DROUGHT ASSESSMENT USING SATELLITE DERIVED METEOROLOGICAL PARAMETERS AND NDVI IN POTOHAR REGION

Researcher: Saad-ul-Haque
Supervisor: Dr. Badar Ghauri

Department of RS & GISc
Institute of Space Technology
Karachi Campus
Overview

- What is Drought
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- Study Area
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- Problem Statement
- Dataset
- Methodology
- Results
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What is Drought?

A natural hazard and is a part of climatic condition for all regions of the world

- Condition of moisture deficit caused by a certain climatic conditions occurring at a specific location for a specific duration
- Stems from the lack of precipitation, precipitation deficiency for a season, a year or longer
- Triggered, when water supplies become insufficient to meet the requirements
Pakistan in Historical Perspective

- During 1999-2000
  - 2.21 million people population affected
  - 23.51 million livestock

- A weak drought developed in mid-2009 to mid-2010
  - Resulting 30% below normal monsoon rains in northern area.
  - 2.5% drop in crop yield (Wheat)

Pakistan Metrological Department & Agricultural Statistics of Pakistan 2010-11
Drought Stages

Natural Climate Variability

Precipitation deficiency (amount, intensity, timings)

Reduced infiltration, runoff, deep percolation, and ground water recharge

High temperature, high winds, low relative humidity, greater sunshine, less cloud cover

Increased evaporation and transpiration

Soil water deficiency

Plant water stress, reduced biomass and yield

Plant water stress, reduced biomass and yield

Economic Impacts

Social Impacts

Environmental Impacts

Meteorological Drought

Agricultural Drought

Hydrological Drought

Study Area

- The Barani (rainfed) Land covers the Salt Range and the Pothohar Plateau
- The climate is semi-arid and sub-tropical
- There is no means of canal irrigation system in this area and the agriculture primarily depends on the amount of rainfall
- Being hilly in nature the water retention is limited due to peculiar drainage pattern of Potohar region
- In the past, several droughts have experienced in this area that left a drastic agricultural and socioeconomic impact
Problem Statement

- The study area is more vulnerable to short term droughts especially in winters due to the absence of Western Depression
- Anomaly of temperatures, humidity and increasing solar flux also accelerate the reduction of water content in soil and atmosphere
- Occurrence of such conditions and prolonged absence of regular rainfall lead to drought conditions, affecting crop yields and thus economy of the country

Objectives

- Utilization of Geo-spatial techniques (RS & GIS) for Drought monitoring, as a cost effective and precise option compared to traditional approaches
- Identification and assessment of drought severity and anomalies in the Potohar region during 2009-2010
- Delineation of significant meteorological parameters that may contribute to the occurrence of short term meteorological droughts.
- Development of spatial extent of drought severity map that can help to identify the most affected area in a region.
Dataset used:
MODIS NDVI Product

- Moderate Resolution Imaging Spectroradiometer (MODIS) Terra Normalized Difference Vegetation Index (NDVI) product (MOD13Q1)
- The dataset having resolution of 250 meters
- The data has 16 days temporal resolution
- Total 303 images were obtained for the period from Feb 2000 to Mar 2013

NCEP Meteorological Data

- Satellite data from “National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR)”.
- The global atmospheric resolution is approximately 38 km, extending to 0.5° beyond the tropics.
- Meteorological data includes:
  - Precipitation
  - Maximum Temperature,
  - Minimum Temperature,
  - Humidity,
  - Solar Radiation
Methodology
Identification of Drought period

- The multi temporal images in NDVI for year 2002 to 2013 were stacked into a single imagery.
- The 13 year collective NDVI image was used to obtain temporal signature of minimum, maximum, and mean NDVI values.
- The signatures showing NDVI trend and deviation from mean NDVI was plotted.
MEAN NDVI (Winter Season)
Vegetation Condition Index (VCI)

- The VCI is a pixel-wise normalization of NDVI that is useful for making relative assessments of changes in the NDVI signal by filtering out the contribution of local geographic resources to the spatial variability of NDVI.

- It shows how close the NDVI of the current month is to the minimum NDVI calculated from the long-term record.

- \[ \text{VCI}_j = \frac{(\text{NDVI}_j - \text{NDVI}_{\text{min}})}{\text{NDVI}_{\text{max}} - \text{NDVI}_{\text{min}}} \times 100 \]

Where,

- NDVI max and NDVI min are calculated from the long-term record (e.g., 23 years) for that month (or week)

- The vegetation condition/health represented by VCI is measurement that is represented in percentage.
## VCI Table

<table>
<thead>
<tr>
<th>Value in Percentage</th>
<th>Vegetation Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between 100 – 50 %</td>
<td>Optimal / Above normal</td>
</tr>
<tr>
<td>Around 50 %</td>
<td>Fair</td>
</tr>
<tr>
<td>Below 50 %</td>
<td>Drought</td>
</tr>
<tr>
<td>Below 35 %</td>
<td>Severe Drought</td>
</tr>
</tbody>
</table>

The SPI is an expression that calculates and represents the deficiency of rainfall for different time scales.

Six-month based SPI indicates medium term trend in precipitation pattern.

Therefore six month SPI was calculated for the winter drought season for the year 2009 – 2010, i.e., cultivation period September-February.

\[ Z \text{ score} = \frac{(X-\mu)}{\text{Standard Deviation}} \]

Where,
- Z score is SPI value
- X is precipitation value
- \( \mu \) represents mean of six month rainfall
## SPI Table

<table>
<thead>
<tr>
<th>Description</th>
<th>Standardized precipitation Index (SPI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No drought</td>
<td>-0.5 and above</td>
</tr>
<tr>
<td>Abnormally Dry</td>
<td>-0.5 - -0.7</td>
</tr>
<tr>
<td>Moderate Drought</td>
<td>-0.8 - -1.2</td>
</tr>
<tr>
<td>Severe Drought</td>
<td>-1.3 - -1.5</td>
</tr>
<tr>
<td>Extreme Drought</td>
<td>-1.6 - -1.9</td>
</tr>
<tr>
<td>Very Severe Drought</td>
<td>-2 or less</td>
</tr>
</tbody>
</table>

Source: (U.S. National Drought Mitigation Centre)
NDVI based Correlation Trend

NDVI base Correlation Trend with Meteorological Parameters

- Sep-09
- Oct-09
- Nov-09
- Dec-09
- Jan-10
- Feb-10

- Humidity
- Max Temp
- Min Temp
- Solar
- SPI
Fuzzy Overlay

- The Fuzzy Overlay tool allows analysis of possibility of a phenomenon belonging to multiple sets in a multi-criteria overlay analysis.
- Fuzzy Overlay not only determines what sets the phenomenon is possibly a member of, it also analyzes the relationships between the memberships of the multiple sets.
- Overlay type lists the methods available to combine the data based on set theory analysis.
- The available methods are Fuzzy And, Fuzzy Or, Fuzzy Product, Fuzzy Sum, and Fuzzy Gamma. Each approach provides a different aspect of each cell's membership to the multiple input criteria.
Discretization criteria for Fuzzy overlay and VCI

<table>
<thead>
<tr>
<th>Fuzzy Overlay</th>
<th>Category</th>
<th>VCI values</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>-3 to -1.5</td>
<td>Extremely dry</td>
<td>0 to 34</td>
<td>Very Low</td>
</tr>
<tr>
<td>-1.49 to -1.0</td>
<td>Dry</td>
<td>35 to 45</td>
<td>Low</td>
</tr>
<tr>
<td>-0.99 to 0.99</td>
<td>Normal</td>
<td>46 to 65</td>
<td>Normal</td>
</tr>
<tr>
<td>1 to 1.5</td>
<td>Wet</td>
<td>66 to 85</td>
<td>High</td>
</tr>
<tr>
<td>1.5 to 3</td>
<td>Extremely Wet</td>
<td>86 to 100</td>
<td>Very High</td>
</tr>
</tbody>
</table>
Overall Spatial Extent of Meteorological Drought

- Drought severity map was generated based on the discretization criteria for resulted fuzzy overlay and VCI into 5 different categories.

- Each 16 day Composite image from September 2009 to February 2010 were than classified using raster reclassify tool, into following classes:

  - Very Severe Drought
  - Severe Drought
  - Moderate Drought
  - Least Drought
  - No Drought affected areas
Overall Spatial Extent of Meteorological Drought

- No Drought
- Least Drought
- Moderate Drought
- Severe Drought
- Very Severe Drought

Dates:
- 30 Sep 09
- 16 Oct 09
- 01 Nov 09
- 17 Nov 09
- 03 Dec 09
- 19 Dec 09
- 17 Jan 10
- 18 Feb 10

Coordinate System: GCS WGS 1984
Datum: WGS 84
Units: Degrees
Results

- There was an unexpected decrease in NDVI value in 2009-2010, which caused a short term drought.

- A negative relationship between NDVI and SPI, in month of October was observed that triggered the condition of drought for that period.

- A decreasing trend was observed in relationship between NDVI and humidity. This could be useful to identify water stresses on crops.

- Overall severity map generated gives a significant understanding about the areas under various degrees of drought stress.
Significance of the study

- Nearly 62 percent of the population in rural areas is directly or indirectly associated with agriculture sector for their livelihood, such studies would have direct impact on their socio-economic condition.

- This study has the potential to act as a benchmark for understanding drought phenomenon using satellite-based meteorological data keeping in view the fact that other means of irrigation were not available in the study area.

- This study provided a methodology which can be used in future to identify any drought condition occurring in this region. Thus it could be used as an early warning tool for farmers, food availability, crop insurance agencies, water management and policy makers.
Thank You