

DROUGHT AS DERIVED FROM NOAA AVHRR DATA IN A PART OF RAJASTHAN STATE

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ABSTRACT

Drought and floods are the two extreme manifestations of the hydrologic cycle on the land surface of the earth. The conventional techniques of drought monitoring are i) Statistical analysis of rainfall data ii) Water balance methods. Recently, the availability of multi-temporal and multi-spectral remote sensing information has enabled measurement and monitoring of land cover condition, especially the Advanced Very High Resolution Radiometer (AVHRR) sensor on National Oceanic and Atmospheric Administration (NOAA) satellite to provide daily data for large area which will help to study the spatial distribution, seasonal and inter annual change of vegetation for large area. The analysis was carried out for a period of four years (2002-2005) and from SPI analysis; it was observed that the year 2002 was drought year. On the basis of satellite-based indices, the study area was divided into various categories of drought and they are extreme, severe, moderate, slight drought and normal condition. It was found that in the year 2002 all the area was affected by drought with greater intensity, mostly by extreme and severe drought condition.

1. INTRODUCTION

2.0 THE STUDY AREA AND DATA USED

The southern part of Rajasthan state, India comprising of 13 districts is selected for the study (Figure 1). It is located in between 23°00' and 26°05' N latitude and 71°18' and 77°42' E longitude. The study area covers the total area of 10.72 Mha. Based on rainfall distribution, soil characteristics, cropping pattern and other physical characteristics the Rajasthan State is divided into nine agro-climatic zones, in which the study area covers four agro-climatic zones viz.

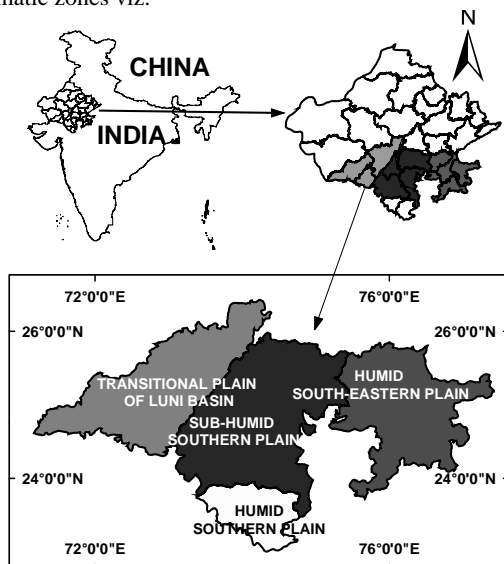


Figure 1: Location of the study area

For this study meteorological data pertaining to monthly precipitation data, was collected for the three stations i.e. Udaipur, Bhilwara and Kota from the College of Technology and Engineering, Udaipur, for Rajsamand and Chittaurgarh from the District collectorate and for the

Dungarpur district from the Irrigation Department, Dungarpur, India for a period of 25 years (1981 to 2005). The National Oceanic and Atmospheric Administration (NOAA) of the USA operate the series of NOAA satellite, which carry the Advanced Very High Resolution Radiometer (AVHRR) sensor. AVHRR is an optical instrument, which provides multi-spectral imaging by sensing reflected sunlight and thermal emissions. It is a five-channel radiometer providing data in visible, near infrared and thermal infrared for a wide range of applications. The thermal channels 4 and 5 are the windows in the range of 10.3-11.3 and 11.5-12.5 μm . AVHRR has a spatial resolution of 1.1 km. 27 Cloud free NOAA 15, 16 & 17 images of the study area were acquired through ftp from Satellite Active Archive site (<http://www.class.noaa.gov>) for a period of 4 years ranging from 2002 to 2005. The time of satellite passes were between 8.30 am and 10.00 am local time. The dates of the satellite data used in the study are 25 April 2002, 24 May 2002, 21 October 2002, 27 November 2002, 14 February 2003, 01 March 2003, 16 March 2003, 15 May 2003, 15 October 2003, 30 October 2003, 16 November 2003, 15 February 2004, 01 March 2004, 15 March 2004, 04 April 2004, 23 April 2004, 31 May 2004, 14 October 2004, 29 October 2004, 28 November 2004, 12 February 2005, 31 March 2005, 28 May 2005, 01 October 2005, 17 October 2005, 30 October 2005, 26 November 2005.

3.0 METHODOLOGY

The main objective of the study was to monitor meteorological and agricultural drought using precipitation data and satellite images. SPI based on precipitation data and NDVI based on satellite data were used to demarcate the drought prone area. The NDVI value was used to map the drought-affected area and estimate its spatial extent for a period of four years. SPI is calculated using the monthly rainfall data through an available computer program. The classified value of SPI was used as an indicator of meteorological drought. Brightness Temperature and drought index NDVI and WSVI were calculated using the NOAA AVHRR satellite data. Based on NDVI, agricultural drought prone year and area was demarcated. This data was

used to estimate the spatial extent and distribution of drought in the study area for a period of four years. The total steps involved in this study are schematically presented below (figure 2).

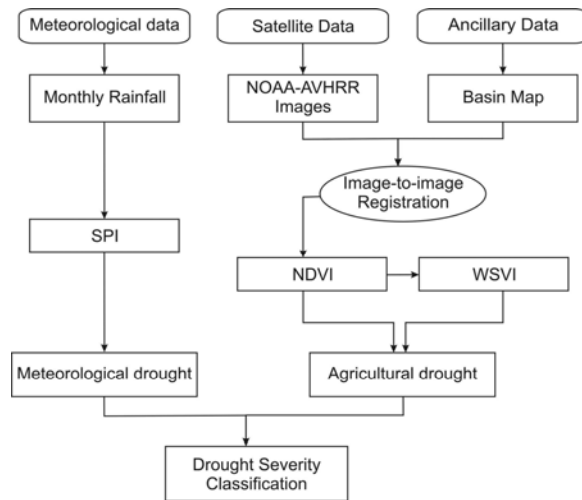


Figure 2: Flowchart illustrating the different steps involved in the drought study

3.1 Drought Indicators

In the present study, two indicators were used for identification of drought prone areas. These indicators are meteorological and satellite based Indicators.

Meteorological Indicators

These indicators are based on meteorological parameters as recorded at meteorological stations. The SPI is a statistical indicator evaluating the lack or surplus of precipitation during a given period of time as a function of the long-term normal precipitation to be expected during the period. It was calculated using a continuous, long-term (25 years) series of historic monthly precipitation records. Since, rainfall is not normally distributed for aggregation period of less than 12 months; a gamma distribution is fitted to the frequency distribution. The SPI for given rainfall amount is given by precipitation deviation from mean of an equivalent normally distributed probability distribution function with a zero mean and a standard deviation of one. Results are given in units of standard deviation.

3.2 SATELLITE BASED INDICATORS

These indicators are calculated from satellite derived surface parameters. Examples are various vegetation indices such as Normalized difference vegetation index (NDVI), Water Supply Vegetation Index (WSVI) etc. For calculation of these indices, spatial database was generated in GIS environment. The base map of the study area was prepared at a scale of 1:10, 00,000 from the River basin Atlas map of India (1999). This map was converted to digital form and processed using Integrated Land and Water Information System (ILWIS) GIS packages. In ILWIS, four polygons have been generated for four zones.

All the 27 NOAA-AVHRR images were calibrated before registration. The image of 30 March 2002 was geo-referenced with the base map. Then the image-to-image registration was carried out by taking the image of

30 March 2002 as the master image and rest of the NOAA-AVHRR images as slave images. A total of more than 30 ground control points were selected in such a way that they are well spread throughout the study area to achieve higher accuracy in geo-referencing. The nearest neighbour re-sampling and 2nd order transformation technique was adopted. The study area was extracted from all the satellite images.

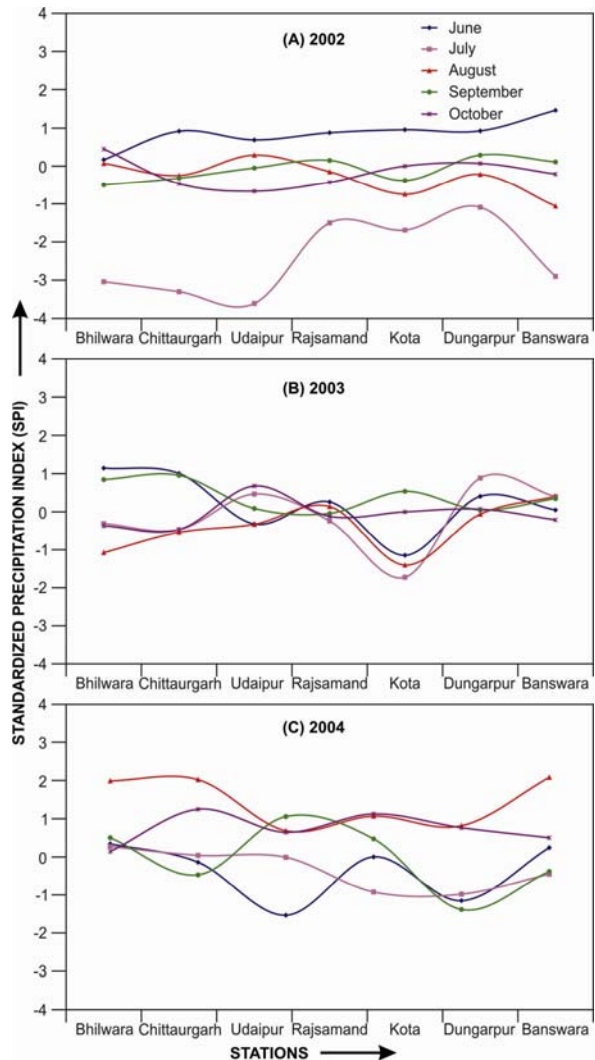


Figure 3: Pattern of change in SPI values among six stations in the year 2002, 2003 and 2004

4.0 RESULTS AND DISCUSSION

The SPI for all the stations for monsoon period (June to October) for three years 2002, 2003 and 2004 have been computed and shown in Figure 3. The NDVI and WSVI for all the years have been generated as described above and shown in Figure 4 and Figure 5 respectively.

Standardized Precipitation Index (SPI)

The regional time series of SPI value was calculated using monthly rainfall for each station. A drought is defined whenever the SPI value reaches a value -1 and continues until the SPI become positive again.

The SPI value shows that in the year 2002 all the six stations i.e. Dungarpur, Chittaurgarh, Rajsamand, Udaipur, Bhilwara and Kota were affected by drought. From Figure 2, it can be seen that in the year 2002, the drought started in the month of July with SPI value -1.09 for the duration 2 months, -3.3 for the duration 4 months, -1.5 for the duration 2 months, -3.61 for duration 1 month, -3.04 of the duration 3 months and -1.69 of the 3 months duration for Dungarpur, Chittaurgarh, Rajsamand, Udaipur, Bhilwara and Kota respectively. This shows that the moderately drought condition at Dungarpur, severe drought condition at Rajsamand and Kota and extreme drought condition at Chittaurgarh, Udaipur and Bhilwara. In the year 2003, only Bhilwara and Kota were affected by one drought event of 3 months duration, which started in August and June with SPI value -1.08 and -1.15 respectively. In the year 2004 Udaipur was affected by one drought event of 1-month duration in the month of June with SPI value -1.53. In the same year, Kota was affected with two drought events of 2 month duration and 1 month duration which started from July with SPI value 1.15 and in September with SPI value -1.38 and it shows the moderately drought condition.

On the basis of SPI values, it was concluded that the year 2002 was most drought affected year and 2005 was the normal year. To have the spatial distribution of the drought condition, various indices using satellite data were computed as explained in the following section.

Normalized Difference Vegetation Index (NDVI):

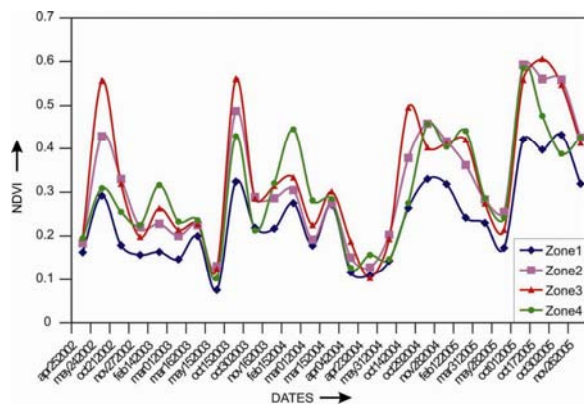


Figure 4: The pattern of change in NDVI values over the time scale for 4 zones

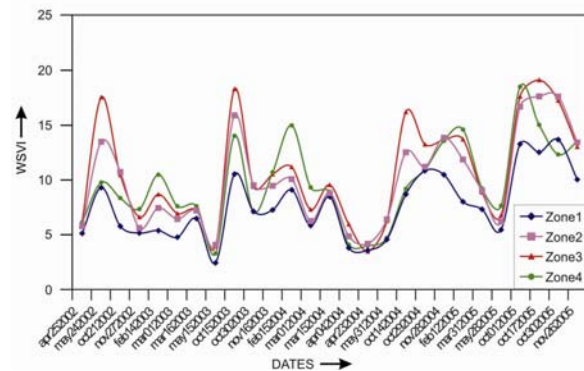


Figure 5: The pattern of change in WSVI values over the time scale for 4 zones

NDVI were calculated for the study area for all the years. Both the seasons viz. Pre-monsoon and Post-monsoon were selected to investigate the spatial and seasonal dynamics of NDVI responses. The spatial distributions of NDVI for post monsoon i.e. for the month of October are shown in Figure 6. On the basis of NDVI values, the study area was divided in five categories viz. extreme, severe, moderate, slight drought and normal condition.

On the basis of various categories obtained using different NDVI values, zone 1 and zone 4 shows the moderate to severe drought in most of the areas. Zone 2 shows the moderate drought condition in most of the parts with normal to slight drought in the small parts. Zone 3 was affected by normal to moderate drought condition. In all other years, 2003 also shows drought like conditions, while year 2005 was having minimum drought conditions. On the basis of drought affected areas under five categories, the area falling under each category were calculated. The Pie diagram was drawn and shown in Figure 7. From this figure, it is evident that the year 2002 was having more areas in extreme and severe drought condition in comparison to other years.

It is observed that during post monsoon months, the NDVI was lowest for the year 2002 and it is of the order of 0.156 to 0.172 while it is maximum in the year 2005 and varies between 0.396 to 0.431. In zone wise analysis, it was observed that zone 1 is having minimum NDVI followed by zone 4, 3 and 2. Figure 4 shows that the curves dip towards the lower NDVI value in the year 2002, which shows the poor vegetal cover in the post monsoon but in all the remaining 3 years NDVI values raise towards the high NDVI value. From Figure 6, it can be seen that the year 2002 was the most affected by the higher intensity of drought followed by year 2004, 2003 and 2005. In post monsoon period, the areas falling under different drought categories were computed and shown in the Figure 6.

Water Supplying Vegetation Index (WSVI):

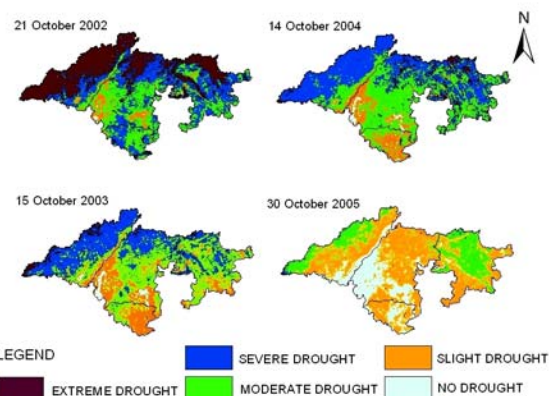


Figure 6: Schematic representation of classified post NDVI images of the study area in four different years

WSVI for all the years were computed for each zone. The analysis of WSVI was also carried out for both the seasons i.e. pre-monsoon and post-monsoon. From

Figure 5, it can be seen that the least average WSVI value was observed as 2.415, 4.077 and 3.279 in the year May, 2003 during the pre-monsoon season in the zone 1, zone 2 and zone 4 respectively and 3.457 in the year 2004 (23 April) in the zone 3. The high average WSVI value was observed as 9.296, 13.495, 17.557 and 9.771 13.690, 17.641, 19.122 and 18.509 in the month of may in the year 2002 for the zone 1, zone 2, zone 3 and zone 4 respectively. In the post monsoon season the lowest WSVI value was observed as 5.153, 5.610, 6.610 and 7.348 in the zone 1, 2, 3 and 4 respectively in the month of November of the year 2002 and the maximum average WSVI value was observed as 13.286, 17.641, 19.122 and 18.509 in the zone 1, 2, 3 and 4 respectively in the month of October of the year 2005. This analysis confirms the results obtained from previous analysis.

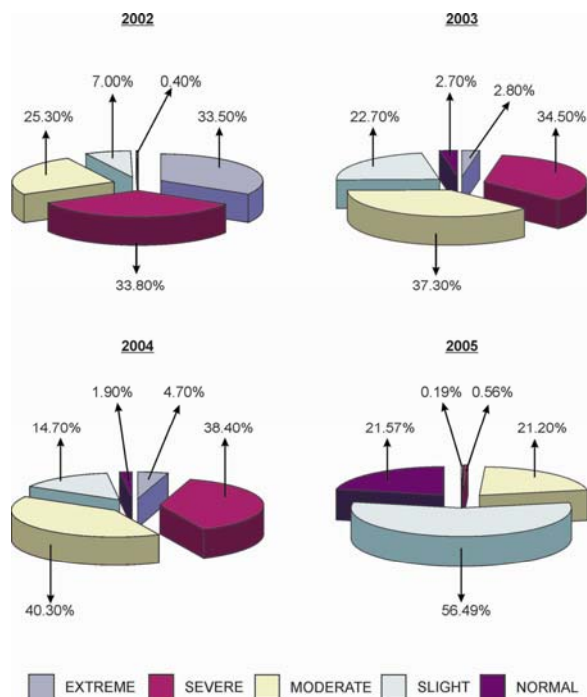


Figure 7: Percentage of area falling under each category of drought in the study area during the year 2002-2005

5.0 CONCLUSIONS

The meteorological and satellite based indicators, gives promising results for mapping and monitoring drought conditions in a study area. The SPI is one of the drought indices that were used more widely by decision makers for quantifying drought severity. The SPI analysis was carried out for one-month interval and it was found that the year 2002 was most effected drought year. The major advantage of using satellite data is seen in the high spatial information, which cannot be obtained using meteorological data. NOAA AVHRR derived NDVI and brightness temperature can give the picture of moisture stress condition on regular basis. Although spatial resolution of NOAA is coarse, yet, the onset of drought condition for a large area in a given year can be assessed by comparative analysis of trend of derived NDVI of that year relative to the trend in a normal year. The result shows that a decrease in NDVI in pre-monsoon of the year 2003 which correlates to the reduced rainfall quantity during year 2002. Similarly, high brightness temperature during year 2002 reflects the drought condition. The zone wise analysis

shows that the areas falling under zone 1 is having maximum drought conditions in all the years. Zone 4 was the next affected by severe drought after the zone 1 in all the years. Zone 2 and zone 3 was the least affected by drought condition. It is concluded that AVHRR based NDVI/WSVI and brightness temperature can provide valuable information for drought detecting and monitoring.

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