Drought Assessment using Satellite based Vegetation Condition Index and Rainfall Anomaly Index over Selected Raipur & Baloda-Bazar Tehsil in Chhattisgarh, India

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Abstract: ***Chhattisgarh state located in central India. Agriculture is dependent on the monsoon is critical in ensuring food availability to people of Chhattisgarh. Drought is environmental phenomenon which can be three types of drought meteorological, agricultural and hydrological drought depending upon its stage – rainfall level of impacts on hydrological cycle and agro-ecosystems. Agricultural drought is one of the most prominent natural hazards affecting economy in study area. 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 drought condition over large area. In the present study LANDSAT-8 data from 2013, 2014, 2017 and 2018 were used for monitoring agricultural drought through NDVI based Vegetation condition index. VCI was calculated for whole study area. Rainfall Anomaly Index was computed from CPC NOAA South Asia observed rainfall data from 2013, 2014, 2017 and 2018 for monitoring of meteorological drought of study area. VCI were compared with meteorological based Rainfall Anomaly index for monitoring drought in study area. Results revealed that RAI and VCI could capture spatial pattern of vegetation condition and dryness within seasons and across different years, the results show that Simga and Palari was the affected area in study area due to drought condition.***

Keywords: Drought condition, LANDSAT-8, NDVI, VCI, RAI.

1. Introduction

Agricultural droughts play a major role in the economic condition of India. Where more than 68% people are dependent in agriculture, about 16% of India total area is drought prone and about 50 million people are annually affected by drought (Dutta et. al. 2015). The drought prone areas of the country are fined to arid, semiarid and sub-humid parts of peninsular and western India. Chhattisgarh had no record of drought, crop failure and consequent scarcity till 1825. The state has its first crop failure in 1828-29 and a greater disaster due to low rainfall during 1832-33-34-35 and 1945. In next 40 years the state faced deficient rainfall 14 years causing crop failure. In eleven years the area west of the river Mahanadi were affected while in 3 years" drought also hit areas like Dhamtari, Raipur, Sarguja, and Sivagaon, when crop failure was at varied scale, price escalation was between 25 and 33 percent and there was loss of life as well. Current drought situation is unprecedented in the region. A historical analysis of rainfall data shows that October rainfall is decreasing in the Chhattisgarh region. Although the quantum of winter rainfall is low, it is sufficient to provide lifesaving moisture to specific crops like linseed and lathyrus. There has been no sowing of crops in many parts of the state. Even the sown area of the Kharif crop is all but lost. Chhattisgarh is more of a mono-crop area, but now it is critical to save the forthcoming Rabi crop. 25 out of 27 districts in Chhattisgarh are currently suffering the unprecedented harsh effects of severe drought, said to be the worst in 50 years. It is estimated that the drought has affected 19945901 populations (State IAG Chhattisgarh Joint Need Assessment Report on Drought in Chhattisgarh May 2016).

Meteorological indices estimation in meteorological drought monitoring is based meteorological satellite data (NOAA CPC) rainfall data. There are many indices which incorporate historic rainfall data for a given time period commonly used indices are, Rainfall Anomaly Index (RAI), (N.R.Patel 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 LANDSAT-8, NDVI data it is easy to monitor short term drought stress as it provides vegetation data.

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2. Study area

Study area is Raipur, Baloda Bazar district in selected Tehsil figure1. It comprises of four Tehsil of Baloda Bazar (Simga, Bhatapara, Baloda Bazar, Palari), and four Tehsil of Raipur (Arang, Abhanpur, Raipur, Tilda) in Chhattisgarh, India.

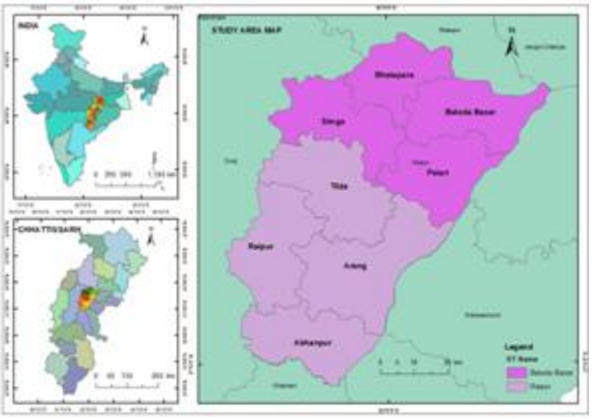

Figure1: Location of study area

3. Materials and Methodology

3.1 Data Acquisition

Data has been acquired from two sources: NDVI derived from satellite sources (04 years - monthly composite) and Rainfall Data from meteorological satellite data (NOAA CPC.) sources (04 years data- monthly composite).

Satellite data LANDSAT-8 satellite data was downloaded through distribution server: www.usgsearthexplorer. The data is kharif season composite NDVI for India from which Chhattisgarh Tehsil was extracted from Jun to Nov for 2013, 2014, 2017, and 2018. This data is used for calculating vegetation condition index for drought monitoring. Its image has a constant resolution of 30 meter.

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 Raipur and Baloda-bazar district was extracted from Jun to Nov for 2013, 2014, 2017, and 2018. 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.

3.2 Methodology

Here is an idea of methodology used in study area. Correlation technique is used to show the relationship between RAI, and VCI (kharif) in study area. The flow chart mentioned below figure 2 explains about the methodology adopted for this research work. VCI was calculated from NDVI image on basis from 2013, 2014, 2017 and 2018. Rainfall data was also used for the 2013, 2014, 2017 and 2018 year. Rainfall data basis calculated in Rainfall anomaly. These indices were then used for some correlation with RAI & VCI for detecting the impact of drought.

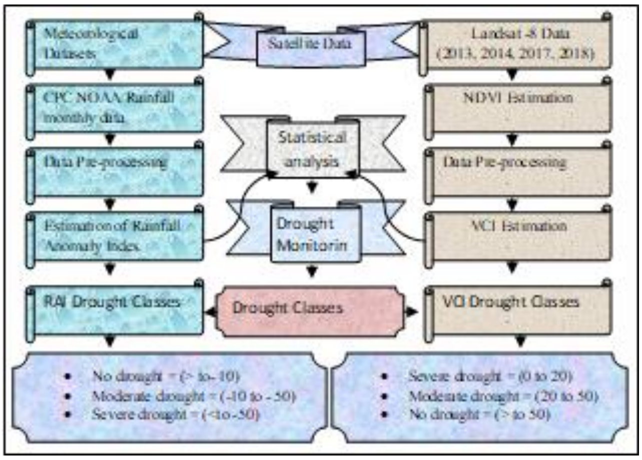

Figure 2: Methodology of study area

3.3 Index Calculation

Place Under this part various indices (satellite and meteorological) are explained.

3.3.1 Normalized Differential Vegetation Index (NDVI)

The drought severity analysis was done on temporal basis for 2013,2014,2017,2018 years. The 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.

3.3.2 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.

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3.3.3 Rainfall Anomaly Index

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).

$$\mathbf{RAI = \{(RFi - RF\ mean) / RF\ mean\} * 100}$$

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.

4. Results and Discussion

This chapter discusses about the total study that evaluate the drought stress in study area 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 LANDSAT-8-NDVI data. The data of 2013, 2014, 2017 and 2018 is considered as the time period for monitoring drought.

4.1 Analysis of satellite based Meteorological and Agricultural drought monitoring

Rainfall anomaly index and Vegetation condition index has been computed for study area. RAI and VCI has been computed for the Jun to Nov; kharif season for the drought year and normal year 2013, 2014, 2017 and 2018.

Satellite based meteorological drought monitoring in study area was carried out using RAI. The results of monitoring drought during kharif season between Jun to Nov during 2013, 2014, 2017 and 2018 show the meteorological drought, which are a series of maps indicating the stress condition in each monthly period. The figure 3 depict that the low values of RAI shows meteorological drought condition and high value of RAI shows the normal condition.

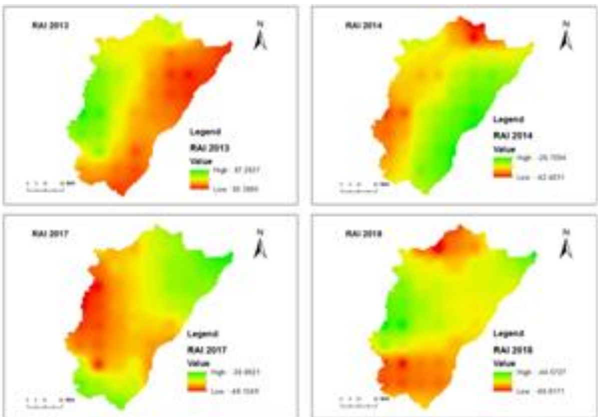

Figure 3: Meteorological drought

Satellite based agricultural drought monitoring in study area was carried out using VCI. The results of monitoring drought during kharif season between Jun to Nov during 2013, 2014, 2017 and 2018 show the agricultural drought, which are a series of maps indicating the stress condition in each monthly period. The figure 4 depict that the low values of VCI shows Agricultural drought condition and high value of VCI shows the normal condition.

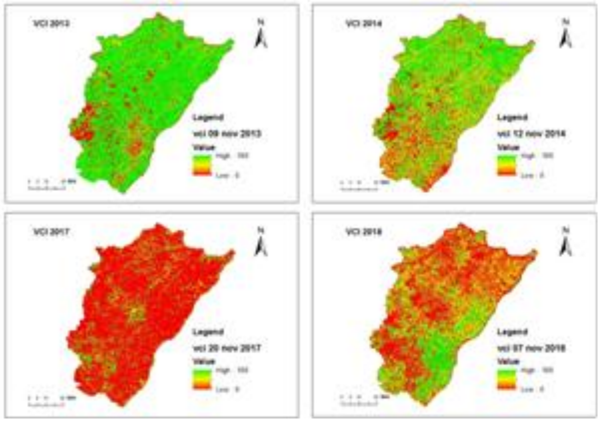

Figure 4: Agricultural drought

4.2 Satellite based RAI Meteorological drought classes monitoring

Satellite based meteorological drought classes monitoring in study area was carried out using RAI and VCI. The results show the meteorological drought classes during kharif growing season between Jun to Nov during 2013, 2014, 2017 and 2018 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 figure 5 shows the drought classes.

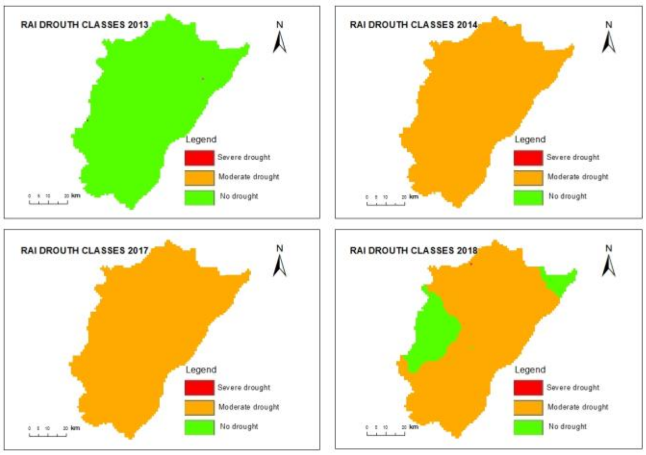

Figure 3: Meteorological drought classes

4.3 Satellite based VCI Agricultural drought classes monitoring

Satellite based agricultural drought classes monitoring in study area was carried out using VCI. The results show the agricultural drought classes during kharif growing season between Jun to Nov during 2013, 2014, 2017 and 2018 which are a series of maps indicating the drought classes' condition in each monthly period. Three types of drought

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classes are defined as no drought, moderate drought and severe drought. The figure 6 shows the drought classes.

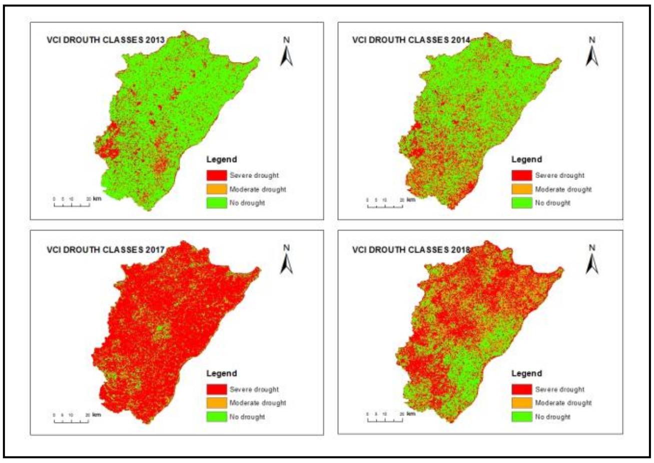

Figure 6: Agricultural drought classes.

4.4 Comparison between RAI and VCI

The Inter - annual variability in RAI & VCI, RAI value, higher value represents the more rainfall and vice versa. In case of VCI value ranges from 0 to 100. Lower VCI value represents the less vegetation condition and higher value as the healthy vegetation condition.

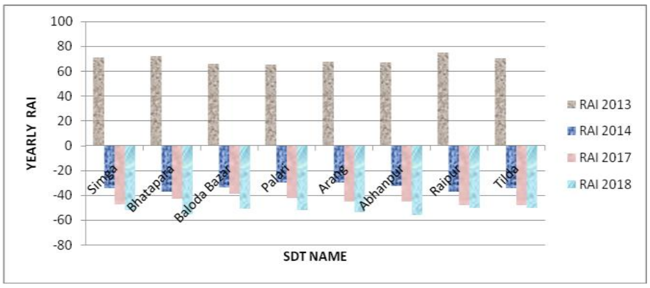

Figure: 7 RAI 2013, 2014, 2017 and 2018

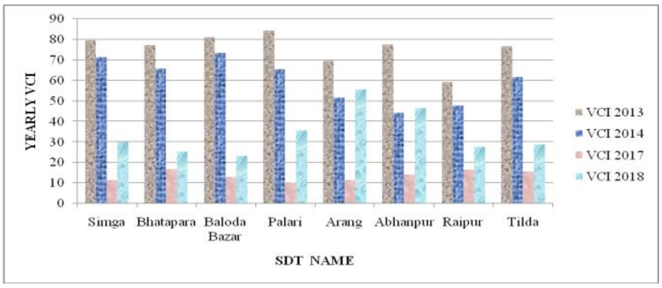

Figure: 8 VCI 2013, 2014, 2017 and 2018

Same result is obtained when spatial pattern was seen RAI vs VCI. The figure 7 RAI and figure 8 VCI shows the variation in drought condition for the duration from 2013, 2014, 2017 and 2018. The graph shows that higher VCI value was governed at the year of higher rainfall and vice versa

4.5 Comparison between VCI and RAI selected district wise

Temporal pattern of RAI & VCI during year 2013, 2014, 2017 and 2018 for selected Tehsil.

4.5.1 Simga RAI &VCI 2013, 2014, 2017, 2018

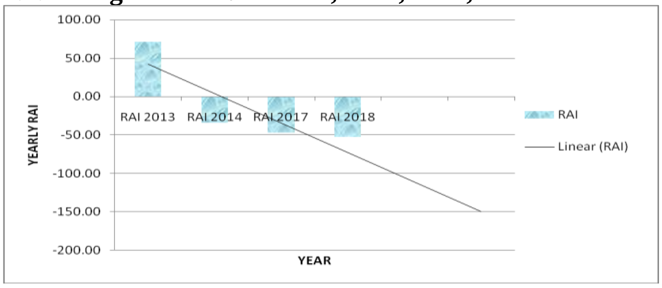

Figure 9: Simga RAI 2013, 2014, 2017 and 2018

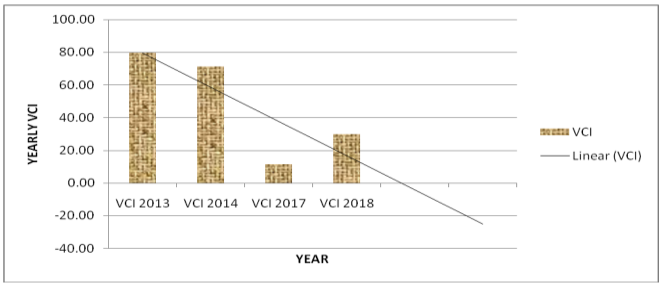

Figure 10: Simga RAI 2013, 2014, 2017 and 2018

The (Figure 9.) shows the Simga had maximum RAI in the year of 2013 and minimum RAI in the year of 2018. In case of VCI the (Figure 10.) shows the Simga had maximum VCI in the year of 2013 and minimum VCI in the year of 2017.

4.5.2 Palari RAI &VCI 2013, 2014, 2017, 2018

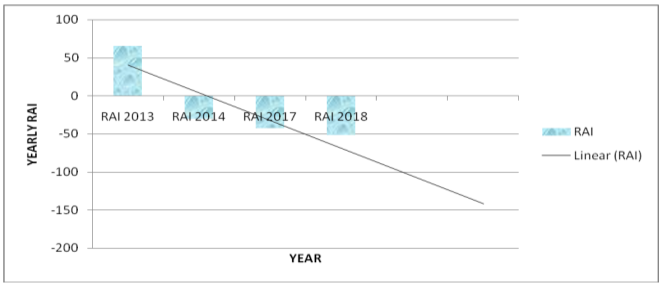

Figure 11: Palari RAI 2013, 2014, 2017 and 2018

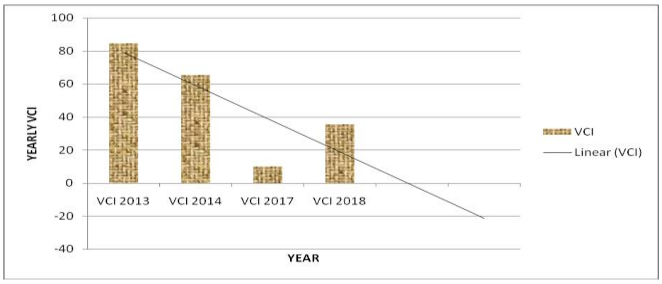

Figure: 12 VCI 2013, 2014, 2017 and 2018

The (Figure 11.) shows the Palari had maximum RAI in the year of 2013 and minimum RAI in the year of 2018. In case of VCI the (Figure 12.) shows the Palari had maximum VCI in the year of 2013 and minimum VCI in the year of 2017.

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5. Conclusion

This section discusses about the extract derived from the results of the various different method used in this study for satellite based drought monitoring.

A practical approach was developed in the study for drought stress in study area. The approach was based on Vegetation Condition index from LANDSAT-8 satellite data and Rainfall Anomaly Index computed from CPC NOAA South Asia observed rainfall data. Assessment of drought stress was then establishes from the correlation RAI and VCI.

The first conclusion which is made from this research is that method for drought monitoring as they account for both satellite as well as meteorological data. They give better results in real time vegetation condition monitoring. VCI provides good information spatially for drought monitoring. The correlation between satellite indices and meteorological indices suggest that VCI gives better information about vegetation because it does not only describe the land use but also depicts the impact of weather on crop condition. VCI is a good indicator for detecting crop on seasonal basis.

The main study area in this research deals with RAI and VCI. The overall outcome of the work is that for monitoring drought spatially RAI and VCI give better results.

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