Using GIS to Support Climate Change Impact Assessment

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Content

1. Climate Change Impact Assessment;
2. GIS;
3. Using GIS: Case Studies
Impact

- Climate change **Impacts** are the consequences of the changes in, and interactions between, our natural and human systems. The **impacts** depend on the **vulnerability** of these systems.

- An **impact** describes a specific change in a system caused by its **exposure** to climate change.

- **Impacts** may be refereed to be harmful or beneficial.
Climate Change Impact Assessment

- exposure
- sensitivity
- potential impact
- adaptive capacity
- vulnerability
Vulnerability?

- **Exposure**: Measured in terms of *climatic changes* and what is exposed to changes
- **Sensitivity**: Measured in terms of *socioeconomic* factors
- **Adaptive capacity**: Measured in terms of *infrastructure, technology, education* etc.

Vulnerability

Regional Workshop on Linking Regional Climate Model Projections to Hydrological Models, 26-28 June 2013...Beirut, Lebanon
The IPCC Technical Paper on *Climate Change and Water* (Bates et al., 2008) provides a comprehensive summary of projected changes in climate as they relate to water (excluding sea level):

1) Precipitation (Including Extremes and Variability) and Water Vapour;
2) Snow and Land Ice;
3) Evapotranspiration;
4) Non-Climate Drivers
Potential Impacts

1) Soil Moisture;
2) Changes in Runoff and Stream Flow;
3) Hydrological Impacts on Coastal Zones;
4) Water Quality Changes;
5) Changes in Groundwater;
6) Changes in Water Demand, Supply and Sanitation.
Relations between Human Activities and Fresh Water Resources

Population, life style, economy, technology...

Emission of GHGs

Land Use

Food Demand

Climate

Terrestrial part of hydrologic cycle (water quality, mean state and variability)

Water Use

Water Resources Management

- A Geographic Information System (GIS) is a system of software, hardware, data and personnel that visualizes, manipulates, analyzes and presents spatially linked information.

- A GIS combines layers of information about a place to give a better understanding of that place.

- Measurements of natural and human-made phenomena and processes taken from a spatial perspective are stored in digital form in a computer database.
Why use GIS?

1) Mapping
2) Measuring
3) Monitoring
4) Modeling
5) Managing

- GIS is about modeling and mapping places and things to assist people in better decision making.
Using GIS: Case Studies

- **Case Study 1:** Impact of Climate Change on Coastal Zone: Coastal Vulnerability Index-\(CVI\).
- **Case Study 2:** Impact of Climate Change on Coastal Zone: Flooding and Inundation.
- **Case Study 3:** Calculating and Revising Environmental Vulnerability Index \(EVI\).
- **Case Study 4:** Assessing Carbon Stocks Resulting from Agricultural Land-Use and Land-Cover Changes for the Period 1986 to 2008.
The Kingdom of Bahrain
Total Area 764Km²

48Km

18-21Km
The Kingdom of Bahrain

- The Kingdom of Bahrain is located in the southern part of the Arabian Gulf, approximately 25Km from the eastern coast of Saudi Arabia, between longitudes of 50° 16´ and 51° 00´ Easting and latitudes 25° 33´ and 27° 12´ Northing.

- The Kingdom represents a unique case of a small island developing country in the Arabian Gulf. It consists of an archipelago of more than thirty-six low-lying islands, numerous small islets, shoals and patches of coral reefs. The main islands occur in two groups of unequal size.
<table>
<thead>
<tr>
<th>Elevation (meter)</th>
<th>Area (Km)</th>
<th>%</th>
</tr>
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<tbody>
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<td>0-5</td>
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<td>54.4</td>
</tr>
<tr>
<td>&gt;&gt;5</td>
<td>341</td>
<td>45.6</td>
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</table>

Elevation (meter) Above Mean Sea Level
- Red: 0-5 meter
- Black: > 5 meter
The CVI (coastal vulnerability index) was developed and used to assess the vulnerability of the coastline of the Kingdom of Bahrain main islands to future SLR (sea level rise). A total of 717 km of the coastline was evaluated.

Six spatial factors acting on the coastal area: erosion/accretion patterns (shoreline change), topography (elevation above mean sea level), geology, geomorphology, slope, and mean sea level rise were incorporated and ranked to develop the CVI.

This index was classified into four levels of vulnerability: low, moderate, high, and very high.

Vulnerable hotspots are located along the central portions of the western and eastern coastlines.
Coastal Vulnerability Index
CVI

\[ CVI = \sqrt{\left( \frac{a \times b \times c \times d \times e \times f}{6} \right)} \]

a: Geology (rock type),
b: Coastal slope (degrees).
c: Geomorphology,
d: Elevation (shoreline exposure),
e: Shoreline change (m/yr.),
f: The relative sea-level rise (mm/yr.).
CVI: Costal Vulnerability Index

1. **Geology:** This corresponds to the rock or soil types along the shoreline;

2. **Geomorphology:** This corresponds to the type of landforms present (e.g., dunes, coastal structures);

3. **Rate of sea-level rise:** This corresponds to historical rates of seal level rise, measured in mm per year.

4. **Coastal slope:** This corresponds to the slope of the shoreline, measured in degrees;

5. **Elevation:** This corresponds to land height above mean sea level, measured in meters;

6. **Shoreline change:** This corresponds to historical erosion rates, measured in meters lost or gained per year (**DSAS:** Digital Shoreline Analysis System).
Geomorphology

Accretion Zone

Aeolian Sand with Dune Forms

Bedrock and Rock-thin Veneers

Coastal Plain and Sabkha surface

Mangrove

Patterned ground - Gypsum (salt pan)

Salt Pan

Sand and Gypsum over Playa Crust

Scarp

Settlements

Shell, Gravel and Sand platforms

Stone Pavements

Worked Ground

Fans and Piedmont Slope

Dilmun mounds
## Ranking of coastal vulnerability

<table>
<thead>
<tr>
<th>Variable</th>
<th>Ranking of coastal vulnerability</th>
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<tr>
<td></td>
<td>V. Low</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>Geology (rock type)</strong></td>
<td></td>
</tr>
<tr>
<td>a</td>
<td></td>
</tr>
<tr>
<td>Coastal slope (degrees)</td>
<td></td>
</tr>
<tr>
<td>b</td>
<td></td>
</tr>
<tr>
<td>Geomorphology</td>
<td></td>
</tr>
<tr>
<td>c</td>
<td></td>
</tr>
<tr>
<td>Elevation (m)</td>
<td></td>
</tr>
<tr>
<td>d</td>
<td></td>
</tr>
<tr>
<td>Shoreline change (m/yr.)</td>
<td></td>
</tr>
<tr>
<td>e</td>
<td></td>
</tr>
<tr>
<td>Mean sea level rise (mm/yr.)</td>
<td></td>
</tr>
<tr>
<td>f</td>
<td></td>
</tr>
</tbody>
</table>

- a: Deposits of unconsolidated sandy clay loams and Sabkhas
- b: Sandy shores backed by bedrock & artificial structures
- c: Sandy shores backed by dunes and plains
- d: 0.0 - 6.0
- e: 1.0 - 1.9
- f: 1.0 - 2.0
The total coastal length in each risk category

- **Low**: 607.7 Km (85%)
- **Moderate**: 22.22 Km (3%)
- **High**: 33 Km (5%)
- **V. High**: 51 Km (8%)
Case Study 2: Impact of Climate Change on Coastal Zone: Flooding and Inundation

- **Significant areas are in risk of inundation** due to SLR with direct and indirect consequences. Direct implications of SLR include possible loss of land to sea and disruption of socio-economic and ecological niches of submerged areas.

- **Nearly 26% of land area of Bahrain is potentially subjected to inundation due to 1.5m increase in sea level by 2100** (conservative estimate). Twenty two percent of this land loss would be in built-up areas compared to 63% of industrials’. This would result in substantial loss to society and economy of the country.
Surface elevation (meter) above mean sea level

DEM
Inundation
### Results of the long-term inundation scenario analysis

<table>
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<tr>
<th>Year</th>
<th>SLR</th>
<th>Total Area</th>
<th>Total %</th>
<th>SLR</th>
<th>Total Area</th>
<th>Total %</th>
<th>SLR</th>
<th>Total Area</th>
<th>Total %</th>
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<tr>
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<td>0.3m</td>
<td>83</td>
<td>11%</td>
<td>0.5m</td>
<td>84</td>
<td>11%</td>
<td>1m</td>
<td>188</td>
<td>25%</td>
</tr>
<tr>
<td>2100</td>
<td>1.5m</td>
<td>189</td>
<td>26%</td>
<td>2m</td>
<td>272</td>
<td>36%</td>
<td>5m</td>
<td>407</td>
<td>54%</td>
</tr>
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</table>
Case Study 3: Calculating and Revising Environmental Vulnerability Index for Kingdom of Bahrain 2009

- Environmental Vulnerability Index (EVI) is an analytical framework to understand the environmental vulnerability for all countries including Islands States.

- EVI describes the relative risk of the various types of environmental problems faced by individual nations.

- The EVI is based on 50 indicators which estimate the vulnerability of the country’s environment against any future shocks.
<table>
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<tr>
<th>المتغير</th>
<th>المؤشرات</th>
<th>المتغير</th>
<th>المؤشرات</th>
<th>المتغير</th>
<th>المؤشرات</th>
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<td>الأنواع المهاجرة</td>
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<td>X_{3}</td>
<td>الفترات الرطبة</td>
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<td>إنتاج النفايات</td>
<td>X_{21}</td>
<td>الأنواع الداخلة للمرة الأولى</td>
<td>X_{4}</td>
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<td>X_{22}</td>
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<td>X_{17}</td>
<td>اختلال توازن النظام البيئي</td>
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</tbody>
</table>
There are three distinct aspects of vulnerability: the risks associated with hazards, resistance, and acquired vulnerability (damage).

Each indicator includes a group of sub-indices to provide a good characterization of environmental vulnerability.

Those sub-indices are seven and they are:

- climate change,
- exposure to natural disasters,
- biodiversity,
- desertification,
- water,
- agriculture and fisheries, and
- human environmental health.
- Geographic information systems (GIS) was used as one of the most important tools to determine the size of hazards, vulnerability and environmental damage to create a digital maps using the results of: Environmental Vulnerability Index, the three aspects of vulnerability, and the seven sub-indices for each governorate.

- Those maps helped to identify, analyze and assess the areas at risk from human activities and natural activities in a very simple an logic ways.
دليل قابلية التأثر البيئي

خرائط رقمية لمظاهر دليل قابلية التأثر البيئي

مظهر قابلية التأثر: الأخطار

دليل قابلية التأثر البيئي
الدليل الفرعي: تغير المناخ

الدليل الفرعي: التعرض للمخاطر الطبيعية
الدليل الفرعي: التنصير

التنوع البيولوجي
الدليل الفرعي: المياه

الدليل الفرعي: مصائد الأسماك والزراعة
الدليل الفرعي: مظاهر الصحة البشرية
Case Study 4: Assessing Carbon Stocks Resulting from Agricultural Land-Use and Land-Cover Changes in The Kingdom of Bahrain for The Period 1986 To 2008

- This study aimed at assessing changes in carbon stocks resulting from land-use and land cover (LULC) changes in the Kingdom of Bahrain for the period 1986 to 2008.
- The methods described by The Intergovernmental Panel on Climate Change were used in this study.
- The study was divided into two time periods. For the first period Landsat Images for the years 1986, 1990 and 1998 was used, and for the second period, Quick Bird Images for the year 2002 and IKONOS Images for 2004 and 2008 were used.
- Results of the study showed a significant reduction in agricultural lands area. that agricultural lands played a significant role in carbon storage.


\[ \Delta C_{\text{CONVERSION}} = \sum_{i} \{(B_{\text{AFTER} \ i} - B_{\text{BEFORE} \ i}) \times \Delta A_{\text{TO-OTHERS} \ i}\} \times CF \]

حيث:

التغيير الأولي في مخزون الكربون بالكتلة الحيوية في الأراضي المتغيرة إلى فئة استخدام أخرى، طن كربون/عام.

\[ \Delta C_{\text{CONVERSION}} = \]

مخزون الكتلة الحيوية في نوع الأراضي مباشرة بعد التغيير، طن مادة جافة هكتار.

\[ = B_{\text{AFTER} \ i} \]

微妙ترة قبل التغيير، طن مادة جافة هكتار.

\[ = B_{\text{BEFORE} \ i} \]

مساحة فئة الاستخدام المتغيرة إلى فئة أخرى في عام معين، هكتار/عام.

\[ = \Delta A_{\text{TO-OTHERS} \ i} \]
التغير في مساحات استخدامات الأراضي والغطاء الأرضي في 1986-2008

اتجاه وكميات التغير في استخدامات الأراضي والغطاء الأرضي المختلفة في 1986-2008

التغير في مساحات استخدامات الأراضي والغطاء الأرضي في 1986-2008

اتجاه وكميات التغير في استخدامات الأراضي والغطاء الأرضي المختلفة في 1986-2008

النوداء
- 5.88
- 3.66
- 60.86
- 25.14

الرطبة
- 7.27
- 9.32
- 44.78
- 21.82

السماكة
- 28.89
- 6.35
- 28.89
- 6.35

الزراعة
- 0.85
- 2.44
- 31.03
- 2.39
التغير الأولي في مخزون الكربون بالكتلة الحيوية في الأراضي الزراعية المحولة إلى فئة استخدام أخرى

التغير الأولي في مخزون الكربون بالكتلة الحيوية بالأراضي الزراعية المحولة إلى أراضي رطبة ومبنيَّة وجرداء

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Thank You

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