Climate Change, Land Degradation and Food Security in Iraq – An Integrated Assessment Using Space Technology

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1. Background: Problems
Why do we need such research?

- Climate change, leading to unfavourable impacts on water resources ($T \uparrow$ and $P \downarrow$) which would further lead to decline of crop production;
- Land degradation, especially, salinization, the common problem in dryland environment, has caused reduction of land productivity and cropland abandonment and hence reduction in crop yield;
- Harsh challenge in food security in future in dryland countries and regions.

Case study: Mesopotamia, Iraq
70% of the land receives annual RF <250mm
Known as the land between two rivers:
- 75% of the total cultivated land
- About 75% of crop production

Problem: salinization since Babylonian period (2300BC)
Salt makes land poisonous and harmful for crops.
Climate change

IPCC (2007) projected climate change in Western Asia including Iraq in 2080/90 in comparison with that of 1980/1990:
- $T$ increase by 2°C with high probability of 0.99
- $P$ decrease by 0.1mm/day

This means water resources ↓ and Evaporation ↑, rainfed agriculture will become no longer possible in some areas. Crop production and food security will be faced with challenge.
Objectives

• To investigate impacts of land degradation, in particular, salinization in space and time;
• To understand the impacts of climate change with higher resolution datasets;
• To conduct an integrated assessment on food security by space technology.

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2. Method and Results

2.1 Multiscale and multitemporal salinity mapping by remote sensing

1) Field sampling (EM38 measurement, soil sampling, AccuPAR reading) in Mesopotamia

<table>
<thead>
<tr>
<th>Sites</th>
<th>Soil Profile (0-100cm)</th>
<th>Surface Soil Samples (0-30cm)</th>
<th>EM38</th>
<th>AccuPAR Mar-Apr 2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Musaib</td>
<td>13</td>
<td>30 (Jul 2011-Apr 2012)</td>
<td>45</td>
<td>23 (Jun-Jul 2012)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 (Supplemental Jun-Jul 2012)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dujaila</td>
<td>5</td>
<td>17 (Jul 2011-Apr 2012)</td>
<td>65</td>
<td>17 (Jun-Jul 2012)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 (Supplemental Jun-Jul 2012)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>West Garraf(Italian)</td>
<td>22</td>
<td>4 (Jul 2011-Apr 2012)</td>
<td>57</td>
<td>17 (Jun-Jul 2012)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 (Supplemental Jun-Jul 2012)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shat-Al-Arab</td>
<td>4</td>
<td>16 (Jul 2011-Apr 2012)</td>
<td>54</td>
<td>36 (Jun-Jul 2012)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Supplemental Jun-Jul 2012)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transects</td>
<td></td>
<td>165 (Total)</td>
<td>485</td>
<td>204 (Total)</td>
</tr>
<tr>
<td>Transect 1</td>
<td>20</td>
<td></td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Transect 2</td>
<td>44</td>
<td></td>
<td>132</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>27</td>
<td></td>
<td>485</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>204</td>
<td></td>
</tr>
</tbody>
</table>
2) Satellite image processing (Landsat ETM+, RapidEye and SPOT) including atmospheric correction using FLAASH model.

3) Multispectral transformation to derive different **vegetation indices** such as NDVI, EVI, SARVI, SAVI; and **non-vegetation indices** such as NDII, PC1, 2, Tasseled Cap Brightness, and spring Surface Temperature (ST, only for Landsat ETM+).

We introduced a new vegetation index, GDVI -- Generalized Difference Vegetation Index, developed by Wu (2012) for this study.

**Why GDVI?**

The mechanism behind is that through power, the vegetation information in near infrared band gets more amplified in comparison with red band. For low vegetation cover, especially, dryland, GDVI is more sensitive than any other vegetation index.
\[ GDVI = \frac{\rho_{NIR}^n - \rho_R^n}{\rho_{NIR}^n + \rho_R^n} \]

where \( \rho_{NIR} \) and \( \rho_R \) are respectively reflectance of the near infrared (NIR) and red (R) bands, and \( n \) is power number. The dynamic range of GDVI is the same as NDVI from -1 to 1; and when \( n = 1 \), GDVI = NDVI.

When \( n = 2 \), GDVI^2 = \[ \frac{\rho_{NIR}^2 - \rho_R^2}{\rho_{NIR}^2 + \rho_R^2} \]

When \( n = 3 \), GDVI^3 = \[ \frac{\rho_{NIR}^3 - \rho_R^3}{\rho_{NIR}^3 + \rho_R^3} \]

When \( n = 4 \), GDVI^4 = \[ \frac{\rho_{NIR}^4 - \rho_R^4}{\rho_{NIR}^4 + \rho_R^4} \]
4) Derivation of the maximum multiyear VIs and Non-VIs for the period e.g., 2009-2012 (this is only applicable for Landsat imagery)

**Why do we need this procedure?**
- To fill the gaps of Landsat ETM+ imagery and
- To avoid crop rotation and fallow (previous studies did not consider this)

5) Salinity models development for pilot sites by coupling remote sensing indicators with field measurements by linear least-square regression analysis
# Salinity models developed from pilot sites: Musaib

<table>
<thead>
<tr>
<th>Vegetated Area</th>
<th>Multiple R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>EM_V = -824.134 + 918.536GDVI - 754.204ln(GDVI) ± 41.7</td>
<td>0.925</td>
</tr>
<tr>
<td>EM_H = -606.197 – 460.043ln(GDVI) + 245.086exp(GDVI) ± 48.559</td>
<td>0.862</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Non-Vegetated Area</th>
<th>Multiple R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>EM_V = 2570683.24 + 1821.24ST - 546476.07ln(ST) ± 62.944</td>
<td>0.829</td>
</tr>
<tr>
<td>EM_H = 2608853.46 + 1842.4ST - 554286.69ln(ST) ± 51.217</td>
<td>0.846</td>
</tr>
</tbody>
</table>

Note: EM_V and EM_H – are respectively vertical and horizontal readings of EM38; ST – multiyear maximum spring surface temperature in K; GDVI – Generalized Difference Vegetation Index
Relationships between EM 38 readings and soil lab EC

based on field measurement and lab analysis in the Mesopotamian Region
Salinity maps of pilot sites

Salinity (EC) in dS/m
- High: 118.42
- Low: 0
- Village

Kilometers
Verification Accuracy: $R^2 = 0.811$
The graph shows the relationship between EC measured on ground and EC estimated by RS, with the equation:

\[ y = 0.8087x + 2.1627 \]

The coefficient of determination, R², is 0.8087.

The map indicates salinity levels in dS/m, with color coding for high and low salinity areas. The locations of field soil EC and Dujaila are also marked.
Regional salinity models

For vegetated areas:
\[ EM_V = 66.338 -258.114 \ln(GDVI) \pm 88.882 \]
(multiple R² = 0.717)

Non-Vegetated areas:
\[ EM_V = 2874415.66+2.035.443 \times ST -610991.724 \ln(ST) \pm 97.653 \]
(multiple R² = 0.662)

Upscaling test
Models developed from high resolution data such as Landsat, RapidEye and SPOT needs a upscaling test, that is to say, to check whether these models are applicable to MODIS data.

Result reveals the these models are applicable (R²= 0.88).
Regional salinity maps

Strongly salinized area (EC >15 dS/m) has increased at a rate of 804km²/yr!!!
2.2 Population growth and crop production

[Graph showing population growth rate from 1960 to 2011, marked with red boxes around specific years.]

Data from World Bank  Last updated: Sep 6, 2012
2.3 Winter T change and its influence on cereal production
3. Food Security

Although more field validation is necessary, cropland decrease due to extending salinity, winter T increase leading to reduction of cereal production (insects can not be killed due to warm winter), and on the contrary, population grows steadily in the country requiring more food supply. Hence, food security is becoming a harsh challenge (the shortage simulation is to be completed in the following months).
4. Summary

Despite this study is still on going (not yet complete), this case study demonstrates the usefulness and power of space technology in assessing land degradation, climate change, and their impacts on food security in dryland countries or regions.

Thank you for your attention!