Climate Induced Changes On The Hydrology Of Mediterranean Basin - Climb

REJECTING UNCERTAINTY AND QUANTIFYING RISK THROUGH AN INTEGRATED MONITORING AND MODELLING SYSTEM

CASE STUDY

GAZA SITE – PALESTINE

2014
Contributors

Environmental and Rural Research Center (ERRC), Faculty of Science
Islamic University of Gaza
Palestine

Prof. Dr. Samir Afifi
Dr. Mohamed Eila
Dr. Khalid Qahman
Eng. Samir Nahal
Ms. Maysrah Abu Hasnien,
Ms. Samah Abu Samrah

Ludwig-Maximilians-Universitaet
Muenchen
Department of Geography
Germany

Prof. Dr. Ralf Ludwig,
Eng. David Gampe,

Bayerische Forschungsallianz
Gemeinnutzige GmbH
Germany

Dr. Thomas Ammerl,

CEMAGREF - UMR TETIS
France

Dr. Nicolas Baghdadi

University of Cagliari
Italy

Prof. Roberto Deidda

CRS4, Building 1, Technological Park 'POLARIS', Loc. Piscina Manna,
Italy

Dr. Marta Dentoni,
Eng. Giuditta Lecca,
Mr. Marino Marrocu

INRS-ETE, Université du Québec
Canada

Prof. Claudio Paniconi

Université François-Rabelais de Tours
France

Dr. Isabelle La Jeunesse

A cluster of collaborative research projects
under the 7th Framework Programme

www.climb-fp7.eu
Environmental and Rural Research Center (ERRC) at IUG

The Environmental and Rural Research Center (ERRC) has been established in 1991 as a part of the IUG program to contribute in developing environmental researches and studies and to serve the Palestinian community with highly qualified human resource in this vital and very important field that can contribute in solving the environmental problems and developing the country. The lack of environmental studies in Palestine makes the establishment of ERRC as one of the top priorities of the IUG policy.

In the last decades, ERR-center has developed co-operative relations with many external and international organization through academic and research programs (UNDP, UNRWA, British Council, EU-Programs (Med Campus, Life, INCO-MED, FF7 and TEMPUS), Norwegian Institute for water research and others). Since 1991 up to day, the IUG conducted several projects and programs in the fields of environment. The main objectives for the establishment of the ERRC are:

- Encourage and developing environmental researches related to the area.
- Cooperate with governmental and non-governmental institutions in solving environmental problems and to improve the quality of the local and global environment.
- Serve local community through conducting various environmental projects, and gives recommendations and professional consultations that cover a wide spectrum of the environmental practice.
- Holding courses and seminars in environmental management and protection, in addition to issuing publications on local environment and environmental problems.
- Serving researches in the environmental field through the laboratory of the center.
Mediterranean and Climate Changes

According to current climate projections, Mediterranean countries are at high risk for an even pronounced susceptibility to changes in the hydrological budget and extremes. These changes are expected to have severe direct impacts on the management of water resources, agricultural productivity and drinking water supply. Threats include severe droughts and extreme flooding, salinization of coastal aquifers, degradation of fertile soils and desertification due to poor and unsustainable management practices. Current projections of future hydrological change, based on regional climate model results and subsequent hydrological modeling schemes, are very uncertain and poorly validated. The conditions required to develop and implement appropriate adaptation strategies are lacking. To the extent that adaptation initiatives are being proposed and adapted, they are primarily by perceptions of individual stakeholders and are rarely based on a multi-disciplinary assessment covering both natural and associated social and economic changes.

UNDP/PAPP had prepared the climate change adaptation strategy in 2011 which sets out in detail the vulnerability assessment and future climate risks. Assessment by which key adaptation needs and options for the Palestinian Territories are justified. The structure of this Palestinian Adaptation Program of Action (PAPA) follows the format for National Adaptation Programs of Action (NAPAs) prepared by Least Developed Countries under the United Nations Framework Convention on Climate Change (UNFCCC); however, as ‘Palestine’ as a Party is not recognized in this convention, the PAPA does not yet have any formal recognition within the UNFCCC.

The current water insecurity in the Gaza Strip is not due to climate variability (short term) or climate change (long term) but mainly the result of unsustainable water extraction and contamination issues (e.g. nitrates). There needs to be a systematic climate change analysis for the Gaza Strip in the context of the wider Eastern Mediterranean region, which needs to address potential changes to groundwater recharge and agricultural crop yields, as well as saline intrusion.
CLIMB Project

The European Union has funded the Climate Induced Changes on the Hydorology of Mediterranean Basins project (CLIMB; http://www.climb.fp7.eu), with the aim of producing a future scenario assessment of climate change for significant hydrological basins of the Mediterranean. The Mediterranean countries constitute an especially interesting area for hydrological investigation by climate scientists, given the high risk predicted by climate scenarios, and the pronounced susceptibility to droughts, extreme flooding, salinization of coastal aquifers and desertification, predicted as a consequence of the expected reduction of yearly precipitation and increase of the mean annual temperature.

The strategy of CLIMB is aiming to employ and integrate advanced field monitoring techniques, remote sensing analyses and retrievals, integrated hydrologic (and biological) modeling and socioeconomic factor assessment in a new conceptual framework to significantly reduce existing uncertainties in climate change impact analysis and to create an integrated risk assessment tool for adaptive water resources management and best agricultural practice under climate change conditions.

The project involved a large number of Master and PhD students and an intense stakeholder dialogue to ensure human capacity building in the participating partner countries.
CLIWASEC a Scientific Synergies and Policy Outreach

CLIMB is embedded in a cluster of independent projects with other two projects funded by European Commission “Seventh Framework Program” which are WASSERMed, and CLICO. The intention of this clustering is to foster scientific synergy and cooperation between the partner projects, identify and utilize complementary methods, harmonize and share data, mutually discuss dissemination strategies and thus conjointly contribute to the identification of and adaptation to climate induced changes in water resources in southern Europe and neighbouring countries as a threat to security.

CLIMB makes decisive contributions to this partnership by developing and implementing a unique research concept.

IUG had a fruitful coordination with the Palestinian Hydrology Group (PHG), the CLICO partner in West Bank, Palestine. It is agreed to have sustainable cooperation in different fields specially the remote sensing techniques.
<table>
<thead>
<tr>
<th>Partner</th>
<th>Organization</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>LMU</td>
<td>Ludwig-Maximilians-Universitaet Muenchen - Department of Geography</td>
<td>Germany</td>
</tr>
<tr>
<td>AGRIS</td>
<td>Agenzia per la Ricerca in Agricoltura – Sardegna DIRVE (Department Vegetal Research)</td>
<td>Italy</td>
</tr>
<tr>
<td>CAU</td>
<td>Christian-Albrechts-Universitaet zu Kiel - Department of Geography, Landscape Ecology &amp; Geoinformation</td>
<td>Germany</td>
</tr>
<tr>
<td>CEMAGREF</td>
<td>Centre national du Machinisme Agricole, du Géne Rural, des Eaux et des Forêts UMR-TETIS</td>
<td>France</td>
</tr>
<tr>
<td>CERTE</td>
<td>Centre de Recherche et des Technologies des Eaux</td>
<td>Tunisia</td>
</tr>
<tr>
<td>CINFAI</td>
<td>Consorzio Interuniversitario Nazionale per la Fisica delle Atmosfere e delle Idrosfere</td>
<td>Italy</td>
</tr>
<tr>
<td>CRS4</td>
<td>Centro di Ricerca, Sviluppo e Studi Superiori in Sardegna</td>
<td>Italy</td>
</tr>
<tr>
<td>DLR</td>
<td>Deutsches Zentrum fuer Luft- und Raumfahrt e.V. - German Remote Sensing Data Center (DFD)</td>
<td>Germany</td>
</tr>
<tr>
<td>FZI</td>
<td>Forschungszentrum Juelich GmbH - Institute of Chemistry and Dynamics of the Geosphere</td>
<td>Germany</td>
</tr>
<tr>
<td>GIT</td>
<td>Gebze Yuksek Teknoloji Enstitüsü - Department of Environmental Engineering</td>
<td>Turkey</td>
</tr>
<tr>
<td>INRS</td>
<td>Institut National de la Recherche Scientifique Eau, Terre et Environnement (ETE)</td>
<td>Canada</td>
</tr>
<tr>
<td>Joanneum</td>
<td>Joanneum Research Forschungsgesellschaft mbH - Institute of Technology and Regional Policy (RTG) and Institute of Energy Research (IEF)</td>
<td>Austria</td>
</tr>
<tr>
<td>IUG</td>
<td>Islamic University of Gaza - Environmental and Rural Research Center (ERRC) Science College</td>
<td>Palestine</td>
</tr>
<tr>
<td>UNIPD</td>
<td>Università degli Studi di Padova - Centro Univ. per la Difesa idrogeol. dell’Ambiente</td>
<td>Italy</td>
</tr>
<tr>
<td>UNITN</td>
<td>Montano – CUDAM</td>
<td>Italy</td>
</tr>
<tr>
<td>UZ</td>
<td>Zagazig University Faculty of Science Geology Department</td>
<td>Egypt</td>
</tr>
<tr>
<td>VISTA</td>
<td>Geowissenschaftliche Forschung GmbH</td>
<td>Germany</td>
</tr>
<tr>
<td>BayFOR</td>
<td>Bayerische Forschungsallianz Gemeinnützige GmbH</td>
<td>Germany</td>
</tr>
<tr>
<td>UT</td>
<td>Université François-Rabelais de Tours</td>
<td>France</td>
</tr>
<tr>
<td>YTU</td>
<td>Yildiz Technical University</td>
<td>Turkey</td>
</tr>
</tbody>
</table>
CLIMB Work Packages

The work plan is divided in eight WPs as presented in the following diagram.
CLIMB Sites

To cover many of the most evident and expected climate change and water security related problems in the region, the Consortium has identified seven study sites located in Sardinia, Northern Italy, Southern France, Tunisia, Egypt, Turkey and Gaza-Palestine.

Gaza Site

The work in Gaza site contributed to the following activities:
- Geo-data Management
- Remote sensing analyses and retrievals
- Climate models auditing and downscaling
- Integrated hydrologic modeling
- Socioeconomic factor assessment
Gaza Site and Climate Change Vulnerability

The climate vulnerability of residents of Gaza is yet further compounded by the expected environmental impacts of climate change. A higher variability in precipitation translates into reduced yields for rainfed agriculture, and could also mean a greater frequency of flash floods. Reduced amounts of precipitation will mean greater strain on the over-strained groundwater resources. Expected increase in temperatures may also lead to greater groundwater pumping because of increased desertification, particularly in the south. The major exposures anticipated can be summarized by sector as follows.

Water
• Increased water shortages from lower rainfall and higher evaporation
• Increased storm water flooding from greater rainfall variability
• Insufficient rain to recharge aquifers.
• Reduced surface and groundwater quality.
• Lower supply of water from Israel.

Agriculture
More frequent droughts and increased desertification.
• Changes in economic viability of crops (e.g. shorter growing seasons)
• Increased crop water requirements
• Decline in grazing ranges and stocks.
• Higher food prices.

Energy
• Increased energy demands to cope with more temperature extremes
• Rising fuel demands to cope with water shortages.

Public health
• Increase in public health ailments related to the lack of water such as diarrhoea, cholera and dehydration.
• Increased heat stress from high temperature extreme events.
• Spatial and temporal alteration of disease vectors, including malaria, Leishmaniasis, and tick-borne diseases.

Coastal management (Gaza)
• Saline intrusion into the Coastal Aquifer.
• Land use impacts from sea-level rise and coastal erosion.
• Soil degradation.
• Loss of biodiversity
Geo-data Management

Collected data from Gaza site was so fragmented. The data was verified using spatial distribution software (ArcGIS 10, Erdas 2011, Surfer 9, Argus One) and temporal distribution software (Ms Excel and Ms Access). IUG staff had developed the CLIMB DATA BASE related to Gaza study site in cooperation with the project’s partners as follows:

1. Topography: Date is available in MS. Excel files and GIS maps.
2. Soil Data: (Soil types): Updated this information was based on satellite images, field survey and laboratory analysis.
3. Land use and land Cover: updated information and map are available based on recent Remote Sensing data 2004 and 2010.
4. Agro-meteorological indicators (climatic data and weather information)
5. Climate Data: (precipitation, Wind, Evapo-transpiration, Humidity, Solar radiation): data is available for the last 15 years.
6. Weather information (weather Temperatures and rainfall): data for the last 20 years are available from the meteorological stations in Gaza.
7. Socio economic information as well as the field analytical sampling methods and protocols.
8. Hydrological and Geological setting: (the sub aquifer layers and depths).
9. History of water and soil management: some data is available the team is working to update this information.
10. Groundwater hydrogeology: (the groundwater (source, flow direction) the groundwater quality, recharge, abstraction, wells and types of the wells).
Remote Sensing and Retrieval of Geophysical Parameters

IUG managed to make use of remote sensing data and satellite images purchased through the French project partner (CEMAGREF) for Gaza area for the years 2004, 2010 and 2011. CEMAGREF and IUG team had managed compile the Remote sensing data, GIS information and field visits to develop land use and land cover (LULC) map of Gaza strip for the years 2004 and 2010.

LULC Classification and Data Validation

In a first step, SPOT images were orthorectified with the help of the SRTM DEM. Coordinates of reference points were obtained from Google Earth. Nine classes and Ten classes were identified on images of 2004 and 2010, respectively. The 10 m resolution of 2004 images did not allow to isolate olive orchards. They were subject to much confusion. As a consequence, olive orchards are part of the “Mixed agriculture” class. Field monitoring and field validation for the remote sensing data in cooperation with CEMAGREF had been done during 2011.

Field monitoring and field validation for remote sensing data in December 2011
Methodology:

With the help of the Erdas Imagine software, the method described hereafter was applied to localize the various types of crops existing in Gaza. The 2004 SPOT images were classified with an unsupervised approach (unsupervised classification with 32 classes). Then, for each date classes were regrouped according to color similarity, as observed on the images displayed in infrared false colors. Images available on Google Earth were used as a help because of their higher resolution. This gave us 11 classes for the 22 May 2004 image and 13 classes for the 9 November 2004 image. Elimination of isolated pixels was then carried out by using the Erdas “Neighborhood” function, with a 3x3 grid.

Ten classes were identified on images of 2010. The 5m resolution of 2010 images allowed to isolate olive orchards.

Results

Results obtained from classification (11 classes) and November classification (13 classes) gave a maximum of 14 classes which correspond to the change of behavior in the span time. After analysis, a few spectral behaviors were grouped, which finally gave 9 classes 2004 and 10 classes in 2010. The maps and figures derived from LULC classification for Gaza Strip in 2004 and 2010 are shown below.
### Gaza Land use/ Land cover map 2004 & 2010

LULC surfaces for the Gaza Strip in years 2004 and 2010

<table>
<thead>
<tr>
<th>Class name</th>
<th>Area (ha) 2004</th>
<th>% 2004</th>
<th>Area (ha) 2010</th>
<th>% 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Water</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Built-up areas</td>
<td>9151</td>
<td>25.0%</td>
<td>8370</td>
<td>22.8%</td>
</tr>
<tr>
<td>Natural vegetation</td>
<td>1265</td>
<td>3.5%</td>
<td>2424</td>
<td>6.6%</td>
</tr>
<tr>
<td>Horticulture</td>
<td>1775</td>
<td>4.8%</td>
<td>2363</td>
<td>6.5%</td>
</tr>
<tr>
<td>Greenhouses</td>
<td>814</td>
<td>2.2%</td>
<td>1365</td>
<td>3.7%</td>
</tr>
<tr>
<td>Sand</td>
<td>3539</td>
<td>9.7%</td>
<td>4263</td>
<td>11.6%</td>
</tr>
<tr>
<td>Citrus orchards</td>
<td>3646</td>
<td>9.9%</td>
<td>3182</td>
<td>8.7%</td>
</tr>
<tr>
<td>Rainfed agriculture</td>
<td>335</td>
<td>0.9%</td>
<td>152</td>
<td>0.4%</td>
</tr>
<tr>
<td>Mixed agriculture</td>
<td>11323</td>
<td>30.9%</td>
<td>14543</td>
<td>39.7%</td>
</tr>
<tr>
<td>Olive orchards</td>
<td>4814</td>
<td>13.1%</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>36662</strong></td>
<td><strong>100.00%</strong></td>
<td><strong>36662</strong></td>
<td><strong>100.00%</strong></td>
</tr>
</tbody>
</table>

LULC classes 2004 & 2010 of Gaza Strip
Comparison Of The Two Soil Maps For The Gaza Strip

In Gaza there are seven major of soil types, which including sandy soil, sandy loam soil, sandy clay loam soil, sandy clay soil, loam soil, clay loam soil and clay soil. The west area is the sandy soil area located in the costal sand dunes and most of it was found medium to rough sand, which is expands in the south and north, and narrower in the meddle and in Gaza City.
Generally, the change process in the soil texture is very slowly comparing to the changes happening in soil aggregate structure; the arrangement of the soil aggregate is more subject to change as a result of the agricultural processes, machinery application, chemical fertilizers practice and misuse of irrigation. Soil aggregate structure changes happen only as a result of human actions or activities. However, texture changes of the soil happen as a result of climatic and environmental change. In addition, it could happen in limited area as a result of adding light soil to heavy soil vice versa as mentioned before.
Climate Models and Auditing Downscaling

In this project 14 Regional Climate Models (RCMs) were considered, from the EU-FP6 ENSEMBLES project, run for the A1B emission scenario on a common 0.22_ (about 24 km) rotated grid over Europe and the Mediterranean region. In the validation period (1951 to 2010) daily precipitation and surface temperatures from the observed data fields (E-OBS) data set, available from the ENSEMBLES project and the data providers in the ECA&D project were adopted. The primary objective was to rank the 14 RCMs for each catchment and select the four best-performing ones to be used as common forcing for hydrological models in the six Mediterranean basins considered in the EU-FP7 CLIMB project.

Using a common suite of four RCMs for all studied catchments reduces the (epistemic) uncertainty when evaluating trends and climate change impacts in the 21st century. The validation setting was presented, as well as the obtained results and, in some detail, the difficulties that experienced when processing the data. In doing so, useful information and advice can be provided for researchers not directly involved in climate modeling, but interested in the use of climate model outputs for hydrological modeling and, more generally, climate change impact studies in the Mediterranean region.

### Acronyms of the Regional Climate Models (RCMs) considered in this study.

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Climatological center and model</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCA</td>
<td>Swedish Metrological and Hydrological Institute (SMHI), Sweden RCA Model</td>
</tr>
<tr>
<td>HIR</td>
<td>Danish Meteorological Institute (DMI), Denmark HIRHAM5 Model</td>
</tr>
<tr>
<td>CLM</td>
<td>Federal Institute of Technology of Zurich (ETHZ), Switzerland CLM Model</td>
</tr>
<tr>
<td>HRM</td>
<td>Hadley Center for Climate Prediction, Met Office, UK Had RM3Q3 Model</td>
</tr>
<tr>
<td>RMO</td>
<td>Royal Netherlands Meteorological Institute (KNMI), Netherlands RACMO2 Model</td>
</tr>
<tr>
<td>REM</td>
<td>Max Planck Institute for Meteorology, Hamburg, Germany REMO Model</td>
</tr>
</tbody>
</table>
Combinations of Global Climate Models (GCMs) and Regional Climate Models (RCMs) considered in this study

<table>
<thead>
<tr>
<th>GCM</th>
<th>HadleyC, Std.</th>
<th>HadleyC, Low</th>
<th>HadleyC, High</th>
<th>ECHam 5</th>
<th>ARPege</th>
<th>BCM</th>
</tr>
</thead>
<tbody>
<tr>
<td>HadRM</td>
<td>HCS-HRM</td>
<td>HCL-HRM</td>
<td>HCH-HRM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>REMo</td>
<td></td>
<td></td>
<td></td>
<td>ECH-REM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HIRham</td>
<td>HCS-HIR</td>
<td></td>
<td></td>
<td>ECH-HIR</td>
<td>ARP-HIR</td>
<td>BCM-HIR</td>
</tr>
<tr>
<td>CLM</td>
<td>HCS-CLM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RacMO</td>
<td></td>
<td></td>
<td></td>
<td>ECH-RMO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RCA 3</td>
<td>HCL-RCA</td>
<td>HCH-RCA</td>
<td>ECH-RCA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The QQplot methodology is used to assess precipitation values in the location of the operational Rainfall Stations. In few words, for each Rainfall Station are assessed precipitations values, by correlating precipitation outputs of one grid point between 2532.nd and 2362.nd of each chosen RCMs with measured precipitations values in the nearest Rainfall Station. The criteria to assign a rainfall station to a grid point are the vicinity, as illustrated in the following figure.

Assigning Rainfall Station to a grid point by the vicinity criteria
**Climate Models Summary Results**

Precipitation (P) and evaporation (ET) patterns above described and calculated for the 4 models ECH_RMO, ECH_REM, ECH_RCA and HCH_RCA, are supposed to impact on the future hydrological cycle of the Gaza site, as they represent the two factors determining net rainfall recharge. In particular, it is supposed that different patterns in P and ET will affect in different way the aquifer system, as these two values are used as the basis of the setup of recharging patterns for the coastal aquifer, aiming in this way to represent the future evolution of the overall system.

Comparison of the mean yearly values of P, ET and NetP (P-ET) for the ECH_RMO not bias and bias corrected modeled values in the inner gridded point (p2362).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Units</th>
<th>1981-2010 (p0)</th>
<th>2011-2040 (p1)</th>
<th>2041-2070 (p2)</th>
<th>Difference (p2)&gt;(p0)</th>
<th>% Difference (p2)&gt;(p0)</th>
<th>Difference (p3)&gt;(p1)</th>
<th>% Difference (p3)&gt;(p1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>mm/y</td>
<td>162.03</td>
<td>178.37</td>
<td>151.55</td>
<td>+16.34</td>
<td>+10.09</td>
<td>-10.48</td>
<td>-6.92</td>
</tr>
<tr>
<td>ET</td>
<td>mm/y</td>
<td>86.00</td>
<td>86.39</td>
<td>78.95</td>
<td>+0.40</td>
<td>+0.46</td>
<td>-7.05</td>
<td>-8.93</td>
</tr>
<tr>
<td>NetP</td>
<td>mm/y</td>
<td>76.03</td>
<td>91.98</td>
<td>72.60</td>
<td>+15.94</td>
<td>+20.97</td>
<td>-3.43</td>
<td>-4.73</td>
</tr>
<tr>
<td>Tmax</td>
<td>°C</td>
<td>23.50</td>
<td>25.98</td>
<td>27.27</td>
<td>+2.48</td>
<td>+2.67</td>
<td>+1.97</td>
<td>+7.21</td>
</tr>
<tr>
<td>Tmin</td>
<td>°C</td>
<td>19.71</td>
<td>20.47</td>
<td>21.68</td>
<td>+0.75</td>
<td>+3.83</td>
<td>+1.97</td>
<td>+9.09</td>
</tr>
<tr>
<td>Tavg</td>
<td>°C</td>
<td>15.21</td>
<td>16.06</td>
<td>17.29</td>
<td>+0.85</td>
<td>+5.58</td>
<td>+2.08</td>
<td>+12.02</td>
</tr>
<tr>
<td>P</td>
<td>mm/y</td>
<td>279.76</td>
<td>318.62</td>
<td>255.01</td>
<td>+38.86</td>
<td>+13.89</td>
<td>-24.74</td>
<td>-9.70</td>
</tr>
<tr>
<td>ET</td>
<td>mm/y</td>
<td>59.67</td>
<td>61.44</td>
<td>55.18</td>
<td>+1.77</td>
<td>+2.97</td>
<td>-4.49</td>
<td>-8.15</td>
</tr>
<tr>
<td>NetP</td>
<td>mm/y</td>
<td>220.09</td>
<td>257.17</td>
<td>199.84</td>
<td>+37.09</td>
<td>+16.85</td>
<td>-20.25</td>
<td>-10.13</td>
</tr>
<tr>
<td>Tmax</td>
<td>°C</td>
<td>21.02</td>
<td>21.77</td>
<td>22.94</td>
<td>+0.75</td>
<td>+3.04</td>
<td>+1.92</td>
<td>+9.12</td>
</tr>
<tr>
<td>Tmin</td>
<td>°C</td>
<td>15.45</td>
<td>16.33</td>
<td>17.62</td>
<td>+0.87</td>
<td>+5.00</td>
<td>+2.16</td>
<td>+14.01</td>
</tr>
<tr>
<td>Tavg</td>
<td>°C</td>
<td>26.46</td>
<td>27.04</td>
<td>28.13</td>
<td>+0.58</td>
<td>+2.09</td>
<td>+1.67</td>
<td>+6.12</td>
</tr>
</tbody>
</table>

It has been proposed a deeper analysis on the Gaza strip area, for only the ECH_RMO modeled variables, which are bias corrected within CRU data (for T variables) and, for P variables, within historical data, both by the means of the QQplot methodology. This last correction highlights that modeled precipitation values (P) are strongly different from historical measured data; this may be due to the different spatial resolutions, and also to series of chained conceptual issues that pertains to RCM gridded points, which actually represents a ‘averaged daily value’ for the representative squared area of about 22-25 km of side. The trend of bias corrected and not bias corrected variables
have been further compared, highlighting quite the same trends for both the considered future periods.

**Climate Change Models' Outcome**

The main outcomes from the analysis on future projected variables coming from 4 different GCM-RCM models applied on the Gaza Strip area are summarized in the following, with reference to 1981-2010 historical periods:

1- Precipitation rates will have an increase in the next 30 years, and then a decrease in the following 30 years;
2- Extremes precipitations events (daily precipitation >10 mm/d) will have an increase in the next 30 years, and then a decrease in the following 30 years;
3- Very extreme precipitation events (daily precipitation >20 mm/d) will have an increase in the next 30 years and then a decrease in the following 30 years;
4- Temperatures will rise up to 2°C in the next 60 years;
5- ET patterns will slightly increase in the next 30 years and then decrease in the following 30 years;
6- The net recharging precipitation (NetP, set equal to P-ET) will increase in the next 30 years and then decrease in the following 30 years.
7- NetP values will have a direct impact on groundwater recharge, and however it must be considered that, due to the increase of extreme events and very extreme events of precipitation, the patterns should be much less than these, as runoff component for sure will be hampered. Further analysis should be done on this issue.
Gaza Hydro-geological Modeling

Analysis of climate change impacts on available water resources is undertaken for Gaza aquifer catchments area. IUG in cooperation with LMU and CRS4 applied two hydrological models (WaSiM-ETH, CODESA-3D). The models delivered estimates of changes in hydrological components. Advanced climate scenario analysis techniques in addition to risk analysis and mitigation of seawater intrusion in coastal aquifers under climate induced changes was employed. The results showed that overexploitation of Gaza coastal aquifer is leading to constant drop in water level, which estimated to be about 20-30 cm/year. In addition, groundwater salinity considered to be most pressing problems.

Gaza Costal Aquifer

The coastal aquifer of the Gaza strip is part of a regional groundwater system. The aquifer is only 40 km long in the Gaza Strip and it is classified as a Pleistocene-age granular aquifer (Kurkar Group), formed by different sandstones, with intercalations of clay and loam. Some of them are lenses randomly distributed in the area, causing local perched water conditions; others begin at the coast, extending 2-5 km inland, and separate the aquifer into various subaquifers. The average thickness of the aquifer body is about 150 m, with a maximum of about 200 m and a minimum of about 20 m.

The internal vertical zoning is based on the geological information provided by the Islamic University of Gaza (IUG), consisting of spatial distributed information (elevation) of the aquifer geological strata for the study domain.

Gaza site is suffering from the followings:

- Increased water shortages from lower rainfall and higher evaporation reflected on groundwater table
- Low surface and groundwater quantity and quality (pollution, saltwater intrusion (SWI))
**Groundwater Chlorides Concentration**

**Gaza Water Quality:** Contour maps representation of 1935 and 2010 groundwater chlorides concentration (taken at the depth of control wells, whose depth ranges from 20 to 100-120 m below the land surface).

**Gaza Water Table:** The overexploitation of the coastal aquifer is leading to a constant drop in the water level, which estimated to be about 20-30 cm each year.
Hydro-geological Modeling Calibration and Validation:

In this work the computational framework COPEGA has been developed and applied to the Gaza Strip coastal aquifer to support the management of groundwater resources under natural and human induced stresses. COPEGA consists of 3 interconnected pre-existing tools:

1. 3D hydrogeological model CODESA-3D,
2. Automatic calibration procedure PEST and
3. Carroll’s GA optimization technique.

The 3D hydrogeological model of the GCA has been set-up using field data available until 2010, calibrated in steady-state conditions using 1935 water levels considering average climate conditions and natural conditions (‘no-pumping’ scenario). Adjustable parameters in the calibration procedure were heterogeneous and anisotropic hydraulic conductivity values and boundary conditions (landward recharge). Based on residual statistics the calibration exercise is satisfactorily for the study scope. To test the robustness of the 697 calibrated dataset a validation exercise was carried out in transient state for 2 time frames (1935-2000 and 2001-2010) using spatial and temporal variable recharge and pumping.

The validation also proves a good agreement with control data set (water levels and near coastline salt concentrations).
As a further step, the model was linked to an optimization tool defining an objective function based on two conflicting goals (maximize pumping at the municipal wells while limiting extracting salt mass from the same wells) with constraints (maximum pumping for each municipal well and maximum allowed concentration). Final results in the period 2011-2020 identified an optimal scheme of water abstraction spatial distribution for municipal wells that, compared with the not-optimized scheme (“go as usual”), is capable to keep the overall abstraction close to the user-defined total amount, while significantly lowering the total mass of salt extracted (around -23%). Yet, the optimized scheme provides for a significant increase in average groundwater heads (+0.34 m, about +4.5%) and decrease in areas affected by SWI (about -5%), with reference to the not-optimized situation. These benefits are quite evident in the northern and southern areas of the GCA, were groundwater levels lowering and SWI phenomena are nowadays quite critical.

**Future Scenarios**

The validated hydrogeological model of the Gaza aquifer is used to simulate the response of the hydrological basin to actual and future scenarios of climate change. The system is studied in the periods 2011-2040 and 2041-2070, on the basis of 2010 simulation results both for water levels and for salt concentrations.

Two different scenarios have been considered, both starting with pumping amount depicted at the end of 2010:

1. **Worst scenario**, which considers, at the end of 2040, the estimated increasing of pumping for municipal wells up to around 200 Mm³/y and a general decrease of pumping for agricultural wells up to around 60 Mm³/y, summing up about 260 Mm³/y of water abstraction;

2. **Best scenario**, which considers, at the end of 2040, the proposed aquifer management scenario considering the illustrated decreasing of pumping for municipal wells up to around 50 Mm³/y and the same general decrease of pumping for agricultural wells as illustrated for the worst scenario, summing up about 110 Mm³/y of water abstraction.

The variables (P, T, W, RH, Rs) are considered for the periods (first (p1): 2011-2040 and second (p2): 2041-2070), and the consideration made was for the 4 RCMs.
Future Scenarios for Gaza Aquifer Modeling

Results:

The analysis of outputs coming from all the simulations shows that the increasing or decreasing in water levels, and higher and lower values of groundwater heads, corresponding in general to the NetP trends. However, different climate scenarios variables, in this case, lead to differences in the groundwater system that can be hardly be appreciated if compared with pumping effects; it is evident, in fact, that pumping scenarios have extremely high impacts on the Gaza aquifer system.

The bellow figure presented the results of the two pumping scenarios, (worst and best) and their impacts on municipal wells production, groundwater level and seawater intrusion at the end of 2040.
End of 2040; $Q_w$ Pumping Scenario; ECH-RMO Climate Scenario

Worst Scenario

Simulated Groundwater level (m a.m.s.l. 2010)

Simulated normalized salt concentration

End of 2040; $Q_B$ Pumping Scenario; ECH-RMO Climate Scenario

Best Scenario

Simulated Groundwater level (m a.m.s.l. 2010)

Simulated normalized salt concentration

Pumping Scenarios and Their Impacts on Municipal Wells Production, Groundwater Level and Seawater Intrusion at the End of 2040
Socioeconomic Factor Assessment

Field Survey

A comprehensive questioners for water managers and water users were conducted by IUG staff in cooperation with University of François-Rabelais de Tours-France, to show the stakeholders' perceptions in terms of water usages in Gaza Strip in 2012. The questionnaires results clearly demonstrate that the usage perceived as being the priority in terms of water allocation is domestic usage (100% of interviewees, as a whole). This perception is supported by official data which stated an annual volume of 160 million m³ to supply a population of more than 1.5 million inhabitants.

The decrease in access to drinking water - in particular due to the salt levels in the resource - has encouraged the development of an industry in water purification packaging.

The results for questioner on the uses and their evolution for stakeholders over the past 20 years show that stakeholders have experienced a significant increase in demand for water, for all uses. However, the most remarkable fact mentioned by around 80% of interviewees (86% of managers and 75% of users) was the increase in population, which is linked to the increase in urban demand for water for almost half of the users interviewed (48%) and a third of managers (33%). This new demand is also linked to changes in lifestyle and consumption which requires a greater quantity of water allocated for this purpose.
Thus, for 43% of managers who were interviewed, the increase in the agricultural demand for water is the second most significant reason for changes concerning water uses in the Gaza Strip over the past 20 years (after population increase).

**Interaction with Stakeholders and Dissemination Activities**

IUG team realized around 50 local activities to notify and update local related stakeholders to ensure dissemination of achieved results and gather future support and implementations of outcome results. Other regional activities (Workshops, conferences, meetings ..) were conducted in close cooperation with regional experts.

**Initiation Local Committee includes related stakeholders:**

- Academic institutions: Engineering Faculty -IUG
- NGOs: Palestinian Hydrological Group (PHG), Palestinian Environmental Friends Association (PEF)
- Governmental Institutions: Palestinian Water Authority (PWA), Environmental Quality Authority (EQA), Ministry of Agriculture
- International organization: United Nation Developing Program (UNDP), EU Office -Gaza
- Coastal Municipal Water Utility (Public Sector)
- Local Authorities and Municipalities
Select dissemination activities, which were conducted by Gaza team include:

1- Introduce the project in websites and published a report about CLIMB Activities "in Arabic language"

2- Coordinate activities with the relevant local institutions
   • Palestinian Water Authority,
   • Ministry of Agriculture Ministry,
   • Water Utility,
   • Environmental Quality Authority

3- Contacted and cooperate with International organizations Implementing project in the field of water and climate change such as UNDP, UNEP, UNESCO, ICRC, GEF-Program, and Word Bank.

4- Participation and Introducing CLIMB in Regional Meeting and Forums:
   • Arab Climate Resilience Initiative: Regional Forum on Addressing Climate Change Impacts in the Arab Countries, Rabat, 3-5 November 2010
   • Impact of climate change on Coastal Erosion and High Sea Level, Cairo: 19-9-2010
   • Impact of Climate changes on Water Resources in the Mediterranean Region, Rabat: 1-4 July 2010
   • The Middle East Green Economy Initiative, Regional Meeting Amman, 25-27.11.2010
   • Sustainable Energy Policy in the Middle East and North Africa, Amman, 6 and 7 November 2010
   • Introduced the CLIMB Activities in the National and Regional Strategies
   • LIMATE VARIABILITY AND CHANGE, Gaza Strip, Palestinian Territories – Report.
   • UNEP MAP Project Preparation Grant (PPG) for the project “Implementation of climatic variability and change into national strategies to implement ICZM Protocol in the Mediterranean”
   • Impact of Flash Flood on Wadi Gaza Area, Annual Assembly Meeting, Cagliari - 31st January to 4th February 2011
   • Seawater Intrusion in Gaza Coastal Aquifer, annual Assembly Meeting, Cagliari - 31st January to 4th February 2011

5- Present the project finding in posters and regular news letters
CLIMB Case Study: 
Gaza Site, Palestine

Prof. Dr. Sami Alfi
Islamic University of Gaza (IUG)
samii@ugaza.edu.ps

Geographical Overview

The Gaza Strip is a part of the Mediterranean coastal plain between Egypt and Israel, where it forms a long and narrow rectangle. Its area is about 365 km² and its length is approximately 45 km. The population (currently 1.5 millions) characteristics of the Gaza Strip are strongly influenced by political developments which have played a significant role in the growth and population distribution of the Gaza Strip. The average daily mean temperature ranges from 25 °C in summer to 13 °C in winter. The daily relative humidity fluctuates between 65% in the daytime and 85% at night, and between 60% and 80% respectively in winter. The mean annual solar radiation is 2200 J/cm²/day. The average annual rainfall varies from 450 mm/yr in the north to 200 mm/yr in the south. Most of the rainfall occurs in the period from October to March, the rest of the year being completely dry. Precipitation patterns include thunderstorms and rain showers, but only a few days of the wet months.

Figures: Borders of the Gaza Strip

Partners of this Case Study

- Ludwig-Maximilians-Universität (LMU), Munich, Germany
- Centre National du MACHinisme Agricole, du Genie Rural, des Eaux et des Forêts (CEMAGREF), Montpellier, France
- Centro di Ricerca, Sviluppo e Studi Superiori, Sardigna (CRS4), Italy
- Forschungszentrum Jülich GmbH, Jülich, Germany
- Joanneum Research Forschungsgesellschaft mbH, Graz, Austria

Focus of this Case Study

Water
- Groundwater is the only current resource of fresh water in Gaza. Due to the tremendous increase of population, it is enough to meet the current and future demands.
- The groundwater is exposed to the risk of overexploitation, seawater intrusion and anthropogenic contamination (nitrate and biological matter).
- Increasing water shortage from lower rainfall and higher evaporation.
Towards A Road Map To Face Climate Changes In Egypt
Contact us

For detailed information about the CLIMP project, please contact:
Prof. Dr. Samir Afifi
Faculty of Science
Islamic university of Gaza
safifi@iugaza.edu.ps
Tel: +970 599 465665

Prof. Dr. Ralf Ludwig
Project coordinator
rludwig@lmu.de,
Tel: +49-89-21806677

Dr. Thomas Ammerl
Project management
ammerl@bayfor.de,
Tel: +49-89-990188817

Moe information available at www.climb-FP7.eu