Monitoring and Mapping Desertification Sensitive Areas along Nara Canal, Pakistan using GIS & RS

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Contents

- Desertification and Pakistan
- Study Area and Objectives
- Material and Methods
- Processing of Data
- Results and Discussions
- Conclusions and Recommendations
Desertification

- Desertification is the degradation of land in progressive environments of desolate areas, in which productive land becomes desert.

- According to UNCOD, annually 6 million ha of crop land lost worldwide, and converted into barren land.

Desertification in Pakistan

- Pakistan is facing dreadful conditions of land degradation, creating the following major problems:
  - Soil erosion
  - Loss of soil productiveness
  - High floods
  - Environmental degradation
  - Biodiversity loss
  - Deforestation
Study Area

- Study area shown in red boundary covers the upper part of Thar Desert, which includes the vegetative part along the Nara Canal.

- Most part of the study area lies in Khairpur district, while a small portion lies in Sukkur and Nawabshah districts of Sindh province.
Study Objectives

- To investigate temporal variations in desertification in the proposed study area using Landsat images
- To analyze changes between land cover features and to develop base-line desertification maps
- To exploit the potential of GIS&RS for desertification monitoring.
Material and Methods
Data Used

- Landsat Images
- Google Earth Images
- GPS Survey / Ancillary Data

Software Used

- ERDAS Imagine 9.1
- eCognition Developer 7
- ArcGIS 9.3
- Microsoft Excel and Word
Work Flow Diagram
Object-Based Image Analysis (OBIA)

OBIA technique decomposes the image into numerous homogenous objects that can also refer to as segments.

Segmentation

Segmentation is a process of representing an image into its smaller image objects.

Multi-resolution Segmentation

The process of group’s areas of homogeneous pixel values into objects is called Multi-resolution segmentation

- Similar areas result in larger objects
- Non similar areas in smaller objects

This is the most common and popular segmentation algorithm.
Parameters of Segmentation

Algorithm Description
Apply an optimization procedure which locally minimizes the average heterogeneity of image objects for a given resolution.

Algorithm parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overwrite existing level</td>
<td>Yes</td>
</tr>
<tr>
<td>Level Settings</td>
<td></td>
</tr>
<tr>
<td>Level Name</td>
<td>level1</td>
</tr>
<tr>
<td>Segmentation Settings</td>
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</tr>
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<td>Image Layer weights</td>
<td>1.1, 1.1, 2.2, 1</td>
</tr>
<tr>
<td>Thematic Layer usage</td>
<td></td>
</tr>
<tr>
<td>Scale parameter</td>
<td>10</td>
</tr>
<tr>
<td>Composition of homogeneity criterion</td>
<td></td>
</tr>
<tr>
<td>Shape</td>
<td>0.1</td>
</tr>
<tr>
<td>Compactness</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Loops & Cycles

- Loop while something changes only
- Number of cycles: 1
Rule Set Development

Rule sets are built up from single process, which are displayed in the Process Tree.

A single process can operate on two levels:

- at the level of image objects
- at the pixel level

Process will run sequentially through each target, applying an algorithm to each.
### Process tree of rule set

<table>
<thead>
<tr>
<th>Rule ID</th>
<th>Conditions</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>04.103</td>
<td>10 [shape:0.1 compct.:0.5] creating 'level1'</td>
<td></td>
</tr>
<tr>
<td>04.336</td>
<td>2 [shape:0.1 compct.:0.5] creating 'level3'</td>
<td></td>
</tr>
<tr>
<td></td>
<td>with ndvi &gt;= 0.01 and ndvi &lt;= 0.03 at Level3: Grasses\Bushes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>with ndvi &gt;= 0.17 and ndvi &lt;= 0.22 at Level3: Agriculture</td>
<td></td>
</tr>
<tr>
<td></td>
<td>with ndvi &gt;= 0.24 and ndvi &lt;= 0.5 at Level3: vege1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>with ndvi &gt;= 0.13 and ndvi &lt;= 0.1647 at Level3: vege2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>with ndvi &gt;= 0.22 and ndvi &lt;= 0.2302 at Level3: vege2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>with ndvi &gt;= 0.2304 and ndvi &lt;= 0.2397 at Level3: vege2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>with ndvi &gt;= 0.34 and ndvi &lt;= 0.59 at Level3: Water</td>
<td></td>
</tr>
<tr>
<td></td>
<td>unclassified with ndwi &gt;= 0.1393 and ndwi &lt;= 0.1568 at Level3: Water</td>
<td></td>
</tr>
<tr>
<td></td>
<td>unclassified with ndwi &gt;= 0.2179 and ndwi &lt;= 0.2186 at Level3: Water</td>
<td></td>
</tr>
<tr>
<td></td>
<td>unclassified with ndwi &gt;= 0.1807 and ndwi &lt;= 0.1835 at Level3: Water</td>
<td></td>
</tr>
<tr>
<td></td>
<td>unclassified with ndwi &gt;= 0.2362 and ndwi &lt;= 0.2442 at Level3: Water</td>
<td></td>
</tr>
<tr>
<td></td>
<td>unclassified with Name: water1 &gt; 0 and Name: water1 &lt;= 1 at Level3: water1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>unclassified with Mean Layer 4 &lt; 65535 at Level3: Soil</td>
<td></td>
</tr>
<tr>
<td></td>
<td>unclassified with ndvi &lt;= -0.02 and ndvi &gt;= -0.08 at Level3: Sparse Arva\Salvadora</td>
<td></td>
</tr>
</tbody>
</table>
Classification

Classification is the process of assigning pixels of a continuous raster image to predefined classes:

- Classification algorithm was run on the Landsat Dataset and thematic map was generated by using output from the classification.

- The output classified image was recorded and each land cover class area was calculated.
Classified Image

Class Name

- Wet Soil / Sand Dunes
- Sand / Soil
- Water
- Grasses / Bushes
- Sparse Arva / Salvadora
- Sand/Soil
- Vegetation 1
- Vegetation 2
- Vegetation 3
- Vegetation 4
- Agriculture Fields
Ground Truthing

- Ground truthing is important in order to relate Digital Number (DN) values of satellite image data to the ground features.

- It correlates the reflectance values of the satellite image with the ground realities.

- GPS coordinates of the training samples are used for land cover mapping.

- For the ground truth data collection, a field visit was conducted by WWF-Pakistan.

- During the survey more than 90 field observation points were collected.

- Forest patch was observed during the land cover survey.
Survey Points on Satellite Images
Results and Discussions
## Temporal Changes in the Land Covers

<table>
<thead>
<tr>
<th>Land Cover Classes</th>
<th>Area (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>26-Jul-92</td>
</tr>
<tr>
<td>Sparse Forest/Reeds</td>
<td>230.49</td>
</tr>
<tr>
<td>Sparse Arva/Salvadora</td>
<td>289.62</td>
</tr>
<tr>
<td>Agriculture Fields</td>
<td>97.3</td>
</tr>
<tr>
<td>Grasses/Bushes</td>
<td>70.42</td>
</tr>
<tr>
<td>Soil/Sand</td>
<td>1,557.84</td>
</tr>
<tr>
<td>Water</td>
<td>27.45</td>
</tr>
<tr>
<td>Total</td>
<td>2273.12</td>
</tr>
</tbody>
</table>
LU/LC Map - 1992

Land Cover derived from 1992 satellite data

Legend
- Study Area
- River
- District Boundary
- Provincial Boundary

Land Cover Classes
- Sparse Forest/Reeds
- Sparse Arva/Salvadora
- Agriculture
- Grasses/Bushes
- Soil/Sand
- Water

Soil / Sand: 69%
Agriculture: 4%
Grasses/Bushes: 3%
Sparse Forest/Reeds: 10%
Sparse Arva/Salvadora: 13%
Water: 1%
LU/LC Map - 2001

Land Cover derived from 2001 satellite data

Legend
- Study Area
- River
- District Boundary
- Provincial Boundary

Land Cover Classes
- Sparse Forest/Reeds
- Sparse Arva/Salvadora
- Agriculture
- Agriculture
- Grasses/Bushes
- Sparse Forest/Reeds
- Soil/Sand
- Water

Data Source
Satellite Image: Landsat 5-TM
Acquisition Year: 2001
LU/LC Map - 2011

- Water: 2%
- Agriculture: 8%
- Grasses/Bushes: 4%
- Sparse Forest/Reeds: 5%
- Soil/Sand: 71%
- Sparse Arva/Salvadora: 10%

Land Cover derived from 2011 satellite data

Legend:
- Study Area
- River
- District Boundary
- Provincial Boundary

Land Cover Classes:
- Sparse Forest/Reeds
- Sparse Arva/Salvadora
- Agriculture
- Grasses/Bushes
- Soil/Sand
- Water

Data Source:
- Satellite Image: Landsat 5-TM
- Acquisition Year: 2011
## Land covers change statistics

<table>
<thead>
<tr>
<th>Land Cover Class</th>
<th>Exist in 1992 (km²)</th>
<th>Exist in 2011 (km²)</th>
<th>No change (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest</td>
<td>88.21</td>
<td>42.21</td>
<td>78.55</td>
</tr>
<tr>
<td>Agriculture</td>
<td>84.00</td>
<td>102.39</td>
<td>77.30</td>
</tr>
<tr>
<td>Soil</td>
<td>139.81</td>
<td>181.13</td>
<td>1417.59</td>
</tr>
<tr>
<td>Water</td>
<td>8.41</td>
<td>18.35</td>
<td>18.58</td>
</tr>
</tbody>
</table>
Land covers and their temporal changes
1. Forest Cover

Forest cover of the study area shows the decreasing trend in the past 20 years. Moreover;

- In 1992, total forest cover was almost 10 % of the study area
- Current forest cover estimate almost 5 % of the study area
- About 42% of forest cover has been vanished from 1992 to 2011

Loss of the forest in these patches may be due to:

- Drought
- Demand of food
- Increase in population
- Poverty
- Low productivity on rangelands
- Wood for fuel
- Cutting but not the replantation of trees
- Grazing rangeland pressure
Consequences of Deforestation

- This deficiency of forests results in widespread wind erosion and the microclimate becomes more and more arid.

- The dry season becomes more accentuated and rainfall decreases.

- These factors made a chain, interconnected to the various social, economic and ecological issues.
2. Land Soil

- Land-soil of the study area exposed gradually so the bare area increases
- About 181 km$^2$ of soil has been increased in last two decades
- This increase in soil may be due to decrease in forest cover, which leads the land to desert

This increase in land soil:
- leads the land to wind erosion
- reduces the soil fertility
- is responsible of exclusive erosion.

This erosion produces reduction in carbon storage in soil, which results global warming and biodiversity loss.
Forest conversion to soil

*Source*: Google Earth
3. Agriculture Land

Agriculture land increases day by day in the result of forest cutting;

- about 102 km\(^2\) land of agriculture has been increased
- few low lands (tarais) have been converted into agricultural fields.
Tarai that has been transformed into Agriculture Land

October, 2006

May, 2010

Source: Google Earth
4. Water

According to statistics about 18 km² of water has been increased;

- This increase in water may be resulted from heavy monsoon rains in 2010 and 2011
- These heavy rains cause floods in most of the part of Khairpur district
Water Scarcity

Images show that some of the lakes have been dried.

Source: Google Earth
Conversion of Forest into Agriculture

Sample Area 1

Sample Area 2

1992 2011
Conversion of Soil into Agriculture

Sample Area 1

Sample Area 2
Conversion of Forest into Soil and Grasses/Bushes

Sample Area 1

Sample Area 2
Accuracy Assessment

- Accuracy Assessment was done by comparing a sample of the reference data and the output results generated by the classifier.
- Error matrix was used.
- Assessment of accuracy was conducted by using GCPs in ERDAS Imagine.
## Classification Error Matrix

<table>
<thead>
<tr>
<th>Classified Data</th>
<th>Water</th>
<th>Agriculture</th>
<th>Grasses/Bushes</th>
<th>Sparse Forest/Reeds</th>
<th>Soil/Sand</th>
<th>Sparse Arva/Salvadora</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Agriculture</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Grasses/Bushes</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sparse Forest/Reeds</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Soil/Sand</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>44</td>
<td>7</td>
</tr>
<tr>
<td>Sparse Arva/Salvadora</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>11</td>
</tr>
</tbody>
</table>
## Overall Accuracy

<table>
<thead>
<tr>
<th>Class Name</th>
<th>Reference Total</th>
<th>Classified Total</th>
<th>Number Correct</th>
<th>Producers Accuracy (%)</th>
<th>Users Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Agriculture</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Grasses/Bushes</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Sparse Forest/Reeds</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>33.33</td>
<td>100</td>
</tr>
<tr>
<td>Soil/Sand</td>
<td>45</td>
<td>53</td>
<td>44</td>
<td>97.78</td>
<td>83.02</td>
</tr>
<tr>
<td>Sparse Arva/Salvadora</td>
<td>18</td>
<td>12</td>
<td>11</td>
<td>61.11</td>
<td>91.67</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>72</strong></td>
<td><strong>72</strong></td>
<td><strong>62</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Overall Accuracy

The Overall Classification Accuracy  =  90.91%

The Overall Kappa (K) Statistics  =  0.8623

Kappa ranges from 1 (accurate) to 0 (inaccurate):

- K is less than 0.4, it is poor agreement
- K is between 0.4 and 0.7, it is good agreement
- K is greater than 0.7, it is excellent agreement

The Kappa coefficient of (0.8632) is highly accurate, and the general acceptable accuracy limit is ≥ 85%.
Conclusions

- Desertification in Nara desert proceeded gradually from 1992 to 2011:
  - Area of sand/soil expanded up to 3%
  - Vegetation cover decreased by about 4.7% in the whole study.

- Few areas show forest loss, increase in soil/sand, decrease in desertic vegetation, Intensive agricultural land use is higher:
  - Some of the forest land has been transformed into the agriculture land
  - This shows that in future this land could be completely desertified and converted into bare land.

- Vegetation productivity loss increases:
  - Poverty
  - Reduces carbon storage in soil.

- This contributes to global warming and loss of biodiversity.
Recommendations

For detailed interpretation/identification of desertification it is suggested:

- to arrange extensive ground measurements for better evaluation of desertification.
- to address land desertification through multidisciplinary approach based on scientific principles.
- SAR imageries would also be highly useful for such investigations.

Technological improvements and new approaches are required to reverse land degradation.
References


Verstraete M., (1986), Defining desertification, a review, Climatic Change, 5-18


Thank you