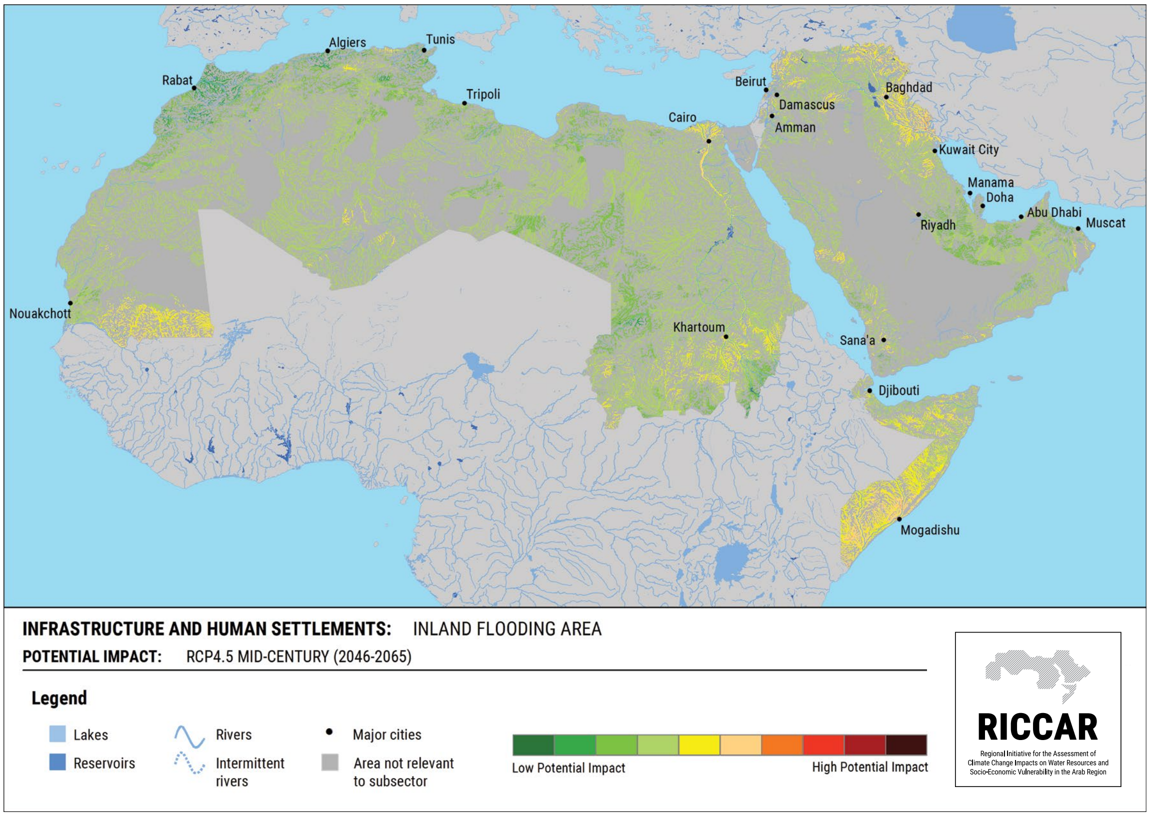


FIGURE 185: Inland flooding area – Mid-century RCP 8.5 – Potential impact

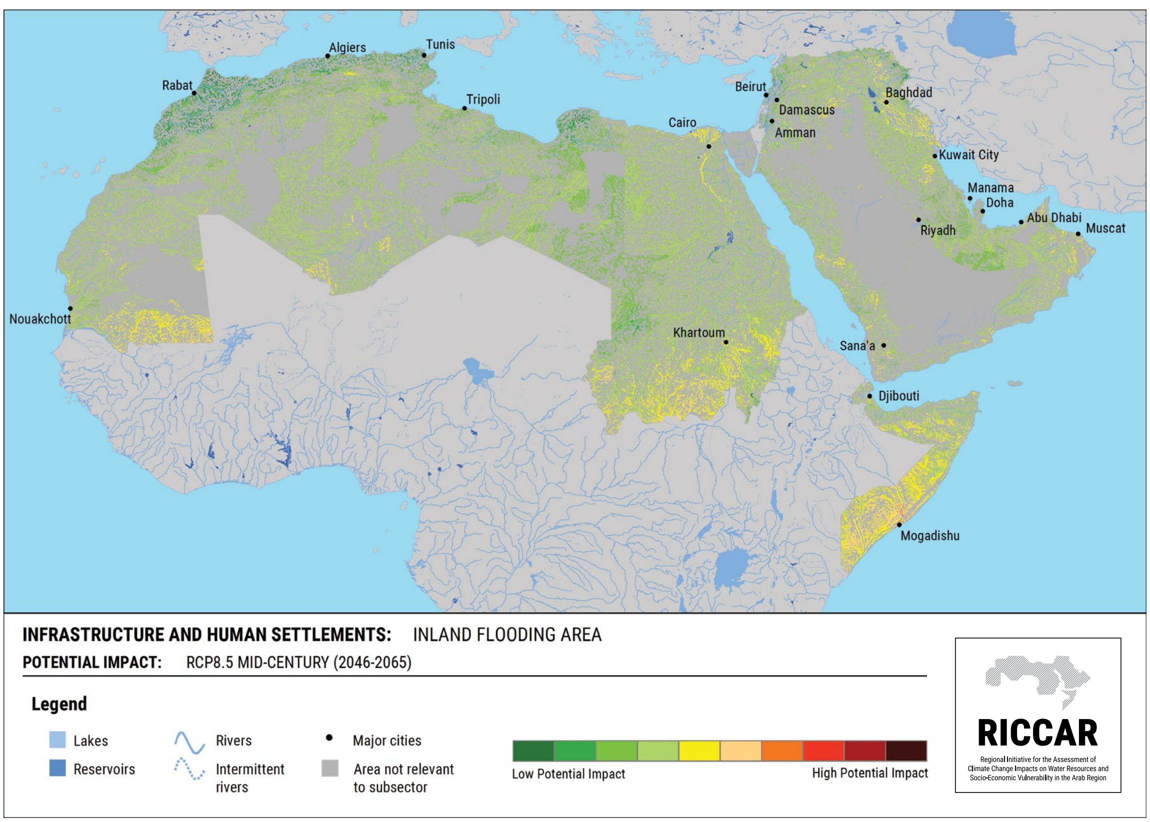


FIGURE 186: Inland flooding area – End-century RCP 4.5 – Potential impact

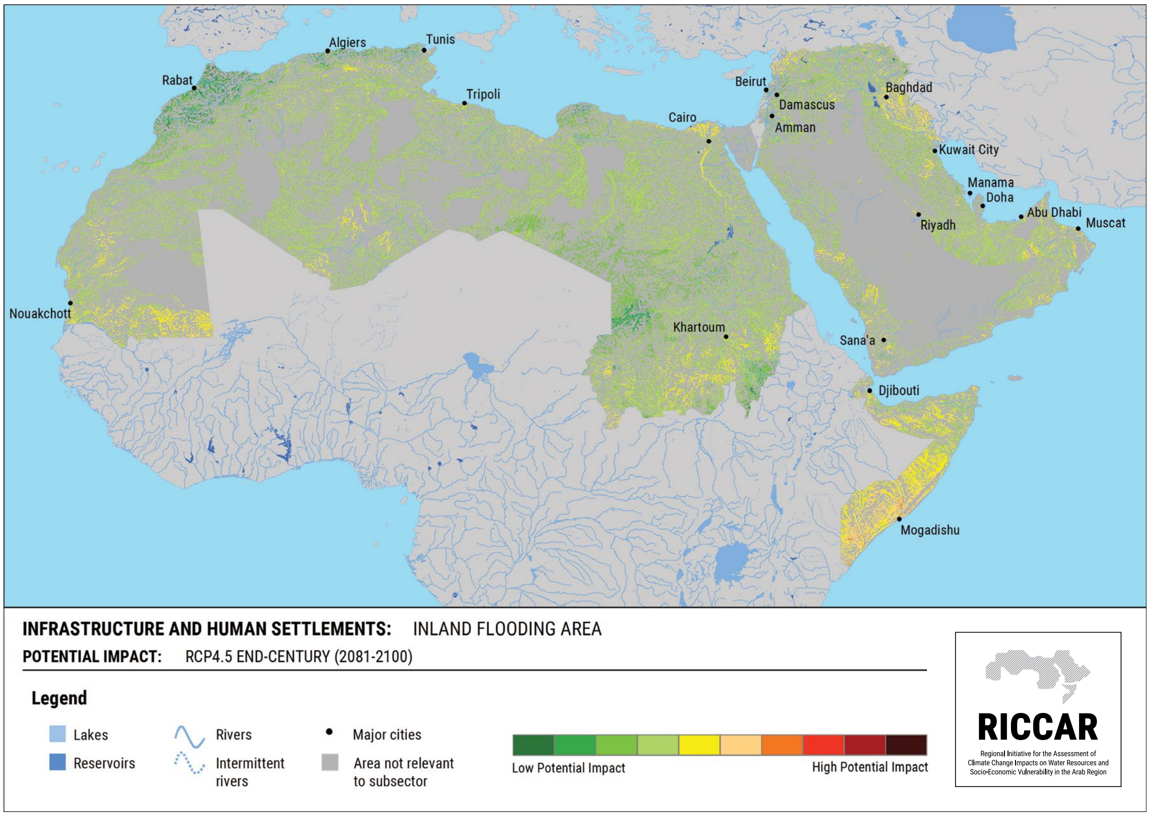
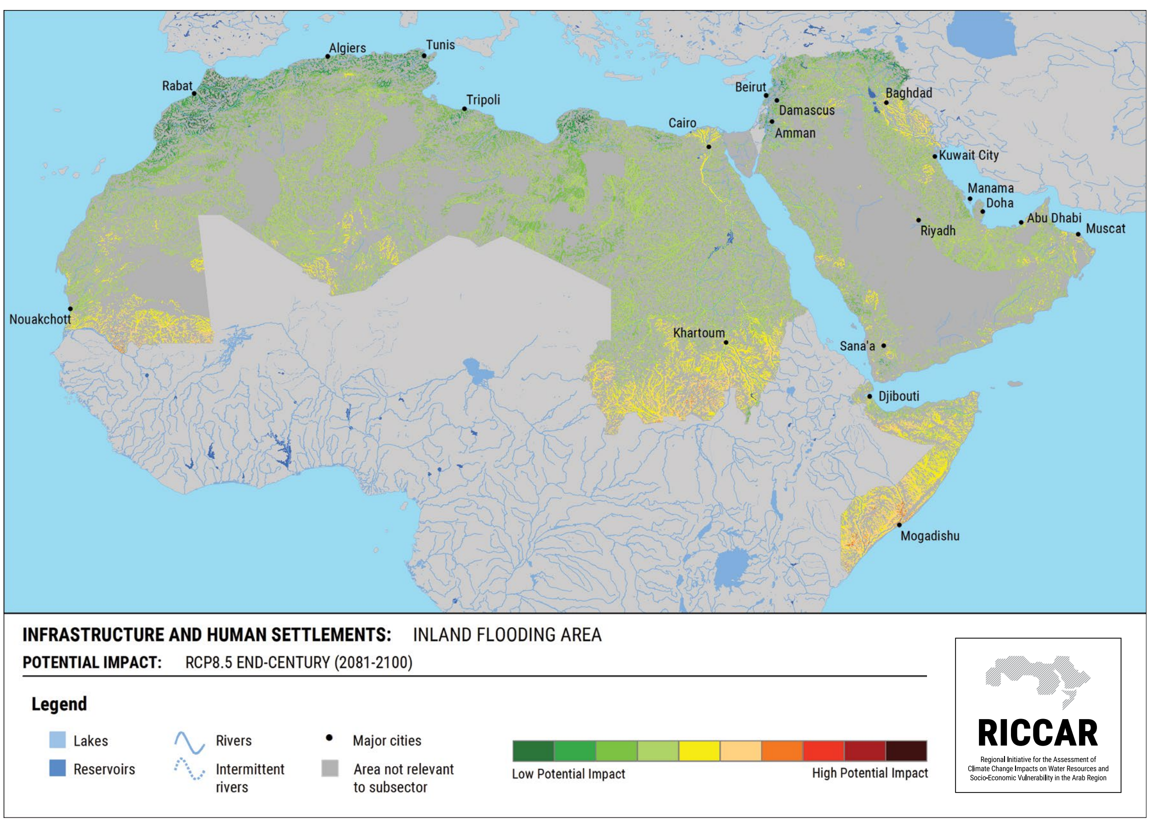


FIGURE 187: Inland flooding area – End-century RCP 8.5 – Potential impact



12.1.2.2 Vulnerability

Vulnerability is expected to increase in the region, particularly in urban areas, if there is little improvement in poverty reduction, disaster preparedness and improved construction standards. Assuming there are no changes in sensitivity or adaptive capacity, most of the study area (about 90%) suggests moderate vulnerability for all scenarios (Table 31). Remaining areas are divided between low and high vulnerability.

Vulnerability exhibits a generally increasing gradient from north to south, whereas coastal areas indicate a relatively low vulnerability and sub-Saharan Africa reveals a generally higher vulnerability (Figure 188 to Figure 191).

Vulnerability trends from mid- to end-century suggest limited change for RCP 4.5. For RCP 8.5, changes are also minimal, although a slight increase in vulnerability is indicated in sub-Saharan Africa and the eastern Arabian Desert; slight decreases in vulnerability are noted towards the Mediterranean coast and the Zagros Mountains.

TABLE 31: Percentage of study area by vulnerability classification for inland flooding area

Scenario	Vulnerability (% of study area)		
	Low	Moderate	High
Mid-Century RCP 4.5	2%	94%	4%
Mid-Century RCP 8.5	3%	93%	4%
End-Century RCP 4.5	2%	94%	4%
End-Century RCP 8.5	4%	89%	7%

FIGURE 188: Inland flooding area – Mid-century RCP 4.5 – Vulnerability

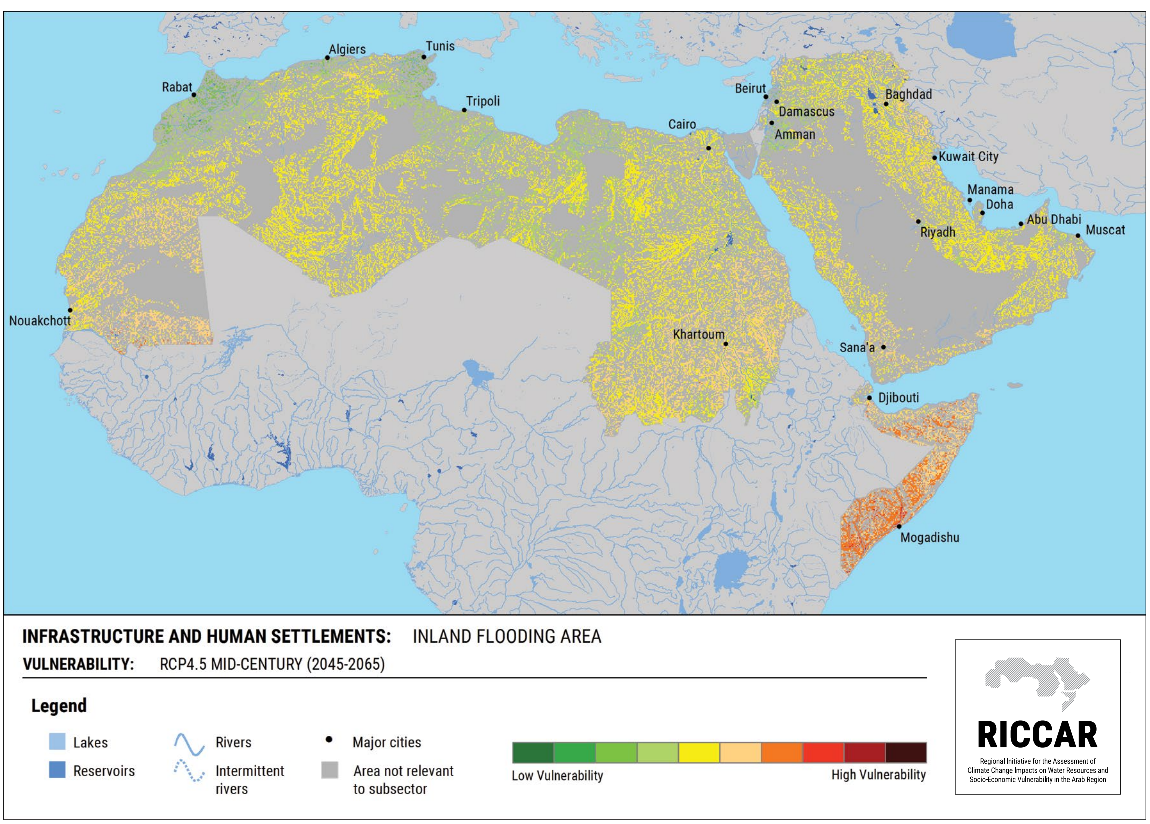


FIGURE 189: Inland flooding area – Mid-century RCP 8.5 – Vulnerability

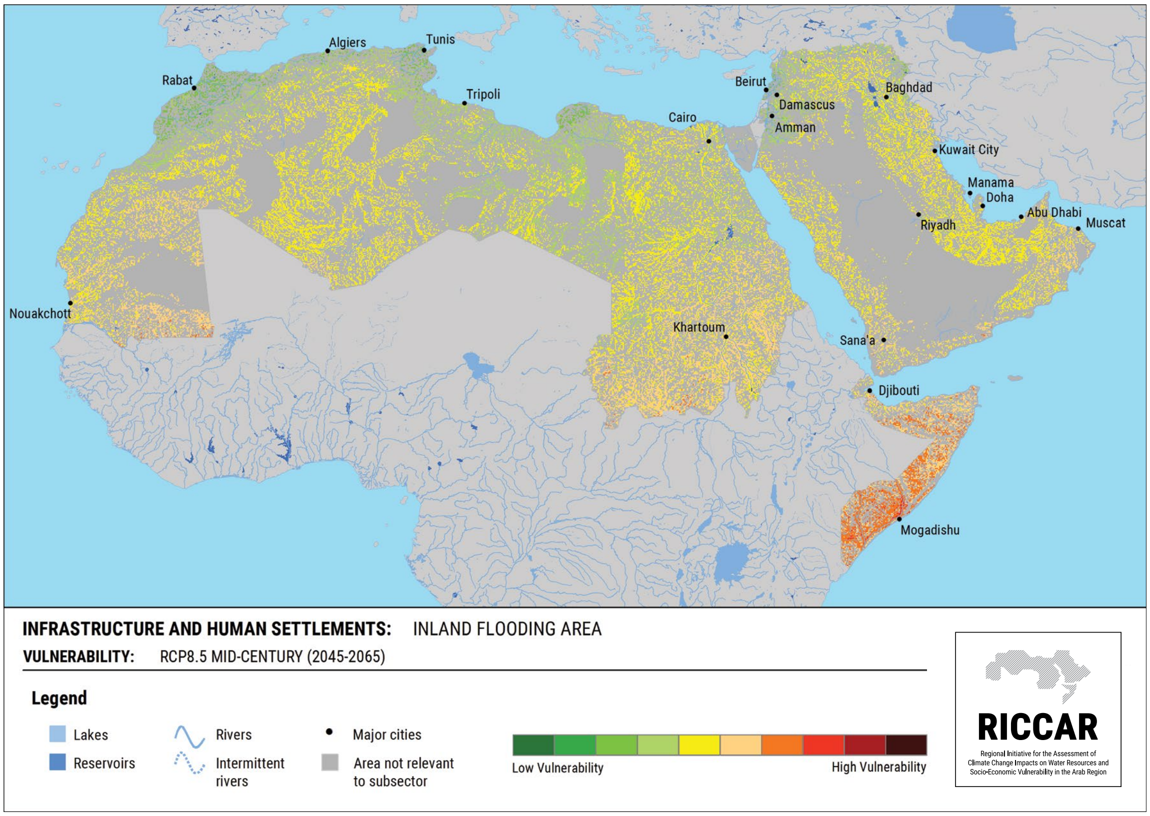


FIGURE 190: Inland flooding area – End-century RCP 4.5 – Vulnerability

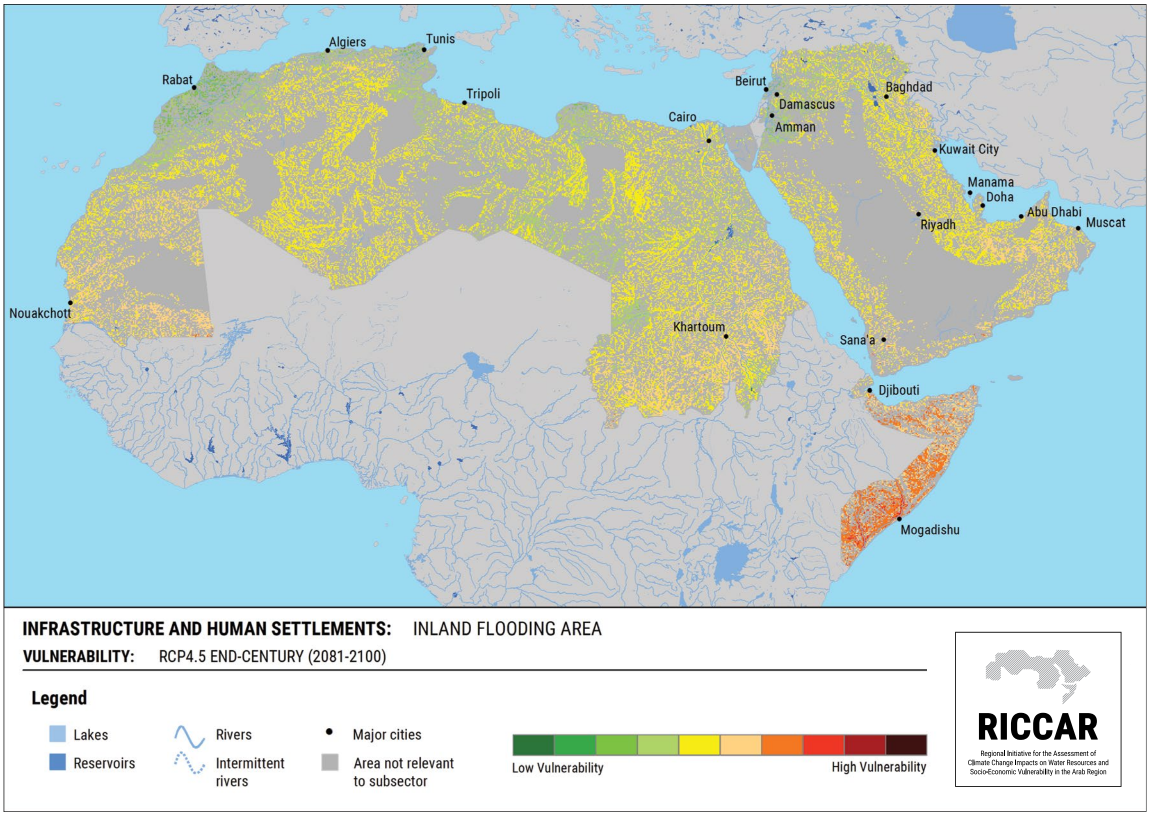
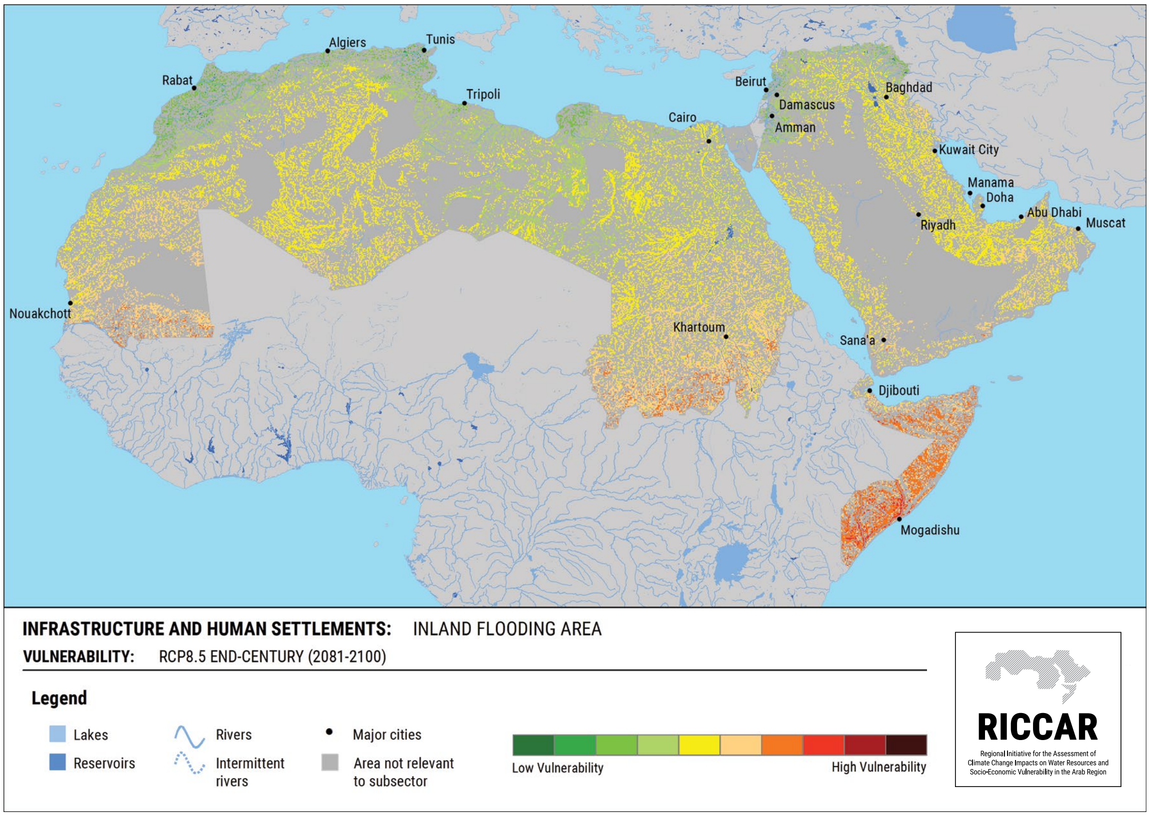


FIGURE 191: Inland flooding area – End-century RCP 8.5 – Vulnerability



12.1.3 Hotspots

Hotspots reveal areas with the highest projected vulnerability and represent up to 8% of the inland flooding study area. Hotspots are found in both the eastern and western Sahel, the Horn of Africa (particularly the Jubba and Shabelle river floodplains) and isolated areas in the southern Arabian Peninsula. Recent flooding in the western Sahel (August to September 2013) devastated crops and livestock in agricultural areas, damaged infrastructure and tainted the water supply in urban areas, including Nouakchott. Inland flooding in the eastern Sahel is common, particularly near the confluence of the White Nile and Blue Nile rivers; residents have built floodwalls which separate agricultural areas from the rivers.

The Jubba and Shabelle river floodplains have also been subjected to recurrent floods: recent events were in April 2010, April 2013 and May 2013. These floods tend to occur during two distinct rainy seasons: the *Gu* (April to June) and the *Deyr* (October to November). Steps to reduce vulnerability in this area include the development of a Flood Risk and Response Management Information System (FRRMIS), which is a web- and GIS-based information dissemination and sharing platform delivering regular updated flood information. It promotes flood preparedness and contingency planning and has developed a geodatabase of riverbank breakages and potential flooding areas.[4]

Luxor, Egypt, 2016. Source: Dounia Chouchani.

ENDNOTES

1. UN-HABITAT, 2016
2. DesInventar, 2016
3. Ibid.
4. SWALIM, 2017

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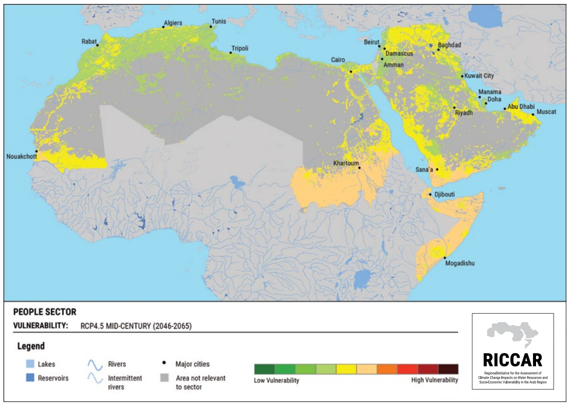
PEOPLE SECTOR

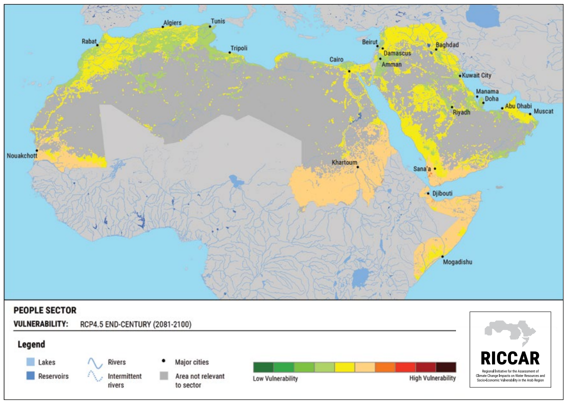
OVERALL VULNERABILITY

RCP 4.5

2046-2065

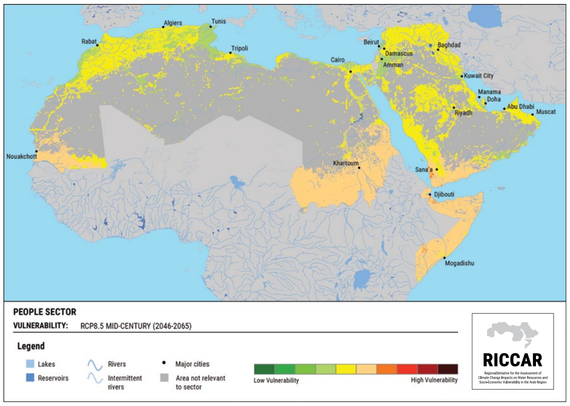


2081-2100

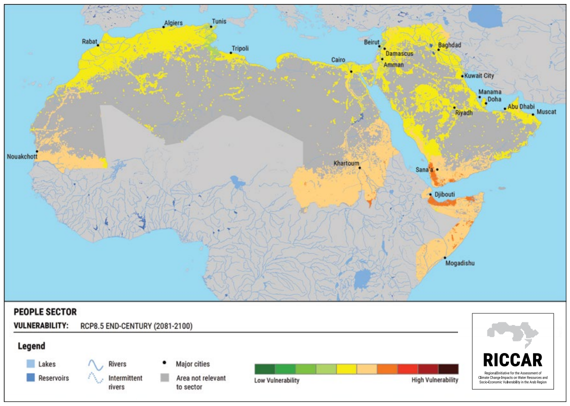


RCP 8.5

2046-2065



2081-2100



CHAPTER 13

PEOPLE SECTOR – VULNERABILITY

Water, already a scarce resource in the Arab region, may further decrease in quality and quantity which will put pressure on the availability of drinking water for the population. Climate change effects on agricultural production in already arid and semi-arid areas may lead to a loss of labour opportunities in the agricultural sector and trigger further migration to urban centres: this, in turn, may cause social disturbances and put further stress on already densely populated areas. About 20% of the current workforce in the Arab region is employed in the agricultural sector.[1]

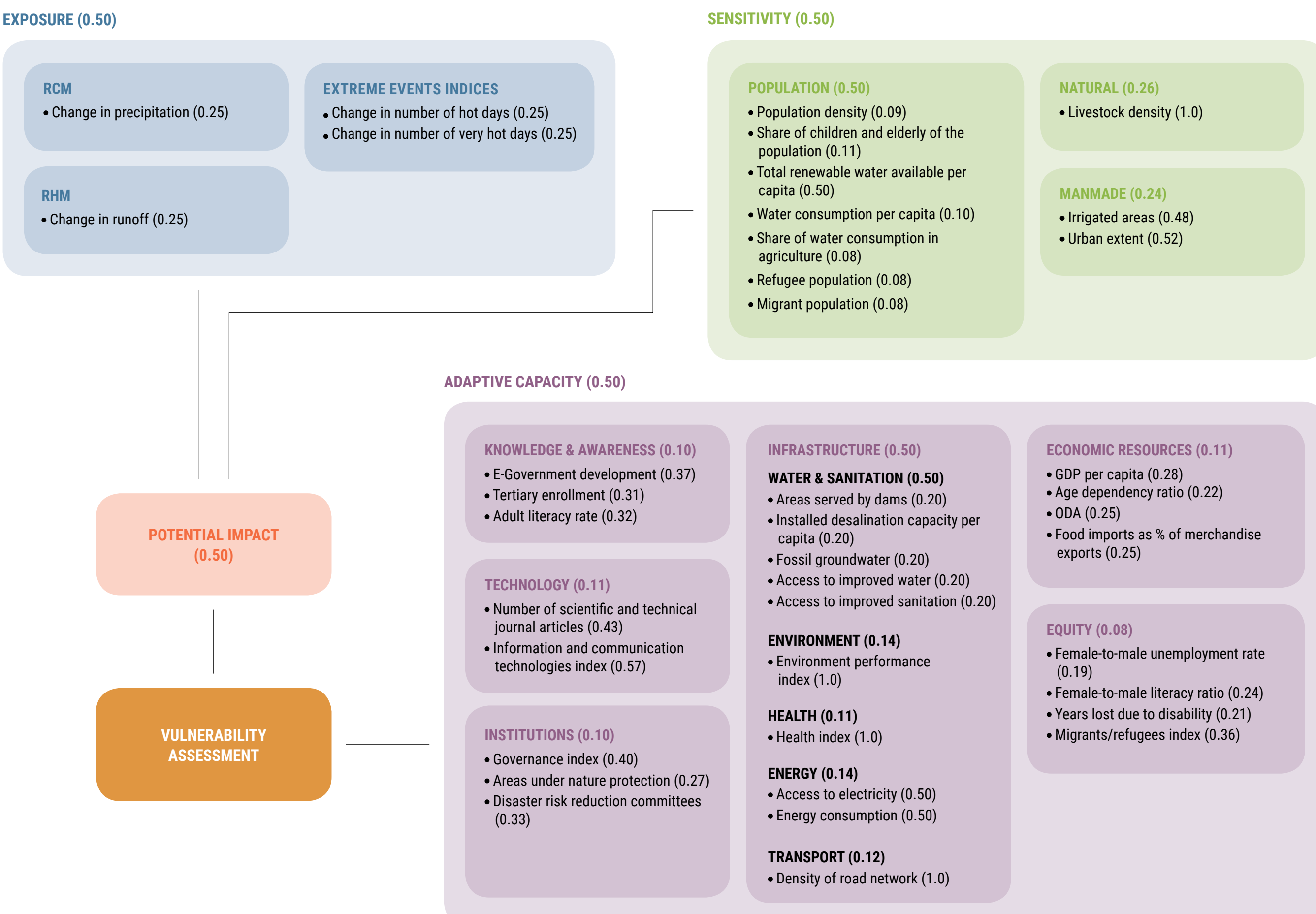
Moreover, higher temperatures, especially in the summer months, may have severe impacts on public health, in particular affecting the young and elderly and those working in economic sectors requiring outside work, such as agriculture, security and construction. For these reasons, the VA-WG members selected the following three key climate change impacts on people to be included into the assessment: (a) *Change in the water available for drinking*; (b) *Change in health conditions due to heat stress*, and (c) *Change in employment rate for the agricultural sector*. Outcomes from the vulnerability assessment for this sector and associated subsectors are described in the following sections.

The study area for all three subsectors, as well as the sector itself, is based on populated areas. This defined the population density indicator and includes areas with at least two inhabitants per square kilometre. The resultant study area represents 44% of the entire Arab region.

13.1 WATER AVAILABLE FOR DRINKING

The impact chain shown in Figure 192 presents the indicators used under each component and its associated weights for this subsector.

FIGURE 192: Impact chain and weights for water available for drinking



13.1.1 Reference period

13.1.1.1 Potential impact

Potential impact reflects the aggregated result between exposure and sensitivity. Exposure is based on four hydrological indicators (precipitation and runoff) and extreme heat indices to include number of hot days (SU35) and number of very hot days (SU40). As the number of hot days increase, drinking water consumption is expected to increase correspondingly.

Exposure for the reference period is nearly equally divided between low, moderate and high: moderate and high exposure represent 37% and 33% of the study area, respectively. Areas of high exposure are generally located within the Sahara and Arabian deserts, whereas areas of low exposure are primarily located along the Mediterranean coast and the Zagros Mountains. Moderate exposure transitions between the two areas.

Exposure does not consider humidity because bias-corrected data for this parameter were not developed under RICCAR. Humidity can, however, be an important factor with regard to drinking-water needs as humidity can impact the Heat Index or apparent temperature, as discussed in Chapter 7. Humidity and the resultant Heat Index are expected to be a factor in coastal areas such as the Gulf. These areas are subject to a conceivable increase in exposure, as well as a resultant increase in potential impact and exposure.

Sensitivity indicators were selected with a strong emphasis on the population dimension, particularly the total renewable water available per capita indicator. Indicators from the other dimensions were identified based on competing water users. In addition, urban areas are expected to induce an urban heat island effect (causing localized temperature increases) and highlight dense population centres. Most of the study area (87%) is indicative of low sensitivity relative to the region and remaining areas can be considered moderate.

Sensitivity maintains a modest correlation with indicators from the man-made dimension, population density, and total available renewable water. Areas with the highest sensitivity include the lower Nile River Valley and Delta, the Asir Mountains, the northern coast of the Gulf of Aden and the Strait of Hormuz coastal area. Sensitivity is arguably artificially low because it is limited by the available indicators. Not only is water limited by resource availability, drinking water must consider environmental factors and quality. Much of the region is faced with the degradation of water resources.

The resultant potential impact for the reference period (Figure 193) reveals a split between low and moderate potential impact (51% and 49% of the study area, respectively). Areas with the highest potential impact include the lower Nile River, the central Arabian Desert and the eastern Red Sea coastline. Conversely, areas with low potential impact relative to the region are the Atlas Mountains and adjacent coastal plains, the coastal Levant, the Zagros Mountains and sections in the northern Horn of Africa.

13.1.1.2 Adaptive capacity

Adaptive capacity indicators were selected with an emphasis on water and sanitation infrastructure. They include desalination, dams, fossil groundwater and repair and prevention of leaks. Coping mechanisms require capital investment, institutional reforms and capacity-building. In addition, as for sensitivity, water rights and ethics should be considered.

The Arab region is evenly divided between areas of low and moderate adaptive capacity (48% and 52%, respectively). Areas with the lowest adaptive capacity include the Horn of Africa, the western Sahel and the south-western Arabian Peninsula (Figure 194).

Young boys carrying water, Jowhar, Somalia, 2013. Source: UN Photo/Tobin Jones.

FIGURE 193: Water available for drinking – Reference period – Potential impact

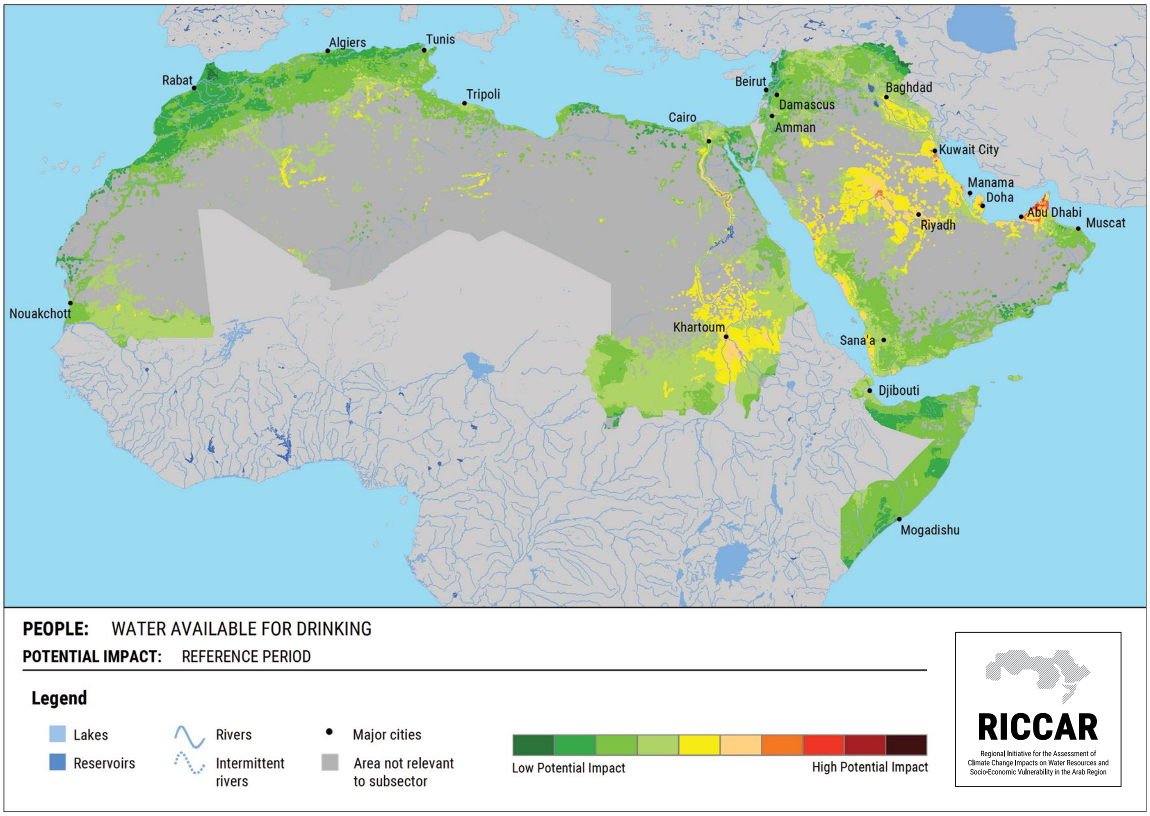
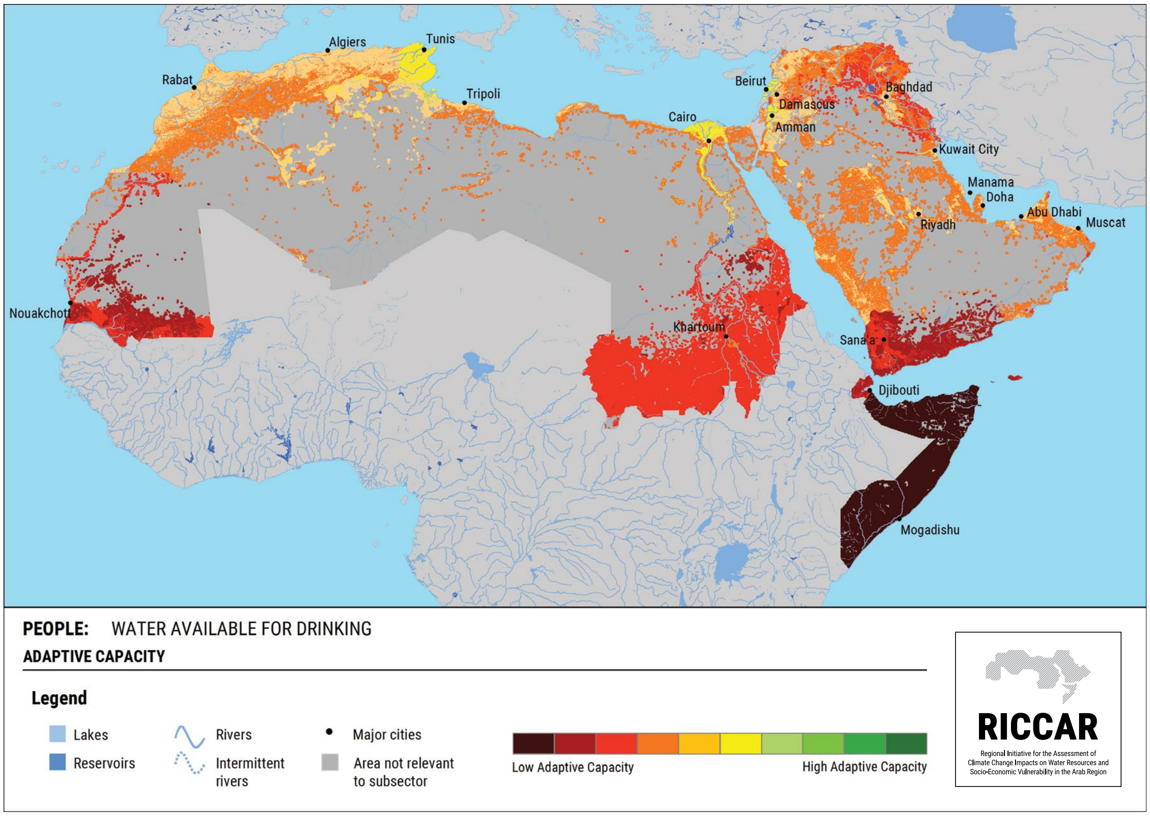


FIGURE 194: Water available for drinking – Adaptive capacity



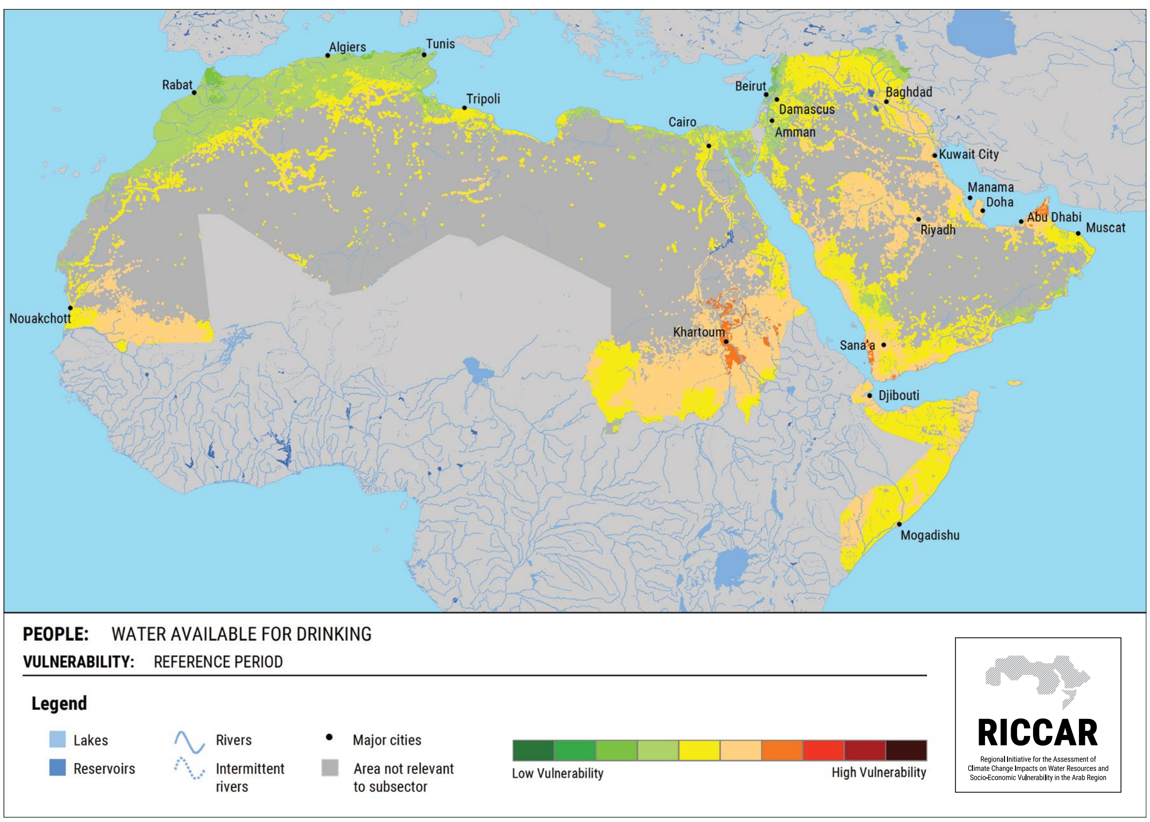
13.1.1.3 Vulnerability

Because of relatively low potential impact and low adaptive capacity for much of the region, the resultant vulnerability for the reference period is overwhelmingly moderate, covering 98% of the study area (Figure 195). Remaining areas are divided between areas of low and high vulnerability.

Areas with the highest vulnerability include the upper Nile region near the confluence of the Nile, Blue Nile and White Nile rivers, the south-western Arabian Peninsula coastline and the Jabal Yibir area near the Strait of Hormuz. Vulnerability is primarily a function of exposure for this subsector as evidenced by a strong correlation. In addition, areas with high exposure tend to coincide with areas of high vulnerability. Correlation with adaptive capacity is modest and correlation with sensitivity is very weak. Changes in sensitivity will thus have little impact on vulnerability, although it will have a modest effect on potential impact.

Women collecting water from well, Kuma Garadayat, Sudan, 2012. Source: UN Photo/Albert González Farran.

FIGURE 195: Water available for drinking – Reference period – Vulnerability



13.1.2 Future periods

13.1.2.1 Potential impact

Exposure is largely projected as moderate, representing 72% (RCP 4.5) to 77% (RCP 8.5) of the study area at mid-century and 52% (RCP 8.5) to 72% (RCP 4.5) at end-century. High exposure is revealed in 14% (RCP 4.5) to 18% (RCP 8.5) of the study area at mid-century and 18% (RCP 4.5) to 43% (RCP 8.5) at end-century. Thus, for RCP 4.5, exposure is mostly unchanging, but changes are magnified for RCP 8.5. As a result, areas of high exposure are generally confined to the eastern Sahel for most future scenarios but expand to several coastal areas for RCP 8.5 end-century while, for the same scenario, the eastern Sahel suggests a much lower exposure due to increasing precipitation and runoff.

Assuming static sensitivity, projected potential impact is generally split between low and moderate.

For mid-century (Figure 196 and Figure 197), moderate potential impact is revealed in 41% (RCP 4.5) to 54% (RCP 8.5) of the study area, but increases to 47% (RCP 4.5) to 72% (RCP 8.5) at end-century (Figure 198 and Figure 199). Other areas suggest low potential impact. Areas with elevated potential impact are the Asir Mountains, the lower Nile River and the Jabal Yibir area. Changes in sensitivity, including consideration of certain parameters like water quality, can ensue changes in potential impact.

FIGURE 196: Water available for drinking – Mid-century RCP 4.5 – Potential impact

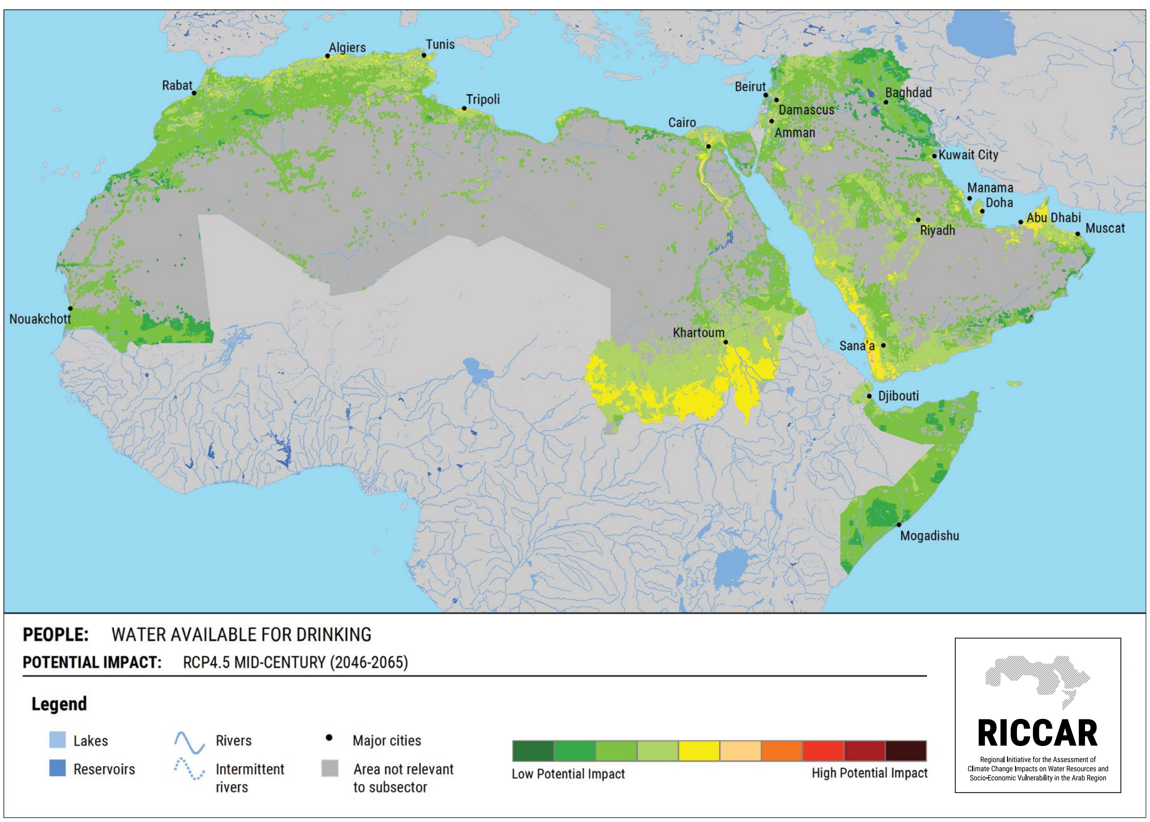


FIGURE 197: Water available for drinking – Mid-century RCP 8.5 – Potential impact

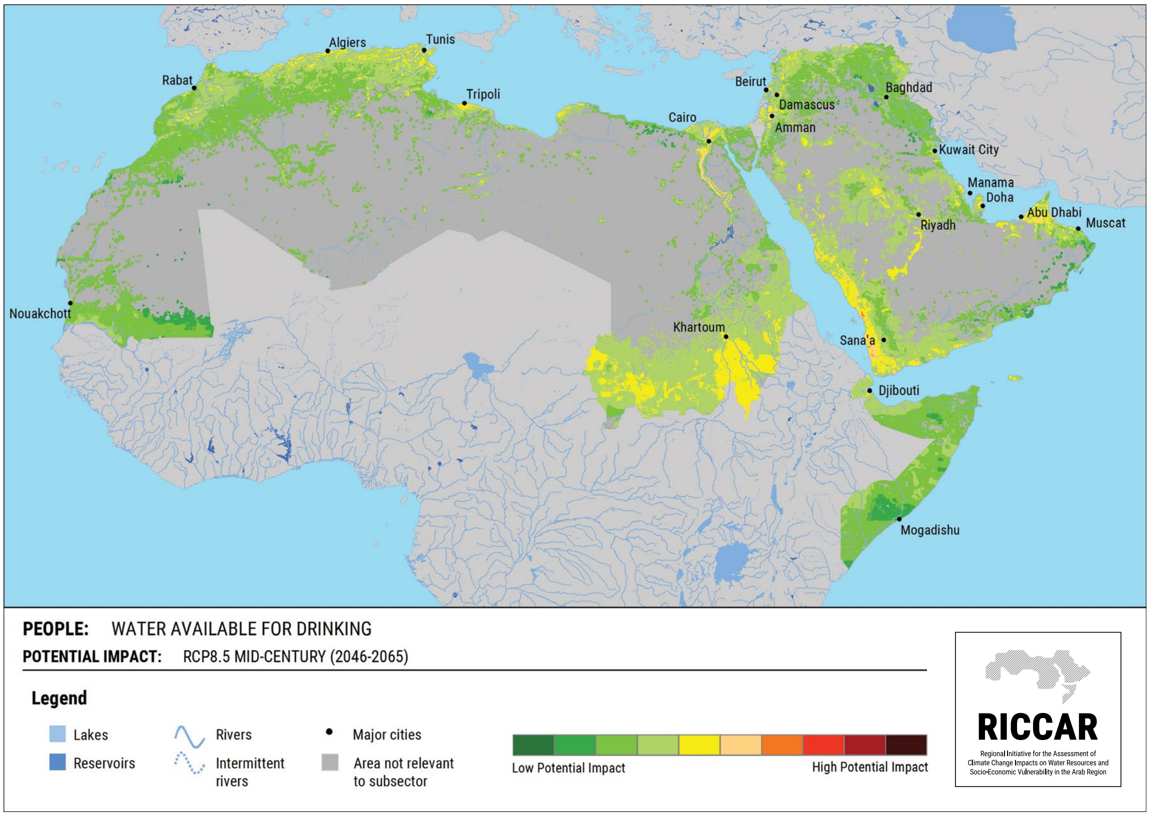


FIGURE 198: Water available for drinking – End-century RCP 4.5 – Potential impact

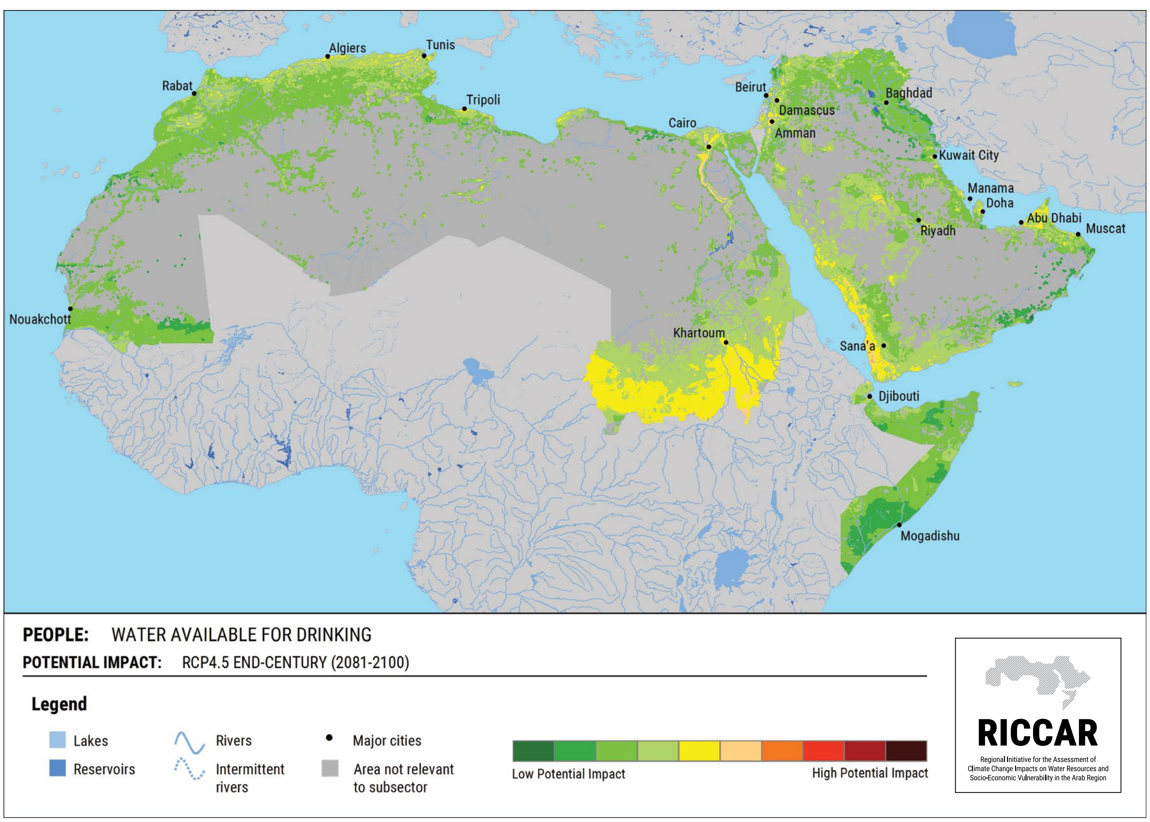
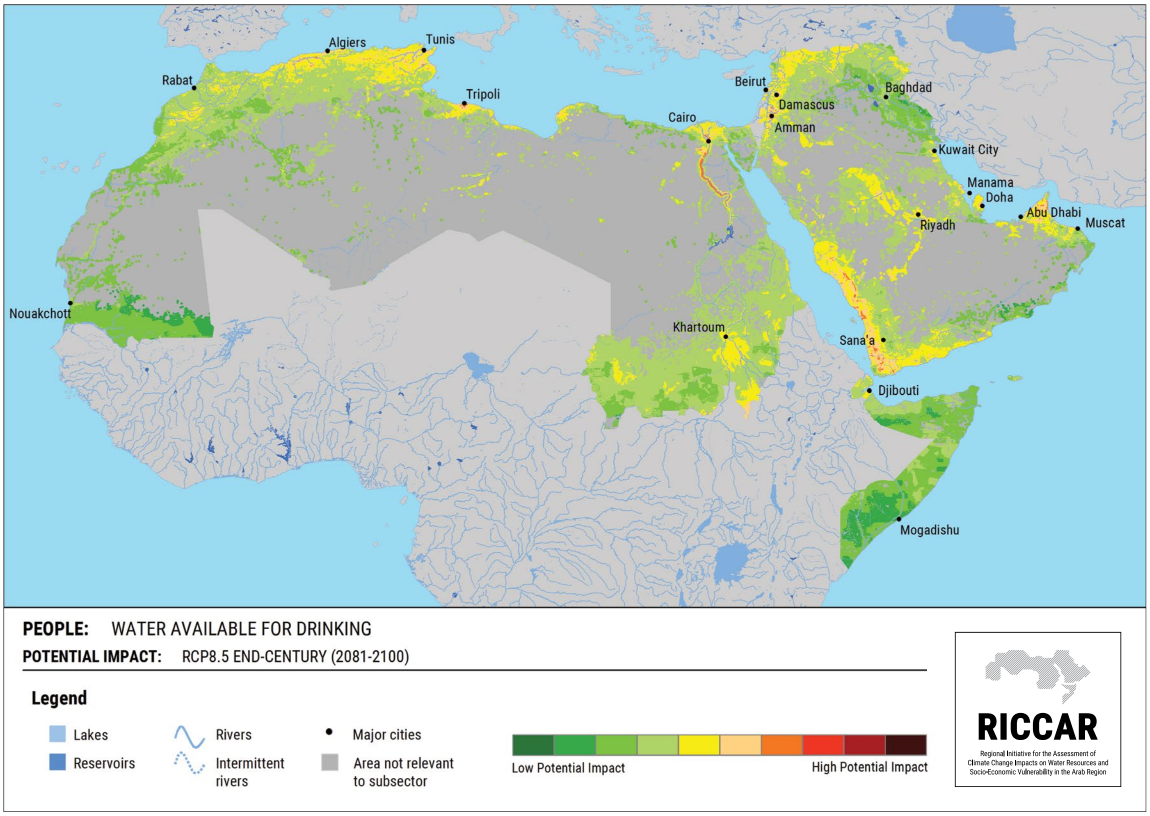


FIGURE 199: Water available for drinking – End-century RCP 8.5 – Potential impact



13.1.2.2 Vulnerability

Nearly the entire study area (greater than 98%) faces moderate drinking water vulnerability for both mid- and end-century under both RCP 4.5 and RCP 8.5, due primarily to exposure (Table 32). Areas with the lowest relative vulnerability are the lower Tigris-Euphrates Basin, the Gulf of Aden north central coastline, selected areas in the Maghreb and the lower Tindouf basin in the western Sahel (Figure 200 to Figure 203).

Vulnerability trends reveal only slight differences from mid- to end-century, particularly under RCP 4.5.

For this scenario, areas of increasing vulnerability tend to be located in the Zagros Mountains and the central western Red Sea coastal region. Conversely, areas of decreasing vulnerability are located in the Oman Mountains region, selected areas in the Horn of Africa and the northern Grand Erg Oriental region. Under RCP 8.5, changes are more pronounced and areas of increasing vulnerability include the Red Sea region, the northern Maghreb, the Levant and the Zagros Mountains. Areas of decreasing vulnerability are located in the Sahel and the Horn of Africa.

TABLE 32: Percentage of study area by vulnerability classification for water available for drinking

Scenario	Vulnerability (% of study area)		
	Low	Moderate	High
Mid-Century RCP 4.5	0%	100%	0%
Mid-Century RCP 8.5	0%	99%	1%
End-Century RCP 4.5	0%	99%	1%
End-Century RCP 8.5	0%	98%	2%

FIGURE 200: Water available for drinking – Mid-century RCP 4.5 – Vulnerability

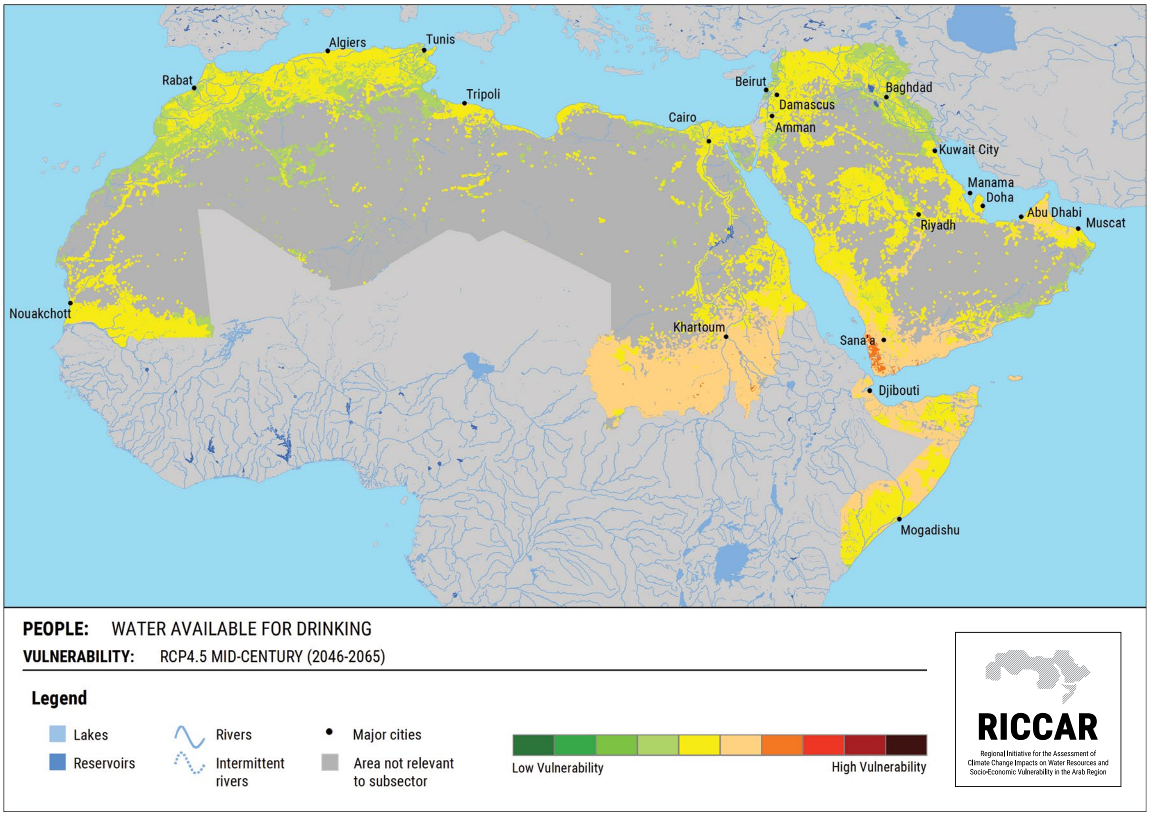


FIGURE 201: Water available for drinking – Mid-century RCP 8.5 – Vulnerability

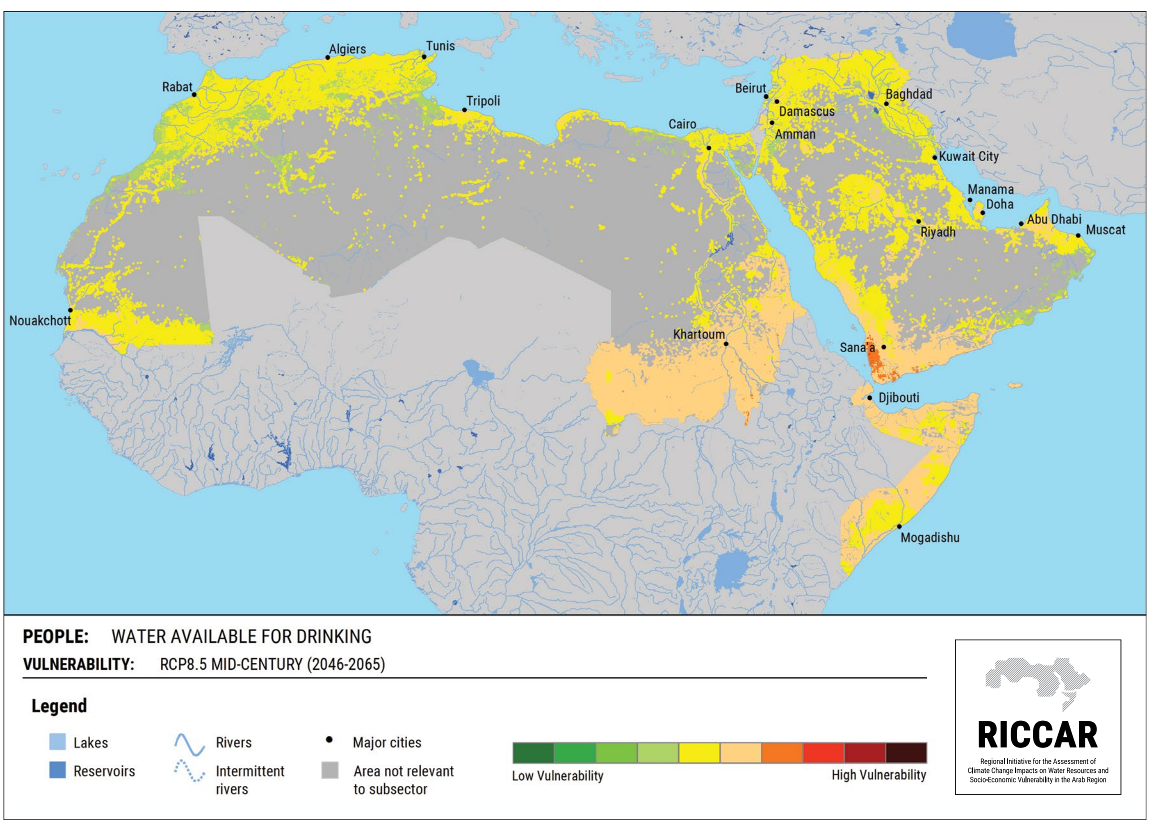


FIGURE 202: Water available for drinking – End-century RCP 4.5 – Vulnerability

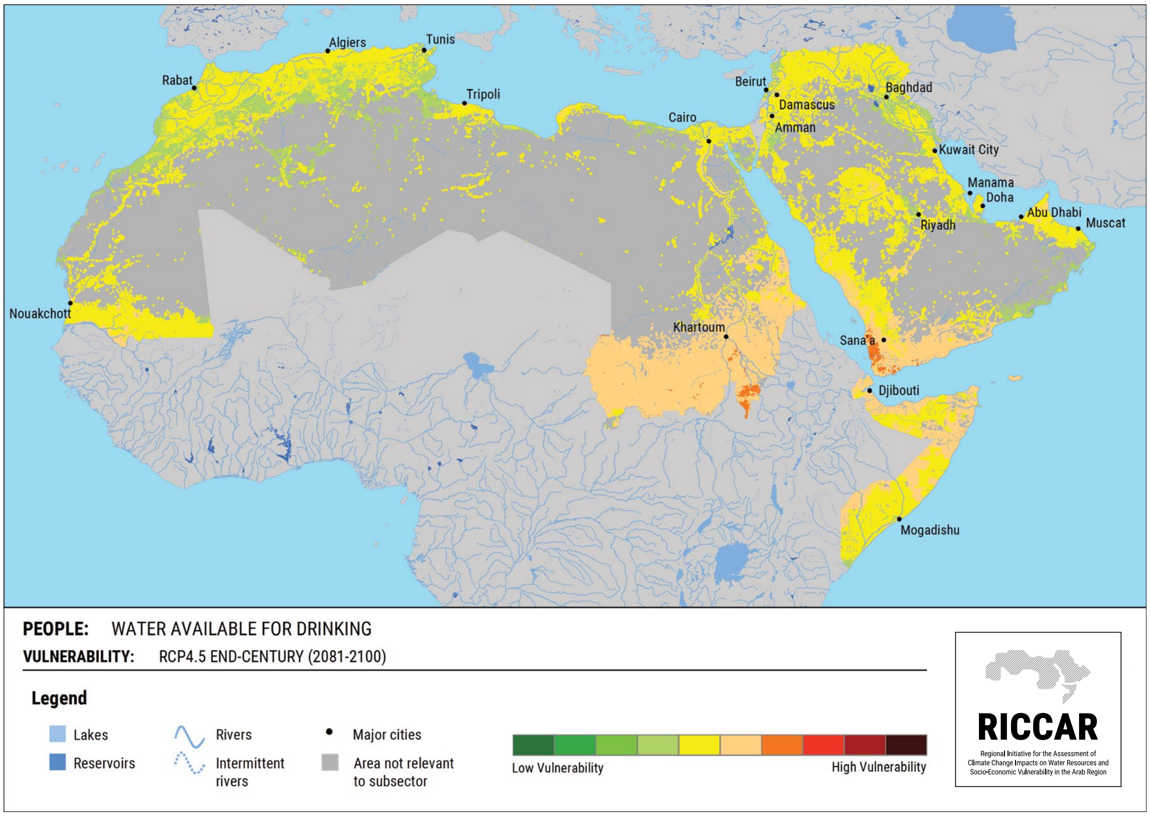
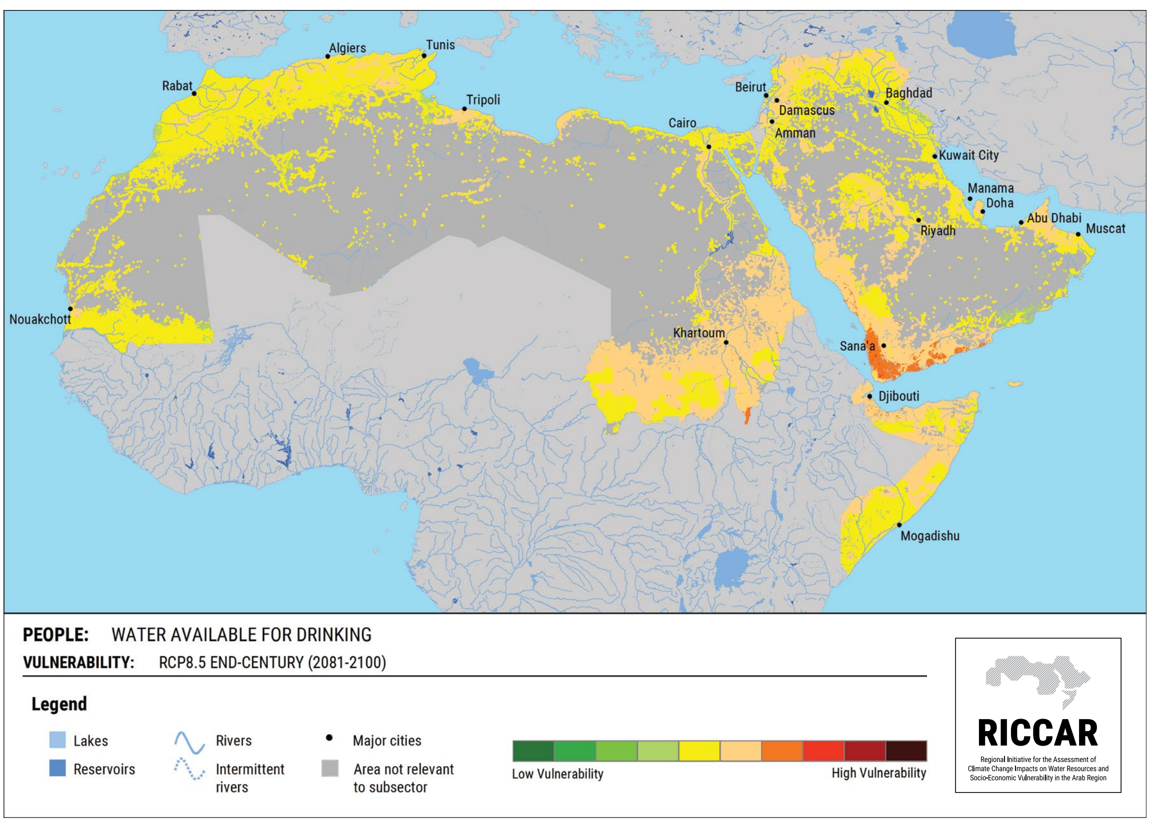


FIGURE 203: Water available for drinking – End-century RCP 8.5 – Vulnerability



13.1.3 Hotspots

Water available for drinking hotspots reveal areas with the highest vulnerability and represent about 1% of the study area. Hotspots include the south-western Arabian Peninsula near the Red Sea and Gulf of Aden coastlines, the northern coast of the Horn of Africa and the White Nile–Blue Nile watershed in the eastern Sahel. Most of these areas are rural and as low as 16% of the population have access to improved water sources.[2] These improved water sources do not factor water quality, so access to drinking water is probably significantly lower. Recently, the south-western Arabian Peninsula faced a very high incidence of cholera due to a lack of clean drinking water, resulting in several deaths.

In the Horn of Africa, drinking-water availability suffers due to lack of sanitation (only about 10% of the population has access)[3], recent drought and other problems. Although rainfall and runoff are expected to increase in much of the Horn of Africa, it will remain largely the same as the reference period along the northern coast. This, coupled with increasing numbers of hot days and very hot days, will potentially increase drought risk in the area. Local inhabitants use rainfall-harvesting storage, known as *berkads*, for a supplementary water supply, but these units are ineffective during prolonged drought.

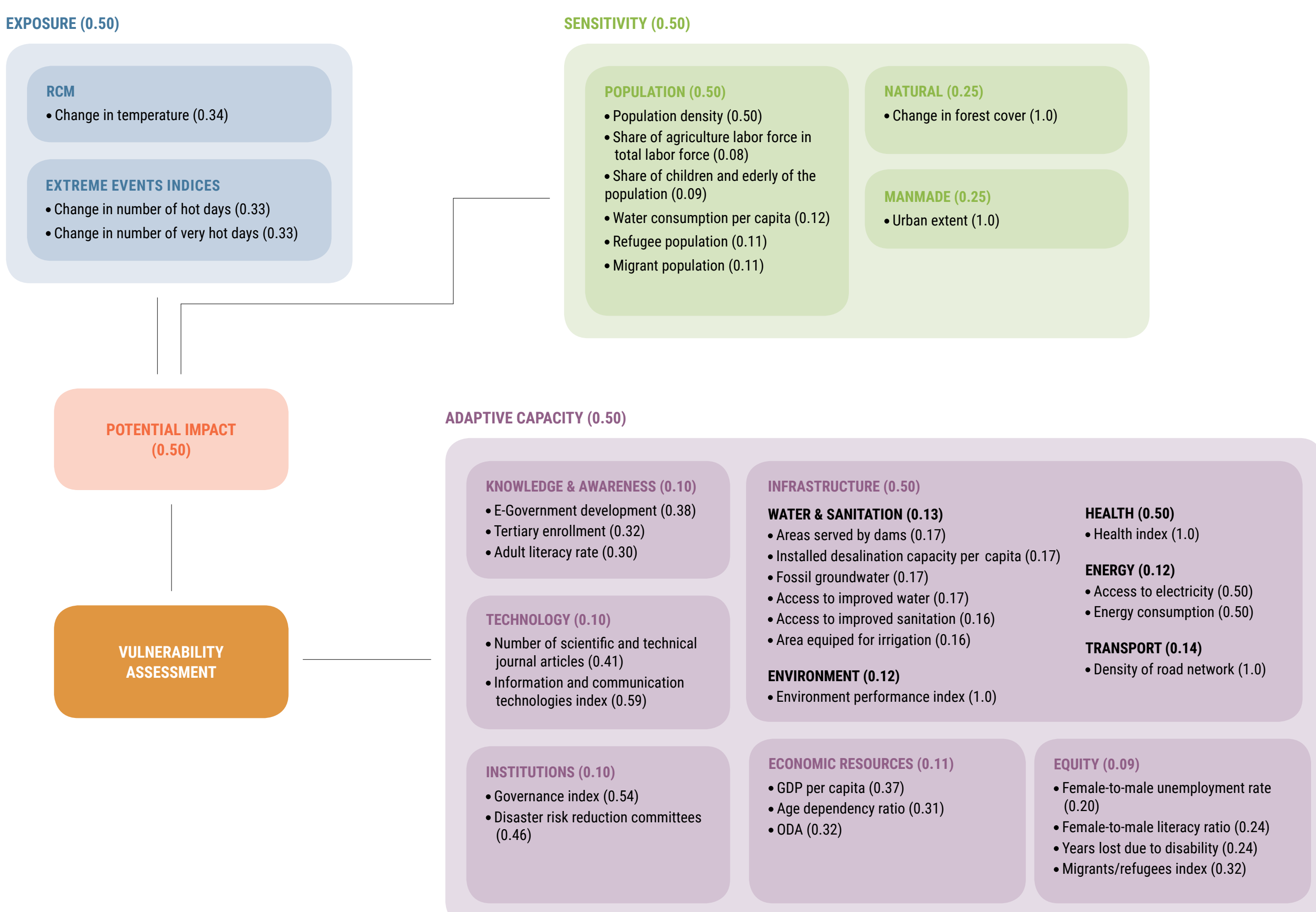
Despite the proximity to large rivers, the White Nile–Blue Nile watershed is also projected to suffer from the lack of available drinking water. Most water resources (about 96% of total available renewable water)[4] are allocated to agricultural needs.

Because the area is largely agricultural, drinking water sources are subject to contamination from fertilizers and pesticides. The region currently maintains a moderately dense population, which can be expected to grow in the future, placing a further strain on water resources.

13.2 HEALTH CONDITIONS DUE TO HEAT STRESS

Figure 204 highlights the impact chain for this subsector showing the set of indicators considered for analysis and its assigned weights.

FIGURE 204: Impact chain and weights for health conditions due to heat stress



13.2.1 Reference period

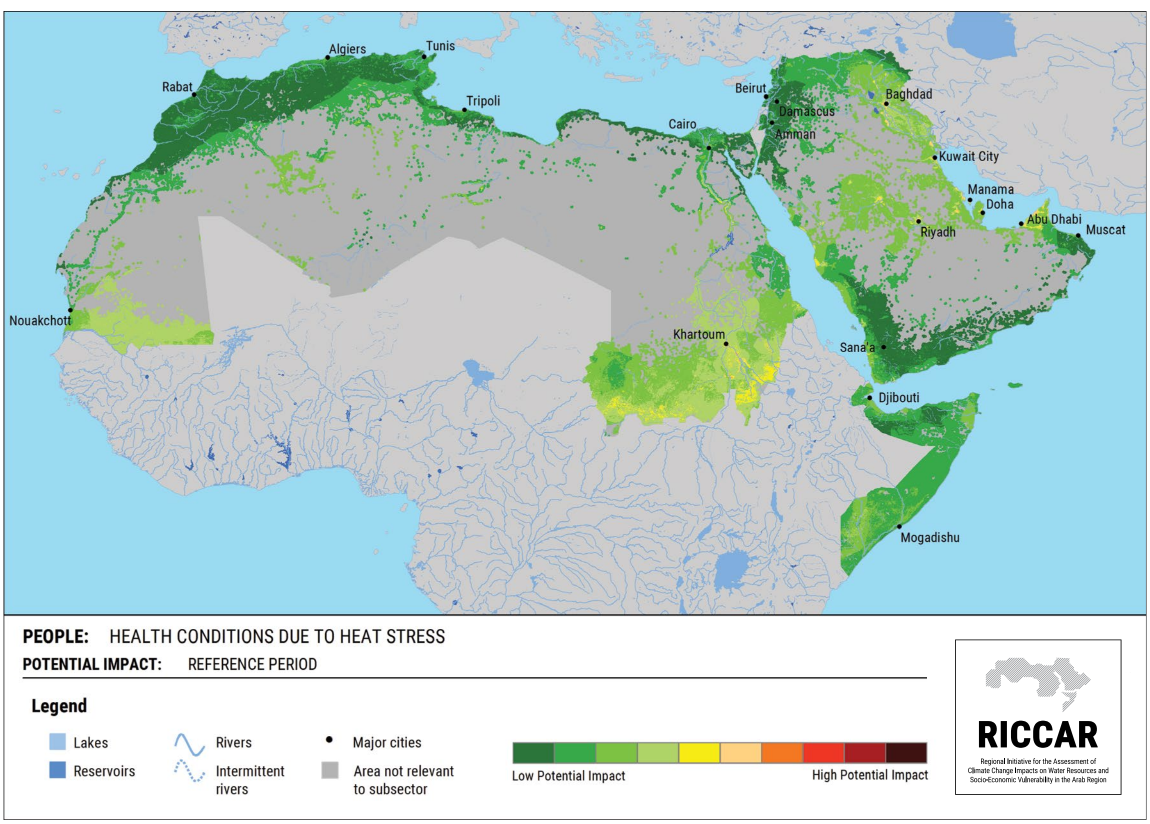
13.2.1.1 Potential impact

Potential impact reflects the combination of exposure and sensitivity. Abnormally high temperatures can provoke heat stress-related ailments, such as heat rash, heat cramps, heat exhaustion and heat stroke. Severe heat stroke can occur when the core body temperature exceeds 39 °C, potentially inducing organ failure or mortality. Nearly the entire study area (98%) has at least one day a year which exceeds 40 °C while 20% of the study area has at least 100 days per year which exceed 40 °C. Heat stress and its correlation with temperature-related factors was the basis for selecting temperature, the annual number of hot days (SU35) and the annual number of very hot days (SU40) as exposure indicators. Areas with highest exposure include the Sahara Desert, while areas of low exposure tend to be in coastal and mountainous regions. It should be noted that exposure is based on annual averages and thus seasonality is not considered; exposure is expected to be significantly higher during the summer months.

Selected sensitivity indicators focus on the population, particularly groups more susceptible to heat stress, including the elderly, children and marginalized groups. In addition, people who work outdoors are also stress-prone. Other sensitivity indicators consider change in forest cover based on shading and cooling effects and urban extent because of urban heat inland effects. Nearly the entire study area (98%) indicates low sensitivity; remaining areas suggest moderate sensitivity and are confined to isolated locations near urban settings.

The resultant potential impact (Figure 205) follows similar trends as exposure due to sensitivity homogeneity. Low potential impact is indicated in 82% of the study area and remaining areas suggest moderate potential impact. Areas with the highest potential impact relative to the region are located in the upper Nile Valley, isolated areas of the Arabian Desert and the Nahr Diyala Valley in Mesopotamia. Actual potential impact is likely higher in certain areas due to exposure factors such as humidity, which can increase apparent temperature. Additionally, sensitivity parameters such as the prevalence of cardiovascular disease, housing characteristics and air-conditioning availability are also not considered due to data unavailability.

FIGURE 205: Health conditions due to heat stress – Reference period – Potential impact



13.2.1.2 Adaptive capacity

Adaptive capacity is primarily affected by the health pillar under the infrastructure dimension, consisting solely of the Health index. This index is a composite of three parameters: per capita total expenditure on health, general government expenditure on health and number of hospital beds. Access to improved medical facilities enables the ability to treat ailments such as heat-related disorders quickly. Adaptive capacity is largely moderate, representing 75% of the study area. Low adaptive capacity is indicated in 21% of the study area, primarily in the Horn of Africa. Remaining areas suggest high adaptive capacity (Figure 206).

13.2.1.3 Vulnerability

Heat stress vulnerability for the reference period is largely moderate, representing 64% of the study area; remaining areas suggest low vulnerability.

Areas with relatively high vulnerability are the Sahel, sections along the northern coast of the Horn of Africa, the Jubba River Valley in the southern Horn of Africa and isolated areas within the Tigris–Euphrates basin. Conversely, areas with low vulnerability are the Atlas Mountains and the Levant (Figure 207).

As expected, heat stress vulnerability has a strong correlation with exposure. Areas with high vulnerability have an average of 254 hot days (SU35) and 115 very hot days (SU40) annually.

On the other hand, areas of low vulnerability have an average of 49 hot days and 6 very hot days; considering the threshold for heat-stroke risk (39 °C), even areas with low vulnerability warrant concern. At least 52 heatwave events occurred during the reference period in the Levant,[5] an area of relatively low vulnerability.

FIGURE 206: Health conditions due to heat stress – Adaptive capacity

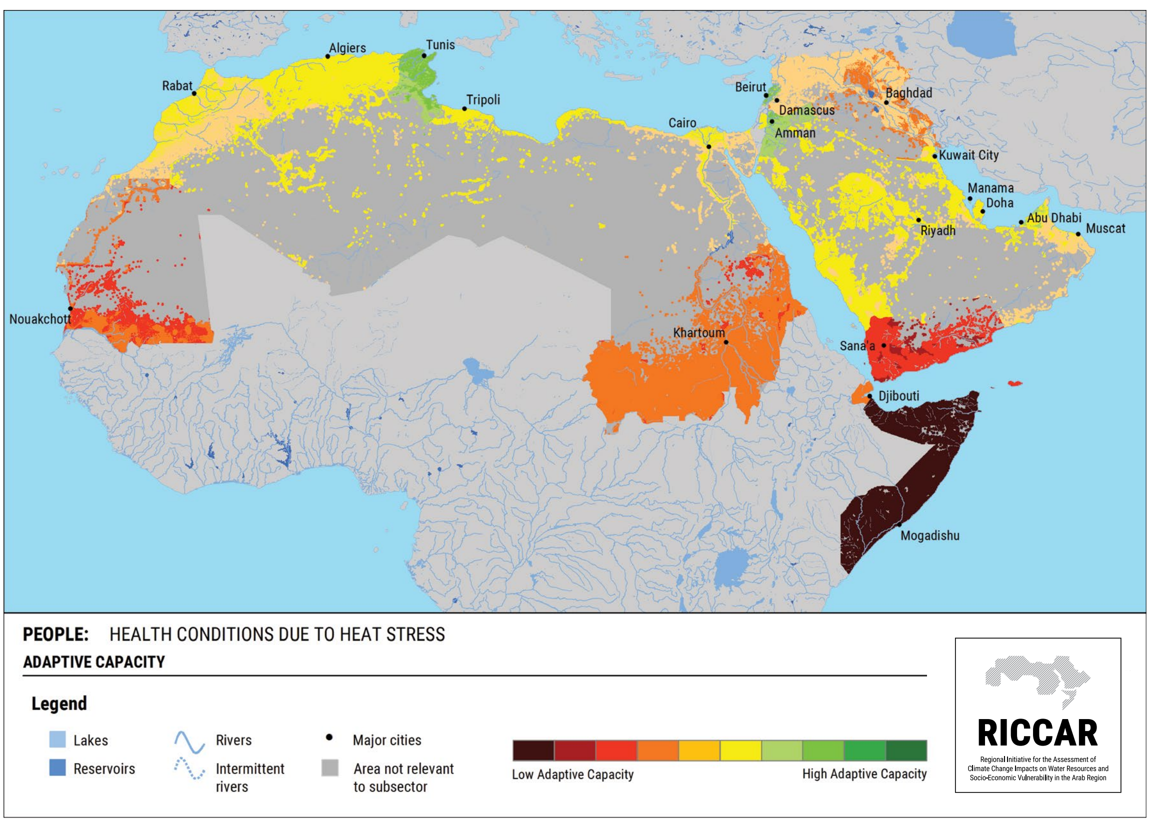
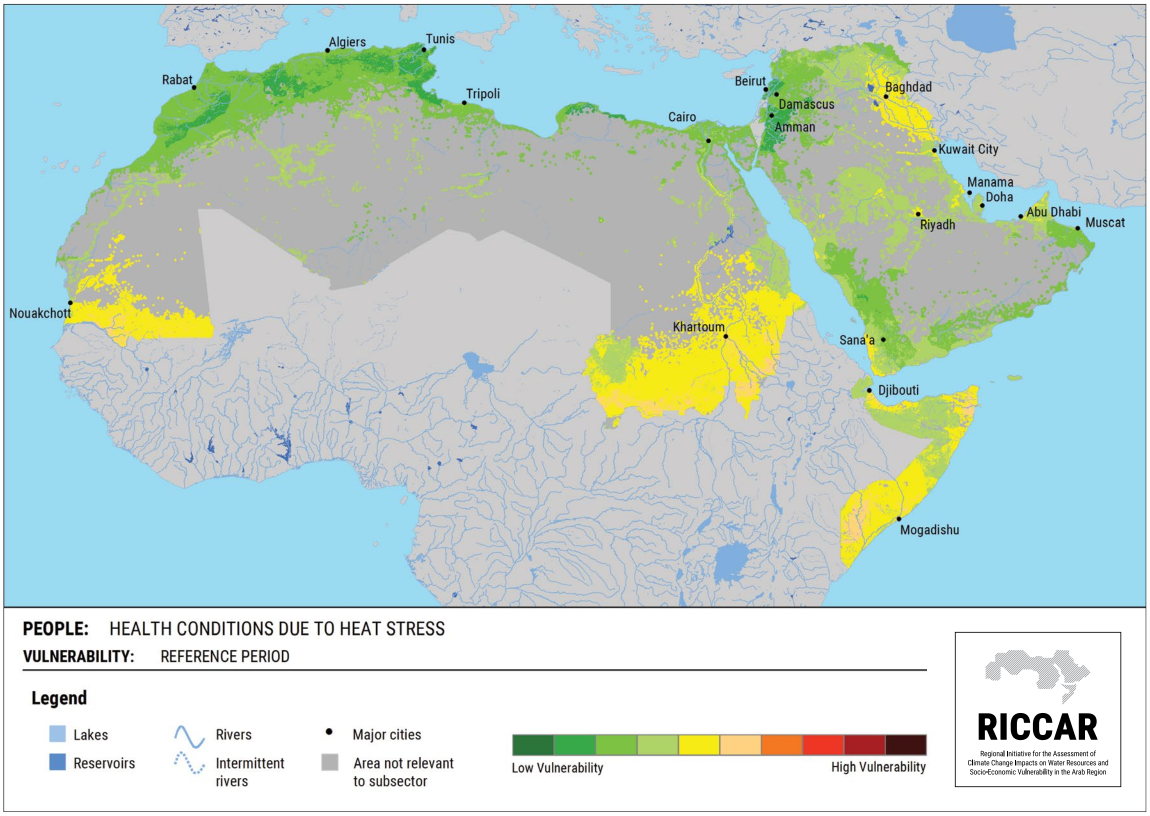


FIGURE 207: Health conditions due to heat stress – Reference period –Vulnerability



13.2.2 Future period

13.2.2.1 Potential impact

Like the reference period, areas of projected higher exposure tend to be located in desert regions, while low exposure is generally in coastal or mountainous areas. Nonetheless, areas of low, moderate and high exposure tend to be wide-ranging throughout the study area. At mid-century (Figure 208 and Figure 209), areas of moderate exposure range from 39% (RCP 4.5) to 51% (RCP 8.5) of the study area, while areas of high exposure range from 0% (RCP 4.5) to 22% (RCP 8.5). At end-century, exposure increases such that 23% (RCP 8.5) to 46% (RCP 4.5) of the study area represents moderate exposure and 15% (RCP 4.5) to 75% (RCP 8.5) indicates high exposure (Figure 210 and Figure 211). Remaining areas indicate low exposure. Humidity was not considered: it can impact the Heat Index and raise exposure in coastal areas such as the Gulf.

Due to low sensitivity, low potential impact is revealed in a majority of the study area for all scenarios, ranging from 89% (RCP 8.5) to 97% (RCP 4.5) at mid-century and from 63% (RCP 8.5) to 90% (RCP 4.5) at end-century. Remaining areas suggest moderate potential impact. Like the reference period, future potential impact is closely correlated with exposure due to sensitivity homogeneity.

Research has shown that in major cities, where the warmest months exceed 30 °C, a 3% increase in death rates is expected per 1 °C increase in temperature.[6] Based on this assumption, more than 330 million people in the Arab region (92% of total in 2014)[7] could be subjected to at least a 9% increase in death rates and over 111 million people (31% of total in 2012) will be subjected to at least a 12% increase under RCP 8.5 at the end of the century.

Potential impact can differ based on differences in sensitivity. For example, it is anticipated that population growth rates will correspondingly result in an increase in heat stress instances. In addition, population growth often coincides with areas of high urban heat island potential. On the other hand, areas with significant temperature increases may render the region uninhabitable and force migration.

FIGURE 208: Health conditions due to heat stress – Mid-century RCP 4.5 – Potential impact

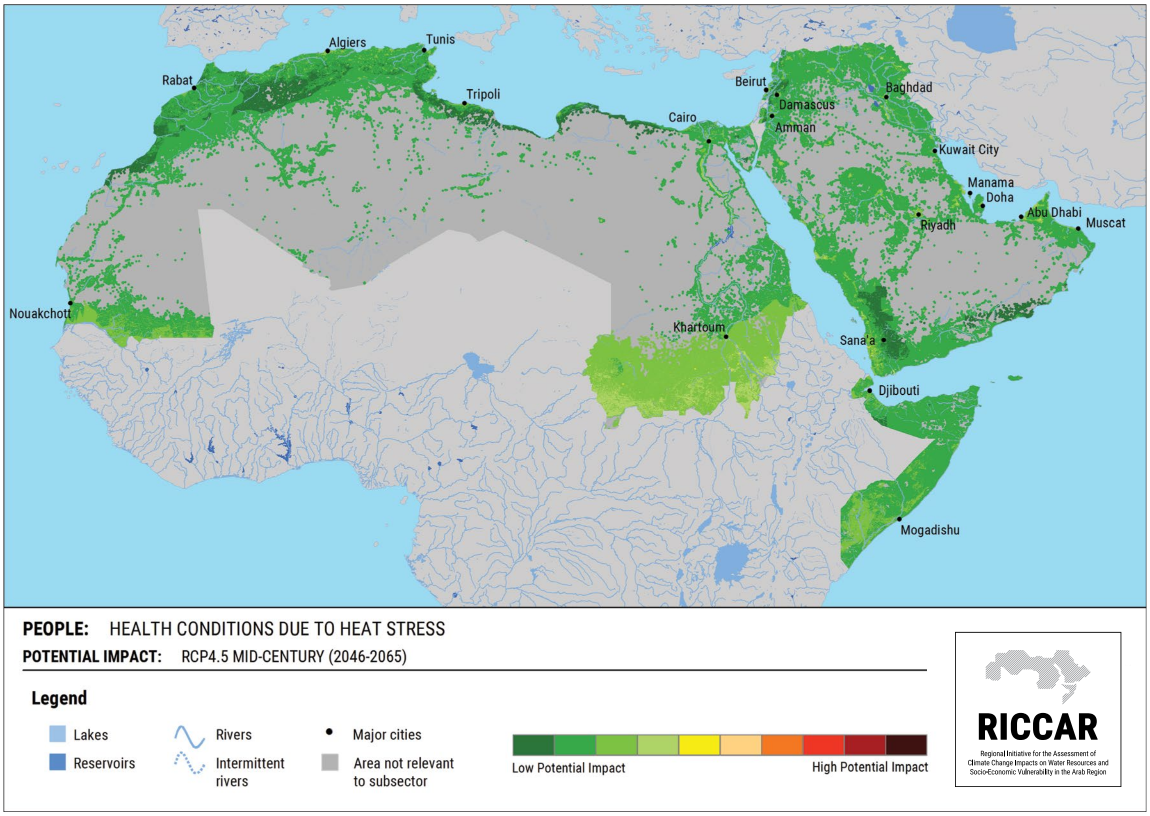


FIGURE 209: Health conditions due to heat stress – Mid-century RCP 8.5 – Potential impact

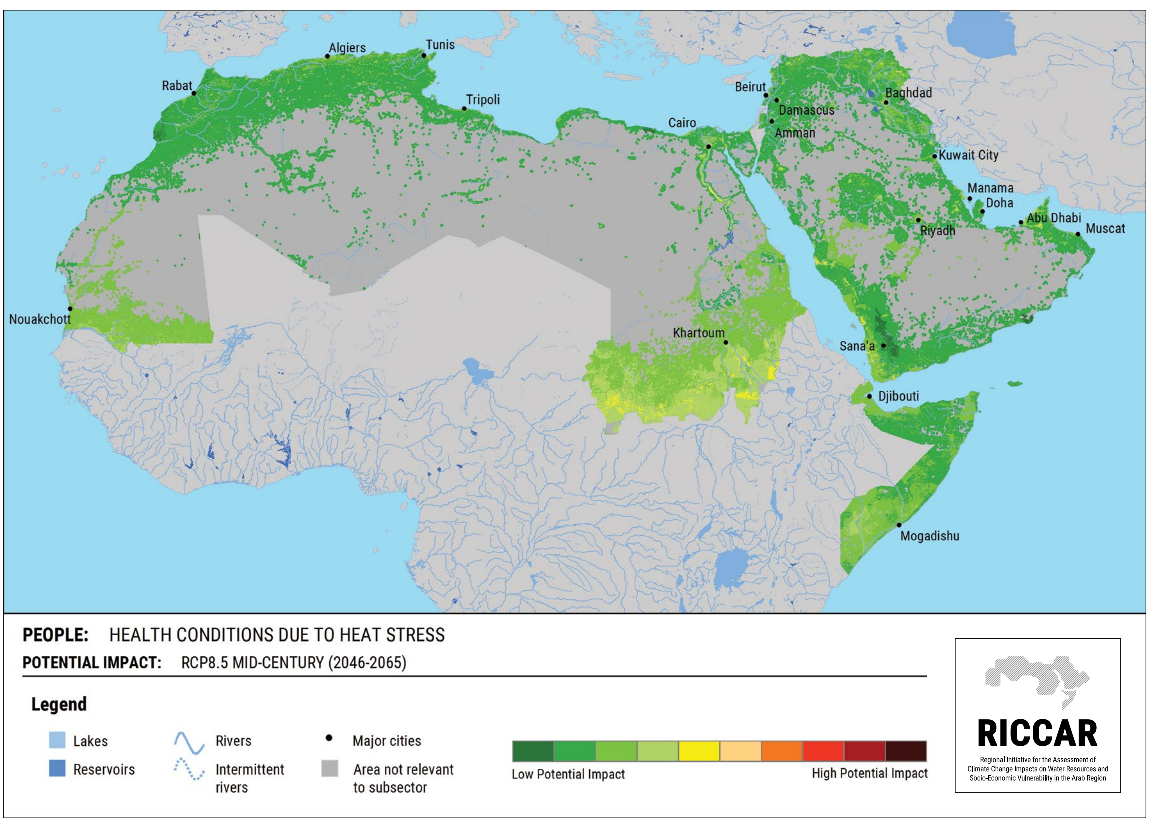


FIGURE 210: Health conditions due to heat stress – End-century RCP 4.5 – Potential impact

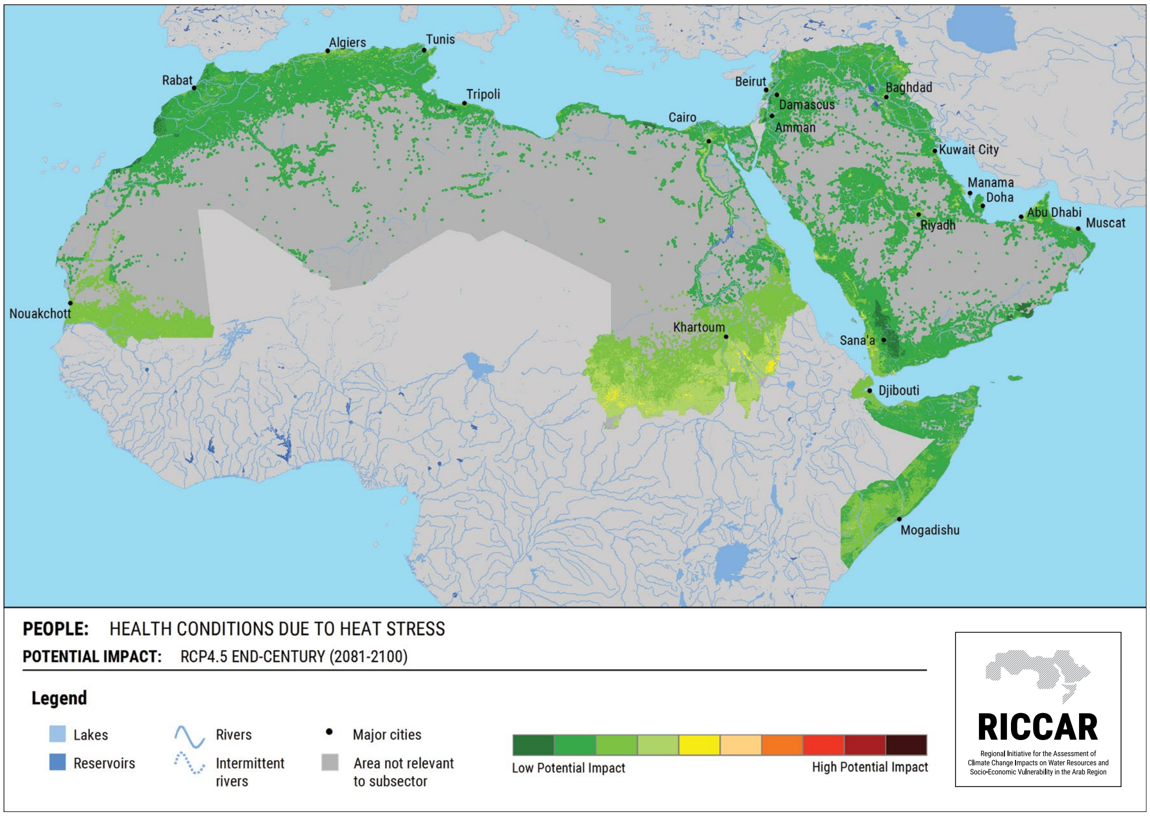
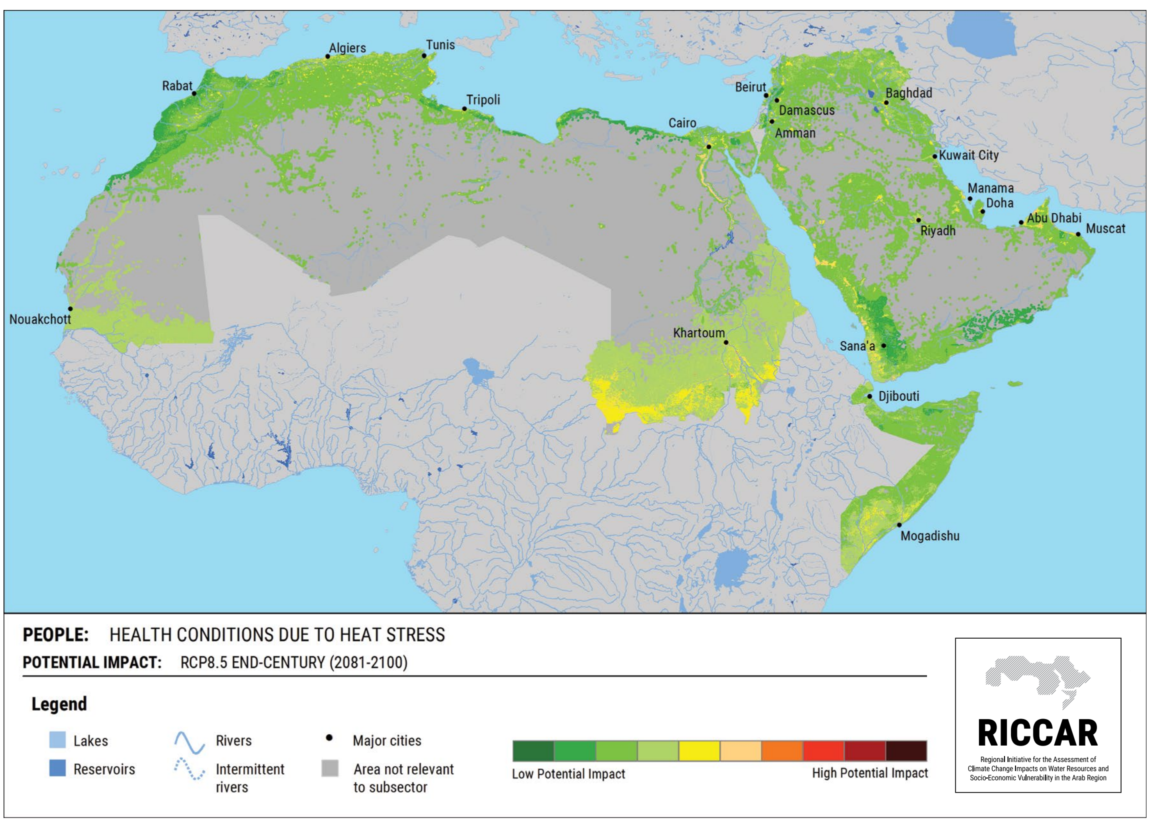


FIGURE 211: Health conditions due to heat stress – End-century RCP 8.5 – Potential impact



13.2.2.2 Vulnerability

At mid-century, moderate heat stress vulnerability is forecast for over half the study area, ranging from 55% (RCP 4.5) to 70% (RCP 8.5) of the study area. At end-century, this increases to 63% (RCP 4.5) to 95% (RCP 8.5) of the study area. Most remaining areas suggest low vulnerability, ranging from 30% (RCP 8.5) to 45% (RCP 4.5) of the study area at mid-century and 4% (RCP 8.5) to 37% (RCP 4.5) at end-century (Table 33). Vulnerability trends exhibit a low-to-moderate gradient from north to south, with areas of elevated vulnerability in the Levant and Mesopotamia (Figure 212 to Figure 215).

Because health problems due to heat stress vulnerability stems largely from exposure, the change in exposure indicators was evaluated by vulnerability classification (Table 34). Areas of high vulnerability retain a greater increase in indicator values than the Arab region as a whole. Because even areas of low vulnerability had periods when high temperatures were of concern, increases in these periods are problematic in terms of human health.

Trends reveal either nearly static vulnerability or increasing vulnerability from mid- to end-century. For RCP 4.5, areas of increasing vulnerability tend to be located in the Sahara Desert, the eastern Atlas Mountains, and the central Mashriq. However, these areas indicate nearly static vulnerability for RCP 8.5 but most of the remaining study area reveals increasing vulnerability.

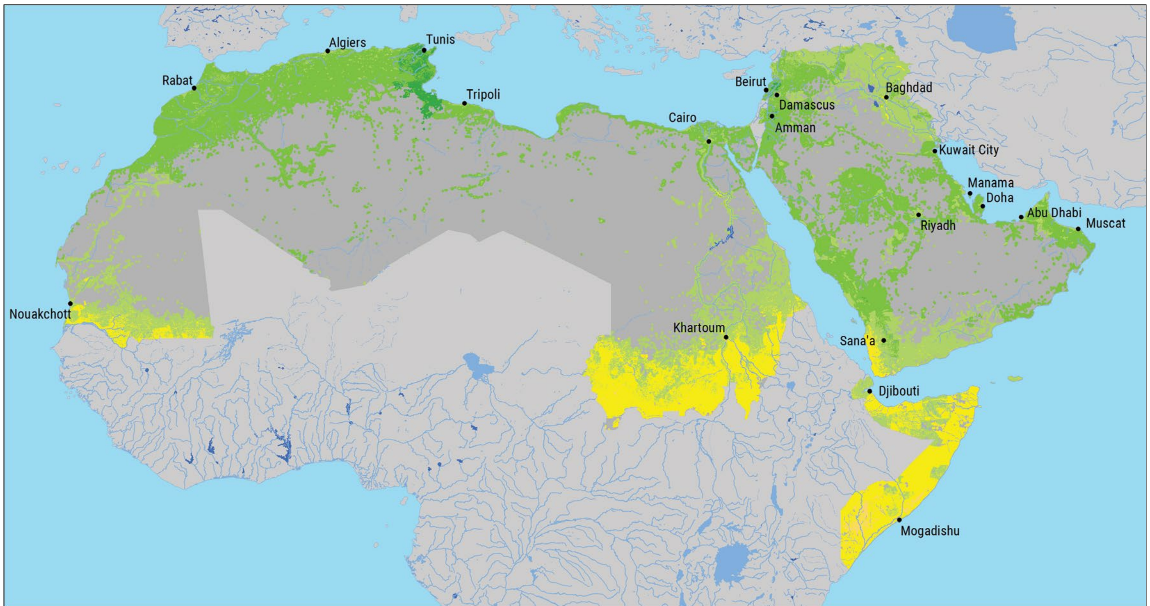
TABLE 33: Percentage of study area by vulnerability classification for health due to heat stress

Scenario	Vulnerability (% of study area)		
	Low	Moderate	High
Mid-Century RCP 4.5	45%	55%	0%
Mid-Century RCP 8.5	30%	70%	0%
End-Century RCP 4.5	37%	63%	0%
End-Century RCP 8.5	4%	95%	1%

TABLE 34: Average climate parameters by vulnerability classification

Exposure indicator	Units	Climate scenario	Average indicator value by vulnerability classification for subsector		Average indicator value for Arab region
			Low	Moderate	
Change in temperature (compared to reference period)	°C	Mid-Century RCP 4.5	+1.4	+1.5	+1.5
		Mid-Century RCP 8.5	+2.1	+2.1	+2.1
		End-Century RCP 4.5	+1.8	+1.9	+1.9
		End-Century RCP 8.5	+3.5	+4.0	+4.0
Change in number of hot days (SU35) (compared to reference period)	days/year	Mid-Century RCP 4.5	+22	+46	+30
		Mid-Century RCP 8.5	+30	+55	+41
		End-Century RCP 4.5	+27	+54	+38
		End-Century RCP 8.5	+54	+84	+74
Change in number of very hot days (SU40) (compared to reference period)	days/year	Mid-Century RCP 4.5	+15	+38	+28
		Mid-Century RCP 8.5	+16	+48	+39
		End-Century RCP 4.5	+18	+46	+36
		End-Century RCP 8.5	+26	+77	+76

FIGURE 212: Health conditions due to heat stress – Mid-century RCP 4.5 – Vulnerability



PEOPLE: HEALTH CONDITIONS DUE TO HEAT STRESS
VULNERABILITY: RCP4.5 MID-CENTURY (2046-2065)

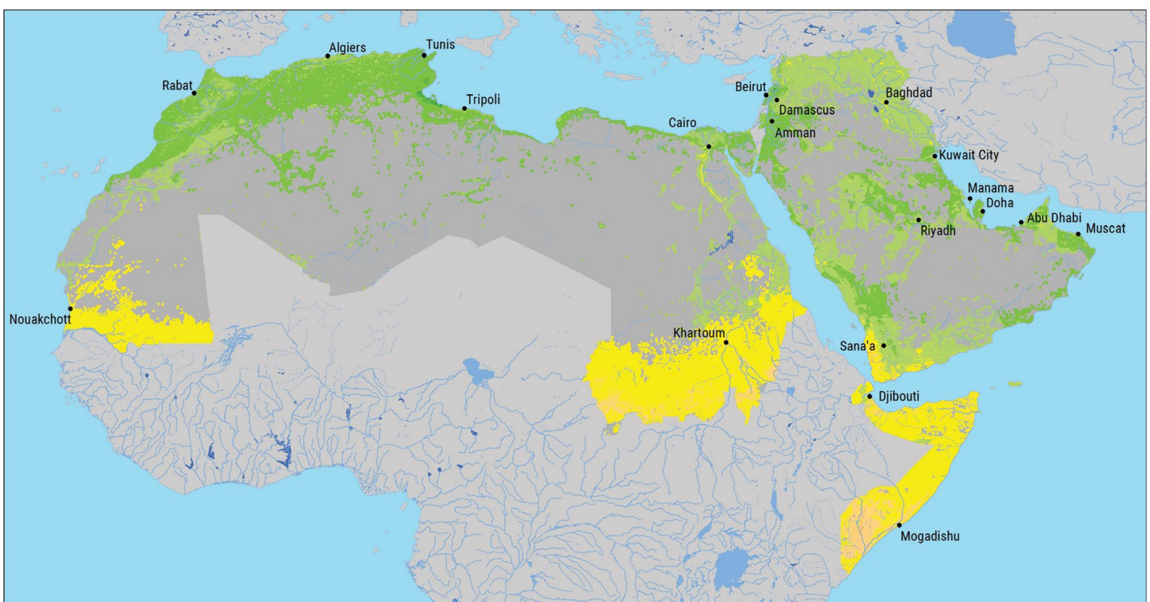
Legend

Lakes
Reservoirs
Rivers
Intermittent rivers
Major cities
Area not relevant to subsector

Low Vulnerability — High Vulnerability

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

FIGURE 213: Health conditions due to heat stress – Mid-century RCP 8.5 – Vulnerability



PEOPLE: HEALTH CONDITIONS DUE TO HEAT STRESS
VULNERABILITY: RCP8.5 MID-CENTURY (2046-2065)

Legend

Lakes
Reservoirs
Rivers
Intermittent rivers
Major cities
Area not relevant to subsector

Low Vulnerability — High Vulnerability

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

FIGURE 214: Health conditions due to heat stress – End-century RCP 4.5 – Vulnerability

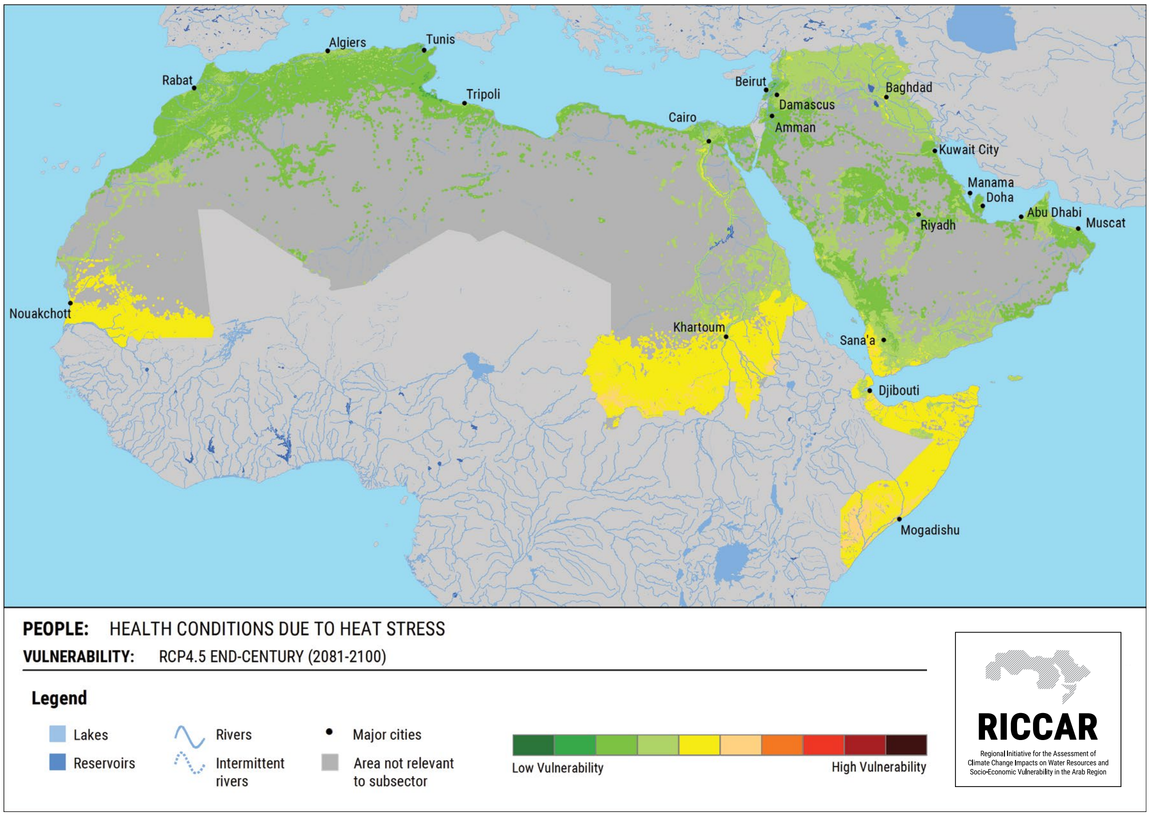
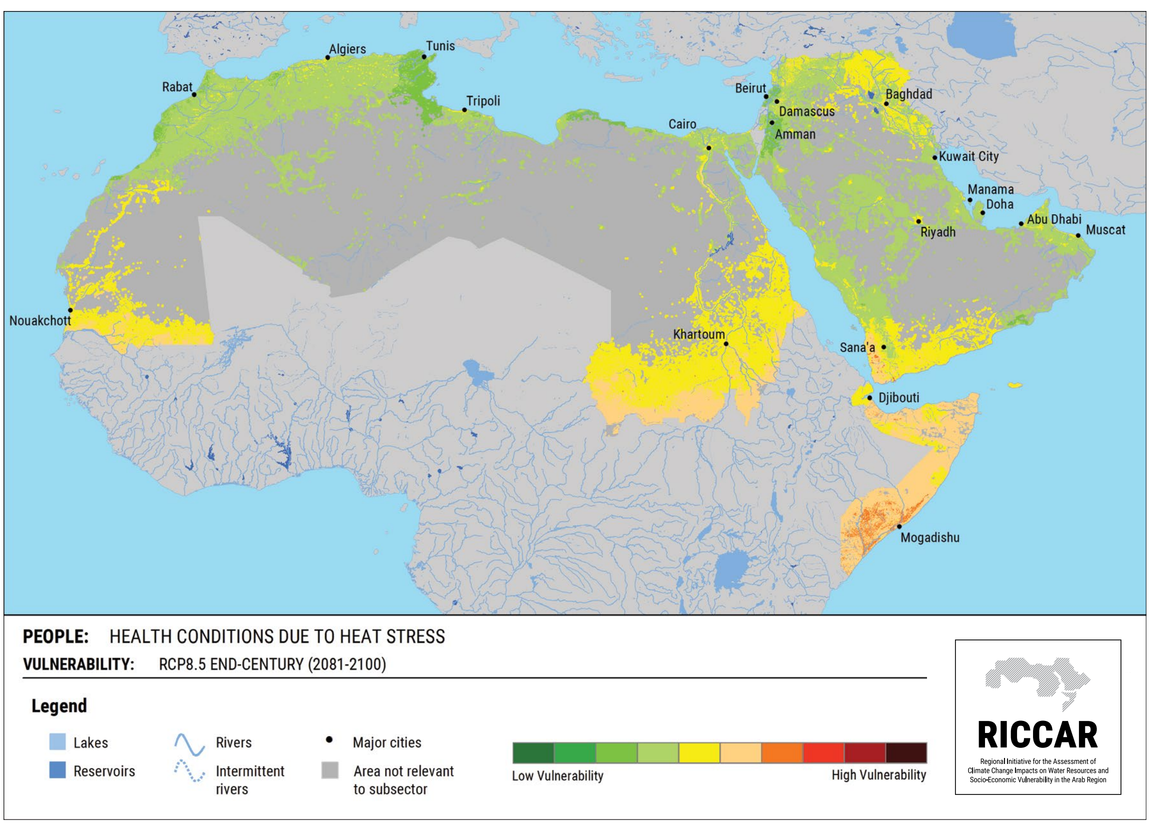


FIGURE 215: Health conditions due to heat stress – End-century RCP 8.5 – Vulnerability



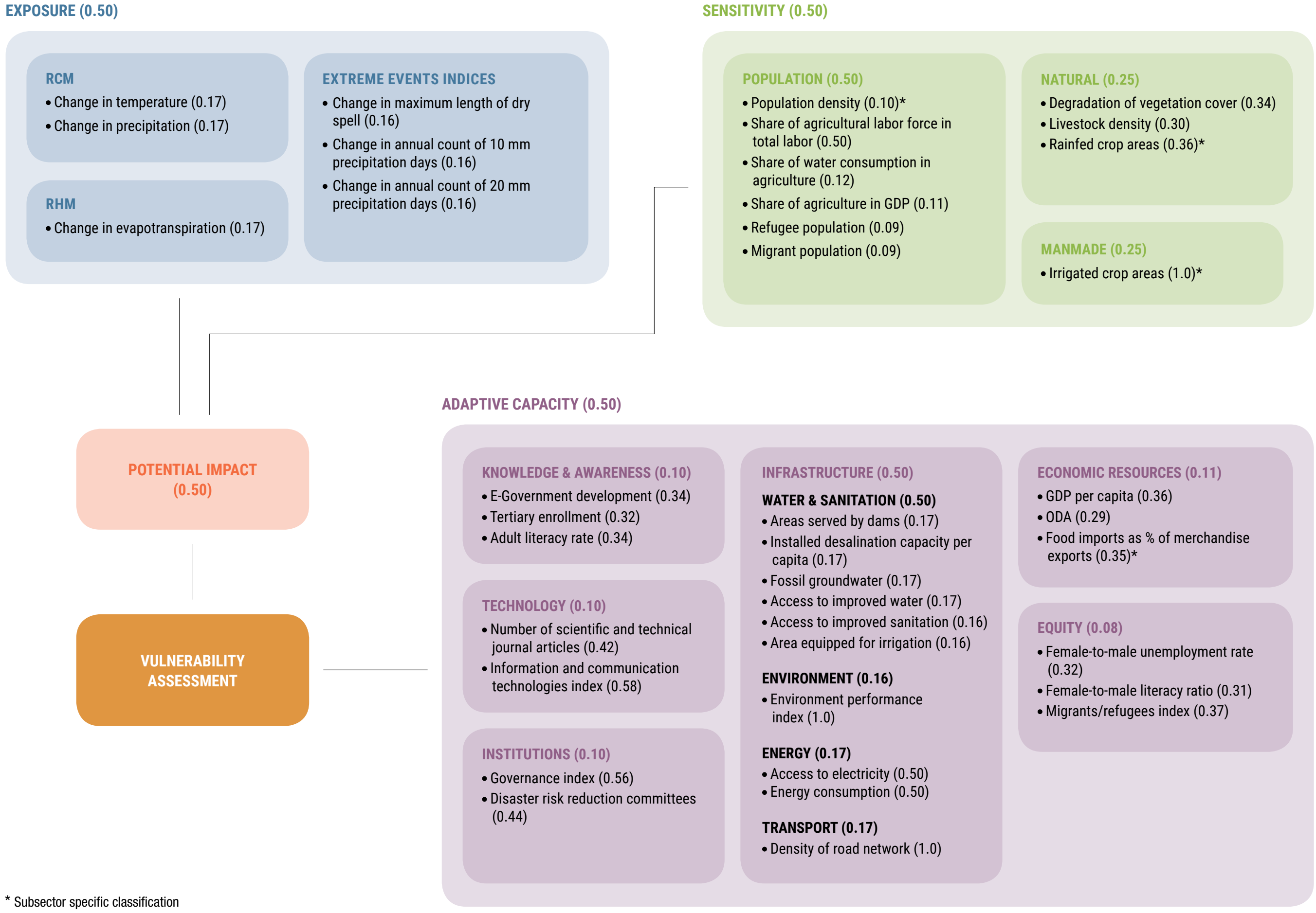
13.2.3 Hotspots

Areas with the highest vulnerability have been identified as hotspots and include very few areas, impacting up to 6% of the study area. Hotspots result from insufficient adaptation capacity measures in place, as well as temperature changes. Hotspots are located in sub-Saharan Africa, particularly in the southern Horn of Africa and the south-western Arabian Peninsula. Even though these areas are small on a regional scale, heat stress hotspots are projected to affect significantly more people by the end of the century, compared to the mid-century period, with the number of very hot days projected to reach 98 days annually.

13.3 EMPLOYMENT RATE FOR THE AGRICULTURAL SECTOR

The different indicators used under each component for this subsector and their corresponding weights are presented in the impact chain in Figure 216.

FIGURE 216: Impact chain and weights for employment rate for the agricultural sector



* Subsector specific classification

13.3.1 Reference period

13.3.1.1 Potential impact

Potential impact reflects the equal aggregation of exposure and sensitivity. Selection of exposure indicators for this subsector is not necessarily as evident as for other evaluated subsectors. Nevertheless, agriculture is highly contingent on meteorological parameters; thus, farmers and pastoralists also depend on suitable weather conditions.

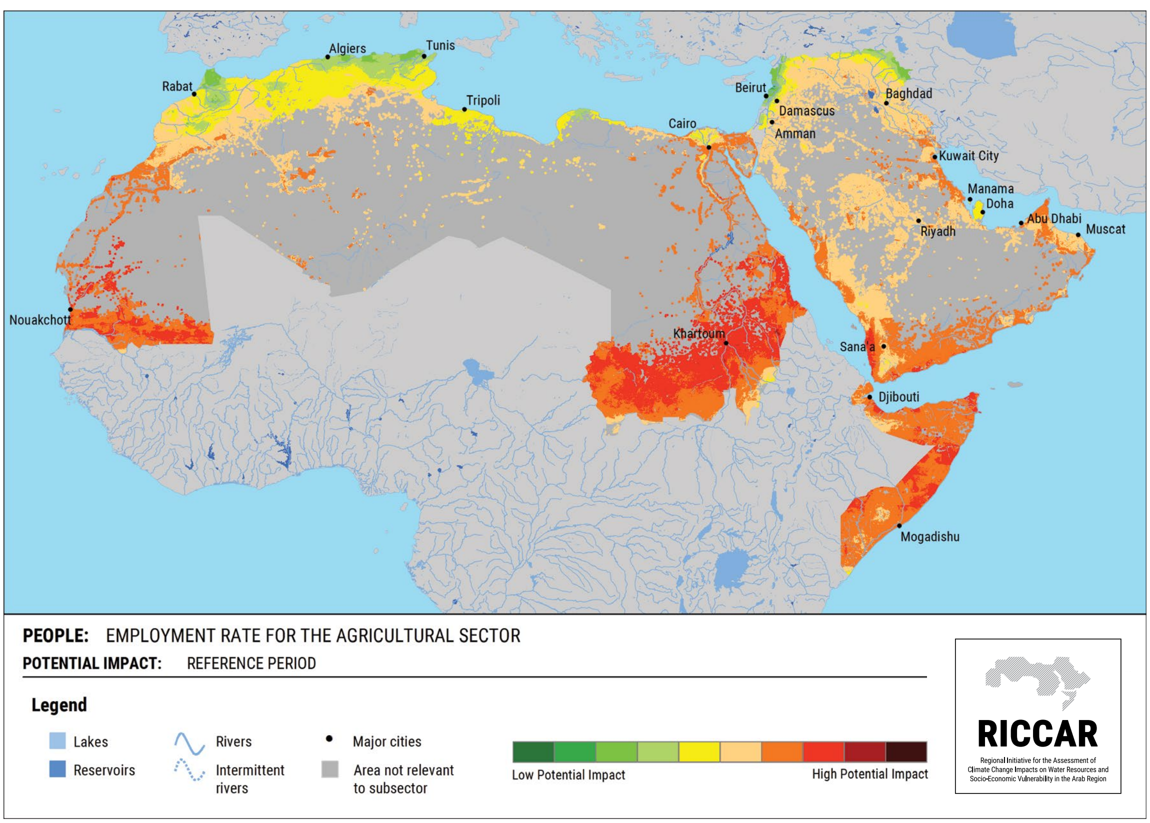
Moreover, as climate change impacts tend to be more severe for those who work in rainfed agriculture, precipitation-related indicators were selected, including those that can signify drought. Nearly half (42%) of the study suggests high exposure, primarily located in the Sahara Desert. High exposure transitions to moderate exposure (51% of the study area) until low exposure areas, which are located in the Rif region, the eastern Tell Atlas region, the coastal Levant and the Zagros Mountains.

Sensitivity indicators are largely population-based, with a focus on the rural population, who is most likely to work in agriculture. In addition, indicators related to agriculture were also considered. The resultant sensitivity is generally high. High sensitivity represents 64% of the study area and includes sub-Saharan Africa, the western Maghreb and the southern Arabian Peninsula.

Remaining areas suggest moderate sensitivity. Sensitivity for this subsector is generally higher than other subsectors because the rainfed croplands and irrigated croplands indicators were reclassified such that areas of lower cropland area were more sensitive due to limited agricultural employment opportunity in such areas.

The resultant potential impact for the reference period (Figure 217) is nearly equally divided between moderate (48% of the study area) and high (51% of the study area). Areas with the highest potential impact include sub-Saharan Africa (other than the Sahel), the central Horn of Africa and coastal areas of the south-western Arabian Peninsula.

FIGURE 217: Employment rate for the agricultural sector – Reference period – Potential impact



13.3.1.2 Adaptive capacity

Adaptive capacity is primarily influenced by the infrastructure dimension, specifically indicators which comprise the water pillar. While more advanced water infrastructure helps facilitate irrigation capabilities, the other five dimensions are also significant. Although the indicators within are not directly related to agricultural employment, they can be considered as proxies for the dimension they represent.

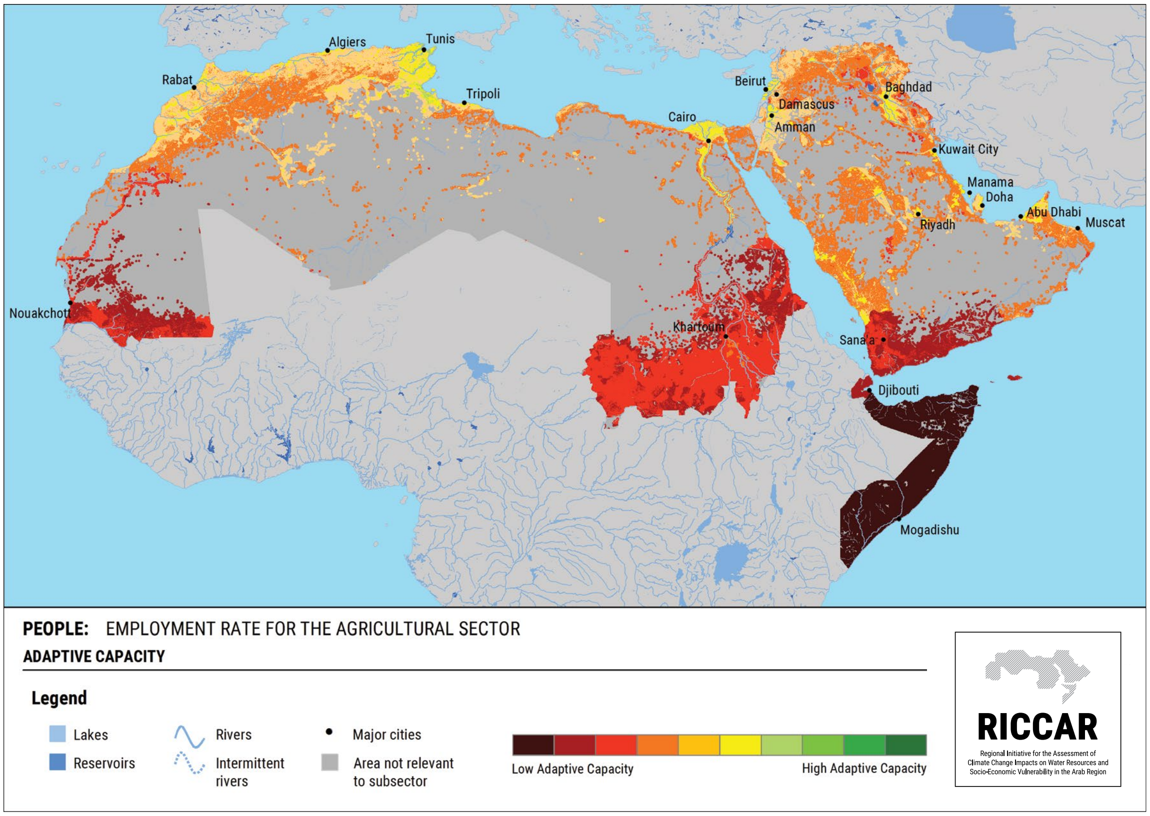
Knowledge and awareness can provide guidance for more advanced techniques using current technology. Government institutions can help facilitate participation by small farmers in decision-making processes and economic resources. Lastly, women have occupied a greater role in agriculture, representing about 30% of the agricultural workforce in the Arab region.[8]

The study area is divided between low and moderate adaptive capacity (45% and 54%, respectively) with the remaining area indicating high adaptive capacity (Figure 218). Areas with the lowest adaptive capacity include the Horn of Africa, parts of the Sahara Desert, and the Wadi Hadramawt region.

Conversely, areas with relatively high adaptive capacity include the eastern Atlas Mountains and Tell Atlas region, the Jafara Plain and small areas near the Jordan and Litani Rivers.

Agricultural workers in Debel, Lebanon, 2006. Source: Carol Chouchani Cherfane.

FIGURE 218: Employment rate for the agricultural sector – Adaptive capacity



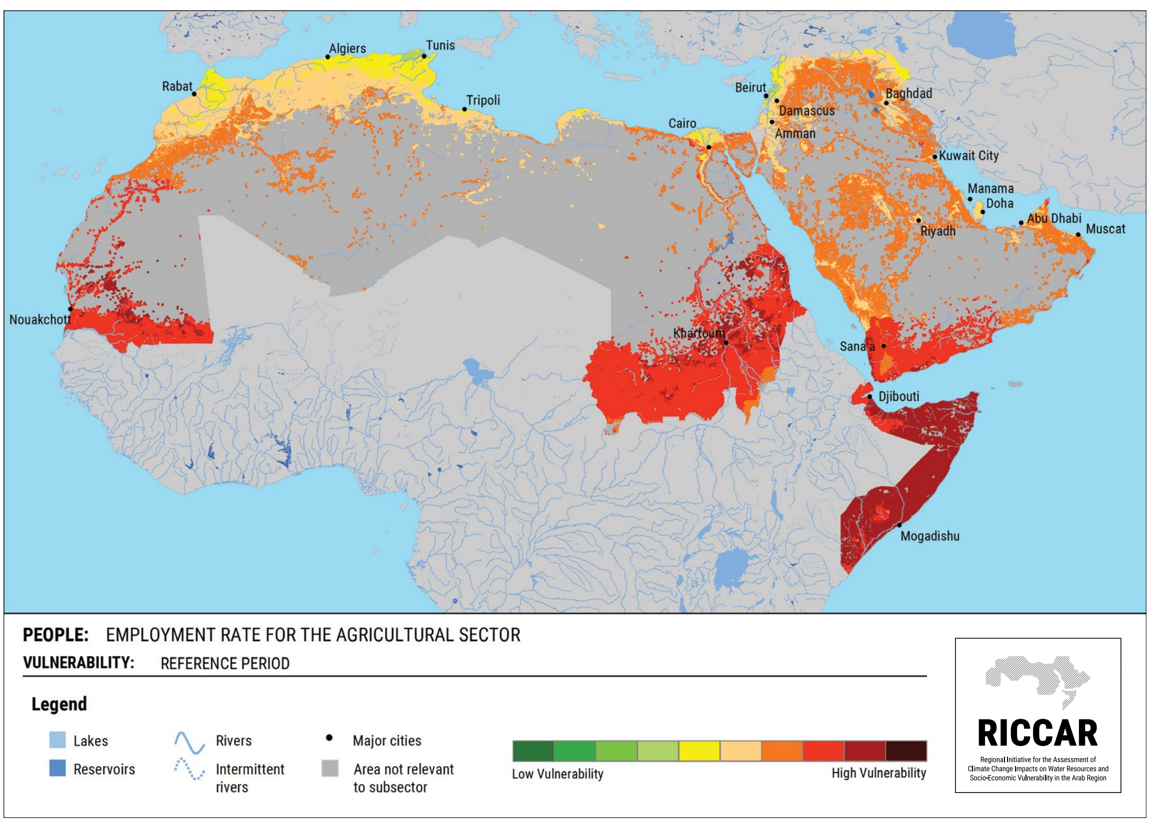
13.3.1.3 Vulnerability

Vulnerability for the reference period is rather high overall, representing 75% of the studied area (Figure 219). Remaining areas suggest moderate vulnerability. Areas of high vulnerability include the Horn of Africa, sub-Saharan Africa and the southern Arabian Peninsula. Pastoralists are considered most at risk for employment opportunities because vulnerability is highest (7.4) in livestock areas. Conversely, vulnerability is lowest (5.7) in irrigated areas. Vulnerability is moderate for both rainfed areas (6.5) and rural areas (6.6), although vulnerability tends to decrease as rural population increases.

Once the primary employment sector in the Arab region, agricultural occupations have been declining since the 1970s. The only area where agriculture represents > 50% of the labour market is the Horn of Africa.[9] Oil wealth and resultant opportunities in the industrial, construction and service sectors partly contributed to the decline. Rural-urban migration occurred as a result, shifting government priorities away from rural areas and agriculture towards urban challenges, further contributing to the decline.[10]

Livestock in Barakna State, Mauritania, 2010. Source: Ihab Jnad.

FIGURE 219: Employment rate for the agricultural sector – Reference period – Vulnerability



13.3.2 Future periods

13.3.2.1 Potential impact

Exposure is largely moderate for most scenarios, representing 92% (RCP 4.5) to 94% (RCP 8.5) of the study area at mid-century. At end-century, exposure remains largely unchanged under RCP 4.5 but, for RCP 8.5, areas of moderate exposure decline to 66% of the study area and high exposure areas increase to 30%. Other areas predict low exposure. Areas of moderate to high exposure are dispersed throughout the study area, depending on the climate scenario, but are consistently located in the Rif region, the western Tindouf basin, the western North Africa coastline, the upper Nile Basin and the southern coastline of the Arabian Peninsula.

Similarly, projected potential impact is generally moderate, assuming static sensitivity. Moderate potential impact represents 70% (RCP 8.5) to 86% (RCP 4.5) of the study area at mid-century (Figure 220 and Figure 221), decreasing to 54% (RCP 8.5) to 71% (RCP 4.5) at end-century (Figure 222 and Figure 223). Remaining areas suggest high potential impact. Areas of high potential impact are located near the Atlantic, the upper Nile Basin, the south-western Arabian Peninsula and the northern Horn of Africa.

Potential impact can change due to differing population demographics, cropland areas and rangeland areas. Although population trends predict a growth rate, Arab youth have signalled a declining interest in agricultural employment. Land-use changes can also affect the ability and accessibility to work in agriculture.

A man herding goats in Tunisia, 2005. Source: Priit Kallas.

FIGURE 220: Employment rate for the agricultural sector – Mid-century RCP 4.5 – Potential impact

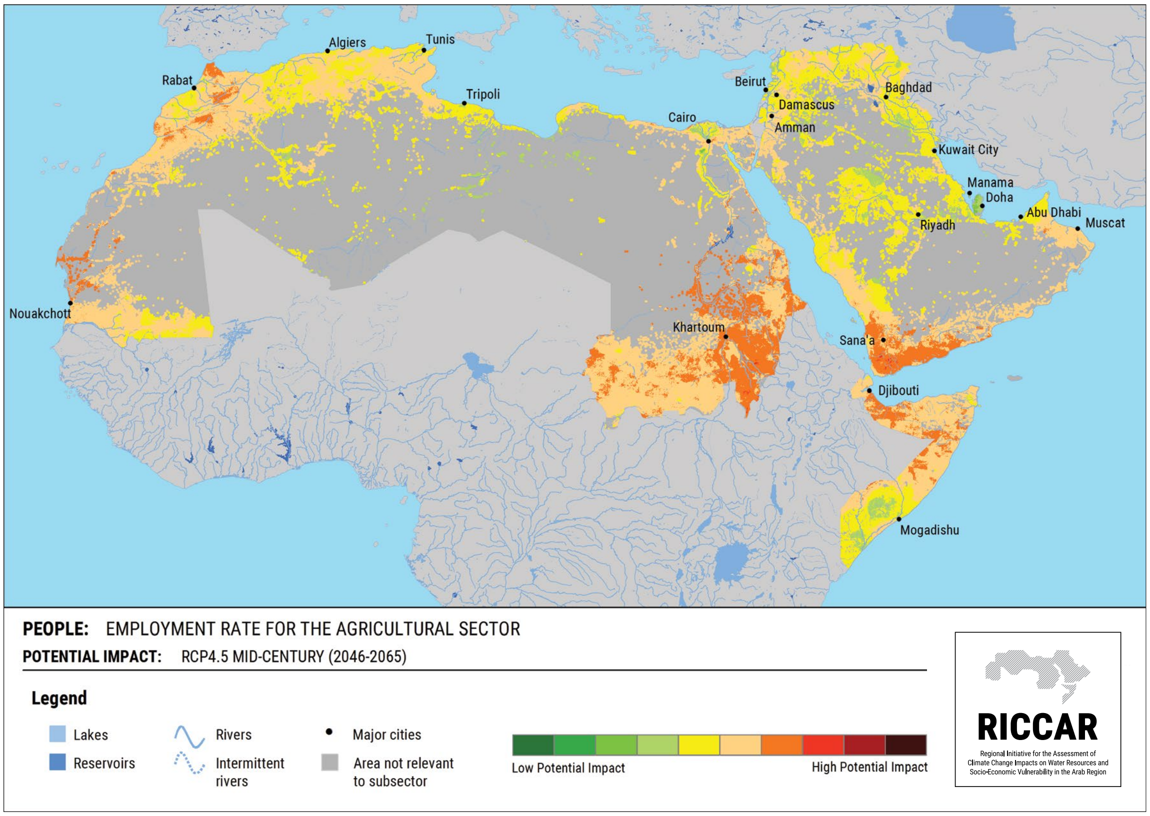


FIGURE 221: Employment rate for the agricultural sector – Mid-century RCP 8.5 – Potential impact

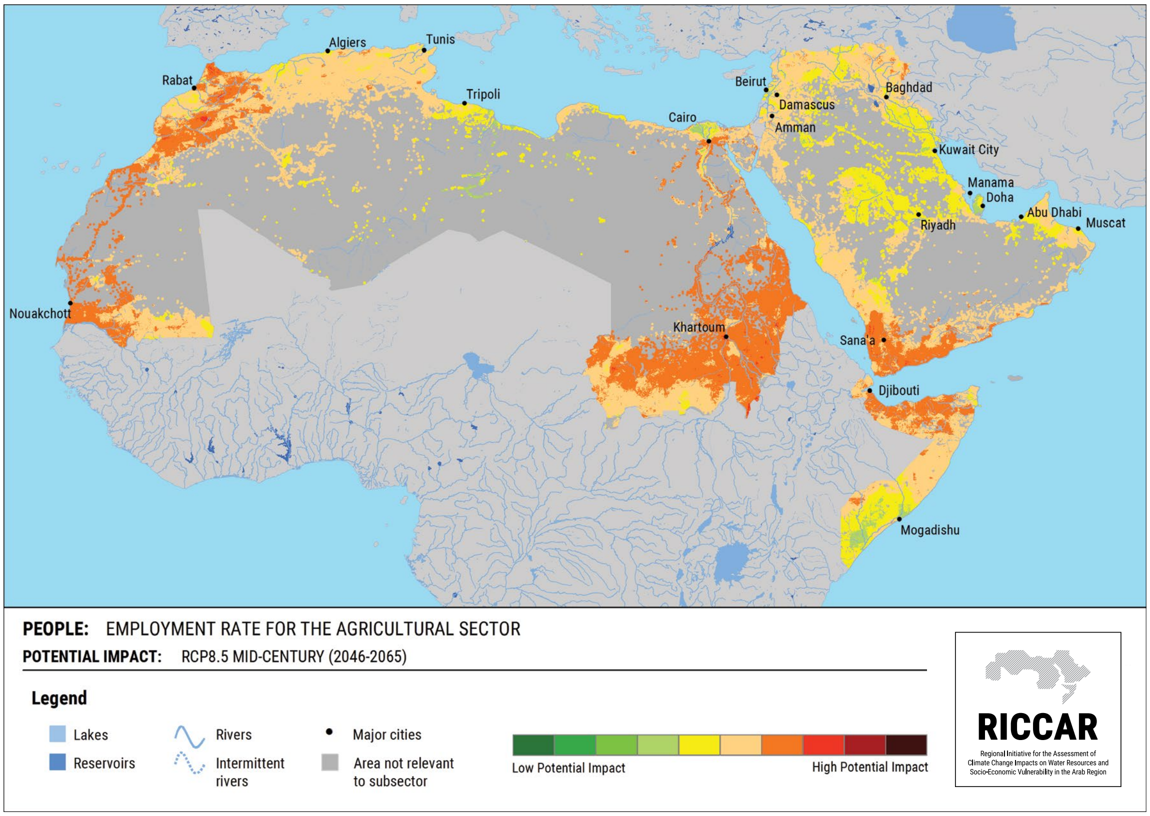


FIGURE 222: Employment rate for the agricultural sector – End-century RCP 4.5 – Potential impact

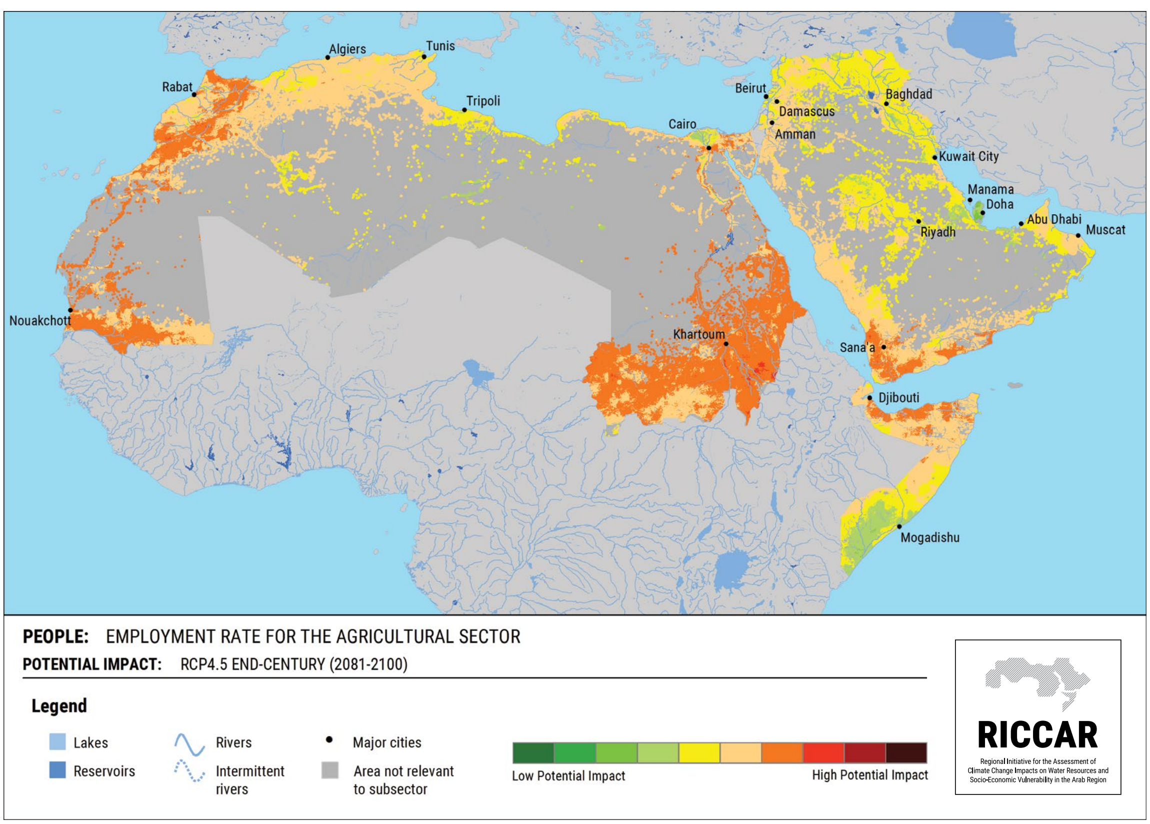
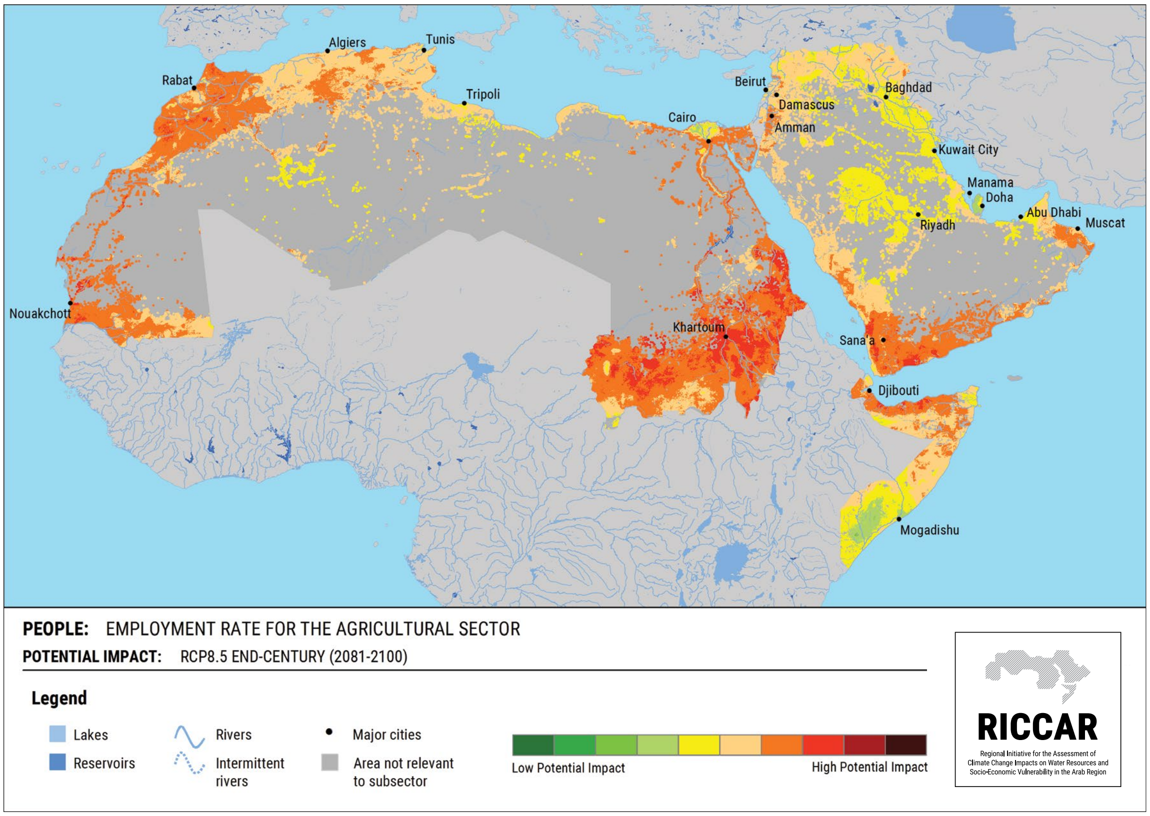


FIGURE 223: Employment rate for the agricultural sector – End-century RCP 8.5 – Potential impact



13.3.2.2 Vulnerability

A majority of the study area predicts high vulnerability, thus rendering employment difficult in the agricultural sector (Figure 224 to Figure 227). At mid-century, high vulnerability represents 61% (RCP 4.5) to 72% (RCP 8.5) of the study area, while, at end-century, high vulnerability is forecast in 65% (RCP 4.5) to 77% (RCP 8.5) of the study area (Table 35). Remaining areas suggest moderate vulnerability.

A comparison between selected sensitivity indicators and projected vulnerability indicates an above-average livestock density is located in areas of high projected vulnerability, while a below-average cropland area is located in this same area (Table 36). Thus, pastoralists are more vulnerable than farmers, assuming values from these indicators remain nearly the same.

Trend analysis reveals similar tendencies from mid- to end-century for both scenarios. Increasing vulnerability is apparent in sub-Saharan Africa, the northern Maghreb and the central eastern Red Sea area. Conversely, decreasing trends are apparent in the Horn of Africa, the Tigris–Euphrates basin and the Oman Mountains.

TABLE 35: Percentage of study area by vulnerability classification for employment rate for the agricultural sector

Scenario	Vulnerability (% of study area)		
	Low	Moderate	High
Mid-Century RCP 4.5	0%	39%	61%
Mid-Century RCP 8.5	0%	28%	72%
End-Century RCP 4.5	0%	35%	65%
End-Century RCP 8.5	0%	23%	77%

TABLE 36: Averages for selected sensitivity indicators for employment rate for the agricultural sector

Sensitivity indicator	Units	Climate scenario	Average vulnerability classification for subsector		Average all agricultural areas
			Moderate	High	
Per cent rainfed cropland area	%	Mid-Century RCP 4.5	14.5	5.4	10.2
		Mid-Century RCP 8.5	17.3	5.7	
		End-Century RCP 4.5	15.9	5.3	
		End-Century RCP 8.5	17.8	6.3	
Per cent irrigated cropland area	%	Mid-Century RCP 4.5	5.4	0.6	2.7
		Mid-Century RCP 8.5	7.1	0.6	
		End-Century RCP 4.5	6.0	0.6	
		End-Century RCP 8.5	8.4	0.6	
Average livestock density	heads/km^2	Mid-Century RCP 4.5	17	35	33
		Mid-Century RCP 8.5	18	32	
		End-Century RCP 4.5	18	34	
		End-Century RCP 8.5	18	31	

FIGURE 224: Employment rate for the agricultural sector – Mid-century RCP 4.5 – Vulnerability

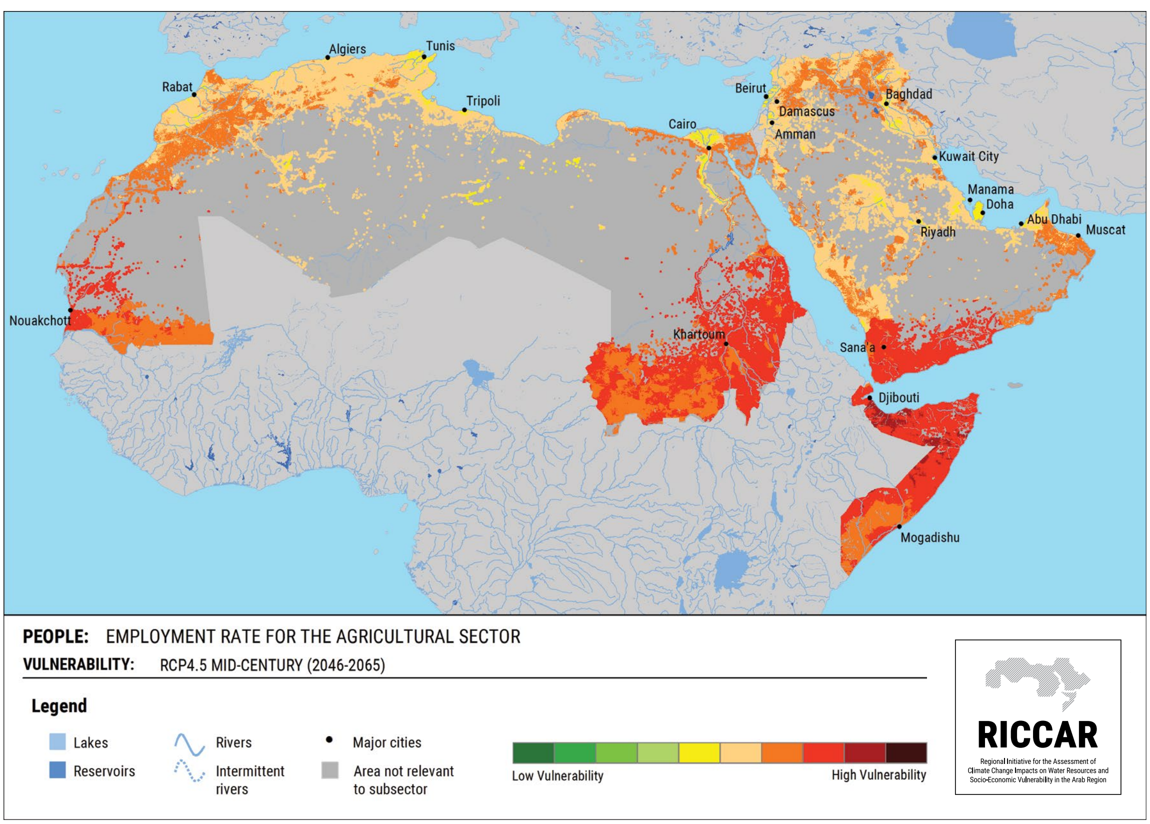


FIGURE 225: Employment rate for the agricultural sector – Mid-century RCP 8.5 – Vulnerability

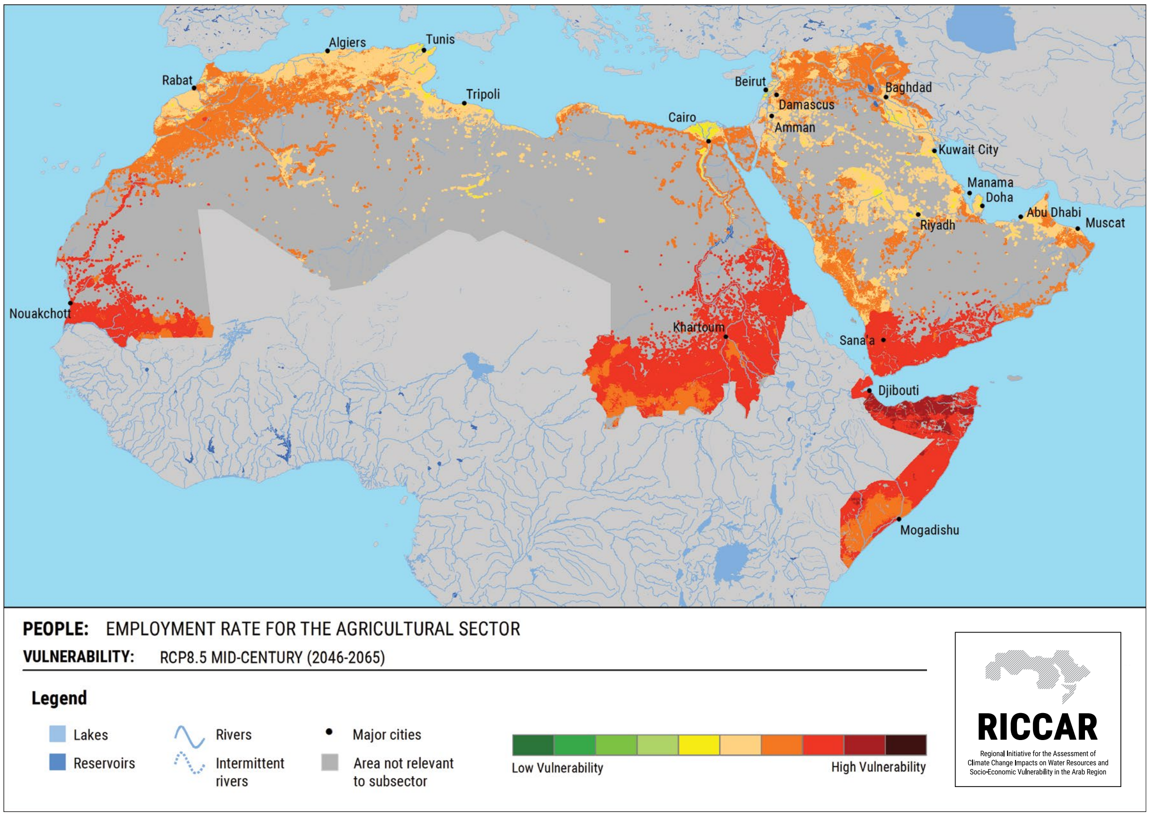


FIGURE 226: Employment rate for the agricultural sector – End-century RCP 4.5 – Vulnerability

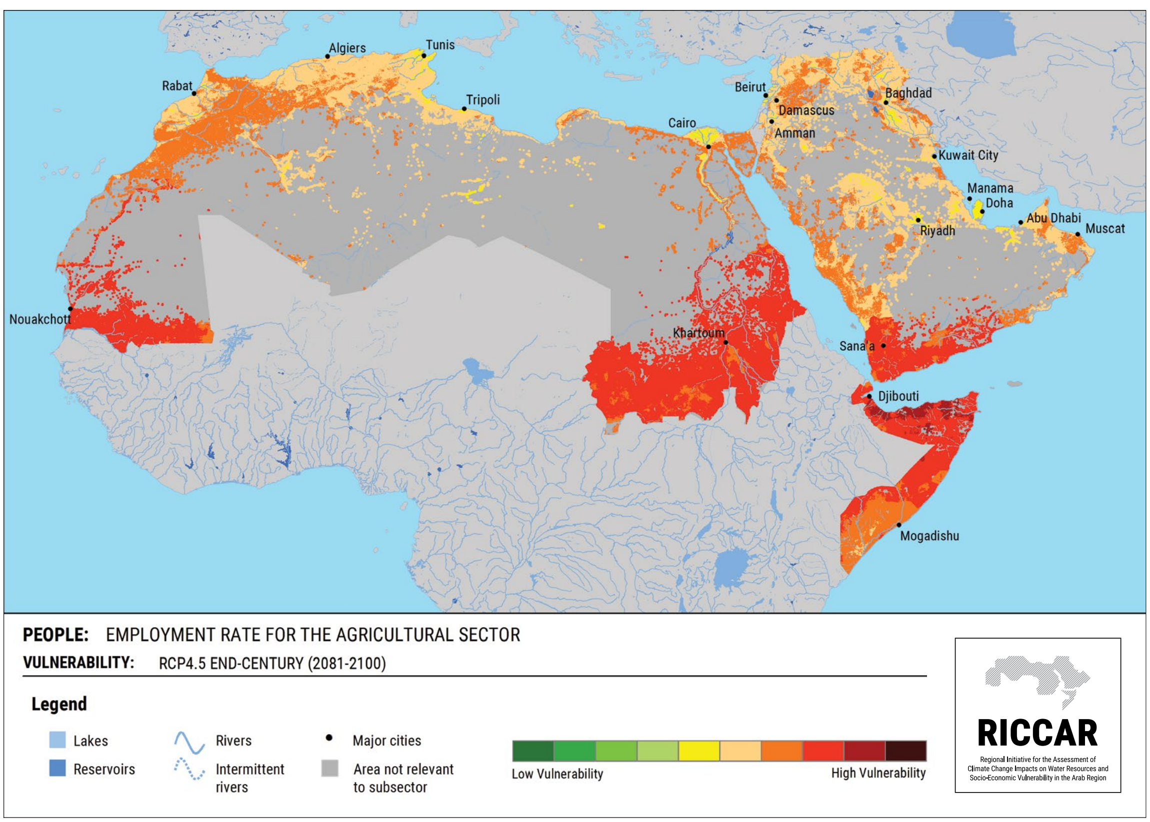
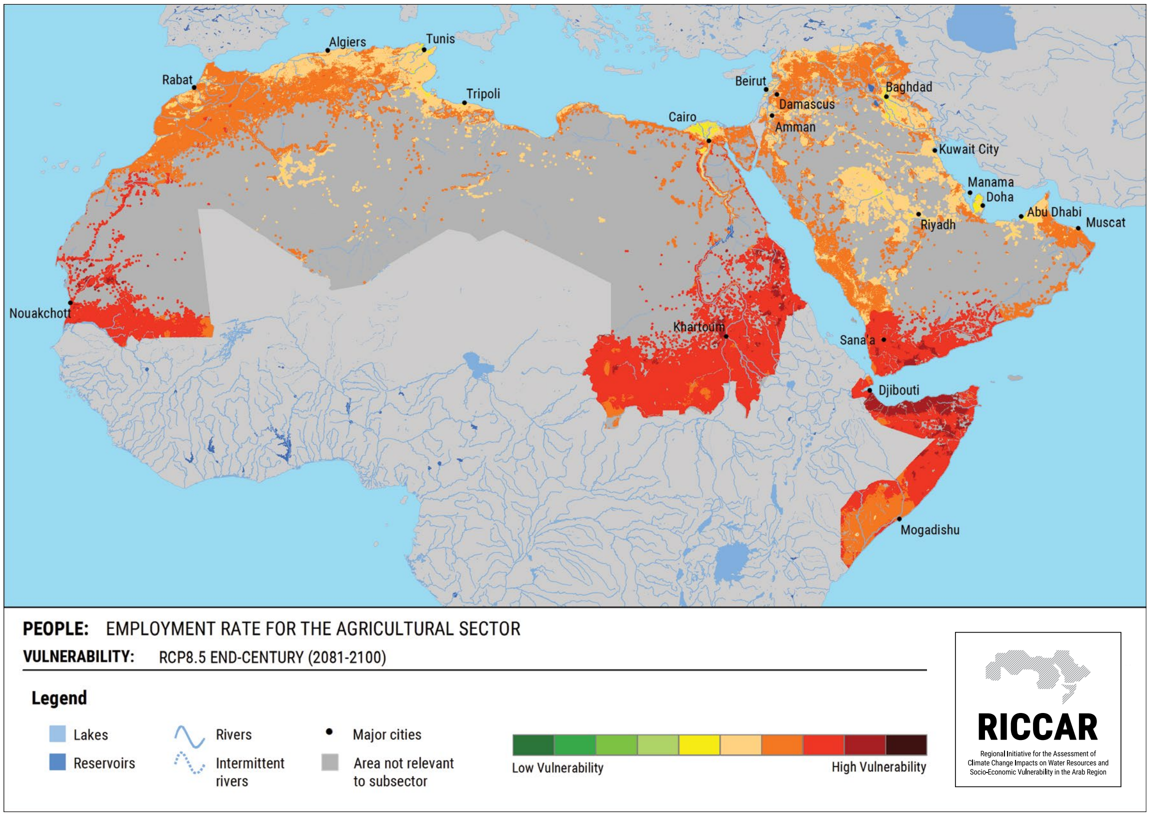


FIGURE 227: Employment rate for the agricultural sector – End-century RCP 8.5 – Vulnerability



13.3.3 Hotspots

Hotspots signify areas with the highest vulnerability for a given subsector. Hotspots revealed for the subsector *Employment rate for the agricultural sector* are the largest of all studied subsectors, representing up to 28% of the study area and up to 12% of the entire Arab region.

Such areas include the Tindouf basin, parts of the Taoudeni basin, the lower eastern Sahara Desert, the south-western Arabian Peninsula and the northern Horn of Africa. Most livelihoods in these hotspots depend on agriculture, often representing more than 50% of the workforce.

High vulnerability can result in adverse impacts to rural incomes, as well as a decline in food security for the region as a whole.

Nomadic herders, Djibouti, 2012. Source: EU/ECHO/Martin Karimi.

13.4 PEOPLE SECTOR: OVERALL VULNERABILITY

13.4.1 Reference period

Three subsectors contribute toward the *People* sector aggregated result, of which the subsector *Health conditions due to heat stress* has the strongest correlation.

Nearly the entire study area (98%) indicates moderate vulnerability for the reference period, with remaining areas divided between low and high vulnerability (Figure 228).

Areas with the highest vulnerability include the upper Nile Valley and lower Blue Nile basin near Khartoum; the north-western coast, Wadi Jaceyl Bid and the upper Jubba River in the Horn of Africa; and coastal areas in the south-western Arabian Peninsula. Conversely, areas with the lowest vulnerability include the Rif region, the eastern Tell Atlas region and the central Levantine coastal region.

13.4.2 Future periods

13.4.2.1 Vulnerability

Results for the *People* sector vulnerability are presented in Figure 229 and Figure 230 for mid-century, and in Figure 231 and Figure 232 for end-century. Like the reference period, projected vulnerability is also largely moderate, reflecting the entire region for all scenarios except for RCP 8.5 end-century (Table 37). This scenario reflects moderate vulnerability for 98% of the study area and high vulnerability for remaining areas. Vulnerability generally indicates a lower-to-higher gradient from north to south. Areas of lowest vulnerability are located in the eastern Tell Atlas region and the Levant. Trend analysis from mid- to end-century reveals generally static to increasing vulnerability for both scenarios. For RCP 4.5, areas of increasing vulnerability are the Sahara Desert and the Atlas Mountains. However, the southern Horn of Africa suggests static-to-declining vulnerability. For RCP 8.5, many coastal areas indicate increasing vulnerability, such as the coastal Atlas Plains, the southern Red Sea and the southern coast of the Gulf of Aden.

FIGURE 228: People sector – Vulnerability – Reference period

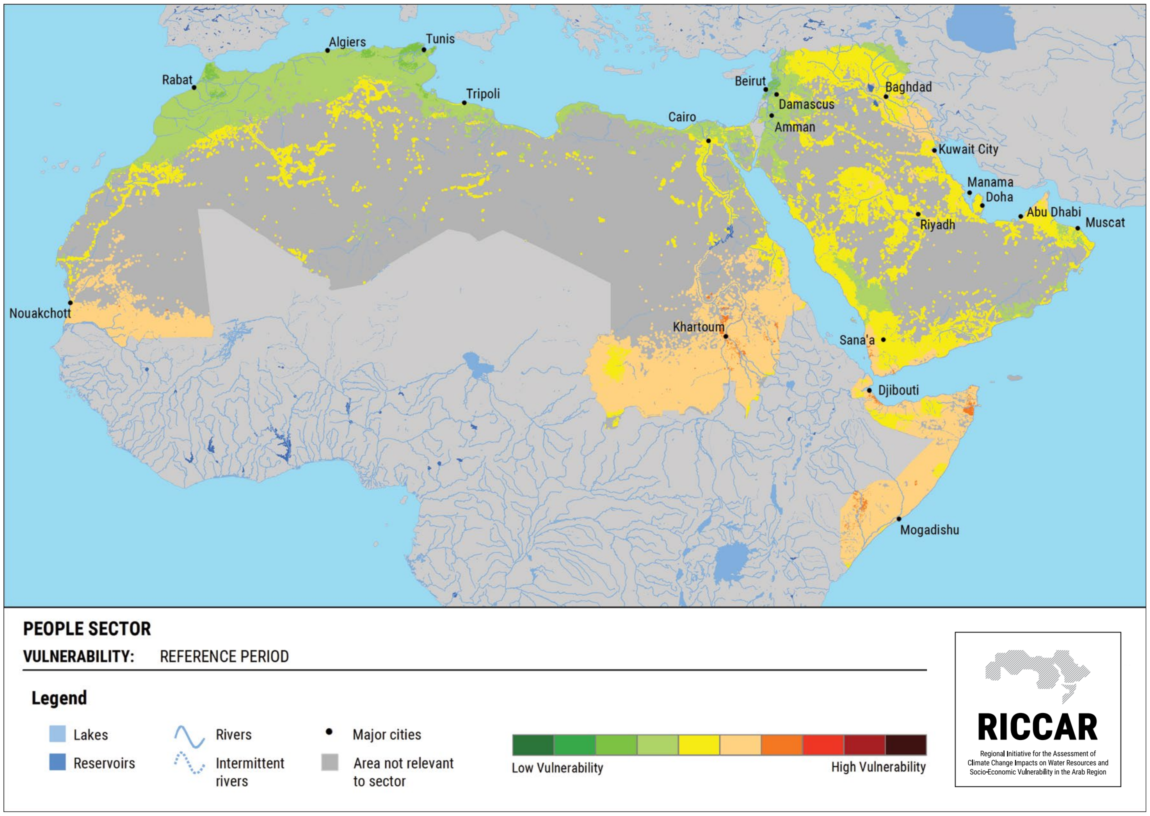


TABLE 37: Percentage of study area by vulnerability classification for people sector

Scenario	Vulnerability (% of study area)		
	Low	**Moderate**	**High**
Mid-Century RCP 4.5	0%	100%	0%
Mid-Century RCP 8.5	0%	100%	0%
End-Century RCP 4.5	0%	100%	0%
End-Century RCP 8.5	0%	98%	2%

13.4.3 Hotspots

Hotspots project the most vulnerable areas for the *People* sector and reflect up to 3% of the study area. Hotspots include locations in the southern Sahara and the Sahel, the south-western Arabian Peninsula, and the Horn of Africa and affect up to 28 million people (based on 2014 estimates).

Well in Sana'a, Yemen, 2014. Source: Julien Harneis.

FIGURE 229: People Sector – Vulnerability – Mid-century RCP 4.5

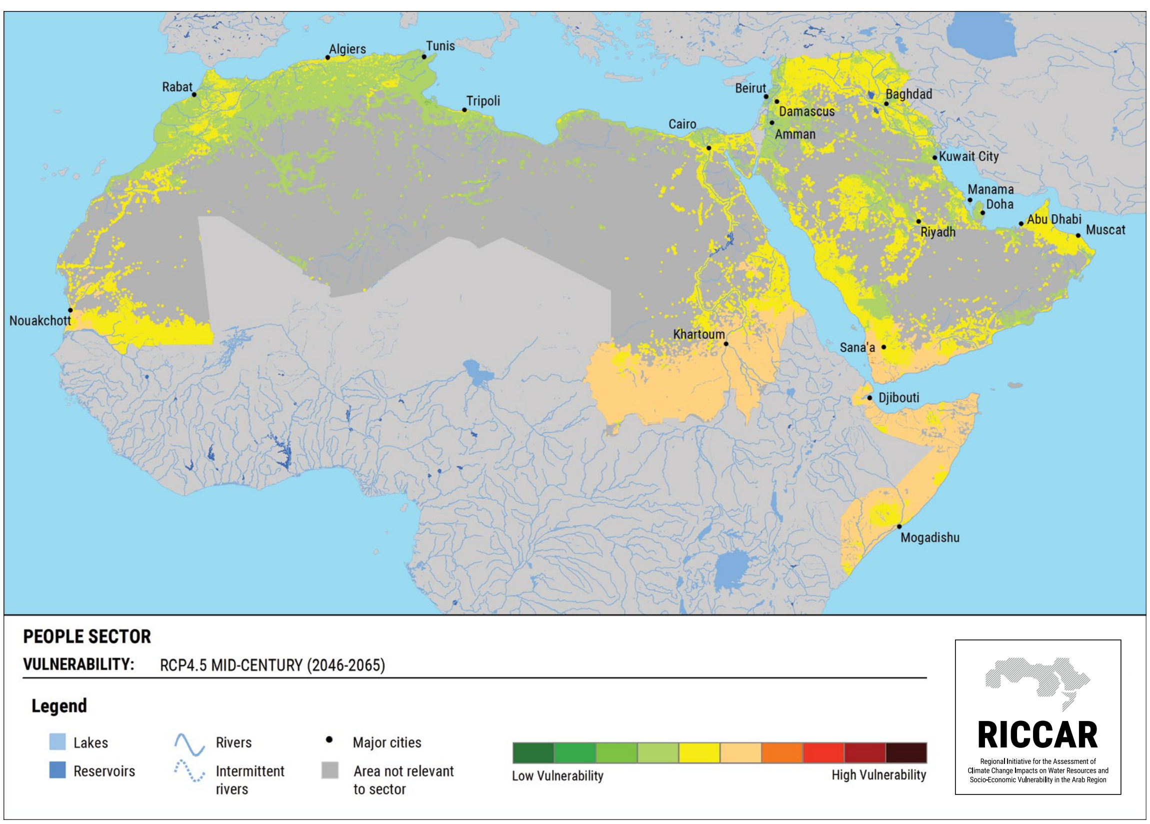


FIGURE 230: People Sector – Vulnerability – Mid-century RCP 8.5

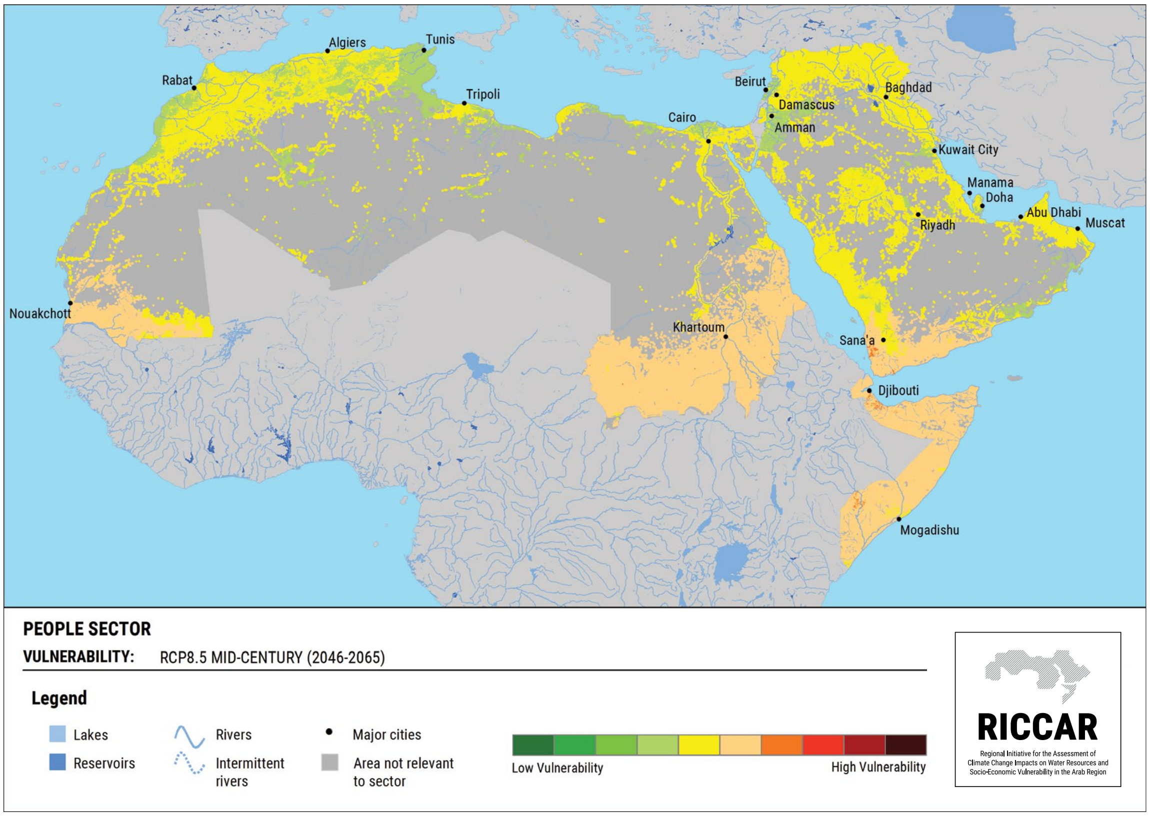


FIGURE 231: People Sector – Vulnerability – End-century RCP 4.5

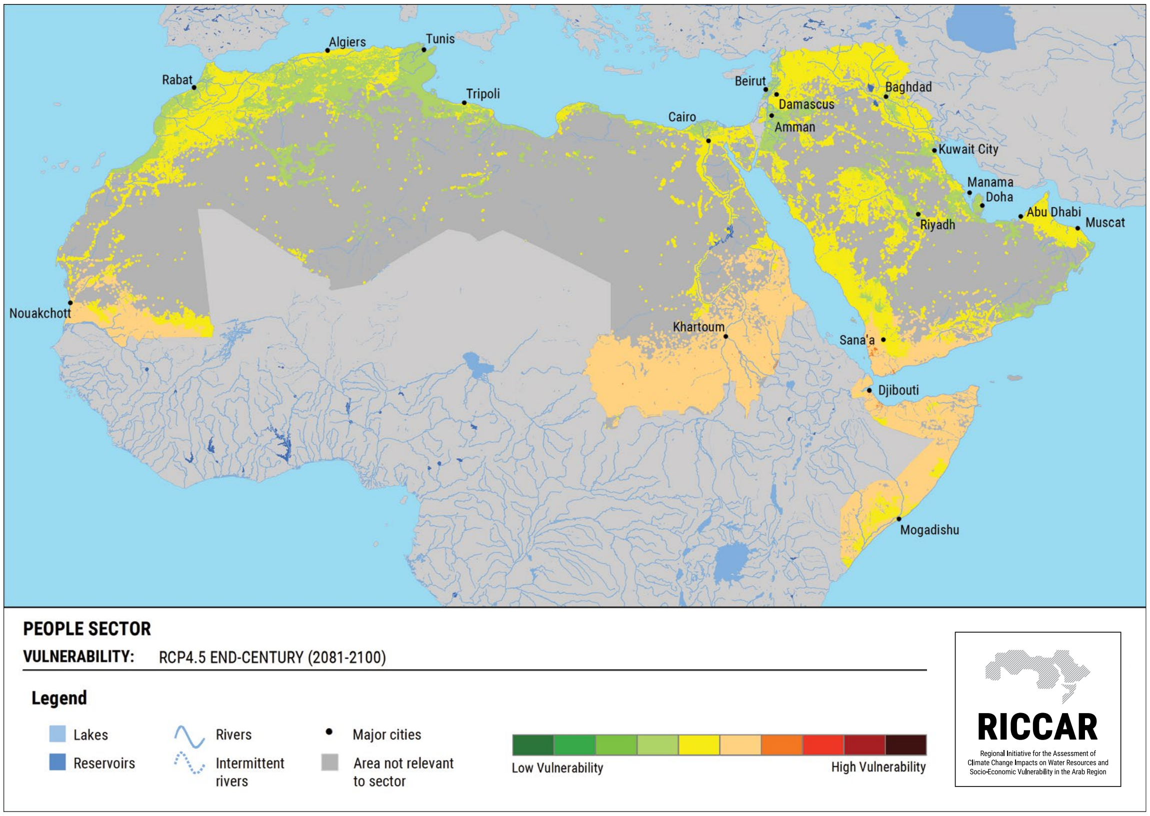
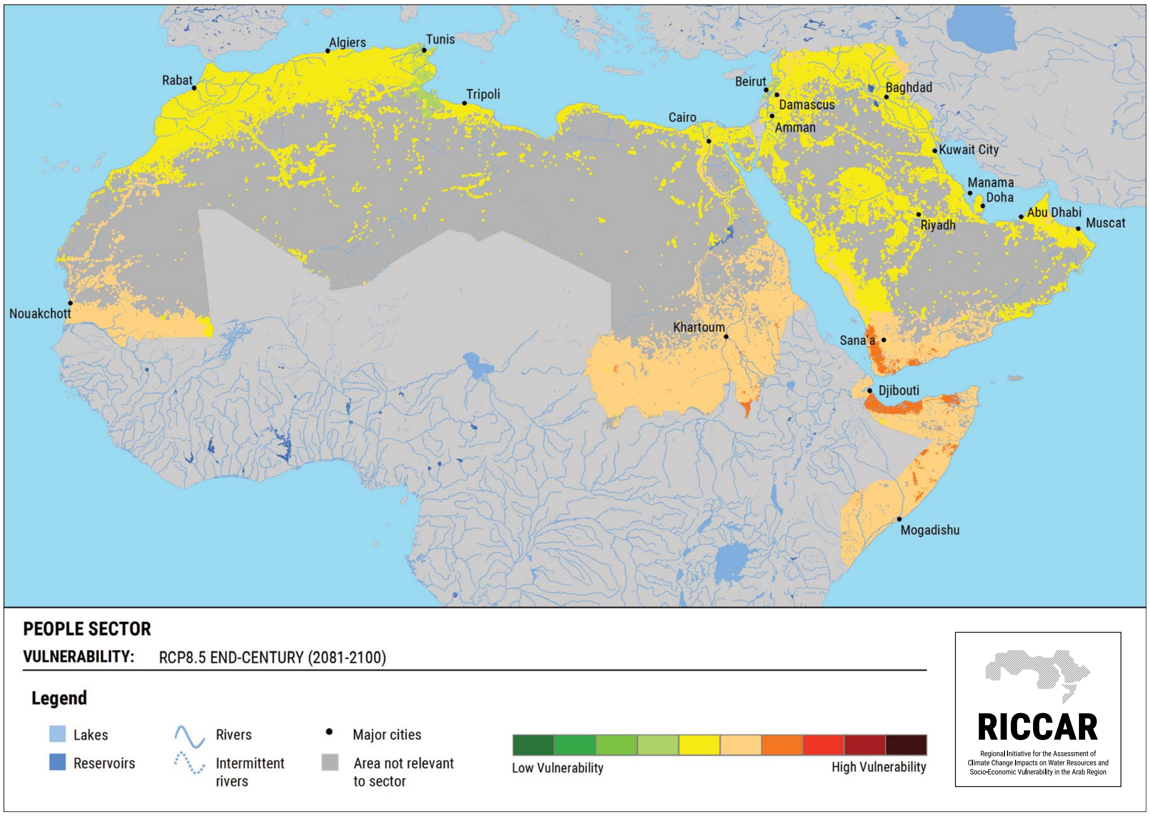


FIGURE 232: People Sector – Vulnerability – End-century RCP 8.5



Agricultural workers in Debel, Lebanon, 2006. Source: Carol Chouchani Cherfane.

ENDNOTES

1. ILO, 2017; AOAD, 2012
2. WHO and UNICEF, 2016
3. Ibid.
4. FAO, 2017
5. DesInventar, 2016
6. McCarthy et al., 2010
7. UN-DESA, 2017
8. ILO, 2017
9. AOAD, 2012
10. Shaban et al., 1994

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CHAPTER 14

INTEGRATED VULNERABILITY ASSESSMENT – SUMMARY

14.1 OVERVIEW OF GENERAL VULNERABILITY TRENDS

Projected vulnerability varies among the different sectors and subsectors, depending upon the selected indicators therein. Nevertheless, some common trends have emerged between the vulnerability components (exposure, sensitivity, adaptive capacity) at a regional level. Moreover, the degree of vulnerability is generally constant in certain areas for a given climate scenario, independent of the sector or subsector.

Exposure exhibits spatial and temporal variability among the differing subsectors but reveals a stronger correlation with change in precipitation than change in temperature. Exposure is a function of various climate-related indicators which can be broadly classified into precipitation-based or temperature-based. The precipitation-based indicators, which include runoff and evapotranspiration, predict areas of increasing precipitation in some areas and decreasing precipitation in others. Areas of decreasing precipitation signal higher exposure for most subsectors (for the subsector *Inland flooding area*, the case is reversed). Conversely, areas of increasing precipitation suggest lower exposure; unchanged precipitation points toward moderate exposure. Temperature, however, is projected to increase throughout the Arab region. Although any increase in temperature is significant, increases are more pronounced for RCP 8.5 end-century compared to the other scenarios. Thus, temperature-based exposure is generally low, except for RCP 8.5 end-century. Because precipitation signals higher variability both spatially and temporally, these indicators tend to dominate resultant exposure. This outcome is logical, given that most subsectors are based upon general or user-specific water availability.

Sensitivity is frequently correlated with population density, which generally confines areas of higher sensitivity to urbanized coastal areas and the lower Nile River Valley. Sensitivity is a function of selected indicators from the population, natural and man-made dimensions. Over half the subsectors have weighted the population dimension more than the other two dimensions. From the population dimension, solely population density reveals subnational data. For remaining subsectors, although emphasis is placed on either the natural or manmade dimension, indicators from these dimensions often correlate with population density to some extent.

Of the three components, adaptive capacity is most likely to influence vulnerability, suggesting the ability of mankind is stronger than climate change and environmental stressors. This is partly because the effective weight of adaptive capacity is higher than either exposure or sensitivity as revealed by the various impact chains. Even so, adaptive capacity often points toward a stronger correlation with vulnerability than potential impact (the aggregated result of exposure and sensitivity), despite being weighted equally. This is partly because areas of low adaptive capacity often occur in areas of high exposure, such as the Sahel and Gulf of Aden coastal zone.

Predicted vulnerability is largely moderate to high (Table 38) and exhibits a generally increasing gradient from north to south (an exception is the subsector *Health conditions due to heat stress*, due to lower exposure stemming from solely temperature-based indicators). More specifically, areas near the Mediterranean coast within the northern sector of the Arab region frequently point toward lower comparative vulnerability while areas in the southern third of the region predict higher vulnerability. Areas with the highest vulnerability are synonymous with hotspots and are summarized in detail in the following section. Lastly, the horizontal middle third of the Arab region suggests moderate vulnerability.

Woman carries water home, Darfur, Sudan, 1994. Source: Stephan Schneiderbauer.

TABLE 38: Summary of vulnerability assessment results

Sector and subsector	Scenario		% of study area experiencing vulnerability			Study area % of Arab region	Defined study area
			Low	Moderate	High		
WATER Water availability	Mid-century	RCP 4.5	0%	57%	43%	49%	• Forested areas • Wetland areas • Rainfed areas • Irrigated areas • Livestock areas > 10 heads/km² • Population density > 2 inhabitants/km²
		RCP 8.5	0%	48%	52%		
	End-century	RCP 4.5	0%	52%	48%		
		RCP 8.5	0%	43%	57%		
BIODIVERSITY AND ECOSYSTEMS	Mid-century	RCP 4.5	1%	98%	1%	7%	• Forested areas • Wetland areas
		RCP 8.5	0%	99%	1%		
	End-century	RCP 4.5	1%	99%	0%		
		RCP 8.5	0%	98%	2%		
Area covered by forests	Mid-century	RCP 4.5	0%	59%	41%	5%	• Forested areas
		RCP 8.5	0%	42%	58%		
	End-century	RCP 4.5	0%	50%	50%		
		RCP 8.5	0%	36%	64%		
Area covered by wetlands	Mid-century	RCP 4.5	5%	94%	1%	2%	• Wetland areas
		RCP 8.5	1%	97%	2%		
	End-century	RCP 4.5	6%	93%	1%		
		RCP 8.5	1%	97%	2%		
AGRICULTURE	Mid-century	RCP 4.5	0%	57%	43%	37%	• Rainfed areas • Irrigated areas • Livestock areas > 10 heads/km²
		RCP 8.5	0%	51%	49%		
	End-century	RCP 4.5	0%	54%	46%		
		RCP 8.5	0%	42%	58%		
Water available for crops	Mid-century	RCP 4.5	0%	50%	50%	22%	• Rainfed areas • Irrigated areas
		RCP 8.5	0%	33%	67%		
	End-century	RCP 4.5	0%	43%	57%		
		RCP 8.5	0%	16%	84%		
Water available for livestock	Mid-century	RCP 4.5	0%	67%	33%	33%	• Livestock areas > 10 heads/km²
		RCP 8.5	0%	55%	45%		
	End-century	RCP 4.5	0%	58%	42%		
		RCP 8.5	0%	46%	54%		
INFRASTRUCTURE AND HUMAN SETTLEMENTS Inland flooding area	Mid-century	RCP 4.5	2%	94%	4%	32%	• Low or greater floodprone potential
		RCP 8.5	3%	93%	4%		
	End-century	RCP 4.5	2%	94%	4%		
		RCP 8.5	4%	89%	7%		
PEOPLE	Mid-century	RCP 4.5	0%	100%	0%	44%	• Population density > 2 inhabitants/km²
		RCP 8.5	0%	100%	0%		
	End-century	RCP 4.5	0%	100%	0%		
		RCP 8.5	0%	98%	2%		
Water available for drinking	Mid-century	RCP 4.5	0%	100%	0%	44%	• Population density > 2 inhabitants/km²
		RCP 8.5	0%	99%	1%		
	End-century	RCP 4.5	0%	99%	1%		
		RCP 8.5	0%	98%	2%		
Health conditions due to heat stress	Mid-century	RCP 4.5	45%	55%	0%	44%	• Population density > 2 inhabitants/km²
		RCP 8.5	30%	70%	0%		
	End-century	RCP 4.5	37%	63%	0%		
		RCP 8.5	4%	95%	1%		
Employment rate for the agricultural sector	Mid-century	RCP 4.5	0%	39%	61%	44%	• Population density > 2 inhabitants/km²
		RCP 8.5	0%	28%	72%		
	End-century	RCP 4.5	0%	35%	65%		
		RCP 8.5	0%	2%	77%		

Lower relative vulnerability is revealed near the Mediterranean coast, specifically the western Maghreb and the Levant, despite declining precipitation and runoff. These relatively large decreases in precipitation and runoff are coupled with comparatively small increases in temperature. The resultant exposure in this area is variable, ranging from low to high, based upon the climate scenario and selected indicators for a given subsector. Sensitivity within this subregion is generally low, except for population centres near the coast. Resultant potential impact is compensated by moderately high adaptive capacity.

Despite signalling strong warming trends, the central Mediterranean coastal and Green Mountains zone indicates moderate projected vulnerability. Within this subregion, exposure is variable; changes in temperature and precipitation are modest, while extreme climate indices such as number of hot days (SU35) reveal a substantial increase. Sensitivity is also wide-ranging, but is often high immediately adjacent to the Mediterranean coast. Lastly, adaptive capacity points toward moderate and most influences resultant vulnerability.

The lower Nile River basin is indicative of moderate projected vulnerability due to variable potential impact coupled with high adaptive capacity. This area is indicative of precarious environmental, economic and social conditions, including a very high population density, which gives rise to high sensitivity. Changes in precipitation and temperature are generally modest and resultant exposure is variable, depending on selected indicators and climate scenario. As elsewhere near the Mediterranean coast, the resultant potential impact is counterbalanced by adaptive capacity, which in this case is high, relative to the rest of the region.

The Euphrates and Tigris river basins subregion is also indicative of moderate vulnerability, despite demographic pressures, hydro-infrastructure developments and other challenges. Exposure in this area is variable, although precipitation is generally decreasing in the upper basin near the Zagros Mountains and slightly increasing in the lower basin. Sensitivity is generally low, even with an increased population density near Baghdad and a high degradation trend of vegetative cover. Adaptive capacity is variable and largely moderate, but relatively higher near Baghdad compared to elsewhere in the subregion.

The final major subregion revealing generally moderate vulnerability is the Gulf region, despite remaining among the hottest areas in the Arab region. The Gulf is projecting low-to-moderate exposure stemming from modest increases in temperature, coupled with unchanged precipitation, which remains low. Additionally, sensitivity indications are low to moderate while adaptive capacity is largely moderate.

Finally, although some of the areas may project lower vulnerability, these results are relative to the Arab region alone and vulnerability may be considerably higher if compared globally. For example, all areas within the region project an increase in temperature and at least 94% of the region forecasts an increase in the number of very hot days (SU40). These changes induce the likelihood of heat stress and other temperature related risks. Similarly, declining precipitation and runoff are valid concerns for a region that already suffers from water scarcity. These changes in climate are exacerbated by elevated natural and physical stressors, which are inhibited by the limited ability to adapt.

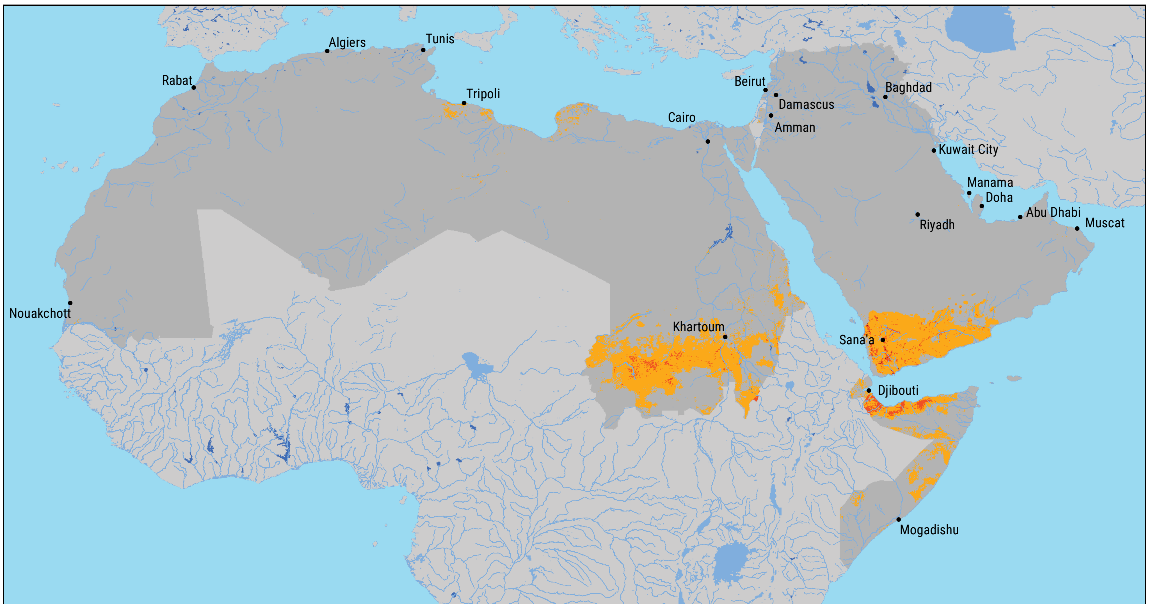
14.2 HOTSPOTS

Hotspots are those areas which signify areas with the highest projected vulnerability. For RICCAR, they have been defined as areas with the highest 10% of aggregated vulnerability values combined with the top 20% and 30% as hotspot buffered areas. Although they have been defined for all sectors and subsectors for all projected climate scenarios, the resultant hotspots are often indistinct when presented on a regional map. For this reason, they have been largely excluded from this report, but will be available on the Regional Knowledge Hub. Even so, hotspot maps developed at the sector level for RCP 8.5 end-century are discernible at a regional scale and have thus been presented herein (Figure 239 to Figure 243). Moreover, these maps represent the worst-case scenario.

Vulnerability hotspots generally recur in the Sahel extending northward into the Sahara Desert, the south-western Arabian Peninsula, and the Horn of Africa. All these areas share low adaptive capacity relative to the rest of the Arab region. In many cases, this low adaptive capacity is coupled with high exposure due to comparatively larger increases in temperature and declining precipitation. However, in much of the Horn of Africa (other than near the Gulf of Aden coast), precipitation is forecast to increase and increasing temperature is moderate. Nevertheless, the resultant generally low projected exposure is not sufficient to counterbalance low adaptive capacity in this case.

Hotspots are intended to draw attention to specific locations and can be effective tools for risk communication and decision-making. Identified areas may stimulate societal responses to climate change such as migration. Steps to increase adaptive capacity should also be investigated: for example, aid agencies and donors may be inclined to prioritize funding in hotspot areas. Above all else, hotspot maps aim to facilitate discourse.

FIGURE 233: Water sector – Vulnerability hotspots – End-century RCP 8.5



WATER SECTOR

VULNERABILITY HOTSPOTS: RCP8.5 END-CENTURY (2081-2100)

Legend

Lakes · Reservoirs · Rivers · Intermittent rivers · Major cities · Area not relevant to sector

Hotspots: Top 30% · Top 20% · Top 10%

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

FIGURE 234: Biodiversity and ecosystems sector – Vulnerability hotspots – End-century RCP 8.5

BIODIVERSITY AND ECOSYSTEMS SECTOR

VULNERABILITY HOTSPOTS: RCP8.5 END-CENTURY (2081-2100)

Legend

Lakes · Reservoirs · Rivers · Intermittent rivers · Major cities · Area not relevant to sector

Hotspots: Top 30% · Top 20% · Top 10%

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

FIGURE 235: Agriculture sector – Vulnerability hotspots – End-century RCP 8.5

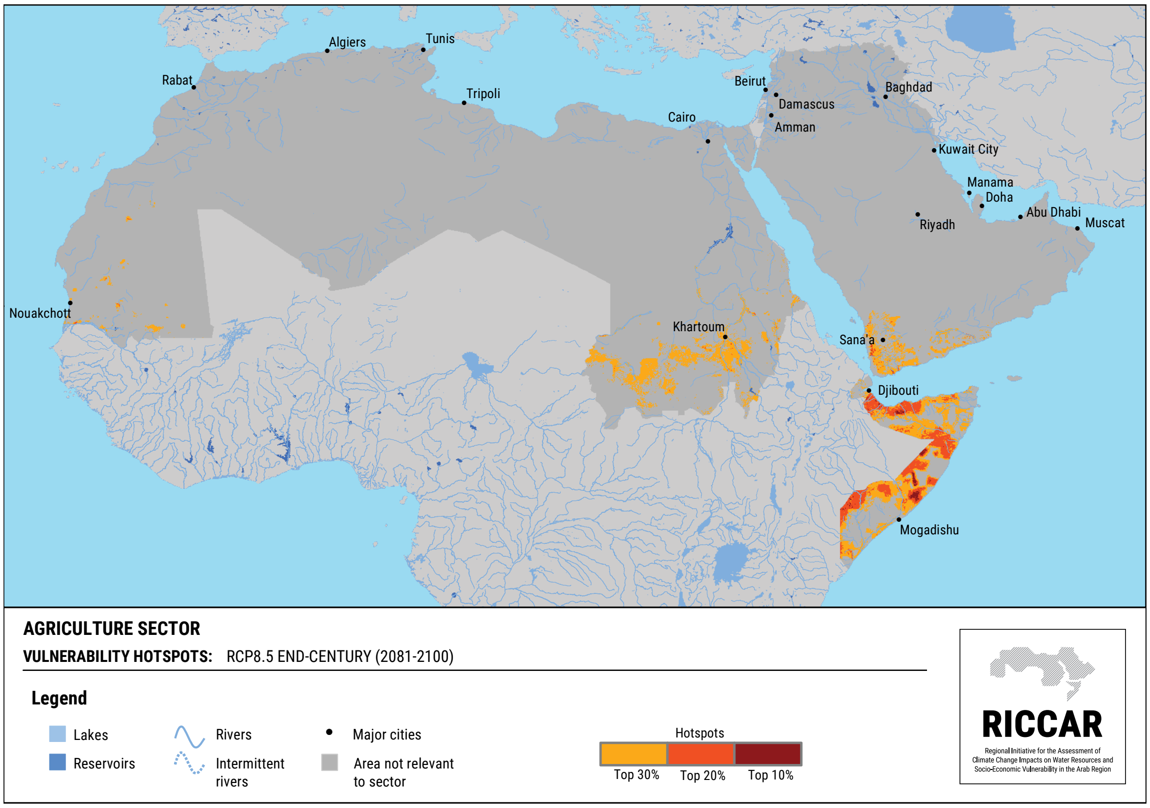


FIGURE 236: Infrastructure and human settlements sector – Vulnerability hotspots – End-century RCP 8.5

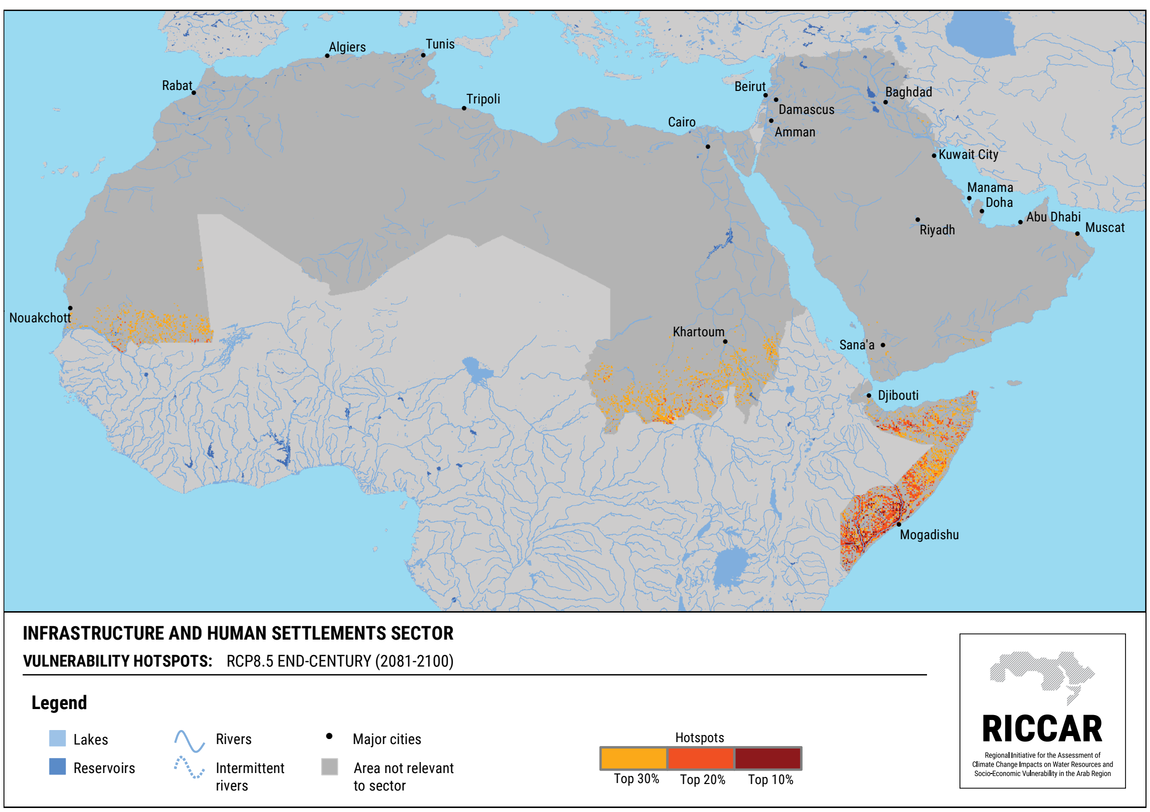
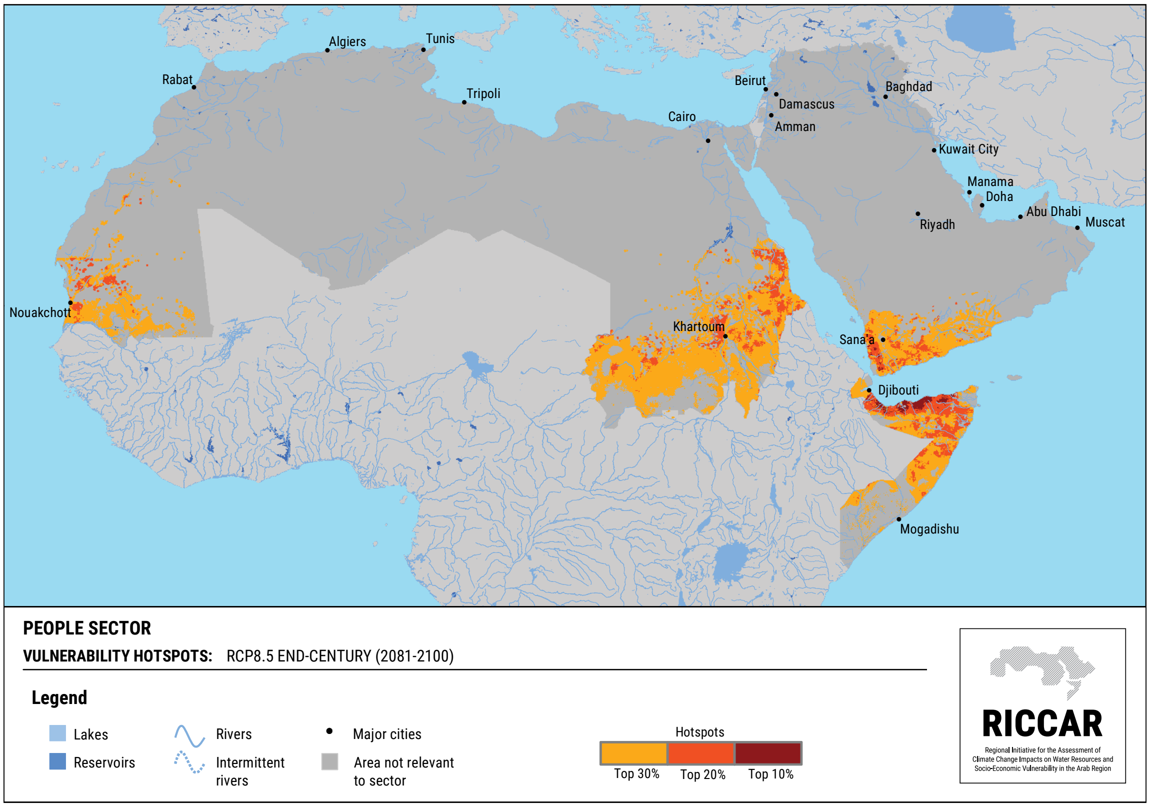


FIGURE 237: People sector – Vulnerability hotspots – End-century RCP 8.5



BOX 8: Country-level application of the integrated vulnerability assessment

RICCAR aims to provide a knowledge base for assessing and addressing climate change impacts on freshwater resources at the regional and national level. The outputs are already being used to inform several projects and processes in this regard, for example in Lebanon.

Lebanon's Third National Communication, submitted in November 2016 by the Ministry of Environment as part of the national reporting framework under the United Nations Framework Convention on Climate Change, includes RICCAR outputs. Results on projected future changes in temperature and precipitation in Lebanon, as well as selected extreme indices, were presented and highlighted as part of the chapter related to the country's vulnerability to climate change.

ACSAD is also working with the Government of Lebanon on an integrated vulnerability assessment of the agricultural sector at the country level with the support of the ACCWaM project. The results will inform action on climate change and is informing consultative processes aimed at formulating policies, positions and future projects.