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

Regional projections: How climate change affects transboundary water resources – RICCAR Highlights

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Chief, Water Resources Section
Climate Change and Natural Resource Sustainability Cluster
UN Economic and Social Commission for Western Asia (ESCWA)

Regional workshop on Enhancing transboundary water cooperation in the MENA region - progress, challenges and opportunities
Beirut, 3-4 March 2020
Intergovernmental Mandates calling for & supporting Climate Change Assessment in the Arab Region

Arab Ministerial Declaration on Climate Change
CAMRE 2007

Arab Economic and Social Summit
Resolution on Climate Change & Water Project
2009

ESCWA Ministerial Session
Resolutions on Climate Change

Arab Permanent Committee for Meteorology

Arab Ministerial Water Council
Resolutions

ACSAD Board of Directors
Resolution 2013

APCM is under new Arab Ministerial Council for Meteorology & Climate

Environment
Foreign Affairs & Planning
Water
Meteorology
Agriculture
Objective: To assess the impact of climate change on freshwater resources in the Arab Region through a consultative regional initiative that scientifically identifies the socio-economic and environmental vulnerability caused by climate change impacts on water resources based on regional specificities.

Purpose: To provide a common platform for assessing, addressing and informing response to climate change impacts on freshwater resources in the Arab region by serving as the basis for dialogue, priority setting and policy formulation on climate change at the regional level.
RICCAR Partnerships
Pillars of Work

REGIONAL KNOWLEDGE HUB

INTEGRATED ASSESSMENT
- Climate Change Impact Assessment
- Climate Change Vulnerability Assessment

CAPACITY BUILDING & INSTITUTIONAL STRENGTHENING

AWARENESS RAISING & INFORMATION DISSEMINATION
Integrated Assessment

GCM: Global Climate Modelling
RCM: Regional Climate Modelling
RHM: Regional Hydrological Modeling

VA: Vulnerability Assessment
IM: Integrated Mapping

Representative Concentration Pathway (RCP)

Impact Assessment

The Arab Region

Vulnerability Assessment
Computing Climate Variables

Vertical level

Atmosphere

Ocean

Heat

T+

T

T−

Sea ice

Oceans

Land

Atmosphere

REF: http://stratus.astr.ucl.ac.be/textbook/chapter3_node8.html
Essential Climate Variables (ECV) datasets provide the empirical evidence needed to understand and predict the evolution of climate.

### Atmosphere
- **Surface**
  - Precipitation
  - Pressure
  - Radiation budget
  - Temperature
  - Water vapour
  - Wind speed and direction
- **Upper-air**
  - Earth radiation budget
  - Lightning
  - Temperature
  - Water vapor
  - Wind speed and direction
- **Atmospheric Composition**
  - Aerosols
  - Carbon dioxide, methane and other greenhouse gases
  - Clouds
  - Ozone
  - Precursors for aerosols and ozone

### Land
- **Hydrosphere**
  - Groundwater
  - Lakes
  - River discharge
- **Cryosphere**
  - Glaciers
  - Ice sheets and ice shelves
  - Permafrost
  - Snow
- **Biosphere**
  - Above-ground biomass
  - Albedo
  - Evaporation from land
  - Fire
  - Fraction of absorbed photosynthetically active radiation (FAPAR)
  - Land cover
  - Land surface temperature
  - Leaf area index
  - Soil carbon
  - Soil moisture

### Ocean
- **Physical**
  - Ocean surface heat flux
  - Sea ice
  - Sea level
  - Sea state
  - Sea surface currents
  - Sea surface salinity
  - Sea surface stress
  - Sea surface temperature
  - Subsurface currents
  - Subsurface salinity
  - Subsurface temperature
- **Biogeochemical**
  - Inorganic carbon
  - Nitrous oxide
  - Nutrients
  - Ocean colour
  - Oxygen
  - Transient tracers
- **Biological/ecosystems**
  - Marine habitats
  - Plankton

### Anthroposphere
- Anthropogenic Greenhouse gas fluxes
- Anthropogenic water use

**RICCAR RCMs are land-based models and do not generate Oceanic Variables**

Computing Climate Variables:
Scale Improving Over Time

Source: IPCC, 2007; Met Office, 2011
Spatial boundaries of the geographical regions used in the IPCC 5th Assessment Report (AR5) (2014)

http://www.ipcc-data.org/guidelines/pages/ar5_regions.html
CORDEX-MENA Working Group

- Preliminary RCM Ensemble Meeting (Brussels, 2013)
- First CORDEX MENA-CA Meeting (Nicosia, November 2014)
- Organized by CORDEX (WMO) with SMHI & Hosted by The Cyprus Institute.

Attending or Interested Centers:

- King Abdulaziz University (KAU) - KSA
- King Abdullah University of Science and Technology (KAUST) - KSA
- Istanbul Technical University (Turkey)
- Bogazici University (Turkey)
- Cairo University
- Jet Propulsion Laboratory (USA)
- Max Plank Institute for Chemistry (Germany)
- Italian Aerospace Research Center (CIRA)
- Qatar Meteorology Department
- SMHI
- ACSAD
- Maroc Meteo
- The Cyprus Institute
- WMO
- ESCWA

CORDEX is the Coordinated Regional Climate Downscaling Experiment of the World Climate Research Program.
Boundary conditions explicitly framed to capture the climate change dynamics affecting the headwaters of the Tigris, Euphrates and Nile Basins.
MENA/Arab Domain
Regional Climate Modeling
Projections available at 50x50 km & 25x25 km

Mashreq Domain
being generated at 10 x 10 km

Usable data is area within the red boundary
Representative Concentration Pathways (RCPs)
Scenarios used in IPCC AR5

Graph adapted from: Meinshausen et al., 2010
Regional Climate Modeling & Hydrological Modeling under RICCAR

Different GCMs

At least 3 projections for the same scenario to generate an Ensemble

GCM ensembles used by IPCC

Extreme Climate Events

Ensemble Average used to reduce uncertainty at level of RCMs & RHMs

Ensembles compare findings of different RCMs & RHMs applied for same RCP & Domain
RICCAR Impact Assessment: Selected Results
Temperature in the region is increasing and is expected to continue to increase until the end of the century.
Temperature Ensembles through a Seasonal Lens

Winter
- RCP 8.5 Ensemble
- RCP 4.5 Ensemble

Summer
- RCP 8.5 Ensemble
- RCP 4.5 Ensemble

Depends on which future (which climate scenario) one plans against.
Precipitation trends are largely decreasing across the region until the end of the century, though limited areas expected to exhibit an increase in the intensity & volume of precipitation.

From RICCAR RCM ensemble outputs
## Extreme events indices

### Extreme temperature indices

<table>
<thead>
<tr>
<th>Index</th>
<th>Full name</th>
</tr>
</thead>
<tbody>
<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>Number of tropical nights</td>
</tr>
</tbody>
</table>

### Extreme precipitation indices

<table>
<thead>
<tr>
<th>Index</th>
<th>Full name</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDD</td>
<td>Maximum length of dry spell</td>
</tr>
<tr>
<td>CWD</td>
<td>Maximum length of wet spell</td>
</tr>
<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>SDII</td>
<td>Simple precipitation intensity index</td>
</tr>
</tbody>
</table>
Maximum length of dry spell (CDD)

RCP 4.5

<table>
<thead>
<tr>
<th>Number of days/year</th>
<th>1986-2005</th>
<th>2046-2065</th>
<th>2081-2100</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986-2005</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2046-2065</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2081-2100</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

RCP 8.5

<table>
<thead>
<tr>
<th>Number of days/year</th>
<th>1986-2005</th>
<th>2046-2065</th>
<th>2081-2100</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986-2005</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2046-2065</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2081-2100</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Regional Climate Modeling to Hydrological Modeling

Different GCMs

Bias Correction of RCM Projections needed before data can be used for water & agricultural modeling

Same RCP

Ensembles used to reduce uncertainty at level of RCMs & RHMs

Ensembles aggregate findings of different RCMs & RHMs applied for same RCP & Domain

50km x 50km

25km x 25km

Regional Climate Model (RCM)

Regional Hydrological Model (RHM)

VIC
HYPE
HEC-HMS
Models Used
Mean change in Annual Runoff

Comparison between 2 hydrological models based on SMHI modeling outputs:
Hydrological Predictions for the Environment (HYPE) and Variable Infiltration Capacity (VIC)

2 Models; 2 RCPs
Mean change in Annual Runoff

2 Models; 2 RCPs
Mean change in Annual Evapotranspiration
Mean change in Annual Evapotranspiration
Locations of subdomains identified for hydrological analysis

See RICCAR Main Report, Technical Annex and Regional Knowledge Hub

<table>
<thead>
<tr>
<th>Identifier</th>
<th>Subdomain Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>EH</td>
<td>Ethiopian Highlands (Blue Nile Headwaters)</td>
</tr>
<tr>
<td>TU</td>
<td>Upper Tigris (Tigris River Headwaters)</td>
</tr>
<tr>
<td>EU</td>
<td>Upper Euphrates (Euphrates River Headwaters)</td>
</tr>
<tr>
<td>MR</td>
<td>Medjorda River</td>
</tr>
<tr>
<td>JR</td>
<td>Jordan River</td>
</tr>
<tr>
<td>SR</td>
<td>Senegal River Headwaters</td>
</tr>
</tbody>
</table>
**Climate Impacts on Transboundary Water Resources: Euphrates River**

**Upper Euphrates River**

(1986-2005) : (2081-2100)

<table>
<thead>
<tr>
<th>Variable</th>
<th>RCP4.5</th>
<th>RCP8.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temp.</td>
<td>2.3°C</td>
<td>4.8°C</td>
</tr>
<tr>
<td>Precip.</td>
<td>3%</td>
<td>0%</td>
</tr>
<tr>
<td>Runoff</td>
<td>-2%</td>
<td>-12%</td>
</tr>
</tbody>
</table>
Upper Tigris River: Seasonal Temperature (RCM output)

Upper Tigris River: Extreme Climate Indicators: Consecutive Dry Days Consecutive Wet Days (RCM output)
Upper Tigris River: Monthly precipitation (mm/day) for mid-century and end-century (RHM output)

Upper Tigris River: Runoff (RHM output)
Climate Impacts on Transboundary Water Resources: Jordan River

For three-member ensemble of RCP 4.5 projections and three-member ensemble of RCP 8.5 projections for the Jordan River

New Mashreq Domain projections will generate a 6-member ensemble for RCP 8.5 and support further surface & groundwater analysis.
RICCAR Vulnerability Assessment Components

- **Exposure (0.50)**
- **Sensitivity (0.50)**
  - **Potential Impacts (0.50)**
  - **Adaptive Capacity (0.50)**

**Vulnerability**
Preparation of a Vulnerability Index:

- **Per Sector**
  - Contains all indicators identified to assess a given sector
  - Attribution of weights for each indicator dependent on impact chains and expert judgment
  - As sector level, aggregated by component: Exposure, Sensitivity, Adaptive Capacity

- **Overall Vulnerability**
  - Aggregates vulnerability of each sector to generate an Overall VA
  - Supports identification of VA Hotspots

Slide graphics: adelphi
Source of maps: ACSAD, SMHI
<table>
<thead>
<tr>
<th>SECTORS</th>
<th>SUBSECTORS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water</strong></td>
<td>Water availability</td>
</tr>
<tr>
<td><strong>Biodiversity</strong></td>
<td>Area covered by forests</td>
</tr>
<tr>
<td>and Ecosystems</td>
<td>Area covered by wetlands</td>
</tr>
<tr>
<td><strong>Agriculture</strong></td>
<td>Water available for crops</td>
</tr>
<tr>
<td></td>
<td>Water available for livestock</td>
</tr>
<tr>
<td><strong>Infrastructure</strong></td>
<td>Inland flooding area</td>
</tr>
<tr>
<td>and Human Settlements</td>
<td></td>
</tr>
<tr>
<td><strong>People</strong></td>
<td>Water available for drinking</td>
</tr>
<tr>
<td></td>
<td>Health conditions due to heat stress</td>
</tr>
<tr>
<td></td>
<td>Employment rate for the agricultural sector</td>
</tr>
</tbody>
</table>
Vulnerability Assessment Impact Chain
Water Availability

**EXPOSURE (0.50)**

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

- **RIIM**
  - 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 (0.10)

**Sensitivity (0.50)**

- **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 (0.25)**
  - Land use/land cover (0.27)
  - Soil storage capacity (0.25)
  - Degradation of vegetation cover (0.26)
  - Wetlands (0.22)

- **Man-made (0.24)**
  - Urban extent (0.47)
  - Areas served by dams (0.53)

**Potential Impact (0.50)**

- **Knowledge & Awareness (0.10)**
  - E-government development (0.33)
  - Tertiary enrollment (0.22)
  - Adult literacy rate (0.35)

- **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 (0.49)

**Infrastructure (0.50)**

- Water & Sanitation (0.56)
  - 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 (0.56)
  - Environment performance index (1.0)

**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)

**Adaptive Capacity (0.50)**

- 6 Exposure indicators
- 10 Sensitivity indicators
- 20 Adaptive Capacity indicators
WATER AVAILABILITY VULNERABILITY

End-Century RCP 4.5

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

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

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

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Low Vulnerability</th>
<th>Moderate Vulnerability</th>
<th>High Vulnerability</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCP 4.5 Mid-century</td>
<td>0%</td>
<td>57%</td>
<td>43%</td>
</tr>
<tr>
<td>RCP 8.5 Mid-century</td>
<td>0%</td>
<td>48%</td>
<td>52%</td>
</tr>
<tr>
<td>RCP 4.5 End-century</td>
<td>0%</td>
<td>52%</td>
<td>48%</td>
</tr>
<tr>
<td>RCP 8.5 End-century</td>
<td>0%</td>
<td>43%</td>
<td>57%</td>
</tr>
</tbody>
</table>
Lebanese Agricultural Sector Vulnerability Assessment

...could be replicated at a basin-level in collaboration will all riparian states
RICCAR Publication Series
Climate Change Adaptation Manual:
Five sector modules drawing on RICCAR outputs were developed by ESCWA in close cooperation with the following leading organizations:

1. **Environment** module with UNEP/ROWA;
2. **Agriculture** module with ACSAD and GIZ;
3. **Health** module with WHO;
4. **Human settlements** (on water supply/sanitation) with ACWUA;
5. **Economic Development** module by ESCWA

A joint introductory chapter by ESCWA render the 5 modules a manual. Five workshops were held with stakeholders from each sector to finalize the modules.