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# Monitoring of Drought using Satellite Data

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# Abstract

Droughts are considered to be one of the major natural hazards causing destructive impact on the environment as well as the economy of countries throughout the world. Drought being attributed to weather conditions cannot be monitored by weather data alone, strictly because these data are most likely to be ill-timed, infrequent and incomplete. Low rainfall has mainly caused droughts and subsequently reduction in agricultural production. Impacts of droughts constitute environmental destruction, economic damage human suffering and loss of lives. Droughts have been a recurring feature of the Indian climate therefore study of historical droughts may help in the delineation of major areas facing drought risk and thereby management plans can be formulated by the government authorities to cope with the disastrous effects of this hazard. In recent years, Remote Sensing (RS) and Geographic Information System (GIS) have played a remarkable role in assessment of various types of hazards either natural or man-made. This paper emphasize upon the use of RS and GIS in the field of drought risk evaluation. The study area taken is a part of the Jamnagar district of Gujrat between latitude  $22^{0}19'46''N$  to  $22^{0}46'01''N$  and longitude  $70^{\circ}20'56''E$  to  $70^{\circ}47'34''E$ . The study was conducted with satellite images of year 1977, 1990 and 1999. Data used for drought monitoring has been acquired from the following two sources, NDVI obtained from satellite sources and rainfall obtained from ground rainfall stations record. In this paper an attempt has been made to identify and extract drought risk areas encountering agricultural and meteorological drought by using the Normalized Difference Vegetation Index (NDVI) obtained from the LANDSAT images. The NDVI images generated from LANDSAT data were used to examine large scale drought patterns and their climatic impact on vegetation. NDVI values reflect the different geographical conditions quite well. The NDVI and rainfall was found to be highly correlated. It is therefore concluded that temporal variations of NDVI are convincingly associated with precipitation.

Keywords: Drought, GIS, RS, NDVI, Satellite data, DEM.

## Introduction

The massive population explosion, economic development and the adverse impacts of land use and climate change is mounting a tremendously increasing pressure on water resources. Any shortage in water supply will be most critical in drought periods, due to challenging water needs. Drought is considered to be the most intricate but least understood of all natural hazards, considering the impact if causes on public affecting more people than any other hazard<sup>1</sup>. Drought affects virtually all climatic regions<sup>2</sup> and more than one half of the earth is susceptible to drought each year<sup>3</sup>.Therefore, the need of the hour is to monitor the spatial as well as temporal variability of droughts in order to design and manage water resources schemes.

Traditional methods of drought monitoring were purely based on rainfall data, which had many limitations like network of stations are limited, the climate data was incomplete and often inaccurate in addition to the human error and most importantly, it was difficult to obtain data in near real time both spatially and temporally. To tackle such shortcomings remote sensing technology has been revolutionary to greatly enhance the ability to monitor and manage the natural resources, particularly in the domain of water resources. The remote sensing tools and technology offers excellent possibilities for collecting this indispensable data. The reason being this technology has capability of collecting data at global and regional scales in very less time and it provides an advantage of repetitively in digital form. Remote sensing further provides an excellent communication medium. As a result satellite or remote sensing techniques are being used to monitor the disasters at crucial phases like before, during or after disaster. Most importantly this technology is being used to gather baseline data against which future changes can be compared and on the other hand GIS techniques provide a suitable framework to integrate and analyze various types of data sources required for disaster monitoring. Remote Sensing and GIS can be used for determination of geomorphologic parameters and design flood<sup>4,5</sup>.

To accurately assess the occurrence extent and severity of drought it is necessary to get an exact picture of the spatial and temporal distribution of key variables like meteorological, hydrological and surface variables. Global warming will have an adverse effect on the climatic conditions and water resources<sup>6</sup>. Drought index is one of the important parameters that assimilates huge amount of data

on rainfall, snow pack, stream flow and other water-supply indicators into a comprehensible picture. Precipitation measurement is another important factor; there are many indices that measure how much precipitation has deviated from historically established norms for a given period of time. The Palmer Drought Severity Index (PDSI)<sup>7</sup>, Crop Moisture Index (CMI)<sup>8</sup>. Standardized Precipitation Index (SPI)<sup>9</sup> and Surface Water Supply Index (SWSI)<sup>10</sup> are most preferred indices for agricultural drought monitoring, forecasting and water resources meteorological management. The stations providing meteorological data being very sparsely distributed does not allow accurate and timely drought detection and monitoring<sup>11</sup>. With the modern day remote sensing technology, the historical drought indices were completely overthrown by the newly developed indices from remote sensing data that are real time. Also, the remote sensing has a tremendous capability to provide a complete coverage over extended regions with a spatial resolution varying from a few hundred meters to a few kilometers. Some of the most preferred vegetation indices are the Normalized Difference Vegetation Index (NDVI), Vegetation Condition Index (VCI), and Temperature Condition Index (TCI).

Tucker first suggested NDVI in 1979 as an index of vegetation health and density<sup>12</sup>. NDVI has been extensively used for vegetation monitoring, crop yield assessment, and drought detection<sup>13, 14</sup>. NDVI is defined as (NIR-RED) / (NIR+RED); Where, NIR and RED are the reflectance in the near infrared and red bands. NDVI is a good indicator of green biomass, leaf area index, and patterns of production<sup>15</sup>. The output of NDVI is a new image file/layer. Values of NDVI range from -1.0 to +1.0, but values less than zero do not have any ecological meaning, so the range of the index is modified to 0.0 to +1.0. Higher values of NDVI refers to a condition associated with highly photosynthetically active vegetation signify a larger difference

between the red and near infrared radiation recorded by the sensor<sup>16</sup>. Low NDVI values is attributed to, when there is little photosynthetic activity, or when there is just very little NIR light reflectance (i.e., water reflects very little NIR light) means there is little difference between the red and NIR signals. The relationship between NDVI and rainfall varies spatially, primarily due to the effects of variation in properties such as vegetation type and soil background<sup>17</sup>, with the sensitivity of NDVI values to fluctuations in rainfall, therefore, showing a notable variation regionally.

# Methodology

Study area: The study area taken is a part of the Jamnagar district of Guirat between latitude  $22^{0}19'46''N$  to  $22^{0}46'01''N$  and longitude  $70^{\circ}20'56''$ E to  $70^{\circ}47'34''$ E. The geographical area of the region in consideration is 2341 km<sup>2</sup>. Jamnagar district experiences a tropical climate, which is very much in tandem with the climate conditions in rest of Gujarat. This region encounters three main seasons throughout the year – summer, winter and monsoon. As far as summer season is concerned the days in Jamnagar are very hot and humid because of it being close to the proximity of the sea while the winters on the other hand are moderately cold. The summer seasons begins from the month of March and continues to the month of June. The maximum temperature during these four months is around 37°C and the minimum temperature is around 26°C. Monsoon begins in the month of June and extends till September in Jamnagar. The highest rainfall is usually experienced during the month of July, and heavy rains occur in the city during the months of August and September. Winter season in Jamnagar normally begins in late October and extends till January. In the month of February the region experiences a moderate climate. The maximum temperature during winters is as high as 32°C and the minimum temperature experienced is as low as 12°C in January.



Figure-1 Index map of study area

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**Data acquisition:** Data used for drought monitoring has been acquired from the following two sources, NDVI obtained from satellite sources and rainfall obtained from ground rainfall stations record.

#### Flow chart of image processing and NDVI calculation





Figure-3 Satellite image (Acquisition date: 17/10/1977) of study area



Figure-4 Satellite image (Acquisition date: 02/11/1990) of study area



Figure-5 Satellite image (Acquisition date: 18/10/1999) of study area



Figure-6 Digital Elevation Model (DEM) of the study area using SRTM



Figure-8 3D View of study area with the help of DEM



Aspect map of the study area





NDVI image for 17/10/1977 imaginary

Legend



Figure-10 NDVI image for 02/11/1990 imaginary

when when when when Figure-11 NDVI Image for 18/10/1999 imaginary

	Table-	1	
Analysis of NDVI	obtained	from 1977	imaginary

Range of digital number value	Vegetation class	Area under each group (km <sup>2</sup> )	Percentage of total area
0 - 100	0 - 5 %	70.09	2.99
101 - 150	5 - 20 %	1770.08	75.61
151 - 200	20 - 35 %	438.81	18.74
201 - 255	> 35 %	62.07	2.65
		2341.05	100.00

Table-2 Analysis of NDVI obtained from 1990 imaginary

Range of digital number value	Vegetation class	Area under each group (km <sup>2</sup> )	Percentage of total area
0 - 100	0 - 5 %	73.99	3.16
101 - 150	5 - 20 %	628.69	26.86
151 - 200	20 - 35 %	1531.31	65.41
201 - 255	> 35 %	107.06	4.57
		2341.05	100.00

 Table-3

 Analysis of NDVI obtained from 1999 imaginary

Range of digital number value	Vegetation class	Area under each group (km <sup>2</sup> )	Percentage of total area
0 - 100	0 - 5 %	85.10	3.64
101 - 150	5 - 20 %	715.90	30.58
151 - 200	20 - 35 %	1474.30	62.98
201 - 255	> 35 %	65.74	2.81
		2341.05	100.00

 Table-4

 Annual rainfalls during different years

Year	Annual rainfall (mm)	Source
1989	533.7	IMD
2000	348.0	IMD
2006	237.8	IMD



Figure-12 Area under different vegetation class in different year

This study began with the downloading of satellite images of study area of year 1977, 1990 and 1999 from archives of Landsat from GLCF. After processing of Landsat images, layers stacked in ERDAS Imagine. Interested parts of the image were cropped considering AOI. The satellite image of 1977 is of database MSS having resolution of 57 m, images of 1990 is of database TM (Thematic Mapper) having resolution of 28.5 m and 1999 having database ETM + (Enhanced Thematic Mapper +) having resolution of 15 m. All the three images were taken during post monsoon period. Figure-3,4 and 5 are original satellite images of 1977, 1990 and 1999 respectively which were downloaded and cropped according to area of interest.

Figure-6 showing the downloaded and cropped digital elevation model (DEM) of the study area from SRTM. A DEM is a digital file consisting a grid of regularly spaced terrain elevations. DEM may be used to generate three-dimensional graphics displaying terrain slope, aspect (direction of slope), and terrain profiles between selected points. DEM may play an important role in the drought monitoring majorly in modeling water flow or mass movement (for example, landslides). Figure-7 showing the aspect map of the study area generated by using DEM with the help of spatial analyst tool of Arc-GIS. Aspect map indicates the direction that slopes are facing, which may help in drought monitoring as it helps in finding the direction of movement of water. Figure 08 indicating the 3D view of study area generated with the help of DEM using ArcScene tool of Arc-GIS. It helps in getting actual information about the study area and also the land use and land cover details.

Figure 09, 10 and 11 are NDVI images generated from satellite images of year 1977, 1990 and 1999 respectively using ERDAS-Imagine. It is an index which differentiates between the vegetative portion recorded by the satellite image with other observed objects including water bodies, buildings, bare lands and others. The differentiation is assessed by the given value derived from the formula which stands between -1 to 1. On the basis of range of digital number, NDVI was classified into four groups. Table-1, 2 and 3 showing area covered by different vegetation class resulting from images of year 1977, 1990 and 1999 respectively. Figure 12 showing the comparative analysis of NDVI images results obtained. It can be observed that in year 1977, there was more area having less or no vegetation. From comparison of annual rainfall of different years it was found that it was more in 1977 among three. It is therefore concluded that the temporal variations of NDVI are convincingly associated with precipitation. The NDVI increases with increase in precipitation.

## Conclusions

Droughts are one of the most catastrophic natural hazards in the world, which are causing large scale damage to agriculture; along with human and wild life. Remote sensing and GIS technology coupled with ground meteorological data significantly contribute towards vegetation drought analysis.

The main objective of the paper was to recognize the relationship between rainfall and NDVI and to see how appropriately drought risk areas can be delineated by integration of satellite, meteorological and other ancillary data. It was concluded from the study that the temporal variations of NDVI are convincingly associated with precipitation and there exist a strong linear relationship between NDVI and precipitation.

Unavailability of data at regular interval of time in public domain was found one major problem during the study. The resolution of data available is also coarse. The analysis will be better if data available at regular interval of time and is of high resolution and there is no mixed pixels. International Research Journal of Earth Sciences\_ Vol. 3(1), 66-72, January (2015)

During present study it was tried to correlate the NDVI with precipitation. If this analysis is performed for a large number of images for continuous years, it is convenient to find the recurrence of drought. On the basis of which the characterization of major areas facing drought risk and thereby management plans can be formulated by the government authorities to cope with the disastrous effects of this hazard. The further research can be the use of the Vegetation Condition Index (VCI) to furthermore separate regional NDVI variation from geographical contributions in order to assess regional drought impacts.

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