ARAB CLIMATE CHANGE ASSESSMENT REPORT

TECHNICAL ANNEX

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

RICCAR PARTNERS

DONORS
PREFACE

The Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR) is a joint initiative of the United Nations and the League of Arab States launched in 2010.

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

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

Funding for the preparation of this technical annex was provided by the Swedish Government through the Swedish International Development Cooperation Agency.


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<td>absolute difference</td>
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<tr>
<td>Apr-Sept</td>
<td>April–September</td>
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<tr>
<td>CDD</td>
<td>maximum length of dry spell</td>
</tr>
<tr>
<td>CNRM-CM5</td>
<td>Centre National de Recherches Météorologiques-Climate Model 5</td>
</tr>
<tr>
<td>CWD</td>
<td>maximum length of wet spell</td>
</tr>
<tr>
<td>EC-EARTH</td>
<td>ECMWF-based Earth-system model</td>
</tr>
<tr>
<td>ESCWA</td>
<td>United Nations Economic and Social Commission for Western Asia</td>
</tr>
<tr>
<td>GCM</td>
<td>Global Climate Model or General Circulation Model</td>
</tr>
<tr>
<td>GDP</td>
<td>gross domestic product</td>
</tr>
<tr>
<td>GFDL-ESM2M</td>
<td>Geophysical Fluid Dynamics Laboratory- Earth System Model 2</td>
</tr>
<tr>
<td>HYPE</td>
<td>Hydrological Predictions for the Environment (hydrological model)</td>
</tr>
<tr>
<td>km</td>
<td>kilometres</td>
</tr>
<tr>
<td>mm</td>
<td>millimetres</td>
</tr>
<tr>
<td>MNA22</td>
<td>25 km resolution (MENA domain 0.22 degrees)</td>
</tr>
<tr>
<td>MNA44</td>
<td>50 km resolution (MENA domain 0.44 degrees)</td>
</tr>
<tr>
<td>no.</td>
<td>number</td>
</tr>
<tr>
<td>Oct-Mar</td>
<td>October–March</td>
</tr>
<tr>
<td>ODA</td>
<td>official development assistance</td>
</tr>
<tr>
<td>RCM</td>
<td>Regional Climate Model</td>
</tr>
<tr>
<td>RCP</td>
<td>representative concentration pathway</td>
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<td>RHM</td>
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<tr>
<td>R10</td>
<td>Annual count of 10 mm precipitation days</td>
</tr>
<tr>
<td>R20</td>
<td>Annual count of 20 mm precipitation days</td>
</tr>
<tr>
<td>SU</td>
<td>number of summer days</td>
</tr>
<tr>
<td>SU35</td>
<td>number of hot days</td>
</tr>
<tr>
<td>SU40</td>
<td>number of very hot days</td>
</tr>
<tr>
<td>TR</td>
<td>tropical nights</td>
</tr>
<tr>
<td>VA</td>
<td>vulnerability assessment</td>
</tr>
<tr>
<td>VIC</td>
<td>Variable Infiltration Capacity (hydrological model)</td>
</tr>
<tr>
<td>ºC</td>
<td>degree Celsius</td>
</tr>
<tr>
<td>%</td>
<td>per cent</td>
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FIGURE 149
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FIGURE 156
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FIGURE 143
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Mean change in SU40 over time for ensemble of three RCP 4.5 and RCP 8.5 projections

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Comparison between 25km (MNA22) and 50km (MNA44) resolutions for mean change in annual discharge over time for two RCP 8.5 projections using HYPE model

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Mean change in monthly precipitation for mid-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period

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Mean change in seasonal runoff (April-September) over time for ensemble of three RCP 4.5 and RCP 8.5 projections using two hydrological models

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Comparison between 25km (MNA22) and 50km (MNA44) resolutions for mean change in seasonal discharge (October-March) over time for two RCP 8.5 projections using HYPE model

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Comparison between 25km (MNA22) and 50km (MNA44) resolutions for mean change in annual runoff over time for two RCP 8.5 projections using HYPE model

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FIGURE 259
Comparison between 25km (MNA22) and 50km (MNA44) resolutions for mean change in seasonal runoff (October-March) over time for two RCP 8.5 projections using HYPE model
Impact Assessment
Explanatory Note

This note aims to provide clarifications on the figures pertaining to the impact assessment outputs presented in the following sections.

The available outputs from Regional Climate Modelling (RCM) are temperature, precipitation, and selected extreme events indices expressed in terms of change from the reference period. They were generated using RCA4 nested in three driving Global Climate Models (GCMs), namely EC-Earth, CNRM and GFDL-ESM combined as an ensemble for the RCP 4.5 and RCP 8.5 emission scenarios through the end of this century at a 50km scale. Results are presented as maps for the entire Arab Domain, and as plotted time series showing area means summarized over specified sub-domains, namely the Moroccan Highlands and the Mediterranean Coast, as well as sub-domains related to shared river basins.

Outputs pertaining to Regional Hydrological Modelling (RHM) using the VIC and/or HYPE hydrological models include runoff, evapotranspiration and mean discharge, and are based on bias corrected results for temperature and precipitation generated by the RCMs. These were modelled until the year 2100 considering RCP 4.5 and RCP 8.5 emission scenarios at a 50km resolution. Comparisons with results of 25km resolution are presented for changes in runoff and discharge for the RCP 8.5 projections, noting that at this resolution only two projections were available and were thus not combined as an ensemble. Analysis for them consisted primarily of comparisons against the respective 50km projections driven by the same Global Climate Model (EC-Earth, GFDL-ESM2M).

The different RCM and RHM outputs are presented for the Arab Domain (Figures 1 through 15); Arab Region (Figures 16 through 31) two selected subdomains (Figures 32 through 79) and for shared river basins (Figures 80 through 259).

All outputs from RCMs and RHMs are expressed in terms of changes from the reference period (1986-2005) and presented as projections for mid-century (2046-2065) and end-century (2081-2100). Results are also provided for two seasonal periods for selected parameters; namely April-September and October-March in order to assess how climate in the Arab region varies between seasons. The figures presented in this annex at the seasonal level are only indicative, noting that the full set of results at this temporal scale for the different parameters will be made available on the Regional Knowledge Hub, providing access to datasets which can be independently studied at more detailed temporal levels (e.g. inter-seasonal, monthly, etc.).

In addition, some figures on ensemble member agreements are presented in this annex for the Arab Domain or the Arab Region such as precipitation (Figures 3, 6 and 7), runoff (Figures 18-19 and 24 to 27) and evapotranspiration (Figures 30 and 31).

Finally, it is important to note that assumptions, further considerations and detailed observations specific to each parameter and output are mentioned in the main report, and it is therefore advised to refer to it consistently while reading through this annex.
CHAPTER 1

REGIONAL CLIMATE MODELLING: ARAB DOMAIN
FIGURE 1
Mean change in annual temperature for mid-century and end-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period

RCP 4.5

1986-2005  
2046-2065  
2081-2100

Temperature (°C)

RCP 8.5

1986-2005  
2046-2065  
2081-2100

Temperature (°C)
1.1. GENERAL PARAMETERS – 1.1.2. PRECIPITATION

**FIGURE 2**
Mean change in annual precipitation for mid-century and end-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period (1986-2005).
1.1. GENERAL PARAMETERS – 1.1.2. PRECIPITATION

**FIGURE 3**

Agreement on mean change in annual precipitation from the reference period between the ensemble of three RCP 4.5 and RCP 8.5 projections for mid-century and end-century

Note: Brown indicates where all ensemble projections agree on a decrease in precipitation, dark blue indicates where 2 out of 3 projections show an increase and light blue indicates where 2 out of 3 projections show a decrease and light blue indicates where 2 out of 3 projections show an increase.
1.1. GENERAL PARAMETERS – 1.1.2. PRECIPITATION

**FIGURE 4**
Mean change in seasonal precipitation for mid-century and end-century for ensemble of three RCP 4.5 projections compared to the reference period

**FIGURE 5**
Mean change in seasonal precipitation for mid-century and end-century for ensemble of three RCP 8.5 projections compared to the reference period
1.1. GENERAL PARAMETERS – 1.1.2. PRECIPITATION

**FIGURE 6**
Agreement on mean change in seasonal precipitation from the reference period between the ensemble of three RCP 4.5 projections for mid-century and end-century

**RCP 4.5**

<table>
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<tr>
<th>2046-2065</th>
<th>2081-2100</th>
</tr>
</thead>
<tbody>
<tr>
<td>APR-SEP</td>
<td>APR-SEP</td>
</tr>
<tr>
<td>OCT-MAR</td>
<td>OCT-MAR</td>
</tr>
</tbody>
</table>

**FIGURE 7**
Agreement on mean change in seasonal precipitation from the reference period between the ensemble of three RCP 8.5 projections for mid-century and end-century

**RCP 8.5**

<table>
<thead>
<tr>
<th>2046-2065</th>
<th>2081-2100</th>
</tr>
</thead>
<tbody>
<tr>
<td>APR-SEP</td>
<td>APR-SEP</td>
</tr>
<tr>
<td>OCT-MAR</td>
<td>OCT-MAR</td>
</tr>
</tbody>
</table>

**Note:** Brown indicates where all ensemble projections agree on a decrease in precipitation, dark blue indicates where all agree on an increase in precipitation, white indicates where 2 out of 3 projections show a decrease and light blue indicates where 2 out of 3 projections show an increase.
1.2. EXTREME EVENTS – 1.2.1. CHANGES IN EXTREME TEMPERATURE

FIGURE 8
Mean change in SU for mid-century and end-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period (1986-2005).
1.2. EXTREME EVENTS – 1.2.1. CHANGES IN EXTREME TEMPERATURE

FIGURE 9: Mean change in SU35 for mid-century and end-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period.
1.2. EXTREME EVENTS – 1.2.1. CHANGES IN EXTREME TEMPERATURE

Mean change in SU40 for mid-century and end-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period.
1.2. EXTREME EVENTS – 1.2.1. CHANGES IN EXTREME TEMPERATURE

Mean change in TR for mid-century and end-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period.

**FIGURE 11**

Mean change in TR for mid-century and end-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period.
FIGURE 12
Mean change in CDD for mid-century and end-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period.
FIGURE 13
Mean change in CWD for mid-century and end-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period

RCP 4.5

<table>
<thead>
<tr>
<th>Number of days/year</th>
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<th>2046-2065</th>
<th>2081-2100</th>
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<td>20</td>
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RCP 8.5

<table>
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</table>
1.2. EXTREME EVENTS – 1.2.2. CHANGES IN EXTREME PRECIPITATION

FIGURE 14
Mean change in R10 for mid-century and end-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period.
FIGURE 15
Mean change in R20 for mid-century and end-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period

RCP 4.5

Number of days/year

1986-2005

2046-2065

2081-2100

RCP 8.5

Number of days/year

1986-2005

2046-2065

2081-2100
CHAPTER 2

REGIONAL HYDROLOGICAL MODELLING: ARAB REGION
2.1. HYDROLOGICAL PARAMETERS – 2.1.1. RUNOFF

Mean change in annual runoff for mid-century and end-century for ensemble of three RCP 4.5 projections compared to the reference period using two hydrological models.
FIGURE 17
Mean change in annual runoff for mid-century and end-century for ensemble of three RCP 8.5 projections compared to the reference period using two hydrological models

2.1. HYDROLOGICAL PARAMETERS – 2.1.1. RUNOFF

RCP 8.5

HYPE MODEL

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<td>100 - 150</td>
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<td>2081-2100</td>
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<td>25 - 50</td>
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<td>50 - 100</td>
<td>100 - 150</td>
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VIC MODEL

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<th>Local Runoff, abs.diff. (mm/month)</th>
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<td></td>
<td>50 - 100</td>
<td>100 - 150</td>
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</table>
FIGURE 18
Agreement on mean change in annual runoff from the reference period between the ensemble of three RCP 4.5 projections for mid-century and end-century using two hydrological models.

Note: Brown indicates where all ensemble projections agree on a decrease (-) in runoff, and green indicates where all agree on an increase (+) in runoff.
FIGURE 19
Agreement on mean change in annual runoff from the reference period between the ensemble of three RCP 8.5 projections for mid-century and end-century using two hydrological models.

RCP 8.5

HYPE MODEL

2046-2065

2081-2100

VIC MODEL

Local runoff, member agreement

- ALL -

+ ALL +

Note: Brown indicates where all ensemble projections agree on a decrease (−) in runoff, and green indicates where all agree on an increase (+) in runoff.
2.1. HYDROLOGICAL PARAMETERS – 2.1.1. RUNOFF

**FIGURE 20**
Mean change in seasonal runoff (April-September) for mid-century and end-century for ensemble of three RCP 4.5 projections compared to the reference period using two hydrological models.

**FIGURE 21**
Mean change in seasonal runoff (October-March) for mid-century and end-century for ensemble of three RCP 4.5 projections compared to the reference period using two hydrological models.
2.1. HYDROLOGICAL PARAMETERS – 2.1.1. RUNOFF

FIGURE 22
Mean change in seasonal runoff (April-September) for mid-century and end-century for ensemble of three RCP 8.5 projections compared to the reference period using two hydrological models

RCP 8.5 APRIL - SEPTEMBER

HYPE MODEL

1986-2005

2046-2065

2081-2100

VIC MODEL

FIGURE 23
Mean change in seasonal runoff (October-March) for mid-century and end-century for ensemble of three RCP 8.5 projections compared to the reference period using two hydrological models

RCP 8.5 OCTOBER - MARCH

HYPE MODEL

1986-2005

2046-2065

2081-2100

VIC MODEL
2.1. HYDROLOGICAL PARAMETERS – 2.1.1. RUNOFF

FIGURE 24
Agreement on mean change in seasonal runoff (April-September) from the reference period between the ensemble of three RCP 4.5 projections for mid-century and end-century using two hydrological models.

RCP 4.5 APRIL - SEPTEMBER

HYPE MODEL

2046-2065

2081-2100

VIC MODEL

FIGURE 25
Agreement on mean change in seasonal runoff (October-March) from the reference period between the ensemble of three RCP 4.5 projections for mid-century and end-century using two hydrological models.

RCP 4.5 OCTOBER - MARCH

HYPE MODEL

2046-2065

2081-2100

VIC MODEL

Note: Brown indicates where all ensemble projections agree on a decrease (-) in runoff, and green indicates where all agree on an increase (+) in runoff.
2.1. HYDROLOGICAL PARAMETERS – 2.1.1. RUNOFF

FIGURE 26
Agreement on mean change in seasonal runoff (April-September) from the reference period between the ensemble of three RCP 8.5 projections for mid-century and end-century using two hydrological models

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<tr>
<td>2081-2100</td>
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FIGURE 27
Agreement on mean change in seasonal runoff (October-March) from the reference period between the ensemble of three RCP 8.5 projections for mid-century and end-century using two hydrological models

<table>
<thead>
<tr>
<th>RCP 8.5</th>
<th>OCTOBER - MARCH</th>
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<tbody>
<tr>
<td>HYPE MODEL</td>
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<td>2081-2100</td>
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**Note:** Brown indicates where all ensemble projections agree on a decrease (-) in runoff, and green indicates where all agree on an increase (+) in runoff.
FIGURE 28
Mean change in annual evapotranspiration for mid-century and end-century for ensemble of three RCP 4.5 projections compared to the reference period using two hydrological models

2.1. HYDROLOGICAL PARAMETERS –
2.1.2. EVAPOTRANSPIRATION

<table>
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<th>RCP 4.5</th>
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Evapotranspiration [mm/month]  
Evapotranspiration, abs.diff. [mm/month]
FIGURE 29
Mean change in annual evapotranspiration for mid-century and end-century for ensemble of three RCP 8.5 projections compared to the reference period using two hydrological models
FIGURE 30
Agreement on mean change in annual evapotranspiration from the reference period between the ensemble of three RCP 4.5 projections for mid-century and end-century using two hydrological models.

RCP 4.5

HYPE MODEL

2046-2065

2081-2100

VIC MODEL

Evapotranspiration, member agreement

ALL -

ALL +

Note: Brown indicates where all ensemble projections agree on a decrease (-) in evapotranspiration, and green indicates where all agree on an increase (+) in evapotranspiration.
Agreement on mean change in annual evapotranspiration from the reference period between the ensemble of three RCP 8.5 projections for mid-century and end-century using two hydrological models.

Note: Brown indicates where all ensemble projections agree on a decrease (-) in evapotranspiration, and green indicates where all agree on an increase (+) in evapotranspiration.
CHAPTER 3

MOROCCAN HIGHLANDS
3.1. GENERAL PARAMETERS – 3.1.1. TEMPERATURE

FIGURE 32
Mean change in annual temperature over time for ensemble of three RCP 4.5 and RCP 8.5 projections

FIGURE 33
Mean change in seasonal temperature (April-September) over time for ensemble of three RCP 4.5 and RCP 8.5 projections

FIGURE 34
Mean change in seasonal temperature (October-March) over time for ensemble of three RCP 4.5 and RCP 8.5 projections

FIGURE 35
Mean change in monthly temperature for mid-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period

FIGURE 36
Mean change in monthly temperature for end-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period
3.1. GENERAL PARAMETERS – 3.1.2. PRECIPITATION

FIGURE 37
Mean change in annual precipitation over time for ensemble of three RCP 4.5 and RCP 8.5 projections

FIGURE 38
Mean change in seasonal precipitation (April-September) over time for ensemble of three RCP 4.5 and RCP 8.5 projections

FIGURE 39
Mean change in seasonal precipitation (October-March) over time for ensemble of three RCP 4.5 and RCP 8.5 projections

FIGURE 40
Mean change in monthly precipitation for mid-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period

FIGURE 41
Mean change in monthly precipitation for end-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period
3.2. EXTREME EVENTS – 3.2.1. CHANGES IN EXTREME TEMPERATURE

**FIGURE 42**
Mean change in SU35 over time for ensemble of three RCP 4.5 and RCP 8.5 projections

**FIGURE 43**
Mean change in SU40 over time for ensemble of three RCP 4.5 and RCP 8.5 projections

**FIGURE 44**
Mean change in TR over time for ensemble of three RCP 4.5 and RCP 8.5 projections

**FIGURE 45**
Mean change in CDD over time for ensemble of three RCP 4.5 and RCP 8.5 projections

**FIGURE 46**
Mean change in CWD over time for ensemble of three RCP 4.5 and RCP 8.5 projections

**FIGURE 47**
Mean change in R10 over time for ensemble of three RCP 4.5 and RCP 8.5 projections

**FIGURE 48**
Mean change in R20 over time for ensemble of three RCP 4.5 and RCP 8.5 projections
3.3. HYDROLOGICAL PARAMETERS – 3.3.1. RUNOFF

**FIGURE 49**
Mean change in annual runoff over time for ensemble of three RCP 4.5 and RCP 8.5 projections using two hydrological models

**FIGURE 50**
Mean change in seasonal runoff (April-September) over time for ensemble of three RCP 4.5 and RCP 8.5 projections using two hydrological models

**FIGURE 51**
Mean change in seasonal runoff (October-March) over time for ensemble of three RCP 4.5 and RCP 8.5 projections using two hydrological models

3.3. HYDROLOGICAL PARAMETERS – 3.3.2. EVAPOTRANSPIRATION

**FIGURE 52**
Mean change in annual evapotranspiration over time for ensemble of three RCP 4.5 and RCP 8.5 projections using two hydrological models
3.3. HYDROLOGICAL PARAMETERS – 3.3.3. COMPARISON 50 KM VS 25 KM RESOLUTIONS - RUNOFF

**FIGURE 53**
Comparison between 25km (MNA22) and 50km (MNA44) resolutions for mean change in annual runoff over time for two RCP 8.5 projections using HYPE model

**FIGURE 54**
Comparison between 25km (MNA22) and 50km (MNA44) resolutions for mean change in seasonal runoff (April-September) over time for two RCP 8.5 projections using HYPE model

**FIGURE 55**
Comparison between 25km (MNA22) and 50km (MNA44) resolutions for mean change in seasonal runoff (October-March) over time for two RCP 8.5 projections using HYPE model
CHAPTER 4

MEDITERRANEAN COAST
4.1. GENERAL PARAMETERS – 4.1.1. TEMPERATURE

**FIGURE 56**
Mean change in annual temperature over time for ensemble of three RCP 4.5 and RCP 8.5 projections

**FIGURE 57**
Mean change in seasonal temperature (April-September) over time for ensemble of three RCP 4.5 and RCP 8.5 projections

**FIGURE 58**
Mean change in seasonal temperature (October-March) over time for ensemble of three RCP 4.5 and RCP 8.5 projections

**FIGURE 59**
Mean change in monthly temperature for mid-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period

**FIGURE 60**
Mean change in monthly temperature for end-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period
4.1. GENERAL PARAMETERS – 4.1.2. PRECIPITATION

FIGURE 61
Mean change in annual precipitation over time for ensemble of three RCP 4.5 and RCP 8.5 projections

FIGURE 62
Mean change in seasonal precipitation (April-September) over time for ensemble of three RCP 4.5 and RCP 8.5 projections

FIGURE 63
Mean change in seasonal precipitation (October-March) over time for ensemble of three RCP 4.5 and RCP 8.5 projections

FIGURE 64
Mean change in monthly precipitation for mid-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period

FIGURE 65
Mean change in monthly precipitation for end-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period
4.2. EXTREME EVENTS – 4.2.1. CHANGES IN EXTREME TEMPERATURE

**FIGURE 66**
Mean change in SU35 over time for ensemble of three RCP 4.5 and RCP 8.5 projections

**FIGURE 68**
Mean change in TR over time for ensemble of three RCP 4.5 and RCP 8.5 projections

4.2. EXTREME EVENTS – 4.2.2. CHANGES IN EXTREME PRECIPITATION

**FIGURE 69**
Mean change in CDD over time for ensemble of three RCP 4.5 and RCP 8.5 projections

**FIGURE 70**
Mean change in CWD over time for ensemble of three RCP 4.5 and RCP 8.5 projections

**FIGURE 71**
Mean change in R10 over time for ensemble of three RCP 4.5 and RCP 8.5 projections

**FIGURE 72**
Mean change in R20 over time for ensemble of three RCP 4.5 and RCP 8.5 projections
4.3. HYDROLOGICAL PARAMETERS – 4.3.1. RUNOFF

FIGURE 73
Mean change in annual runoff over time for ensemble of three RCP 4.5 and RCP 8.5 projections using two hydrological models

FIGURE 74
Mean change in seasonal runoff (April-September) over time for ensemble of three RCP 4.5 and RCP 8.5 projections using two hydrological models

FIGURE 75
Mean change in seasonal runoff (October-March) over time for ensemble of three RCP 4.5 and RCP 8.5 projections using two hydrological models

4.3. HYDROLOGICAL PARAMETERS – 4.3.2. EVAPOTRANSPIRATION

FIGURE 76
Mean change in annual evapotranspiration over time for ensemble of three RCP 4.5 and RCP 8.5 projections using two hydrological models
4.3. HYDROLOGICAL PARAMETERS – 4.3.3. COMPARISON 50 KM VS 25 KM RESOLUTIONS - RUNOFF

**FIGURE 77**
Comparison between 25km (MNA22) and 50km (MNA44) resolutions for mean change in annual runoff over time for two RCP 8.5 projections using HYPE model.

**FIGURE 78**
Comparison between 25km (MNA22) and 50km (MNA44) resolutions for mean change in seasonal runoff (April-September) over time for two RCP 8.5 projections using HYPE model.

**FIGURE 79**
Comparison between 25km (MNA22) and 50km (MNA44) resolutions for mean change in seasonal runoff (October-March) over time for two RCP 8.5 projections using HYPE model.
CHAPTER 5

NILE RIVER: BLUE NILE HEADWATERS
5.1. GENERAL PARAMETERS – 5.1.1. TEMPERATURE

FIGURE 80
Mean change in annual temperature over time for ensemble of three RCP 4.5 and RCP 8.5 projections

FIGURE 81
Mean change in seasonal temperature (April-September) over time for ensemble of three RCP 4.5 and RCP 8.5 projections

FIGURE 82
Mean change in seasonal temperature (October-March) over time for ensemble of three RCP 4.5 and RCP 8.5 projections

FIGURE 83
Mean change in monthly temperature for mid-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period

FIGURE 84
Mean change in monthly temperature for end-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period
5.1. GENERAL PARAMETERS – 5.1.2. PRECIPITATION

**FIGURE 85**
Mean change in annual precipitation over time for ensemble of three RCP 4.5 and RCP 8.5 projections

**FIGURE 86**
Mean change in seasonal precipitation (April-September) over time for ensemble of three RCP 4.5 and RCP 8.5 projections

**FIGURE 87**
Mean change in seasonal precipitation (October-March) over time for ensemble of three RCP 4.5 and RCP 8.5 projections

**FIGURE 88**
Mean change in monthly precipitation for mid-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period

**FIGURE 89**
Mean change in monthly precipitation for end-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period
5.2. EXTREME EVENTS – 5.2.2. CHANGES IN EXTREME TEMPERATURE

**FIGURE 90**
Mean change in SU35 over time for ensemble of three RCP 4.5 and RCP 8.5 projections

**FIGURE 91**
Mean change in SU40 over time for ensemble of three RCP 4.5 and RCP 8.5 projections

**FIGURE 92**
Mean change in TR over time for ensemble of three RCP 4.5 and RCP 8.5 projections

5.2. EXTREME EVENTS – 5.2.3. CHANGES IN EXTREME PRECIPITATION

**FIGURE 93**
Mean change in CDD over time for ensemble of three RCP 4.5 and RCP 8.5 projections

**FIGURE 94**
Mean change in CWD over time for ensemble of three RCP 4.5 and RCP 8.5 projections

**FIGURE 95**
Mean change in R10 over time for ensemble of three RCP 4.5 and RCP 8.5 projections

**FIGURE 96**
Mean change in R20 over time for ensemble of three RCP 4.5 and RCP 8.5 projections
5.3. HYDROLOGICAL PARAMETERS – 5.3.1. RUNOFF

FIGURE 97
Mean change in annual runoff over time for ensemble of three RCP 4.5 and RCP 8.5 projections using two hydrological models

FIGURE 98
Mean change in seasonal runoff (April-September) over time for ensemble of three RCP 4.5 and RCP 8.5 projections using two hydrological models

FIGURE 99
Mean change in seasonal runoff (October-March) over time for ensemble of three RCP 4.5 and RCP 8.5 projections using two hydrological models
5.3. HYDROLOGICAL PARAMETERS – 5.3.2. DISCHARGE

**FIGURE 100**
Mean change in annual discharge over time for ensemble of three RCP 4.5 and RCP 8.5 projections using HYPE model.

**FIGURE 101**
Mean change in seasonal discharge (April-September) over time for ensemble of three RCP 4.5 and RCP 8.5 projections using HYPE model.

**FIGURE 102**
Mean change in seasonal discharge (October-March) over time for ensemble of three RCP 4.5 and RCP 8.5 projections using HYPE model.

5.3. HYDROLOGICAL PARAMETERS – 5.3.3. EVAPOTRANSPIRATION

**FIGURE 103**
Mean change in annual evapotranspiration over time for ensemble of three RCP 4.5 and RCP 8.5 projections using two hydrological models.
5.3. HYDROLOGICAL PARAMETERS – 5.3.4. COMPARISON 50 KM VS 25 KM RESOLUTIONS – 5.3.4.1. RUNOFF

**FIGURE 104**
Comparison between 25km (MNA22) and 50km (MNA44) resolutions for mean change in annual runoff over time for two RCP 8.5 projections using HYPE model.

**FIGURE 105**
Comparison between 25km (MNA22) and 50km (MNA44) resolutions for mean change in seasonal runoff (April-September) over time for two RCP 8.5 projections using HYPE model.

**FIGURE 106**
Comparison between 25km (MNA22) and 50km (MNA44) resolutions for mean change in seasonal runoff (October-March) over time for two RCP 8.5 projections using HYPE model.
5.3. HYDROLOGICAL PARAMETERS – 5.3.4. COMPARISON 50 KM VS 25 KM RESOLUTIONS – 5.3.4.2. DISCHARGE

**FIGURE 107**
Comparison between 25km (MNA22) and 50km (MNA44) resolutions for mean change in annual discharge over time for two RCP 8.5 projections using HYPE model.

**FIGURE 108**
Comparison between 25km (MNA22) and 50km (MNA44) resolutions for mean change in seasonal discharge (April-September) over time for two RCP 8.5 projections using HYPE model.

**FIGURE 109**
Comparison between 25km (MNA22) and 50km (MNA44) resolutions for mean change in seasonal discharge (October-March) over time for two RCP 8.5 projections using HYPE model.
6.1. GENERAL PARAMETERS – 6.1.1. TEMPERATURE

**FIGURE 110**
Mean change in annual temperature over time for ensemble of three RCP 4.5 and RCP 8.5 projections

**FIGURE 111**
Mean change in seasonal temperature (April-September) over time for ensemble of three RCP 4.5 and RCP 8.5 projections

**FIGURE 112**
Mean change in seasonal temperature (October-March) over time for ensemble of three RCP 4.5 and RCP 8.5 projections

**FIGURE 113**
Mean change in monthly temperature for mid-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period

**FIGURE 114**
Mean change in monthly temperature for end-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period
6.1. GENERAL PARAMETERS – 6.1.2. PRECIPITATION

FIGURE 115
Mean change in annual precipitation over time for ensemble of three RCP 4.5 and RCP 8.5 projections

FIGURE 116
Mean change in seasonal precipitation (April-September) over time for ensemble of three RCP 4.5 and RCP 8.5 projections

FIGURE 117
Mean change in seasonal precipitation (October-March) over time for ensemble of three RCP 4.5 and RCP 8.5 projections

FIGURE 118
Mean change in monthly precipitation for mid-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period

FIGURE 119
Mean change in monthly precipitation for end-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period
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**HYPE MODEL**

**VIC MODEL**
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INTEGRATED VULNERABILITY ASSESSMENT
# Integrated Vulnerability Assessment

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Integrated Vulnerability Assessment
Explanatory Note

Results presented include impact chains and maps for each of the sectors studied, namely: Water (Chapter 11); Biodiversity and ecosystems (Chapter 12); Agriculture (Chapter 13); Infrastructure and human settlements (Chapter 14), and People (Chapter 15), along with their associated subsectors.

Results for each subsector were derived from indicators and their impact chains. Impact chains illustrate cause-effect relationships between identified indicators from each vulnerability component (exposure, sensitivity, and adaptive capacity), and the relevant climate change impact. The aggregated results are presented on maps representing exposure, sensitivity, adaptive capacity composite indicators, potential impact, and vulnerability, all of which are provided for the reference period. For future periods, only the exposure composite indicator, potential impact and vulnerability are presented since the sensitivity and adaptive capacity components are based on static data and remain the same as the reference period. Solely vulnerability maps are provided for each sector due to integrating vulnerability outputs from the pertinent subsectors directly. In cases where only one subsector is identified under a given sector, no sector maps are included due to the resultant output being the same. It is important to highlight that all maps pertaining to the future periods represent the change in specific components relative to the reference period.

With regard to exposure, please note that data corresponding to exposure for RHM data was based on the outputs from the hydrological model VIC. It is assumed that classified values obtained from the HYPE hydrological model will be the same. Also note that classified values for the exposure component for the reference period are based on the actual values, while they are based upon the change in value (compared to the reference period) for the future periods; thus caution is advised when comparing results.

Some considerations were made with regard to map presentation. Maps only reveal the area of interest for the given sector or subsector. For example, for the area covered by forests subsector, only forested areas are shown. Also, as a reminder, all results are based on classified data (not value based). Because the resultant range of aggregated results was limited, the final classification was based on the minimum and maximum values obtained for each sector or subsector and divided into equal intervals from 1 to 10. This classification scheme was applied for all provided maps for a given sector or subsector to facilitate ease of comparison between the composite indicators and the vulnerability. Lastly, the colour scheme utilized was based on a “stoplight” such that green is representative of low vulnerability and red is representative of high vulnerability. A similar colour scheme was applied for the differing components.

Selected maps showing vulnerability hotspots, representing areas which are especially vulnerable to climate change impacts, are only presented in the main report. Such areas are intended to draw special attention in terms of vulnerability for a particular sector or subsector. For RICCAR, hotspots were identified based on the top percentage of vulnerability among the two time periods and two scenarios for each climate change impact. 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.

Further details on the methodology and data sources used for the vulnerability assessment are found in the RICCAR Technical Note ‘Integrated Vulnerability Assessment: Arab Regional Application.

Finally, it is essential to note that assumptions, further considerations and detailed observations specific to each output are mentioned in the main report, and it is therefore advised to refer to it consistently while reading through this annex.
CHAPTER 11

WATER SECTOR
## Change in Water Availability – Impact Chain

### Potential Impact (0.50)
- Technology (0.10)
  - Number of scientific and technical journal articles (0.46)
  - Information and communication technologies index (0.54)
- Institutions (0.10)
  - Governance index (0.54)
  - Disaster risk reduction committees (0.46)
- Economic Resources (0.11)
  - GDP per capita (0.36)
  - ODA (0.30)
  - Food imports as % of merchandise exports (0.34)
- Equity (0.09)
  - Female-to-male literacy ratio (0.51)
  - Migrants/refugees index (0.49)
- Environment (0.50)
  - Environment performance index (1.0)
- Infrastructure (0.50)
  - Number of scientific and technical journal articles (0.46)
  - Information and communication technologies index (0.54)
- Knowledge & Awareness (0.10)
  - E-government development (0.33)
  - Tertiary enrollment (0.32)
  - Adult literacy rate (0.39)
- Population (0.50)
  - Population density (0.14)
  - Total renewable water available per capita (0.50)
  - Water consumption per capita (0.13)
  - Share of water consumption in agriculture (0.13)
  - Refugee population (0.10)
- Natural (0.26)
  - Land use/land cover (0.27)
  - Soil storage capacity (0.25)
  - Degradation of vegetation cover (0.26)
  - Wetlands (0.22)
- Manmade (0.24)
  - Urban extent (0.47)
  - Areas served by dams (0.53)

### Exposure (0.50)
- RCM
  - Change in temperature (0.17)
  - Change in precipitation (0.17)
- RHM
  - Change in runoff (0.17)
  - Change in evapotranspiration (0.17)

### Extreme Events Indices
- Change in maximum length of dry spell (0.16)
- Change in maximum length of wet spell (0.16)
- Change in temperature (0.17)
- Change in precipitation (0.17)
- Change in runoff (0.17)
- Change in evapotranspiration (0.17)

### Sensitivity (0.50)
- Change in maximum length of dry spell (0.16)
- Change in maximum length of wet spell (0.16)
- Change in temperature (0.17)
- Change in precipitation (0.17)
11.1. WATER AVAILABILITY – 11.1.2. REFERENCE PERIOD – 11.1.2.1. EXPOSURE

**FIGURE 261**

**WATER: WATER AVAILABILITY**

**EXPOSURE: REFERENCE PERIOD**

**Legend**

- Lakes
- Reservoirs
- Intermittent rivers
- Major cities
- Area not relevant to subsector
- Low Exposure
- High Exposure

11.1. WATER AVAILABILITY – 11.1.2. REFERENCE PERIOD – 11.1.2.2. SENSITIVITY

**FIGURE 262**

**WATER: WATER AVAILABILITY**

**SENSITIVITY**

**Legend**

- Lakes
- Reservoirs
- Intermittent rivers
- Major cities
- Area not relevant to subsector
- Low Sensitivity
- High Sensitivity
11.1. WATER AVAILABILITY – 11.1.2. REFERENCE PERIOD – 11.1.2.3. POTENTIAL IMPACT

FIGURE 263

11.1. WATER AVAILABILITY – 11.1.2. REFERENCE PERIOD – 11.1.2.4. ADAPTIVE CAPABILITY

FIGURE 264
11.1 WATER AVAILABILITY – 11.1.2 REFERENCE PERIOD – 11.1.2.5 VULNERABILITY

FIGURE 265

WATER: WATER AVAILABILITY
VULNERABILITY: REFERENCE PERIOD

Legend

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

Low Vulnerability
High Vulnerability

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11.1. WATER AVAILABILITY – 11.1.3. MID-CENTURY RCP 4.5 – 11.1.3.1. EXPOSURE

**FIGURE 266**

![Map of water availability and exposure](image)

**Legend**

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

**WATER:** WATER AVAILABILITY
**EXPOSURE:** RCP 4.5 MID-CENTURY (2046-2055)

11.1. WATER AVAILABILITY – 11.1.3. MID-CENTURY RCP 4.5 – 11.1.3.2. POTENTIAL IMPACT

**FIGURE 267**

![Map of water availability and potential impact](image)

**Legend**

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

**WATER:** WATER AVAILABILITY
**POTENTIAL IMPACT:** RCP 4.5 MID-CENTURY (2061-2100)
11.1. WATER AVAILABILITY – 11.1.3. MID-CENTURY RCP 4.5 – 11.1.3.3. VULNERABILITY

FIGURE 268

Legend
- Major cities
- Areas not relevant to subsector
- Rivers
- Intermittent rivers

RICCAR

WATER AVAILABILITY:
VULNERABILITY:
RCP4.5 MID-CENTURY (2045-2065)
11.1. WATER AVAILABILITY – 11.1.4. MID-CENTURY RCP 8.5 – 11.1.4.1. EXPOSURE

**FIGURE 269**

![Map of water availability and exposure](image)

**Legend**
- Lakes
- Reservoirs
- Intermittent rivers
- Major cities
- Area not relevant to subsector
- Low Exposure
- High Exposure

**WATER:** WATER AVAILABILITY  
**EXPOSURE:** RCP8.5 MID-CENTURY (2046-2065)

11.1. WATER AVAILABILITY – 11.1.4. MID-CENTURY RCP 8.5 – 11.1.4.2. POTENTIAL IMPACT

**FIGURE 270**

![Map of water availability and potential impact](image)

**Legend**
- Lakes
- Reservoirs
- Intermittent rivers
- Major cities
- Area not relevant to subsector
- Low Potential Impact
- High Potential Impact

**WATER:** WATER AVAILABILITY  
**POTENTIAL IMPACT:** RCP8.5 MID-CENTURY (2046-2065)
11.1. WATER AVAILABILITY – 11.1.4. MID-CENTURY RCP 8.5 – 11.1.4.3. VULNERABILITY
11.1. WATER AVAILABILITY – 11.1.5. END-CENTURY RCP 4.5 – 11.1.5.1. EXPOSURE

FIGURE 272

11.1. WATER AVAILABILITY – 11.1.5. END-CENTURY RCP 4.5 – 11.1.5.2. POTENTIAL IMPACT

FIGURE 273
11.1. WATER AVAILABILITY – 11.1.5. END-CENTURY RCP 4.5 – 11.1.5.3. VULNERABILITY

FIGURE 27A

WATER AVAILABILITY
VULNERABILITY: RCP4.5 END-CENTURY (2081-2100)

Legend

- Major cities
- Intermittent rivers
- Reservoirs
- Lakes
- Areas not relevant to subsector
- High Vulnerability
- Low Vulnerability
11.1. WATER AVAILABILITY – 11.1.6. END-CENTURY RCP 8.5 – 11.1.6.1. EXPOSURE

**FIGURE 275**

11.1. WATER AVAILABILITY – 11.1.6. END-CENTURY RCP 8.5 – 11.1.6.2. POTENTIAL IMPACT

**FIGURE 276**
11.1. WATER AVAILABILITY – 11.1.6. END-CENTURY RCP 8.5 – 11.1.6.3. VULNERABILITY
CHAPTER 12

BIODIVERSITY AND ECOSYSTEMS SECTOR
12.1. AREA COVERED BY FORESTS – 12.1.1. IMPACT CHAIN

**TECHNOLOGY (0.10)**
- Number of scientific and technical journal articles (0.46)
- Information and communication technologies index (0.54)

**INSTITUTIONS (0.11)**
- Governance index (0.32)
- Area under nature protection (0.37)
- Disaster risk reduction committees (0.31)

**KNOWLEDGE & AWARENESS (0.10)**
- E-Governement development (0.38)
- Tertiary enrollment (0.31)
- Adult literacy rate (0.31)

**INFRASTRUCTURE (0.50)**
- Areas served by dams (0.17)
- Installed desalination capacity per capita (0.17)
- Fossil groundwater (0.17)
- Access to improved water (0.17)
- Area equipped for irrigation (0.17)

**ENVIRONMENT (0.50)**
- Environment performance index (1.0)

**TRANSPORT (0.24)**
- Density of road network (1.0)

**ECONOMIC RESOURCES (0.11)**
- GDP per capita (0.53)
- ODA (0.47)

**EQUITY (0.07)**
- Female-to-male unemployment rate (0.40)
- Female-to-male literacy ratio (0.60)

**POPULATION (0.25)**
- Population density (0.60)
- Refugee population (0.40)

**NATURAL (0.50)**
- Soil storage capacity (0.12)
- Degradation of vegetation cover (0.13)
- Livestock density (0.11)
- Change in forest cover (0.50)
- Threatened forested areas (0.13)

**MANMADE (0.25)**
- Flood-prone areas (0.35)
- Urban extent (0.36)
- Road network (0.29)

**ADAPTIVE CAPACITY (0.50)**
- Change in evapotranspiration (0.25)

**EXTREME EVENTS INDICES**
- Change in maximum length of dry spell (0.25)
- Change in temperature (0.25)
- Change in precipitation (0.25)

**POTENTIAL IMPACT (0.59)**

**SENSITIVITY (0.50)**

**EXPOSURE (0.50)**

**VULNERABILITY ASSESSMENT**
12.1. AREA COVERED BY FORESTS – 12.1.2. REFERENCE PERIOD – 12.1.2.1. EXPOSURE

FIGURE 279

12.1. AREA COVERED BY FORESTS – 12.1.2. REFERENCE PERIOD – 12.1.2.2. SENSITIVITY

FIGURE 280
12.1. AREA COVERED BY FORESTS – 12.1.2. REFERENCE PERIOD – 12.1.2.3. POTENTIAL IMPACT

FIGURE 281

12.1. AREA COVERED BY FORESTS – 12.1.2. REFERENCE PERIOD – 12.1.2.4. ADAPTIVE CAPACITY

FIGURE 282
12.1. AREA COVERED BY FORESTS – 12.1.2. REFERENCE PERIOD – 12.1.2.5. VULNERABILITY
12.1. AREA COVERED BY FORESTS – 12.1.3. MID-CENTURY RCP 4.5 – 12.1.3.1. EXPOSURE

**FIGURE 284**

![Map showing area covered by forests in the Mid-Century RCP 4.5 scenario.](image)

**Legend**
- Lakes
- Reservoirs
- Major cities
- Area not relevant to subsector
- Low Exposure
- High Exposure

12.1. AREA COVERED BY FORESTS – 12.1.3. MID-CENTURY RCP 4.5 – 12.1.3.2. POTENTIAL IMPACT

**FIGURE 285**

![Map showing potential impact of forest area in the Mid-Century RCP 4.5 scenario.](image)

**Legend**
- Lakes
- Reservoirs
- Major cities
- Area not relevant to subsector
- Low Potential Impact
- High Potential Impact
12.1. AREA COVERED BY FORESTS – M.1.3. MID-CENTURY RCP 4.5 – 12.1.3.3. VULNERABILITY

FIGURE 286

Biodiversity and ecosystems: Area covered by forests

Vulnerability: RCP4.5 Mid-century (2046-2065)

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

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12.1. AREA COVERED BY FORESTS – 12.1.4. MID-CENTURY RCP 8.5 – 12.1.4.1. EXPOSURE

FIGURE 287

12.1. AREA COVERED BY FORESTS – 12.1.4. MID-CENTURY RCP 8.5 – 12.1.4.2. POTENTIAL IMPACT

FIGURE 288
12.1. AREA COVERED BY FORESTS – 12.1.4. MID-CENTURY RCP 8.5 – 12.1.4.3. VULNERABILITY

FIGURE 289
12.1. AREA COVERED BY FORESTS – 12.1.5. END-CENTURY RCP 4.5 – 12.1.5.1. EXPOSURE

FIGURE 290

12.1. AREA COVERED BY FORESTS – 12.1.5. END-CENTURY RCP 4.5 – 12.1.5.2. POTENTIAL IMPACT

FIGURE 291
12.1. AREA COVERED BY FORESTS – 12.1.5. END-CENTURY RCP 4.5 – 12.1.5.3. VULNERABILITY

FIGURE 292

Biodiversity and Ecosystems:

Area Covered by Forests

Vulnerability: RCP 4.5 End-Century (2081-2100)

Legend:
- Lakes
- Reservoirs
- Intermittent rivers
- Major cities
- Area not relevant to subsector

Low Vulnerability
High Vulnerability
12.1. AREA COVERED BY FORESTS – 12.1.6. END-CENTURY RCP 8.5 – 12.1.6.1. EXPOSURE

FIGURE 293

12.1. AREA COVERED BY FORESTS – 12.1.6. END-CENTURY RCP 8.5 – 12.1.6.2. POTENTIAL IMPACT

FIGURE 294
12.1. AREA COVERED BY FORESTS – 12.1.6. END-CENTURY RCP 8.5 – 12.1.6.3. VULNERABILITY

FIGURE 295

Biodiversity and ecosystems: Area covered by forests
Vulnerability: RCP8.5 end-century (2081-2100)

Legend:
- Lakes
- Reservoirs
- Intermittent rivers
- Major cities
- Area not relevant to subsector

Low Vulnerability
High Vulnerability
FIGURE 296

EXPOSURE (0.50)

RCM
- Change in temperature (0.20)
- Change in precipitation (0.20)

RHM
- Change in runoff (0.20)
- Change in evapotranspiration (0.20)

EXTREME EVENTS INDICES
- Change in maximum length of dry spell (0.20)

SENSITIVITY (0.50)

POPULATION (0.25)
- Population density (1.0)

NATURAL (0.50)
- Degradation of vegetation cover (0.27)
- Livestock density (0.23)
- Wetlands (0.50)*

MANMADE (0.25)
- Floodprone areas (0.35)*
- Urban extent (0.35)
- Road network (0.30)

ADAPTIVE CAPACITY (0.50)

KNOWLEDGE & AWARENESS (0.11)
- E-Governement development (0.38)
- Tertiary enrolment (0.30)
- Adult literacy rate (0.32)

TECHNOLOGY (0.10)
- Number of scientific and technical journal articles (0.45)
- Information and communication technologies index (0.55)

INSTITUTIONS (0.10)
- Governance index (0.32)
- Area under nature protection (0.37)
- Disaster risk reduction committees (0.31)

INFRASTRUCTURE (0.50)
- Areas served by dams (0.17)
- Installed desalination capacity per capita (0.17)
- Fossil groundwater (0.17)
- Access to improved water (0.17)
- Access to improved sanitation (0.16)
- Area equipped for irrigation (0.16)
- Environment performance index (1.0)

ENVIRONMENT (0.50)
- Environment performance index (1.0)

WATER & SANITATION (0.14)
- Access to electricity (0.50)
- Energy consumption (0.50)

ENERGY (0.13)
- Access to electricity (0.50)
- Energy consumption (0.50)

HEALTH (0.11)
- Health index (1.0)

TRANSPORT (0.12)
- Density of road network (1.0)

ECONOMIC RESOURCES (0.11)
- GDP per capita (0.52)
- ODA (0.48)

EQUITY (0.07)
- Migrants/refugees index (1.0)

* Subsector specific classification
12.2. AREA COVERED BY WETLANDS – 12.2.2. REFERENCE PERIOD – 12.2.2.1. EXPOSURE

**FIGURE 297**

12.2. AREA COVERED BY WETLANDS – 12.2.2. REFERENCE PERIOD – 12.2.2.2. SENSITIVITY

**FIGURE 298**
12.2. AREA COVERED BY WETLANDS – 12.2.2. REFERENCE PERIOD – 12.2.2.3. POTENTIAL IMPACT

FIGURE 299

12.2. AREA COVERED BY WETLANDS – 12.2.2. REFERENCE PERIOD – 12.2.2.4. ADAPTIVE CAPACITY

FIGURE 300
12.2. AREA COVERED BY WETLANDS – 12.2.2. REFERENCE PERIOD – 12.2.2.5. VULNERABILITY

FIGURE 301
12.2. AREA COVERED BY WETLANDS – 12.2.3. MID-CENTURY RCP 4.5 – 12.2.3.1. EXPOSURE

FIGURE 302

Biodiversity and Ecosystems: Area Covered by Wetlands

EXPOSURE: RCP4.5 Mid-Century (2044-2065)

Legend:
- Lakes
- Reservoirs
- Intermediate
- Areas not relevant to indicator

Low Exposure

High Exposure

12.2. AREA COVERED BY WETLANDS – 12.2.3. MID-CENTURY RCP 4.5 – 12.2.3.2. POTENTIAL IMPACT

FIGURE 303

Biodiversity and Ecosystems: Area Covered by Wetlands

POTENTIAL IMPACT: RCP4.5 Mid-Century (2044-2065)

Legend:
- Lakes
- Reservoirs
- Intermediate
- Areas not relevant to indicator

Low Potential Impact

High Potential Impact
12.2. AREA COVERED BY WETLANDS – 12.2.3. MID-CENTURY RCP 4.5 – 12.2.3.3. VULNERABILITY

FIGURE 304
12.2. AREA COVERED BY WETLANDS – 12.2.4. MID-CENTURY RCP 8.5 – 12.2.4.1. EXPOSURE

**FIGURE 305**

12.2. AREA COVERED BY WETLANDS – 12.2.4. MID-CENTURY RCP 8.5 – 12.2.4.2. POTENTIAL IMPACT

**FIGURE 306**
Biodiversity and Ecosystems: Area Covered by Wetlands

Vulnerability: RCP 8.5 Mid-Century (2046-2065)

Legend:
- Lakes
- Reservoirs
- Intermittent rivers
- Major cities
- Area not relevant to subsector

Low Vulnerability

High Vulnerability
12.2. AREA COVERED BY WETLANDS – 12.2.5. END-CENTURY RCP 4.5 – **12.2.5.1. EXPOSURE**

**FIGURE 308**

**12.2. AREA COVERED BY WETLANDS – 12.2.5. END-CENTURY RCP 4.5 – **12.2.5.2. POTENTIAL IMPACT**

**FIGURE 309**
12.2. AREA COVERED BY WETLANDS – 12.2.5. END-CENTURY RCP 4.5 – 12.2.5.3. VULNERABILITY

FIGURE 310
12.2. AREA COVERED BY WETLANDS – 12.2.6. END-CENTURY RCP 8.5 – 12.2.6.1. EXPOSURE

FIGURE 311

12.2. AREA COVERED BY WETLANDS – 12.2.6. END-CENTURY RCP 8.5 – 12.2.6.2. POTENTIAL IMPACT

FIGURE 312
12.2. AREA COVERED BY WETLANDS – 12.2.6. END-CENTURY RCP 8.5 – 12.2.6.3. VULNERABILITY

Legend

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

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12.3. BIODIVERSITY AND ECOSYSTEMS SECTOR: VULNERABILITY – 12.3.1. REFERENCE PERIOD

FIGURE 314

[Map showing vulnerability assessment for Biodiversity and Ecosystems Sector.]
12.3. BIODIVERSITY AND ECOSYSTEMS SECTOR: VULNERABILITY – 12.3.2. MID-CENTURY RCP 4.5

FIGURE 315
12.3. BIODIVERSITY AND ECOSYSTEMS SECTOR: VULNERABILITY – 12.3.3. MID-CENTURY RCP 8.5

FIGURE 316

Biodiversity and Ecosystems Sector: Vulnerability – Mid-Century RCP 8.5 (2045-2065)

Legend:
- Major cities
- Area not relevant to sector

Map depicting vulnerability levels across different regions.
12.3. BIODIVERSITY AND ECOSYSTEMS SECTOR: VULNERABILITY – 12.3.4. END-CENTURY RCP 4.5

FIGURE 317

Biodiversity and ecosystems sector: Vulnerability – end-century RCP 4.5

Legend:
- Major cities
- Area not relevant to sector
- Rivers
- Intermittent rivers
- Lakes
- Reservoirs

Map showing vulnerability assessment across different regions.
12.3. BIODIVERSITY AND ECOSYSTEMS SECTOR: VULNERABILITY – 12.3.5. END-CENTURY RCP 8.5

FIGURE 318

Biodiversity and ecosystems sector vulnerability: RCP 8.5 end-century (2081-2100)

Legend:
- Major cities
- Area not relevant to sector
- Rivers
- Intermittent rivers
- Lakes
- Reservoirs

[Map showing vulnerability assessment for the end-century RCP 8.5 scenario in the biodiversity and ecosystems sector.]
13.1. WATER AVAILABLE FOR CROPS – 13.1.1. IMPACT CHAIN

**TECHNOLOGY (0.11)**
- Number of scientific and technical journal articles (0.45)
- Information and communication technologies index (0.59)

**KNOWNLEDGE & AWARENESS (0.11)**
- E-Governement development (0.34)
- Tertiary enrollment (0.33)
- Adult literacy rate (0.33)

**INFRASTRUCTURE (0.50)**
- WATER & SANITATION (0.50)
  - Areas served by dams (0.17)
  - Installed desalination capacity per capita (0.17)
  - Fossil groundwater (0.17)
  - Access to improved water (0.17)
  - Access to improved sanitation (0.16)
  - Area equipped for irrigation (0.16)
- ENVIRONMENT (0.17)
  - Environment performance index (1.0)
- ENERGY (0.17)
  - Access to electricity (0.50)
  - Energy consumption (0.50)
- TRANSPORT (0.16)
  - Density of road network (1.0)

**ECONOMIC RESOURCES (0.10)**
- GDP per capita (0.35)
- ODA (0.28)
- Food imports as % of merchandise exports (0.37)

**EQUITY (0.08)**
- Female-to-male literacy ratio (0.52)
- Migrants/refugees index (0.48)

**POPULATION (0.50)**
- Population density (0.12)
- Share of agricultural labor force in total labor (0.12)
- Share of total water available in agriculture (0.50)
- Share of agricultural GDP (0.13)

**NATURAL (0.26)**
- Soil storage capacity (0.34)
- Degradation of vegetation cover (0.32)
- Rainfed areas (0.34)

**MANMADE (0.24)**
- Floodprone areas (0.46)
- Irrigated areas (0.54)

**SENSITIVITY (0.50)**
- Population density (0.12)
- Share of agricultural labor force in total labor (0.12)
- Share of total water available in agriculture (0.50)
- Share of agricultural GDP (0.13)

**EXPOSURE (0.50)**
- Potential impact (0.50)

**VULNERABILITY ASSESSMENT**
- RHM
  - Change in runoff (0.17)
  - Change in evapotranspiration (0.17)
- RIM
  - Change in temperature (0.17)
  - Change in precipitation (0.17)
  - Change in evapotranspiration (0.17)

**ADAPTIVE CAPACITY (0.50)**
- Extreme events indices
  - Change in number of hot day (0.16)
  - Change in maximum length of dry spell (0.16)

**POTENTIAL IMPACT (0.50)**
- Potential impact (0.50)

FIGURE 320

13.1. WATER AVAILABLE FOR CROPS – 13.1.2. REFERENCE PERIOD – 13.1.2.2. SENSITIVITY

FIGURE 321
13.1. WATER AVAILABLE FOR CROPS – 13.1.2. REFERENCE PERIOD – 13.1.2.3. POTENTIAL IMPACT

FIGURE 322

13.1. WATER AVAILABLE FOR CROPS – 13.1.2. REFERENCE PERIOD – 13.1.2.4. ADAPTIVE CAPACITY

FIGURE 323
13.1. WATER AVAILABLE FOR CROPS – 13.1.2. REFERENCE PERIOD – 13.1.2.5. VULNERABILITY

FIGURE 325

AGRICULTURE: WATER AVAILABLE FOR CROPS
EXPOSURE: RCP4.5 MID-CENTURY (2046-2055)

Legend
- Lakes
- Reservoirs
- Intermittent rivers
- Major cities
- Area not relevant to subsector

Low Exposure
High Exposure

13.1. WATER AVAILABLE FOR CROPS – 13.1.3. MID-CENTURY RCP 4.5 – 13.1.3.2. POTENTIAL IMPACT

FIGURE 326

AGRICULTURE: WATER AVAILABLE FOR CROPS
POTENTIAL IMPACT: RCP4.5 MID-CENTURY (2046-2065)

Legend
- Lakes
- Reservoirs
- Intermittent rivers
- Major cities
- Area not relevant to subsector

Low Potential Impact
High Potential Impact
13.1. WATER AVAILABLE FOR CROPS – 13.1.3. MID-CENTURY RCP 4.5 – 13.1.3.3. VULNERABILITY

FIGURE 328

AGRICULTURE: WATER AVAILABLE FOR CROPS
EXPOSURE: RCP 8.5 MID-CENTURY (2046-2055)

Legend
- Lakes
- Reservoirs
- Intermittent rivers
- Major cities
- Area not relevant to subsector
- Low Exposure
- High Exposure

13.1. WATER AVAILABLE FOR CROPS – 13.1.4. MID-CENTURY RCP 8.5 – 13.1.4.2. POTENTIAL IMPACT

FIGURE 329

AGRICULTURE: WATER AVAILABLE FOR CROPS
POTENTIAL IMPACT: RCP 8.5 MID-CENTURY (2046-2065)

Legend
- Lakes
- Reservoirs
- Intermittent rivers
- Major cities
- Area not relevant to subsector
- Low Potential Impact
- High Potential Impact
13.1. WATER AVAILABLE FOR CROPS – 13.1.4. MID-CENTURY RCP 8.5 – 13.1.4.3. VULNERABILITY

FIGURE 330
13.1. WATER AVAILABLE FOR CROPS – 13.1.5. END-CENTURY RCP 4.5 – 13.1.5.1. EXPOSURE

FIGURE 331

13.1. WATER AVAILABLE FOR CROPS – 13.1.5. END-CENTURY RCP 4.5 – 13.1.5.2. POTENTIAL IMPACT

FIGURE 332
13.1. WATER AVAILABLE FOR CROPS – 13.1.5. END-CENTURY RCP 4.5 – 13.1.5.3. VULNERABILITY

Figure 333

AGRICULTURE: WATER AVAILABLE FOR CROPS
VULNERABILITY: RCP 4.5 END-CENTURY (2021-2100)

Legend
- Major cities
- Intermittent rivers
- Reservoirs
- Lakes

Map showing the water availability for crops and vulnerability assessment for the Arab region under RCP 4.5 climate change scenario.

**FIGURE 334**


**FIGURE 335**
FIGURE 3.37

EXPOSURE (0.50)

RCM
- Change in temperature (0.20)

RHM
- Change in runoff (0.20)
- Change in evapotranspiration (0.20)

EXTREME EVENTS INDICES
- Change in number of very hot days (0.20)
- Change in maximum length of dry spell (0.20)

SENSITIVITY (0.50)

POPULATION (0.26)
- Population density (0.23)
- Share of agricultural labor force in total labor (0.24)
- Total renewable water available per capita (0.27)
- Share of water consumption in agriculture (0.27)

NATURAL (0.50)
- Land use - land cover (0.17)*
- Soil storage capacity (0.16)
- Degradation of vegetation cover (0.17)
- Livestock density (0.50)

MANMADE (0.24)
- Irrigated areas (0.52)*
- Urban extent (0.48)

POTENTIAL IMPACT (0.50)

KNOWLEDGE & AWARENESS (0.11)
- Tertiary enrollment (0.48)
- Adult literacy rate (0.52)

TECHNOLOGY (0.10)
- Number of scientific and technical journal articles (0.46)
- Information and communication technologies index (0.54)

INSTITUTIONS (0.10)
- Governance index (0.50)
- Area under nature protection (0.50)

INFRASTRUCTURE (0.50)
- Areas served by dams (0.17)
- Installed desalination capacity per capita (0.17)
- Fossil groundwater (0.17)
- Access to improved water (0.17)
- Access to improved sanitation (0.16)
- Area equipped for irrigation (0.16)

ENVIRONMENT (0.18)
- Environment performance index (1.0)

ENERGY (0.17)
- Access to electricity (0.50)
- Energy consumption (0.50)

TRANSPORT (0.15)
- Density of road network (1.0)

ADAPTIVE CAPACITY (0.50)

ECONOMIC RESOURCES (0.10)
- GDP per capita (0.36)
- ODA (0.28)
- Food imports as % of merchandise exports (0.36)

EQUITY (0.09)
- Female-to-male literacy ratio (0.51)
- Migrants/refugees index (0.49)

* Subsector specific classification
13.2. WATER AVAILABLE FOR LIVESTOCK – 13.2.2. REFERENCE PERIOD – 13.2.2.1. EXPOSURE

**FIGURE 338**

13.2. WATER AVAILABLE FOR LIVESTOCK – 13.2.2. REFERENCE PERIOD – 13.2.2.2. SENSITIVITY

**FIGURE 339**
13.2. WATER AVAILABLE FOR LIVESTOCK – 13.2.2. REFERENCE PERIOD – 13.2.2.3. POTENTIAL IMPACT

FIGURE 340

13.2. WATER AVAILABLE FOR LIVESTOCK – 13.2.2. REFERENCE PERIOD – 13.2.2.4. ADAPTIVE CAPACITY

FIGURE 341
13.2. WATER AVAILABLE FOR LIVESTOCK – 13.2.2. REFERENCE PERIOD – 13.2.2.5. VULNERABILITY
13.2. WATER AVAILABLE FOR LIVESTOCK – 13.2.3. MID-CENTURY RCP 4.5 – 13.2.3.1. EXPOSURE

FIGURE 343

Agriculture: Water Available for Livestock
Exposure: RCP4.5 Mid-Century (2046-2065)

Legend:
- Lakes
- Reservoirs
- Rivers
- Intermittent rivers
- Major cities
- Area not relevant to subsector
- Low Exposure
- Medium Exposure
- High Exposure

13.2. WATER AVAILABLE FOR LIVESTOCK – 13.2.3. MID-CENTURY RCP 4.5 – 13.2.3.2. POTENTIAL IMPACT

FIGURE 344

Agriculture: Water Available for Livestock
Potential Impact: RCP4.5 Mid-Century (2046-2065)

Legend:
- Lakes
- Reservoirs
- Rivers
- Intermittent rivers
- Major cities
- Area not relevant to subsector
- Low Potential Impact
- Medium Potential Impact
- High Potential Impact
13.2. WATER AVAILABLE FOR LIVESTOCK – 13.2.3. MID-CENTURY RCP 4.5 – 13.2.3.3. VULNERABILITY

FIGURE 345

AGRICULTURE: WATER AVAILABLE FOR LIVESTOCK
VULNERABILITY: RCP4.5 MID-CENTURY (2046-2065)

Legend
- Major cities
- Areas not relevant to subsector
- Rivers
- Intermittent rivers
- Lakes
- Reservoirs

High Vulnerability
Low Vulnerability
13.2. WATER AVAILABLE FOR LIVESTOCK – 13.2.4. MID-CENTURY RCP 8.5 – 13.2.4.1. EXPOSURE

FIGURE 346

13.2. WATER AVAILABLE FOR LIVESTOCK – 13.2.4. MID-CENTURY RCP 8.5 – 13.2.4.2. POTENTIAL IMPACT

FIGURE 347
13.2. WATER AVAILABLE FOR LIVESTOCK – 13.2.4. MID-CENTURY RCP 8.5 – 13.2.4.3. VULNERABILITY

FIGURE 348
13.2. WATER AVAILABLE FOR LIVESTOCK – 13.2.5. END-CENTURY RCP 4.5 – 13.2.5.1. EXPOSURE

FIGURE 349

13.2. WATER AVAILABLE FOR LIVESTOCK – 13.2.5. END-CENTURY RCP 4.5 – 13.2.5.2. POTENTIAL IMPACT

FIGURE 350
13.2. WATER AVAILABLE FOR LIVESTOCK – 13.2.5. END-CENTURY RCP 4.5 – 13.2.5.3. VULNERABILITY

FIGURE 351

Legend
- Lakes
- Reservoirs
- Intermittent rivers
- Major cities
- Area not relevant to subsector

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13.2. WATER AVAILABLE FOR LIVESTOCK – 13.2.6. END-CENTURY RCP 8.5 – 13.2.6.1. EXPOSURE

FIGURE 352

13.2. WATER AVAILABLE FOR LIVESTOCK – 13.2.6. END-CENTURY RCP 8.5 – 13.2.6.2. POTENTIAL IMPACT

FIGURE 353
13.2. WATER AVAILABLE FOR LIVESTOCK – 13.2.6. END-CENTURY RCP 8.5 – 13.2.6.3. VULNERABILITY

FIGURE 354

[Map showing water availability for livestock in the Middle East and North Africa region under RCP 8.5, with color coding indicating vulnerability levels.]
13.3. AGRICULTURE SECTOR: VULNERABILITY – 13.3.1. REFERENCE PERIOD
13.3. AGRICULTURE SECTOR: VULNERABILITY – MID-CENTURY RCP 4.5

**FIGURE 356**

AGRICULTURE SECTOR

VULNERABILITY: RCP4.5 MID-CENTURY (2046-2065)

Legend

- Lakes
- Reservoirs
- Intermittent rivers
- Major cities
- Area not relevant to sector

Low Vulnerability to High Vulnerability
13.3. AGRICULTURE SECTOR: VULNERABILITY – 13.3.3. MID-CENTURY RCP 8.5
13.3. AGRICULTURE SECTOR: VULNERABILITY – 13.3.4. END-CENTURY RCP 4.5

FIGURE 358
13.3. AGRICULTURE SECTOR: VULNERABILITY – 13.3.5. END-CENTURY RCP 8.5

FIGURE 359

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

Legend
- Lakes
- Reservoirs
- Intermittent rivers
- Major cities
- Area not relevant to sector

Low Vulnerability
High Vulnerability

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CHAPTER 14

INFRASTRUCTURE AND HUMAN SETTLEMENTS SECTOR
FIGURE 360

EXPOSURE (0.50)
- RHM
  - Change in runoff (0.34)*

EXTREME EVENTS INDICES
- Change in annual count of 10 mm precipitation days (0.33)*
- Change in annual count of 20 mm precipitation days (0.33)*

SENSITIVITY (0.50)
- POPULATION (0.25)
  - Population density (0.21)
  - Share of agricultural labor force (0.14)
  - Share of children and elderly of the population (0.14)
  - Share of agriculture in GDP (0.15)
  - Refugee population (0.18)
  - Migrant population (0.18)

- NATURAL (0.25)
  - Land use - land cover (0.23)*
  - Soil erodibility (0.21)
  - Degradation of vegetation cover (0.22)
  - Livestock density (0.15)
  - Wetlands areas (0.19)*

- MANMADE (0.50)
  - Flood-prone areas (0.50)
  - Urban extent (0.15)
  - Road network (0.13)
  - Areas under cultural heritage protection (0.11)
  - Wastewater treatment (0.11)

ADAPTIVE CAPACITY (0.50)
- KNOWLEDGE & AWARENESS (0.10)
  - E-Government development (0.38)
  - Tertiary enrollment (0.31)
  - Adult literacy rate (0.31)

- TECHNOLOGY (0.10)
  - Number of scientific and technical journal articles (0.39)
  - Information and communication technologies index (0.61)

- INSTITUTIONS (0.10)
  - Governance index (0.34)
  - Areas under nature protection (0.31)
  - Disaster risk reduction committees (0.35)

- INFRASTRUCTURE (0.12)
  - WATER & SANITATION (0.32)
    - Areas served by dams (1.0)

- ENVIRONMENT (0.32)
  - Environment performance index (1.0)

- TRANSPORT (0.36)
  - Density of road network (1.0)

- ECONOMIC RESOURCES (0.50)
  - GDP per capita (0.50)
  - ODA (0.50)

- EQUITY (0.07)
  - Female to male literacy ratio (0.34)
  - Years lost due to disability (0.29)
  - Migrants/refugees index (0.37)

* Subsector specific classification
14.1. INLAND FLOODING AREA – 14.1.2. REFERENCE PERIOD – 14.1.2.1. EXPOSURE

FIGURE 361

14.1. INLAND FLOODING AREA – 14.1.2. REFERENCE PERIOD – 14.1.2.2. SENSITIVITY

FIGURE 362
14.1. INLAND FLOODING AREA – 14.1.2. REFERENCE PERIOD – 14.1.1.3. POTENTIAL IMPACT

**FIGURE 363**

![Map of Inland Flooding Area: Reference Period - Potential Impact](image)

Legend:
- Lakes
- Reservoirs
- Intermittent rivers
- Major cities
- Area not relevant to subsector
- Low Potential Impact
- High Potential Impact

14.1. INLAND FLOODING AREA – 14.1.2. REFERENCE PERIOD – 14.1.1.4. ADAPTIVE CAPACITY

**FIGURE 364**

![Map of Inland Flooding Area: Reference Period - Adaptive Capacity](image)

Legend:
- Lakes
- Reservoirs
- Intermittent rivers
- Major cities
- Area not relevant to subsector
- Low Adaptive Capacity
- High Adaptive Capacity
14.1. INLAND FLOODING AREA – 14.1.2. REFERENCE PERIOD – 14.1.1.5. VULNERABILITY
14.1. INLAND FLOODING AREA – 14.1.3. MID-CENTURY RCP 4.5 – 14.1.3.1. EXPOSURE

**FIGURE 366**

14.1. INLAND FLOODING AREA – 14.1.3. MID-CENTURY RCP 4.5 – 14.1.3.2. POTENTIAL IMPACT

**FIGURE 367**
14.1. INLAND FLOODING AREA – 14.1.3. MID-CENTURY RCP 4.5 – 14.1.3.3. VULNERABILITY

FIGURE 368

INFRASTRUCTURE AND HUMAN SETTLEMENTS: INLAND FLOODING AREA

VULNERABILITY: RCP4.5 MID-CENTURY (2045-2065)

Legend

- Major cities
- Areas not relevant to subsector

Legend

- Rivers
- Intermittent rivers

Legend

- Lakes
- Reservoirs

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ARAB CLIMATE CHANGE ASSESSMENT REPORT - TECHNICAL ANNEX
14.1. INLAND FLOODING AREA – 14.1.4. MID-CENTURY RCP 8.5 – 14.1.4.1. EXPOSURE

FIGURE 369

14.1. INLAND FLOODING AREA – 14.1.4. MID-CENTURY RCP 8.5 – 14.1.4.2. POTENTIAL IMPACT

FIGURE 370
14.1. INLAND FLOODING AREA - 14.1.4. MID-CENTURY RCP 8.5 - 14.1.4.3. VULNERABILITY

**FIGURE 371**

**INFRASRTUCTURE AND HUMAN SETTLEMENTS: INLAND FLOODING AREA**

**VULNERABILITY:** RCP8.5 MID-CENTURY (2045-2065)

<table>
<thead>
<tr>
<th>Legend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lakes</td>
</tr>
<tr>
<td>Reservoirs</td>
</tr>
<tr>
<td>Rivers</td>
</tr>
<tr>
<td>Intermittent rivers</td>
</tr>
<tr>
<td>Major cities</td>
</tr>
<tr>
<td>Area not relevant to subsector</td>
</tr>
</tbody>
</table>

- Low Vulnerability
- High Vulnerability
14.1. INLAND FLOODING AREA – 14.1.5. END-CENTURY RCP 4.5 – 14.1.5.1. EXPOSURE

**FIGURE 372**

INFRASTRUCRURE AND HUMAN SETTLEMENTS: INLAND FLOODING AREA

**EXPOSURE:** RCP4.5 END-CENTURY (2081-2100)

**Legend**
- Lakes
- Reservoirs
- Rivers
- Intermittent rivers
- Major cities
- Area not relevant to subsector
- Low Exposure
- High Exposure

**FIGURE 373**

INFRASTRUCRURE AND HUMAN SETTLEMENTS: INLAND FLOODING AREA

**POTENTIAL IMPACT:** RCP4.5 END-CENTURY (2081-2100)

**Legend**
- Lakes
- Reservoirs
- Rivers
- Intermittent rivers
- Major cities
- Area not relevant to subsector
- Low Potential Impact
- High Potential Impact
14.1 INLAND FLOODING AREA – 14.1.5. END-CENTURY RCP 4.5 – 14.1.5.3. VULNERABILITY

FIGURE 374

INFRASTRUCUTRE AND HUMAN SETTLEMENTS: INLAND FLOODING AREA

VULNERABILITY: RCP4.5 END-CENTURY (2081-2100)

Legend
- Lakes
- Reservoirs
- Intermittent rivers
- Major cities
- Area not relevant to subsector

Low Vulnerability
High Vulnerability

FIGURE 375

14.1. INLAND FLOODING AREA – 14.1.6. END-CENTURY RCP 8.5 – 14.1.6.2. POTENTIAL IMPACT

FIGURE 376
14.1. INLAND FLOODING AREA – 14.1.6. END-CENTURY RCP 8.5 – 14.1.6.3. VULNERABILITY
CHAPTER 15

PEOPLE SECTOR
15.1. WATER AVAILABLE FOR DRINKING – 15.1.1. IMPACT CHAIN

**TECHNOLOGY (0.11)**
- Number of scientific and technical journal articles (0.43)
- Information and communication technologies index (0.57)

**INSTITUTIONS (0.10)**
- Governance index (0.40)
- Disaster risk reduction committees (0.33)

**KNOWLEDGE & AWARENESS (0.10)**
- E-Government development (0.37)
- Tertiary enrollment (0.31)
- Adult literacy rate (0.32)

**INFRASTRUCTURE (0.50)**
- WATER & SANITATION (0.50)
  - Areas served by dams (0.20)
  - Installed desalination capacity per capita (0.20)
  - Fossil groundwater (0.20)
  - Access to improved water (0.20)
  - Access to improved sanitation (0.20)

**ENVIRONMENT (0.14)**
- Environment performance index (1.0)

**HEALTH (0.11)**
- Health index (1.0)

**ENERGY (0.14)**
- Access to electricity (0.50)
- Energy consumption (0.50)

**TRANSPORT (0.12)**
- Density of road network (1.0)

**ECONOMIC RESOURCES (0.11)**
- GDP per capita (0.28)
- Age dependency ratio (0.22)
- Food imports as % of merchandise exports (0.25)

**EQUITY (0.08)**
- Female-to-male literacy ratio (0.24)
- Years lost due to disability (0.21)
- Migrants/refugees index (0.36)

**POPULATION (0.50)**
- Population density (0.09)
- Share of children and elderly of the population (0.11)
- Total renewable water available per capita (0.50)
- Water consumption per capita (0.10)
- Share of water consumption in agriculture (0.08)
- Refugee population (0.08)

**NATURAL (0.26)**
- Livestock density (1.0)

**MANMADE (0.24)**
- Irrigated areas (0.48)
- Urban extent (0.52)

**ADAPTIVE CAPACITY (0.50)**

**SENSITIVITY (0.50)**

**EXPOSURE (0.50)**

**POTENTIAL IMPACT (0.50)**

**VULNERABILITY ASSESSMENT (0.50)**
15.1. WATER AVAILABLE FOR DRINKING – 15.1.2. REFERENCE PERIOD – 15.1.2.1. EXPOSURE

**FIGURE 379**

15.1. WATER AVAILABLE FOR DRINKING – 15.1.2. REFERENCE PERIOD – 15.1.2.2. SENSITIVITY

**FIGURE 380**
15.1. WATER AVAILABLE FOR DRINKING – 15.1.2. REFERENCE PERIOD – 15.1.2.3. POTENTIAL IMPACT

FIGURE 381

15.1. WATER AVAILABLE FOR DRINKING – 15.1.2. REFERENCE PERIOD – 15.1.2.4. ADAPTIVE CAPACITY

FIGURE 382
15.1. WATER AVAILABLE FOR DRINKING – 15.1.2. REFERENCE PERIOD – 15.1.2.5. VULNERABILITY
15.1. WATER AVAILABLE FOR DRINKING – 15.1.3. MID-CENTURY RCP 4.5 – 15.1.3.1. EXPOSURE

FIGURE 384

PEOPLE: WATER AVAILABLE FOR DRINKING
EXPOSURE: RCP4.5 MID-CENTURY (2046-2065)

Legend

![Legend Image]

15.1. WATER AVAILABLE FOR DRINKING – 15.1.3. MID-CENTURY RCP 4.5 – 15.1.3.2. POTENTIAL IMPACT

FIGURE 385

PEOPLE: WATER AVAILABLE FOR DRINKING
POTENTIAL IMPACT: RCP4.5 MID-CENTURY (2046-2065)

Legend

![Legend Image]
15.1. WATER AVAILABLE FOR DRINKING – 15.1.3. MID-CENTURY RCP 4.5 – 15.1.3.3. VULNERABILITY
15.1. WATER AVAILABLE FOR DRINKING – 15.1.4. MID-CENTURY RCP 8.5 – 15.1.4.1. EXPOSURE

**FIGURE 387**

15.1. WATER AVAILABLE FOR DRINKING – 15.1.4. MID-CENTURY RCP 8.5 – 15.1.4.2. POTENTIAL IMPACT

**FIGURE 388**
15.1. WATER AVAILABLE FOR DRINKING – 15.1.4. MID-CENTURY RCP 8.5 – 15.1.4.3. VULNERABILITY
15.1. WATER AVAILABLE FOR DRINKING – 15.1.5. END-CENTURY RCP 4.5 – 15.1.5.1. EXPOSURE

FIGURE 390

15.1. WATER AVAILABLE FOR DRINKING – 15.1.5. END-CENTURY RCP 4.5 – 15.1.5.2. POTENTIAL IMPACT

FIGURE 391
15.1. WATER AVAILABLE FOR DRINKING – 15.1.5. END-CENTURY RCP 4.5 – 15.1.5.3. VULNERABILITY
15.1. WATER AVAILABLE FOR DRINKING – 15.1.6. END-CENTURY RCP 8.5 – 15.1.6.1. EXPOSURE

FIGURE 393

15.1. WATER AVAILABLE FOR DRINKING – 15.1.6. END-CENTURY RCP 8.5 – 15.1.6.2. POTENTIAL IMPACT

FIGURE 394
15.1. WATER AVAILABLE FOR DRINKING – 15.1.6. END-CENTURY RCP 8.5 – 15.1.6.3. VULNERABILITY
15.2. HEALTH CONDITIONS DUE TO HEAT STRESS – IMPACT CHAIN

**EXPOSURE (0.50)**

- RCM
  - Change in temperature (0.34)

**EXTREME EVENTS INDICES**

- Change in number of hot days (0.33)
- Change in number of very hot days (0.33)

**SENSITIVITY (0.50)**

- POPULATION (0.50)
  - Population density (0.50)
  - Share of agriculture labor force in total labor force (0.38)
  - Share of children and elderly of the population (0.29)
  - Water consumption per capita (0.12)
  - Refugee population (0.11)
  - Migrant population (0.11)

- NATURAL (0.25)
  - Change in forest cover (1.0)

- MANMADE (0.25)
  - Urban extent (1.0)

**ADAPTIVE CAPACITY (0.50)**

- KNOWLEDGE & AWARENESS (0.10)
  - E-Government development (0.38)
  - Tertiary enrolment (0.32)
  - Adult literacy rate (0.30)

- TECHNOLOGY (0.10)
  - Number of scientific and technical journal articles (0.41)
  - Information and communication technologies index (0.59)

- INSTITUTIONS (0.10)
  - Governance index (0.54)
  - Disaster risk reduction committees (0.46)

- INFRASTRUCTURE (0.50)
  - WATER & SANITATION (0.13)
    - Areas served by dams (0.17)
    - Installed desalination capacity per capita (0.17)
    - Fossil groundwater (0.17)
    - Access to improved water (0.17)
    - Access to improved sanitation (0.16)
    - Area equipped for irrigation (0.16)
  - ENVIRONMENT (0.12)
    - Environment performance index (1.0)

- ECONOMIC RESOURCES (0.11)
  - GDP per capita (0.37)
  - Age dependency ratio (0.31)
  - ODA (0.32)

- EQUITY (0.09)
  - Female-to-male unemployment rate (0.20)
  - Female-to-male literacy ratio (0.24)
  - Years lost due to disability (0.24)
  - Migrants/refugees index (0.32)

**VULNERABILITY ASSESSMENT**

**CHANGE IN HEALTH CONDITIONS DUE TO HEAT STRESS – IMPACT CHAIN**

- Technology (0.10)
- Number of scientific and technical journal articles (0.41)
- Information and communication technologies index (0.59)
- Populations (0.50)
- Population density (0.50)
- Share of agriculture labor force in total labor force (0.38)
- Share of children and elderly of the population (0.29)
- Water consumption per capita (0.12)
- Refugee population (0.11)
- Migrant population (0.11)
- Natural (0.25)
- Change in forest cover (1.0)
- Manmade (0.25)
- Urban extent (1.0)

**POTENTIAL IMPACT (0.50)**

**15.2.1. IMPACT CHAIN**

- Change in temperature (0.34)
- Change in number of hot days (0.33)
- Change in number of very hot days (0.33)
15.2. HEALTH CONDITIONS DUE TO HEAT STRESS – 15.2.2. REFERENCE PERIOD – 15.2.2.1. EXPOSURE

FIGURE 397

15.2. HEALTH CONDITIONS DUE TO HEAT STRESS – 15.2.2. REFERENCE PERIOD – 15.2.2.2. SENSITIVITY

FIGURE 398
15.2. HEALTH CONDITIONS DUE TO HEAT STRESS – 15.2.2. REFERENCE PERIOD – 15.2.2.3. POTENTIAL IMPACT

FIGURE 399

15.2. HEALTH CONDITIONS DUE TO HEAT STRESS – 15.2.2. REFERENCE PERIOD – 15.2.2.4. ADAPTIVE CAPACITY

FIGURE 400
15.2. HEALTH CONDITIONS DUE TO HEAT STRESS – 15.2.2. REFERENCE PERIOD – 15.2.2.5. VULNERABILITY
15.2. HEALTH CONDITIONS DUE TO HEAT STRESS – 15.2.3. MID-CENTURY RCP 4.5 – 15.2.3.1. EXPOSURE

FIGURE 402

PEOPLE: HEALTH CONDITIONS DUE TO HEAT STRESS
EXPOSURE: RCP4.5 MID-CENTURY (2046-2055)

Legend
- Lakes
- Reservoirs
- Rivers
- Intermittent rivers
- Major cities
- Area not relevant to subsector
- Low Exposure
- High Exposure

15.2. HEALTH CONDITIONS DUE TO HEAT STRESS – 15.2.3. MID-CENTURY RCP 4.5 – 15.2.3.2. POTENTIAL IMPACT

FIGURE 403

PEOPLE: HEALTH CONDITIONS DUE TO HEAT STRESS
POTENTIAL IMPACT: RCP4.5 MID-CENTURY (2046-2055)

Legend
- Lakes
- Reservoirs
- Rivers
- Intermittent rivers
- Major cities
- Area not relevant to subsector
- Low Potential Impact
- High Potential Impact
15.2. HEALTH CONDITIONS DUE TO HEAT STRESS – 15.2.3. MID-CENTURY RCP 4.5 – 15.2.3.3. VULNERABILITY
15.2. HEALTH CONDITIONS DUE TO HEAT STRESS – 15.2.4. MID-CENTURY RCP 8.5 – 15.2.4.1. EXPOSURE

**FIGURE 405**

15.2. HEALTH CONDITIONS DUE TO HEAT STRESS – 15.2.4. MID-CENTURY RCP 8.5 – 15.2.4.2. POTENTIAL IMPACT

**FIGURE 406**
15.2. HEALTH CONDITIONS DUE TO HEAT STRESS – 15.2.4. MID-CENTURY RCP 8.5 – 15.2.4.3. VULNERABILITY
15.2. HEALTH CONDITIONS DUE TO HEAT STRESS – 15.2.5. END-CENTURY RCP 4.5

15.2.5.1. EXPOSURE

FIGURE 408

PEOPLE: HEALTH CONDITIONS DUE TO HEAT STRESS
EXPOSURE: RCP4.5 END-CENTURY (2081-2100)

Legend
- Lakes
- Reservoirs
- Major cities
- Area not relevant to subsector

Low Exposure
High Exposure

15.2.5.2. POTENTIAL IMPACT

FIGURE 409

PEOPLE: HEALTH CONDITIONS DUE TO HEAT STRESS
POTENTIAL IMPACT: RCP4.5 END-CENTURY (2081-2100)

Legend
- Lakes
- Reservoirs
- Major cities
- Area not relevant to subsector

Low Potential Impact
High Potential Impact
15.2. HEALTH CONDITIONS DUE TO HEAT STRESS – 15.2.5. END-CENTURY RCP 4.5 – 15.2.5.3. VULNERABILITY

FIGURE 410

PEOPLE: HEALTH CONDITIONS DUE TO HEAT STRESS
VULNERABILITY: RCP4.5 END-CENTURY (2081-2100)

Legend
- Lakes
- Reservoirs
- Intermittent rivers
- Major cities
- Area not relevant to subsector

Low Vulnerability
High Vulnerability
15.2. HEALTH CONDITIONS DUE TO HEAT STRESS – 15.2.6. END-CENTURY RCP 8.5 – 15.2.6.1. EXPOSURE

FIGURE 411

PEOPLE: HEALTH CONDITIONS DUE TO HEAT STRESS
EXPOSURE: RCP8.5 END-CENTURY (2081-2100)

Legend

- Lakes
- Reservoirs
- Intermittent rivers
- Major cities
- Area not relevant to subsector
- Low Exposure
- High Exposure

15.2. HEALTH CONDITIONS DUE TO HEAT STRESS – 15.2.6. END-CENTURY RCP 8.5 – 15.2.6.2. POTENTIAL IMPACT

FIGURE 412

PEOPLE: HEALTH CONDITIONS DUE TO HEAT STRESS
POTENTIAL IMPACT: RCP8.5 END-CENTURY (2081-2100)

Legend

- Lakes
- Reservoirs
- Intermittent rivers
- Major cities
- Area not relevant to subsector
- Low Potential Impact
- High Potential Impact
15.2. HEALTH CONDITIONS DUE TO HEAT STRESS – 15.2.6. END-CENTURY RCP 8.5 – 15.2.6.3. VULNERABILITY

FIGURE 413
15.3. EMPLOYMENT RATE FOR THE AGRICULTURAL SECTOR – 15.3.1. IMPACT CHAIN

- **Population density (0.10)**
  - Share of agricultural labor force in total labor force (0.06)
  - Share of agriculture in GDP (0.05)
  - Refuge population (0.06)
  - Migrant population (0.06)

- **Economic resources (0.11)**
  - GDP per capita (0.36)
  - ODA (0.29)
  - Food imports as % of merchandise exports (0.35)

- **Knowledge & awareness (0.10)**
  - E-Government development (0.34)
  - Tertiary enrollment (0.33)
  - Adult literacy rate (0.33)

- **Water & sanitation (0.50)**
  - Areas served by dams (0.17)
  - Installed desalination capacity per capita (0.17)
  - Fossil groundwater (0.17)
  - Access to improved water (0.17)
  - Access to improved sanitation (0.16)
  - Area equipped for irrigation (0.16)

- **Environment (0.16)**
  - Environment performance index (1.0)

- **Energy (0.16)**
  - Access to electricity (0.50)
  - Energy consumption (0.50)

- **Transport (0.16)**
  - Density of road network (1.0)

- **Adaptive capacity (0.50)**
  - Irrigated crop area (0.17)

- **Vulnerability assessment**

**Sensitivity (0.50)**

- **Technology (0.10)**
  - Number of scientific and technical journal articles (0.42)
  - Information and communication technologies index (0.58)

- **Economy (0.11)**
  - GDP per capita (0.36)
  - ODA (0.29)
  - Food imports as % of merchandise exports (0.35)

- **Equity (0.08)**
  - Female-to-male unemployment rate (0.32)
  - Female-to-male literacy ratio (0.31)
  - Migrants/refugees index (0.37)

**Potential impact (0.50)**

- **Exposure (0.50)**
  - Change in evapotranspiration (0.17)

- **RIM**
  - Change in maximum length of dry spell (0.16)
  - Change in annual count of 10 mm precipitation days (0.16)
  - Change in annual count of 20 mm precipitation days (0.16)

- **RCM**
  - Change in temperature (0.17)
  - Change in precipitation (0.17)

**Adaptation capacity (0.50)**

- **Change in employment rate for the agricultural sector – 15.3.1. Impact Chain**

- **Change in evapotranspiration (0.17)**

- **Extreme events indices**
  - Change in maximum length of dry spell (0.16)
  - Change in annual count of 10 mm precipitation days (0.16)
  - Change in annual count of 20 mm precipitation days (0.16)
15.3. EMPLOYMENT RATE FOR THE AGRICULTURAL SECTOR – 15.3.2. REFERENCE PERIOD – 15.3.2.1. EXPOSURE

**FIGURE 415**

![Map showing Employment Rate for the Agricultural Sector - Exposure](image)

**Legend**
- Lakes
- Reservoirs
- Intermittent rivers
- Major cities
- Area not relevant to subsector
- Low Exposure
- High Exposure

15.3. EMPLOYMENT RATE FOR THE AGRICULTURAL SECTOR – 15.3.2. REFERENCE PERIOD – 15.3.2.2. SENSITIVITY

**FIGURE 416**

![Map showing Employment Rate for the Agricultural Sector - Sensitivity](image)

**Legend**
- Lakes
- Reservoirs
- Intermittent rivers
- Major cities
- Area not relevant to subsector
- Low Sensitivity
- High Sensitivity
15.3. EMPLOYMENT RATE FOR THE AGRICULTURAL SECTOR – 15.3.2. REFERENCE PERIOD – 15.3.2.3. POTENTIAL IMPACT

FIGURE 417

15.3. EMPLOYMENT RATE FOR THE AGRICULTURAL SECTOR – 15.3.2. REFERENCE PERIOD – 15.3.2.4. ADAPTIVE CAPACITY

FIGURE 418
15.3. EMPLOYMENT RATE FOR THE AGRICULTURAL SECTOR – 15.3.2. REFERENCE PERIOD – 15.3.2.5. VULNERABILITY

FIGURE 419
15.3. EMPLOYMENT RATE FOR THE AGRICULTURAL SECTOR – 15.3.3. MID-CENTURY RCP 4.5 – 15.3.3.1. EXPOSURE

FIGURE 420

PEOPLE: EMPLOYMENT RATE FOR THE AGRICULTURAL SECTOR
EXPOSURE: RCP4.5 MID-CENTURY (2046-2095)

Legend
- Lakes
- Reservoirs
- Intermittent rivers
- Major cities
- Area not relevant to subsector

FIGURE 421

PEOPLE: EMPLOYMENT RATE FOR THE AGRICULTURAL SECTOR
POTENTIAL IMPACT: RCP4.5 MID-CENTURY (2046-2095)

Legend
- Lakes
- Reservoirs
- Intermittent rivers
- Major cities
- Area not relevant to subsector
15.3. EMPLOYMENT RATE FOR THE AGRICULTURAL SECTOR – 15.3.3. MID-CENTURY RCP 4.5 – 15.3.3.3. VULNERABILITY
15.3. EMPLOYMENT RATE FOR THE AGRICULTURAL SECTOR – 15.3.4. MID-CENTURY RCP 8.5 – 15.3.4.1. EXPOSURE

FIGURE 423

15.3. EMPLOYMENT RATE FOR THE AGRICULTURAL SECTOR – 15.3.4. MID-CENTURY RCP 8.5 – 15.3.4.2. POTENTIAL IMPACT

FIGURE 424
15.3. EMPLOYMENT RATE FOR THE AGRICULTURAL SECTOR – 15.3.4. MID-CENTURY RCP 8.5 – 15.3.4.3. VULNERABILITY
15.3. EMPLOYMENT RATE FOR THE AGRICULTURAL SECTOR – 15.3.5. END-CENTURY RCP 4.5 – 15.3.5.1. EXPOSURE

FIGURE 426

15.3. EMPLOYMENT RATE FOR THE AGRICULTURAL SECTOR – 15.3.5. END-CENTURY RCP 4.5 – 15.3.5.2. POTENTIAL IMPACT

FIGURE 427
15.3. EMPLOYMENT RATE FOR THE AGRICULTURAL SECTOR – 15.3.5. END-CENTURY RCP 4.5 – 15.3.5.3. VULNERABILITY

FIGURE 428

PEOPLE: EMPLOYMENT RATE FOR THE AGRICULTURAL SECTOR
VULNERABILITY: RCP4.5 END-CENTURY (2081-2100)

Legend
- Lakes
- Reservoirs
- Intermittent rivers
- Major cities
- Area not relevant to subsector

Low Vulnerability
High Vulnerability

RICCAR
Regional Centre for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region
15.3. EMPLOYMENT RATE FOR THE AGRICULTURAL SECTOR – 15.3.6. END-CENTURY RCP 8.5 – 15.3.6.1. EXPOSURE

FIGURE 429

15.3. EMPLOYMENT RATE FOR THE AGRICULTURAL SECTOR – 15.3.6. END-CENTURY RCP 8.5 – 15.3.6.2. POTENTIAL IMPACT

FIGURE 430
15.3. EMPLOYMENT RATE FOR THE AGRICULTURAL SECTOR – 15.3.6. END-CENTURY RCP 8.5 – 15.3.6.3. VULNERABILITY

FIGURE 431

PEOPLE EMPLOYMENT RATE FOR THE AGRICULTURAL SECTOR
VULNERABILITY: RCP 8.5 END-CENTURY (2081-2100)

Legend

- Major cities
- Areas not relevant to subsector
- Rivers
- Intermittent rivers
- Lakes
- Reservoirs

Low Vulnerability
High Vulnerability
15.4. PEOPLE SECTOR: VULNERABILITY – 15.4.1. REFERENCE PERIOD

FIGURE 432
15.4. PEOPLE SECTOR: VULNERABILITY – 15.4.2. MID-CENTURY RCP 4.5

FIGURE 433
15.4. PEOPLE SECTOR: VULNERABILITY – 15.4.3. MID-CENTURY RCP 8.5

FIGURE 434

PEOPLE SECTOR
VULNERABILITY: RCP8.5 MID-CENTURY (2046-2065)

Legend
- Lakes
- Reservoirs
- Intermittent rivers
- Major cities
- Area not relevant to sector

Low Vulnerability
High Vulnerability
15.4. PEOPLE SECTOR: VULNERABILITY – RCP 4.5 END-CENTURY (2081-2100)
15.4. PEOPLE SECTOR: VULNERABILITY – END-CENTURY RCP 8.5