Drought assessment using satellite based vegetation condition index and rainfall anomaly index over Bundelkhand region, India

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ABSTRACT

Agricultural drought is one of the most prominent hazards affecting economy in Bundelkhand region. Agricultural drought has been a recurrent phenomenon in many part of India. Remote sensing plays an important role for near-real time monitoring of the agricultural drought condition over large area. In the present study MODIS – NDVI data from 2002 to 2015 were used for monitoring agricultural drought through NDVI based Vegetation condition index. VCI was calculated for whole Bundelkhand using the long term NDVI variation. Rainfall Anomaly Index was computed from CPC NOAA South Asia observed rainfall data from 2002 to 2015 for monitoring of meteorological drought of study area. VCI were compared with meteorological based Rainfall Anomaly index for monitoring drought in Bundelkhand. Results revealed that VCI and RAI could capture spatial pattern of vegetation condition and dryness within seasons and across different years. The VCI and RAI had significant correlation with crop yield anomaly of both food grains and pulses which shows the trend of crop production in study area. A comparative study on monthly drought conditions captured using VCI and RAI was made for different pair of year's viz., 2002 & 2003, 2009 & 2010 and 2013 & 2014 as drought and normal year, respectively. In drought year, crop production severely affected which clearly discernable with both VCI and RAI of particular year. The results show that Hamirpur and Banda was the most drastically affected area in Bundelkhand region due to drought condition.

Keyword: - *Drought, MODIS-NDVI, VCI, RAI, crop yield anomaly.*

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1. INTRODUCTION-1

Bundelkhand region is situated in central India and is a semi-arid plateau. It comprises of six districts of Northern Madhya Pradesh (Datia, Tikamgarh, Chhatarpur, Panna, Damoh and Sagar and Lahar, and BhanderTahsils) and seven districts of Southern Uttar Pradesh (Jhansi, Lalitpur, Jalaun, Hamirpur, Banda, Mahoba and Chitrakoot) (www.indiawaterportal.org) The location of this region is between 23°8′–26°30′N lat. and 78°11′–81°30′E. The total area covered by this region is 71,619 km2. Rainfall received in this region is in the range of 768 to 1087mm.

Meteorological indices estimation in meteorological drought monitoring is based mainly rainfall data. There are many indices which incorporate historic rainfall data for a given time period commonly used indices are, Rainfall Anomaly Index (RAI), (Patel N.R.et. al., 2015), Crop Moisture Index (CMI),(Jie WEI and Ailikun, 2009), Palmer Drought Severity Index (PDSI) (Jie WEI and Ailikun, 2009), and Standardized Precipitation Index SPI,(Nalbantis&Tsakiris, 2009). Every index has its own advantages and disadvantages.

Satellite data are effective in regional estimation and also for early warning of drought. It gives spatial information which is necessary for regular monitoring of drought. Various satellite based indices are developed like Normalized Difference Vegetation Index NDVI, Vegetation Condition Index VCI (Kogan, 1990), Temperature condition index was also suggested by (Konag 1997), (Thenkabail et. al. 2004), Vegetation Temperature condition index (Z. Wang et. al. 2004) and many more are used for drought monitoring. With the availability of MODIS-NDVI data it is easy to monitor short term drought stress as it provides vegetation data on large scale.et. al. 2004) and many more are used for drought monitoring. With the availability of LANDSAT 8 data it is easy to monitor short term Agricultural crop condition as it provides vegetation data on 30m scale.

2. STUDY AREA-2

Study area is Bundelkhand region is comprises of six districts of Northern Madhya Pradesh (Datia, Tikamgarh, Chhatarpur, Panna, Damoh and Sagar and Lahar, and BhanderTahsils) and seven districts of Southern Uttar Pradesh (Jhansi, Lalitpur, Jalaun, Hamirpur, Banda, Mahoba and Chitrakoot).

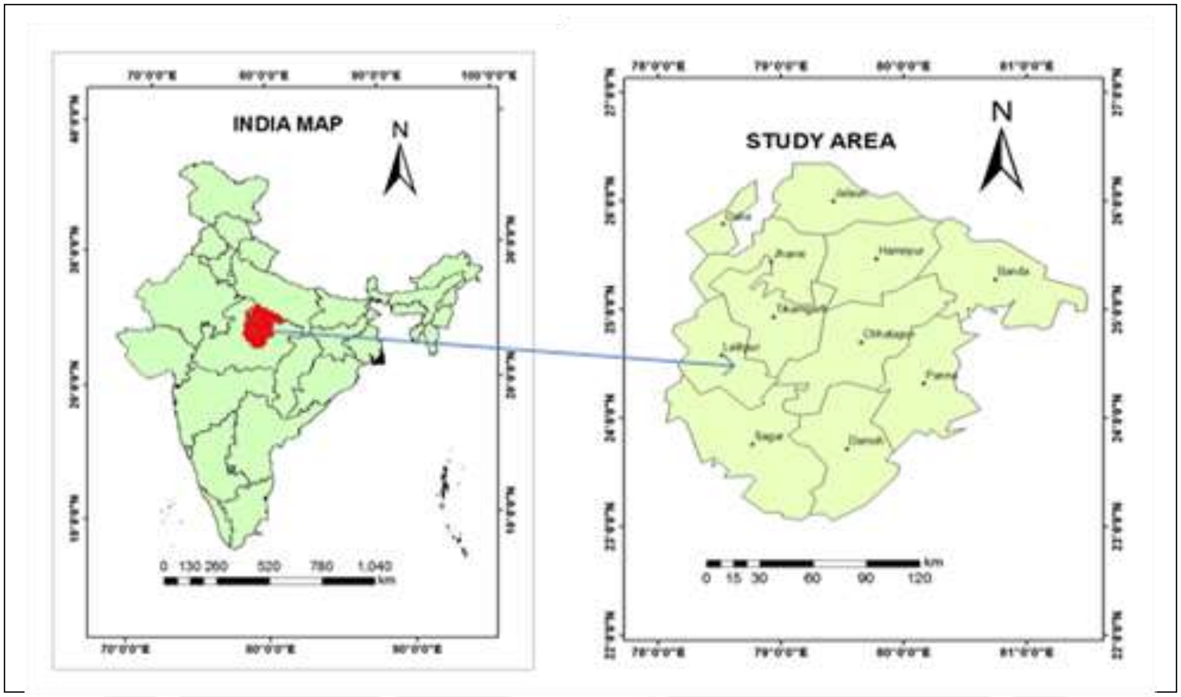


Figure 1.Location of study area

3. MATERERALS AND METHODOLOGY-3

3.1 Data Acquisition-1

Data has been acquired from two sources: NDVI derived from satellite sources (14 years - monthly composite) and Rainfall Data from meteorological satellite data (NOAA CPC.) sources (14 years data- monthly composite).Satellite data MODIS-NDVI satellite data was downloaded through public distribution website (http://e4ftl01.cr.usgs.gov//).The data is monthly composite NDVI for India from which Bundelkhand district was extracted from Jun to Nov for 2002 to 2015. This data is used for calculating vegetation condition index for drought monitoring. Its image has a constant resolution of 250 meter providing monthly coverage of earth's surface.

Meteorological data NOAA- CPC satellite data was downloaded freely through server: ftp://ftpprd.ncep.noaa.gov/pub/cpc/fews/S.Asia/data/ . The data is monthly composite climate prediction center in South Asia reason for India from which Bundelkhand district was extracted from Jun 2002 to Nov 2015. This data is used for calculating Rainfall Anomaly index for meteorological drought monitoring. Its image has a constant resolution of 0.1 degree providing monthly coverage of earth's surface.

Statistical data related to crop yield mainly food grains and pulses has been used to find out the relationship between various like VCI and rainfall used in the study. Crop yield data was obtained from Statics of a science Department of Agriculture Corporation, New Delhi.

Overall methodology is presented through mentioned below explains about the methodology adopted for this research work. VCI was calculated from NDVI image on basis from 2002 to 2015. Rainfall data was also used for the 2002 to 2015 year. Rainfall data basis calculated in Rainfall anomaly in 2002 to 2015. We used correlation analysis between RAI and VCI to depict sensitivity of VCI to drought. Furthermore, these indices were then used to established correlation with crop yield anomaly for detecting the impact of drought on crop performance. Methodological formulation for various indices (satellite and meteorological) are explained as follows.

Normalized Differential Vegetation Index (NDVI):

The drought severity analysis was done on temporal basis for 2002 to 2015 years. The MODIS-NDVI was used to estimate the vegetation condition on basis as given in this equation.

NDVI = (NIR-R) / (NIR+R)

Where NIR is reflectance in near infrared band and R is reflectance in red band. Its value ranges between -1 to +1. Negative value indicates weak vegetation and positive indicates healthy vegetation.

Vegetation Condition Index (VCI):

It is a pixel wise normalization of NDVI over some time period, developed by Kogan (1990, 1995) to make a relation statement of changes in the NDVI signal by filtering out the contribution of local geographic resources to the spatial variability of NDVI. The VCI is computed as.

VCI = (NDVIi – NDVImin) / (NDVImax- NDVImin)

Where, NDVIi is the smoothed weekly NDVI, NDVImax, and NDVImin are maximum and minimum NDVI, respectively, for that pixel and monthly period from multiyear smoothed NDVI data and i define the monthly interval. Its value ranges from 0 to 100.It is measured as percent. VCI with 50% value reflects fair vegetation condition, 50-100% indicates above normal. When VCI is 100%it suggests that NDVI value of that month is equal to NDVImax which indicates the optimum condition for vegetation. The VCI is classified into three drought classes such as No drought = (> to 50), Moderate drought = (20 to 50), Severe drought = (0 to 20).

Rainfall Anomaly index (RAI):

To indicate the meteorological drought for the growing season of kharif crop rainfall anomaly index is computed. Rainfall anomaly index give the drought years, the year with highest and lowest as well as the impact of drought and its severity in the study area. In this technique, the rainfall values for the period of study were ranked in the descending order of the magnitude with the highest rainfall being ranked first and lowest rainfall being ranked last. This technique developed by Van Rooy (1965).

RAI = {(RFi –RF mean) / RF mean} * 100

Where, RFi – is rainfall during month, RF mean - average rainfall at the same time during many years. Unit in mm the value ranges from -100 to ∞.Higher the RAI, higher rainfall in a decade period. The RAI was classified into three drought classes. No drought = (> to- 10), Moderate drought = (-10 to - 50), Severe drought = (<to -50).

Crop Yield Anomaly:

The crop yield trend was calculated using time series data then crop yield anomaly was computed. The crop yield anomaly was calculated as

Ya = (Yi – Ym / Ym)*100

Where Ya are yield anomaly, Yi is yield in particular years; Ym is yield in 12 years. Yield anomaly has been estimated for district level using correlation.

Analysis:

VCI values of selected districts are compared with RAI values for the year 2002 – 2003, 2009 – 2010, and 2013 – 2014 to know the trend of both variables in monitoring drought and monthly wise compared VCI and RAI. 2002 – 2003, 2009 – 2010, 2013 – 2014. Yearly time series of RAI and VCI compared for a period of 2002 to 2015. Crop yield of food grains and pulses correlated with VCI for detecting crop loss in the drought year. Correlation has been used for analyzing the relationship between VCI and yield anomaly. All the above correlation analysis is done in Statistical software. The correlation shows the significant time-period for food grains and pulses as it is evaluated on the decadal basis.

4. RESULTS AND DISCUSSION- 4

This chapter discusses about the total study that evaluate the drought stress in Bundelkhand region using Satellite derived index (VCI), meteorological based index (RAI) and the comparison between VCI and RAI for getting the idea that which approach is best for monitoring drought using MODIS-NDVI data. The data of 2002 and 2015 is considered as the time period for monitoring drought. Crop yield data is also used for the kharif crop for estimating the crop yield anomaly. Comparison between VCI with crop yield anomaly is made for detecting the better for detecting drought.

4.1 Spatial pattern of VCI and RAI

Rainfall anomaly index and Vegetation condition index has been computed for all Bundelkhand region of the study area. RAI and VCI has been computed for the Jun to Nov; kharif crop growing season for the drought year (2002, 2014) and normal year (2003, 2014).

Satellite based meteorological and agricultural drought monitoring in study area was carried out using RAI and VCI. The results of monitoring drought during kharif growing season between Jun to Nov during 2002 & 2003 and 2013 & 2014 show the meteorological and agricultural drought, which are a series of maps indicating the stress condition in each monthly period. The figures 2 depict that the low values of RAI and VCI shows meteorological and Agricultural drought condition and high value of RAI and VCI shows the normal condition.

4.2 Drought categories based on VCI and RAI

Satellite based meteorological and agricultural drought classes monitoring in study area was carried out using RAI and VCI. The results show the meteorological and agricultural drought classes during kharif growing season between Jun to Nov during 2002 & 2003 and 2013 & 2014, which are a series of maps indicating the drought classes' condition in each monthly period. Three types of drought classes are defined as no drought, moderate drought and severe drought. The (Figures 3.) shows the drought classes.

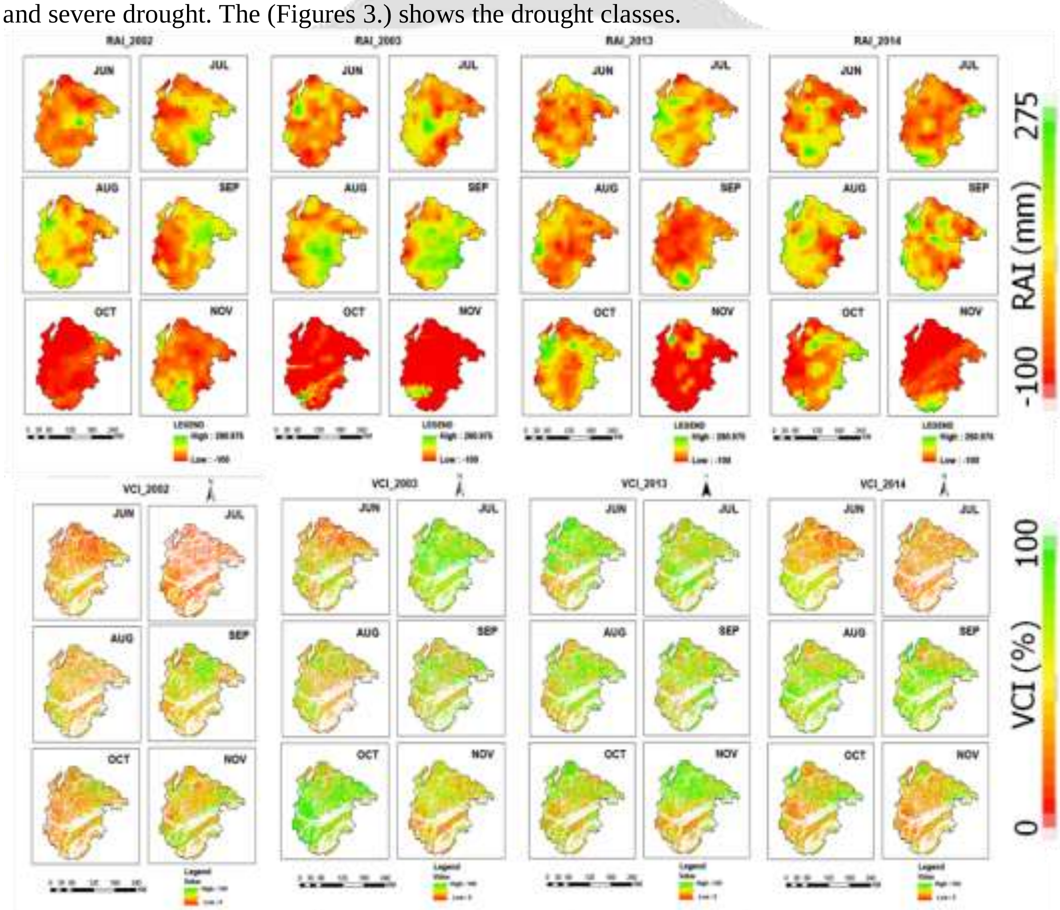


Fig. 2 Monthly spatial patterns of RAI and VCI for drought (2002, 2014) and normal (2003, 2013) years

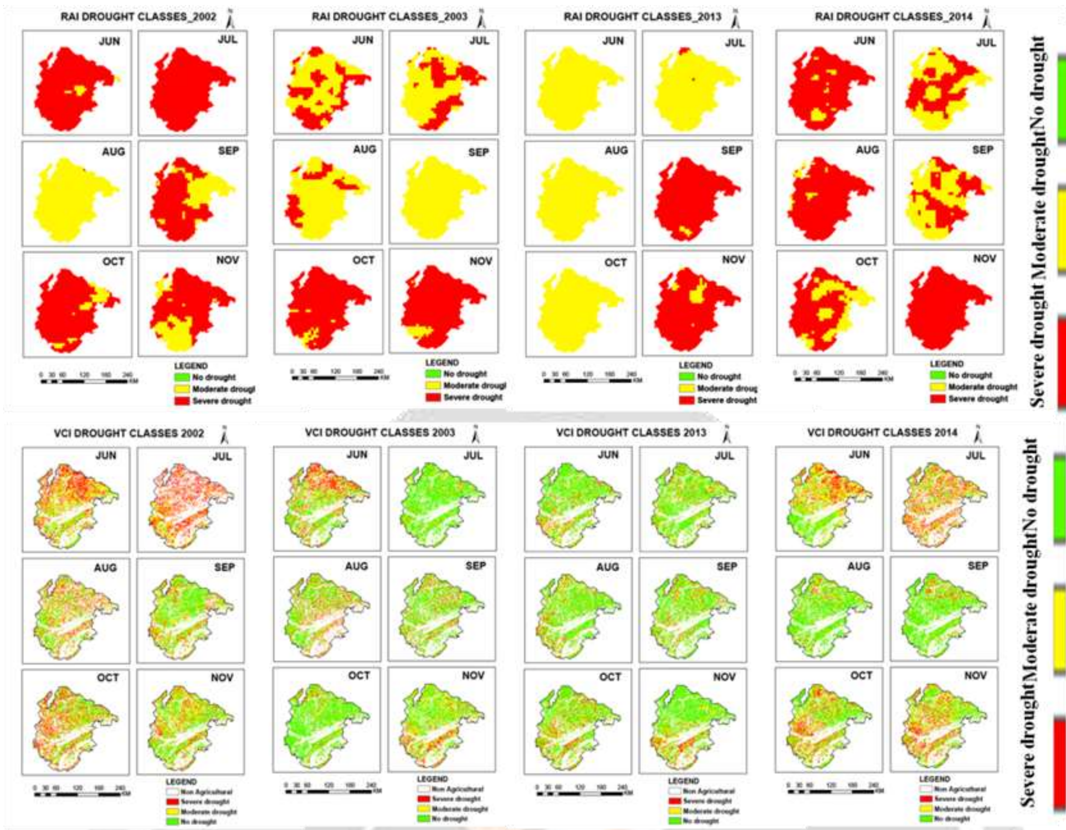
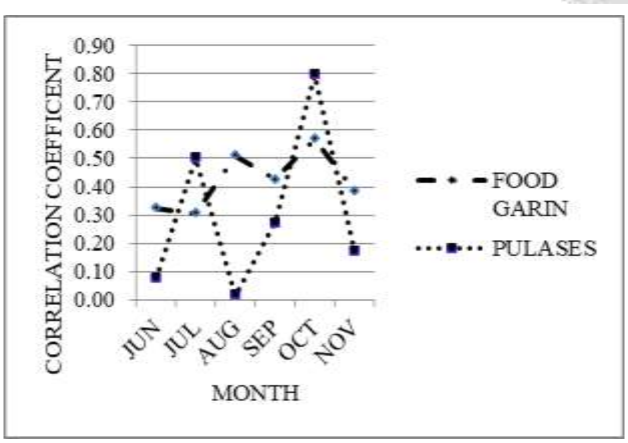


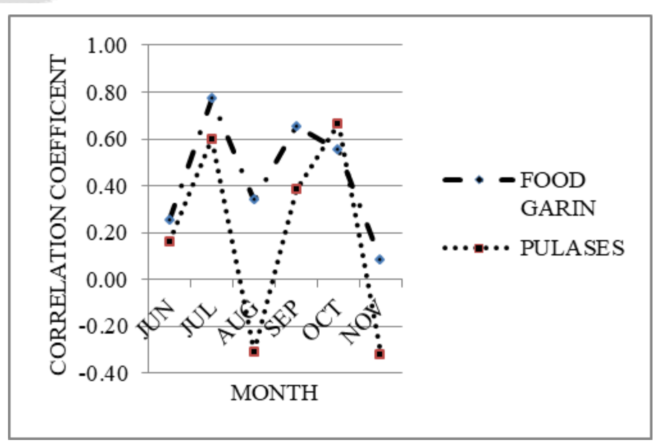
Fig. 3 Spatial pattern of drought classes based on RAI and VCI for drought (2002, 2014) and normal (2003, 2013) years

4.3 Correlation between district wise VCI and Crop yield Anomaly

This trend was computed to know the pattern of crop production during kharif growing season for each decade of June to November for the year 2002 to 2013. A correlation between VCI and crop yield anomaly was calculated for food grain and pulses crop production data and the same is represented in and Figure 3(a) and Figure 3(b) A significant correlation is found in between food grain and VCI for August and October and same for pulses and VCI for October for Hamirpur district which shows that correlation was good at mid-season to late season for crops, whereas in start of the season it was least. In Banda district, correlation between food grain and VCI was better as compare to pulses which show negative for the months of August and November that depicts a negative change in pulses production continuously for each decade of months.

(a) Hamirpur (b) Banda

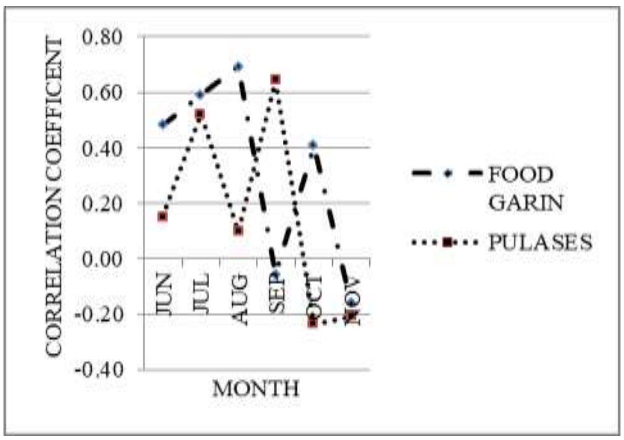




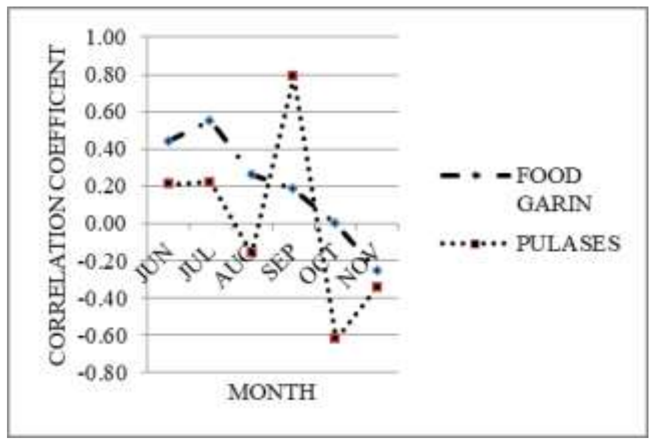
4.4 Correlation between VCI & RAI in Food grain and pulses in selected district

This trend was computed between correlation coefficient of VCI with crop yield anomaly of food grain and pulses for the each decade of months from June to November for 2002 to 2013 for Hamirpur. The Figure 3(c) shows the relationship between VCI and RAI with crop yield anomaly of food grain and pulses. This figure depicts that VCI has better correlation with yield anomaly of pulses as compared that of food grain. A negative correlation is found between RAI and pulses which shows the negative trend of production in case of pulses; where as food grain has positive correlation with RAI.

(c) Hamirpur



(d) Banda



This trend was computed between correlation coefficient of VCI with food grain production & pulses production and RAI with food grain & pulses for the each decade of months from June to November for 2002 to 2013 for Banda. The figure 3(d) shows that relationship between VCI and RAI with crop yield anomaly of food grain and pulses. This figure depicts that Banda was drastically affect due to abnormal rainfall event and VCI has better correlation with pulses and food grain. A negative correlation is found between RAI and pulses which shows the negative trend of production in case of pulses; where as food grain has no trend at the time of harvesting with RAI.

5. CONCLUSIONS - 5

The approach was based on Vegetation Condition index from MODIS-NDVI data and Rainfall Anomaly Index computed from CPC NOAA South Asia observed rainfall data. A comprehensive index for assessment of drought stress was then establishes from the correlation VCI and RAI. The first conclusion which is made from this research is that integrated approaches are better than individual method for monitoring drought as they account for both satellite as well as meteorological data. They give better results in real time drought monitoring. VCI was found to better capture drought and its impact on crop performance.

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