Example Applications of the Use of Remote Sensing and GIS for Assessing Climate Change Impacts and Exploring Water Resources in the MENA Region

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Impact of Climate Change:

- Flood Inundation
- Coastal Erosion
- Drought
RS & GIS for Flood Inundation

Flood is a rising and overflowing of water onto land that is normally dry
Digital Elevation Model (DEM)

1. Scanned topographic maps (Contour lines & spot heights)

2. Global Positioning Systems (GPS) total station survey (RTK-GPS)

3. Airborne & Spaceborne Remote Sensing

- **LiDAR** (Light Detection And Ranging). *Very high spatial res (cm)*
- **SRTM** (Shuttle Radar Topography Mission). Low-Moderate spatial res (90m)
- **ASTER GDEM2** (Advanced Spaceborne Thermal Emission and Reflection Radiometer). Moderate-high spatial res (30m)
4. Stereo-Pair Satellite Images

1m DEM Extracted from Stereo IKONOS Satellite Image data at 0.6m resolution

Sahara Desert - Southern Tunisia
Land Use Land Cover (LULC) Decision Tree Classification algorithm
Digital Elevation Model (DEM)

DEM & 1m SLR

Land Use Land Cover & 1m SLR

land cover types that could potentially be lost to rising sea levels.
Hydrological Delineation

1. DEM
2. FLOWDIRECTION
3. SINK

Are there any pits?

- Yes → Fill
- No → Delineate stream network

Delineate Watersheds

Watershed
Basins

Delineate stream network

FLOWACCUMULATION

Stream network = \text{con} (\text{flowacc} \geq 5,000, 1)

Stream Line
Stream Link
Stream Order
USGS - 50-year Flood Inundation Map and Digital Orthophoto of Choloma, Honduras
RS & GIS for Coastal Erosion

Coastal erosion is the wearing away of land and the removal of beach by wave action, tidal currents or drainage.
RS is used to automatically extract different shoreline positions from the mid-infrared channels of large series of satellite images.

These shorelines are used to calculate the rate of coastal change in the GIS environment.
- The tip of the promontory had an average retreating rate of \(~137\, \text{m/y}\) before the construction of the 5-km-long seawalls.

- This large rate has been terminated after the coastal protection.
Based on the computed rate of coastal change it is possible to predict future shoreline positions.

1) Predict where the coastline could have been today had the seawalls not been constructed in 1991.

2) Project where today’s coastline could potentially be in 2030 if efforts are not made to preserve the shoreline of the Nile Delta.
RS & GIS for Drought

Drought is a period of unusually dry weather that persists long enough to cause environmental or economic problems.
The development of Earth observation satellites from the 1980s onwards equipped with optical sensors opened a new path for drought monitoring and detection.
## Sensors used in Drought Risk Analysis

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Spatial Resolution (meters)</th>
<th>Coverage (raw data)</th>
<th>NDVI Product (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landsat</td>
<td>30</td>
<td>(1972 – pres)</td>
<td>No ready production (generated by user)</td>
</tr>
</tbody>
</table>
| MODIS     | 250, 500 & 1000            | (1999 – pres)       | 250 (16 days)  
|           |                            |                     | 500 (16 days)  
|           |                            |                     | 1000 (16 days & Monthly) |
|           |                            |                     | 4000 (16 days) - (2009 – 2013)  
|           |                            |                     | 16000 (weekly) – (1981 – present) |

### MODIS: Moderate Resolution Imaging Spectro-Radiometer

- **Spacecraft**: Has 2 instruments (carry by Terra and Aqua)
- **Launched**: Terra > 1999, Aqua > 2002
- **Swath width**: 2330 km
- **Spatial resolution**: 250 m – 1 km
- **Spectral resolution**: 36 spectral bands (0.405 - 14.835 μm)
- **Temporal resolution**: daily
- **Radiometric resolution**: 12-bit (0-4095)
Vegetation Index

High: 0.896
Low: -0.1967

MODIS

AVHRR

(250 m)

(1 km)

(16 km)
MODIS data at a 1km spatial resolution provides more detailed representation of landscape temperature.
Risk Map (Hot Spots)

- Coastal Erosion
  - Shorelines Erosion Map (Input from RS, GIS)
- Flooding Inundation
  - Coastal Inundation Map (Input from RS, GIS)
  - Riverine Inundation Map (Input from RS, GIS, RHM)
- Drought Severity
  - Remote Sensing Drought Index (Input from RS)
  - Metrological Drought Index (Input from RCM)

- Multiple Hazard Map
- Population (Density & Rate of Growth)
- Land Use Land Cover (Residential, Agriculture, Infrastructure)

Overall Risk Map (Hotspots)
RS and GIS for Water Resources
Prehistoric stone tools and extensive rock paintings indicate that the Sahara was once green and experienced wetter climate in the past.
During these wet periods the Sahara surface was veined by rivers and dotted by large lakes.

Much of their water would have been seeped and recharged the regional groundwater aquifers.

Presently, the courses of these rivers and lakes are mostly buried beneath the Sahara sands.
The Electromagnetic Spectrum

<table>
<thead>
<tr>
<th></th>
<th>Wavelength (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UV</td>
<td>0.4</td>
</tr>
<tr>
<td>BLUE</td>
<td>0.5</td>
</tr>
<tr>
<td>GREEN</td>
<td>0.6</td>
</tr>
<tr>
<td>RED</td>
<td>0.7</td>
</tr>
<tr>
<td>IR</td>
<td>1.0</td>
</tr>
</tbody>
</table>

1000 µm = 1 mm
SRTM is an active radar system that operates in the C-Band of the microwave region.

And thus has the capability to penetrate the Sahara sands and map the subsurface terrain*.

500 wells have been drilled to water wheat, chickpeas and other crops.

The proven water resources are estimated to be capable of supporting agriculture over **150,000** acres for at least **100** years.

Ghoneim et al., 2007. 

This research was started by identifying an arcuate linear feature in the Landsat image. This feature is shown in Radarsat-1 image as an intact line zone of 1 km wide with four parallel lines.

In the SRTM data this linear feature is shown as a terrace with a height of 3-6m at an altitude of ~573m asl.
At its maximum extent, the MegaLake would have occupied an area of about 30,750 km² (larger than the area of lake Erie in North America) and would have contained ~2530 km³ of water when it was filled in the past.
If the soil is wet, much of the incident sunlight’s energy is used up in evaporating the water, which cools the soil surface since water absorbs a large quantity of heat as it turns into vapor.
The figures shows:

- The persistence of the cooler anomaly for several days.
- The drop of the surface temperature by 20 °C below the ambient temperature of the surrounding.

In view of the results of this study:

- A geophysical research conducted by the University of Rolla-Missouri has conclusively confirmed the presence of the suggested fault beneath the desert sand.

- Schlumberger company, which was hired by the Sharjah Electricity and Water Authority (SEWA), has so far drilled a total of 23 wells in the cooler anomaly site that currently supply freshwater to the population of the city of Sharjah.
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