Water Resources Management and Hydrological Models

ACSAD Experience in the Arab region

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Expert Group Meeting on the Development of a vulnerability assessment for the Arab Region to Assess Climate change Impacts on the Water Resources Sector

UN-ESCWA - Beirut 8-10 November 2010
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V - Assessment of vulnerability of fresh water to climate change in Eastern Mediterranean region
Rainfall Distribution in The Arab Region

Legend

<table>
<thead>
<tr>
<th>area (%)</th>
<th>qty (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 100</td>
<td>52.0</td>
</tr>
<tr>
<td>100 - 200</td>
<td>22.0</td>
</tr>
<tr>
<td>200 - 300</td>
<td>8.0</td>
</tr>
<tr>
<td>300 - 500</td>
<td>7.0</td>
</tr>
<tr>
<td>500 - 800</td>
<td>5.5</td>
</tr>
<tr>
<td>More than 800</td>
<td>5.5</td>
</tr>
</tbody>
</table>

For areas and quantities calculation, Albers equal area Projection was used. Standard Parallels 7° 40' N and 38° 20' N.
I- Evidence of climate change – Syria case study

Recent Technical Paper on Climate Change and Water (IPCC Working Group II, 2008) outlines some general statements that are relevant for the Middle East region – such as, “many semi-arid and arid areas (for example, the Mediterranean basin) are particularly exposed to the impacts of climate change and are projected to suffer a decrease of water resources due to climate change (high confidence)”. Figure below shows annual precipitation departure for 30 stations.
A 52-year record (1955 - 2006) of 30 selected synoptic stations was used to assess the long term climatic variations and trends in the country.

**Precipitation seasonal and annual trends**

Generally speaking, Mann-Kendall trend test showed a coherent area of **significant change in precipitation of both winter and autumn seasons**. Winter precipitation in northern and north eastern zones of Syria showed a sign of decrease for the last five decades. On the other hand, autumn precipitation increased at the stations that lie mostly in northern zone of the central Syria.
Seasonal and Annual Precipitation Trends for the period 1955-2006

● denotes no trend  ▲ significant increase  ▲ insignificant increase
▼ significant decrease  ▼ insignificant decrease and decreases

Winter

Spring

Autumn

Annual
Surface Temperature Trends

- The result of Mann-Kendall trend analysis applied to seasonally and annual average surface air temperature series between 1955-2006 showed a widespread increase in summer temperature in all stations in the country with prominent increase in coastal and western regions. On the other hand, winter temperatures showed a general tendency of decrease in the country.
Seasonal and Annual Temperature Trends for the period 1955-2006

- ● denotes no trend
- ▲ significant increase
- ▲ insignificant increase
- ▼ significant decrease
- ▼ insignificant decrease
- ● insignificant increase and decreases

Figure 3. Mann-Kendall trend analysis applied to seasonally average annual temperature series between 1955-2006.
Climate Change Scenarios (2041-2070-2100)

Annual precipitation changes for 2010-2039 using Hadleyodel-CM3 (Syrian first national communication to UNFFCCC (2009)).

Annual temperature difference (2039-2069-2099) (Syrian first national communication to UNFFCCC (2009)).
Zabadani Sub-Basin –Syria;

The karstic spring of Barada constitutes an important resource for the drinking water supply of Damascus city.

The model developed by ACSAD and BGR of the Barada karst system was applied. The model had been calibrated according to the daily rainfall data (from 1985 to 2007) for four climatic stations.
An annual decrease in rainfall of 5.1% accompanied with the same annual pumping rate of 2007 was applied using the same pattern of rainfall of year 2006-2007. The model result shows that the continuous decrease in spring discharge is clear. The low flow period of the spring disappears gradually and the spring discharges mainly in peak time. The model expected a decrease of 37% in 2039.
Assessment of Impacts of climate change on agriculture production in Syria

- Nearly 70% of the cropped area (5,523,356 ha) in Syria depends on rainfall. Consequently, variations in the amounts and timing of rainfall can immediately cause substantial shifts in areas planted, productivity and yields in most of the major agro-ecological zones in the country.

- The expected increase in temperature and decline in rainfall will have an impact on the crop water supply-demand relationship, crop water use efficiency, reduction of the growing season and decreases in water availability. This depends by itself on the extent of changes in the form of precipitation and the timing of its events.
The two most important crops in Syria are wheat and cotton. Wheat is considered as the most important strategic crop in Syrian agriculture. It occupies 34% of the cropping area in the country with 55% of this production is coming from irrigated farming.

Furthermore wheat occupies 70% of the irrigated land that is devoted to strategic crops. The crop is of paramount importance for food security of the country because it is the main source for protein and energy.
- CROPWAT is an irrigation management model developed by FAO Land and Water Management Division used to evaluate crop water requirements and irrigation needs. The model was utilized to assess the effect of climate change on wheat (irrigated and rainfed), cotton, and olive trees water use and yield.
- The results should be used as indicatives on the effect of climate change on agricultural crops due to inherent deficiency in the model itself, the assumption that nutrients are not limiting, and the inconsideration of the effects of warming on length of growing season.
predicted median change in annual temperature and precipitation as generated from the MMD-A1B models for the 2080 to 2099 period

<table>
<thead>
<tr>
<th>Season</th>
<th>DJF</th>
<th>MAM</th>
<th>JJA</th>
<th>SON</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature response (°C)</td>
<td>2.6</td>
<td>3.2</td>
<td>4.1</td>
<td>3.3</td>
<td>3.5</td>
</tr>
<tr>
<td>Precipitation response (%)</td>
<td>-6</td>
<td>-16</td>
<td>-24</td>
<td>-12</td>
<td>-12</td>
</tr>
</tbody>
</table>
Impact of climate change on irrigated wheat

<table>
<thead>
<tr>
<th></th>
<th>Crop water requirement (mm)</th>
<th>Production (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under Current climate conditions</td>
<td>563</td>
<td>3.5</td>
</tr>
<tr>
<td>under climate change conditions</td>
<td>614</td>
<td>3.15</td>
</tr>
</tbody>
</table>
### Impact of climate change on rainfed wheat

<table>
<thead>
<tr>
<th></th>
<th>Crop water requirement (mm)</th>
<th>production (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Under Current climate conditions</strong></td>
<td>428</td>
<td>1.4</td>
</tr>
<tr>
<td><strong>under climate change conditions</strong></td>
<td>469</td>
<td>1.2</td>
</tr>
</tbody>
</table>
## Impact of climate change on cotton

<table>
<thead>
<tr>
<th></th>
<th>Crop water requirement (mm)</th>
<th>Production (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under Current climate conditions</td>
<td>1169</td>
<td>4</td>
</tr>
<tr>
<td>under climate change conditions</td>
<td>1265</td>
<td>3.8</td>
</tr>
</tbody>
</table>
The impact of climate change on irrigated olive tree production is highlighted in the table below:

<table>
<thead>
<tr>
<th></th>
<th>Crop water requirement (mm)</th>
<th>production (kg/tree)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under Current climate conditions</td>
<td>858</td>
<td>17.5</td>
</tr>
<tr>
<td>under climate change conditions</td>
<td>942</td>
<td>16.6</td>
</tr>
</tbody>
</table>
II-Integrated Water Resources Management Using Decision Support System (ACSAD-BGR)

WATER EVALUATION & PLANNING SYSTEM - www.weap21.org

Added Models:
- Modflow (Groundwater modeling)
- MABIA (Soil, Plant & Climate Model with soil and crop databases, FAO 56)
- Optimization (Groundwater Management Optimization (cost, quality & drawdown) as Pre-Processor for WEAP-MODFLOW)
- Modpath (Particle tracking)
Arab-German Cooperation Project (www.acsad-bgr.org): Management, Protection and Sustainable Use of Water and Soil Resources
WEAP linked to MODFLOW (spatially linked thru shape-file)
System structure

The project has been implemented in two pilot areas in Syria and Morocco

Decision Support – Water Management
- Groundwater Protection Zones
- Site Location (Industry, Waste Water Treatment Plant, etc.)
- Water Balance/ Abstraction Limits/ Safe Yield

Standard Output (WEAP, GIS)
- Groundwater Contour/ Drawdown/ Vulnerability Map
- Hydrochemical Map
Weap – Modflow interaction
(for each WEAP time step)

**WEAP:**
Calculates GW recharge, abstraction rates, river stage for one timestep (based on parameters defined for the respective WEAP-scenario)

**Next time step**

**WEAP:**
Reads the Modflow result-files and updates the WEAP-internal parameters

**WEAP:**
Transcribes the result into a Modflow-conformal ascii-file (*.rch, *.wel, *.riv)

**WEAP:**
Runs mf2k.exe

**Modflow:**
Calculates cell-head, storage volumes, flows ...

Arab-German Cooperation Project (www.acsad-bgr.org):
The project has been implemented in two pilot areas:

1- Berrachid plain in Morocco

2- Zabdani Plain in Syria

140km2
Results A): groundwater head 2D-view, time series Zabdani

dry years
wet year
Impact on Barada Spring discharge

Yearly Discharge of Barada Spring applying respective scenarios

- 80_RAIN
- 50_RAIN
- DRA_2x_DAWSSA_3x_AGR_0.7
- NO_GW_INFLOW

most severe scenario
III- Flood risk management Using Hydrological modeling

Study Area
El-Qa'a city is subject to annual flash flood which results from heavy and intense rainfall events. Torrent coming from the nearby valleys causes severe damage to houses and properties in the city.
The watershed outlet
# Rainfall

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total yearly rainfall</td>
<td>208.0</td>
<td>169.8</td>
<td>284.2</td>
<td>216.1</td>
<td>162.3</td>
<td>208.1</td>
</tr>
<tr>
<td>Max daily rainfall</td>
<td>20.0</td>
<td>22.0</td>
<td>23.0</td>
<td>35.0</td>
<td>16.0</td>
<td></td>
</tr>
</tbody>
</table>
The Watershed Modeling System

It is a hydrological program which can delineate the watershed boundaries, the geomorphological characteristics (the total area, slope, length of the wadi), calculate the hydrological parameters, the total precipitation, volume of runoff, maximum flow, flooding area...
Hydrological study

\[ Q_{\text{max}} = 40 \text{ m}^3/\text{sec} \]

Flood Volume = 190,000 m³
Proposed Structures based on Hydrological modeling

These structures were planned to function in several different ways:

- to assist in the rehabilitation of vegetative cover.
- to provide soil and water conservation;
- to decrease the velocity of runoff water; and
- to provide on-site storage of runoff water) to serve in total the purpose of flood control.
Rain water harvesting structures

Total storage volume 70000m³
The Hafir filled with water after the flood of 18 May 2007
III-2- Flood management in Northern Lebanon
ACSAD – UNDP – Ministry of Agriculture, Lebanon
The Wadi watershed
Flood problem

The total area of runoff collection is 94 km²

A precipitation of about 64mm can produce a runoff of about 1750000 m³ with a flow of about 200m³/s at the Al Fakha bridge
Soil erosion due to flood

Damages in cultivated areas happened after the flood of ١٣٠٢/٥/٣١
Destruction of road structures
## Results of hydrological model

<table>
<thead>
<tr>
<th>Hafer number</th>
<th>Total excavated volume (1000 m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>30</td>
</tr>
<tr>
<td>7</td>
<td>86</td>
</tr>
<tr>
<td>8</td>
<td>18</td>
</tr>
<tr>
<td>10</td>
<td>17</td>
</tr>
<tr>
<td>11</td>
<td>42</td>
</tr>
<tr>
<td>13</td>
<td>106</td>
</tr>
<tr>
<td>16</td>
<td>17.4</td>
</tr>
<tr>
<td>17</td>
<td>13.6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>330</strong></td>
</tr>
</tbody>
</table>
Locations of implemented ponds of total volume of about 400000m³
The objective of the construction of Hafeer are:
- Reduce the speed of the flow,
- Reduce soil erosion
- Decrease the flow and volume of water
Al-Shihah village is located in a mountainous area approximately 45 KM west of the city of Hama at an elevation of 1030 m above mean sea level and an average precipitation of 1000 mm.
Study of the desertification in the South West Saudi Arabia Period; 2007 -2009

The objective is to propose a plan for rehabilitation of degraded lands and agriculture development based on conjunctive use of surface (rainwater harvesting) and groundwater. WMS has been used for defining different hydraulic structures.

Selected areas for Hafirs

Pilot areas
IV-Water resources management using groundwater modeling
IV-1 Larger Orontes Basin groundwater Model

Technical cooperation between ACSAD & TNO & MoI
2007-2008
# Model Outputs for Orontes Basin

## Water Budget

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rain</td>
<td>39</td>
<td>11</td>
<td>19</td>
<td>30</td>
<td>50</td>
<td>60</td>
<td>55</td>
</tr>
<tr>
<td>Constant heads</td>
<td>289</td>
<td>276</td>
<td>275</td>
<td>273</td>
<td>273</td>
<td>273</td>
<td>273</td>
</tr>
<tr>
<td>General heads</td>
<td>453</td>
<td>443</td>
<td>448</td>
<td>593</td>
<td>532</td>
<td>675</td>
<td>700</td>
</tr>
<tr>
<td>Rivers</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>41</td>
<td>43</td>
<td>43</td>
</tr>
<tr>
<td>Recharge</td>
<td>236</td>
<td>236</td>
<td>236</td>
<td>236</td>
<td>236</td>
<td>236</td>
<td>236</td>
</tr>
<tr>
<td>Zone 1 to zone 3</td>
<td>869</td>
<td>885</td>
<td>869</td>
<td>911</td>
<td>877</td>
<td>946</td>
<td>946</td>
</tr>
<tr>
<td>Total IN</td>
<td>4061</td>
<td>4041</td>
<td>4042</td>
<td>4598</td>
<td>4854</td>
<td>4797</td>
<td>4207</td>
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<td>BUY:</td>
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<td></td>
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<td></td>
<td></td>
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<tr>
<td>Storage</td>
<td>222</td>
<td>141</td>
<td>25</td>
<td>32</td>
<td>17</td>
<td>19</td>
<td>0</td>
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<tr>
<td>Constant heads</td>
<td>112</td>
<td>115</td>
<td>116</td>
<td>117</td>
<td>118</td>
<td>119</td>
<td>119</td>
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<tr>
<td>Ghina</td>
<td>1239</td>
<td>1258</td>
<td>1144</td>
<td>969</td>
<td>533</td>
<td>496</td>
<td>432</td>
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<td>573</td>
<td>572</td>
<td>481</td>
<td>486</td>
<td>452</td>
<td>452</td>
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<tr>
<td>Rivers</td>
<td>304</td>
<td>301</td>
<td>301</td>
<td>308</td>
<td>290</td>
<td>281</td>
<td>281</td>
</tr>
<tr>
<td>Wells</td>
<td>202</td>
<td>203</td>
<td>412</td>
<td>1643</td>
<td>2144</td>
<td>2186</td>
<td>2186</td>
</tr>
<tr>
<td>Evapotranspiration</td>
<td>257</td>
<td>263</td>
<td>246</td>
<td>196</td>
<td>175</td>
<td>167</td>
<td>167</td>
</tr>
<tr>
<td>Zone 3 to zone 1</td>
<td>1139</td>
<td>1138</td>
<td>1137</td>
<td>1138</td>
<td>1154</td>
<td>1155</td>
<td>1155</td>
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<tr>
<td>TOTAL OUT</td>
<td>3047</td>
<td>3064</td>
<td>3069</td>
<td>3075</td>
<td>3071</td>
<td>3077</td>
<td>3077</td>
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<tr>
<td>SUMMARY:</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-7</td>
<td>33</td>
<td>-14</td>
<td>-17</td>
<td>-18</td>
<td>-462</td>
<td></td>
</tr>
</tbody>
</table>

## Prediction of Groundwater Reduction to reach the sustainable use.

### Areas with overexploitation

**Promising Areas for Groundwater Exploitation**

[Map showing areas with overexploitation]
IV-2 Groundwater modeling of Northern part of Khabour basin (ACSAD, 2008)

- The study area is located in the northern part of Syrian Khabour basin. The area is about 3600 km² and is suited within the Northern Fertile Crescent which has an average rainfall of 400 mm/year.
IV-3 Development of a GW Mathematical Model for Damascus basin in Syria
Model Calibration
First Scenario
Pumping 18 Million m$^3$/y of groundwater in Adra area
V- Assessment of Vulnerability of fresh water to climate change in Eastern Mediterranean region

- The approach used for this vulnerability assessment, based on the Methodological Guidelines prepared by UNEP and Peking University (UNEP, 2009).
- Analysis is based on the premise that the vulnerability assessment must have a precise understanding of four components of water resources system, including their states and relationships, these are:
  - Total water resources.
  - Water resources development and use.
  - Ecological health.
  - Management capacity.
V - Vulnerability of fresh water to climate change in Eastern Mediterranean region

Vulnerability Index VI 2005

Legend
VI
- NoData
- 0.45 (High)
- 0.50 (High)
- 0.55 (High)
- 0.60 (High)
- 0.65 (High)
- 0.7 (High)

Vulnerability Assessment Of Fresh Water Resources To Environmental Changes

Geographic Projection WGS_1984
Vulnerability of fresh water resources to climate change
Euphrates case study

Euphrates Basin_Vulnerability Index VI 2000

Legend
VI
- NoData
- 0.40 (High)
- 0.45 (High)
- 0.50 (High)
- 0.55 (High)
- 0.60 (High)
- 0.65 (High)
- 0.7 (High)

Vulnerability Assessment Of Fresh Water Resources To Environmental Changes
Case Study - Euphrates Basin
thanks

شاکرین لکم
حسن استعمالکم