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DROUGHT MONITORING AND ASSESSMENT USING REMOTE SENSING AND GIS APPLICATION: A CASE STUDY OF JHARKHAND, INDIA

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Abstract

In this study drought monitoring and assessment have been studied over Jharkhand state of India. Now a days, climate uncertainty is one of the major problem due to climate change and anthropogenic activities over the globe. The identification of the problem is the key element for mitigate the above mentioned issues using historical data sets. For the purpose three different indices have been utilized i.e., Standard Precipitation Index (SPI), Normalized Vegetation Index (NDVI) and Vegetation Condition Index (VCI). Hence, Python based programme and Remote Sensing and GIS based techniques have been used to quantify the SPI, NDVI and VCI respectively. The study highlights the drought characteristics such as intensity, onset and offset of drought using SPI at 3, 6 and 12 months' time scales during 1951 to 2002 for 18 districts in Jharkhand. MODIS satellite imageries have been utilised during 2000 to 2018 (October month) to derive the VCI and NDVI maps. The SPI analysis reveals that year 1966 found to be the water deficit year followed by 1992 from the span of 1951 to 2002 in Jharkhand. From the analysis it was also found that, about 78% and 56% stations experienced with extreme drought condition in year 1966 and 1992 respectively. It was also observed that as the time scale increases, the duration of drought also increases whereas, the intensity and frequency are decreases. The present study highlights spatial and temporal variations of drought severity at different location at different scales. The study can be helpful for priority based remedial solution and legislative decision making process over the state against the drought issues.

Keywords: Drought, Standardized Precipitation Index, Vegetation Condition Index, Normalized Difference Vegetation Index.

1. INTRODUCTION

Rainfall deficiency is the major cause of drought, various study showed that the trend of rainfall is declining in most of the regions of India, (Warwade et al., 2017, Warwade et al., 2018). Drought may classified into different types, mainly researchers are focusses on agricultural drought, hydrological drought, meteorological drought and socio-economical drought. Hence, it threats the living beings directly or indirectly. But it is difficult to identify as well as define, detect and monitor as it occurs slowly with time (Wilhite, 2005). Drought may be studied with spatio-temporal with respect to phenology.

Drought monitoring can be prepared with timely information on drought onset, advancement and areal extent using different drought indices. These indices help the decision makers by providing information on drought severity, frequency and duration

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which can be used to develop drought eventuality plan, if available. Palmer Drought Severity Index (Palmer, 1965), operational in United States, The Decile Index (Gibbs and Mather, 1967) used in Australia, China-Z Index (CZI) used by National Meteorological Centre of China (Wu et al., 2001), Surface Water Supply Index (SWSI- Shafer and Dezman, 1982), used by different states in USA and Standardized Precipitation Index (McKee et al., 1993) are some of the drought indices that have gained popularity till date. Most of these indices are calculated using climatic data (mostly rainfall and in some cases temperature such as PDSI). McKee et al., (1993) developed the Standardized Precipitation Index (SPI) to monitor the status of drought in Colorado State of USA. SPI is advantageous for monitoring dry and wet periods over wide duration of time i.e., 1-72 months. SPI is considered as the most authentic index for generating drought than the Palmer Drought Severity Index. The Indian Meteorological Department (IMD) report states that about 330 million people in India are affected by drought annually. Water shortage and below average crop yield are some of the commons effects of drought in India. This is evident in drought prone areas like southern and eastern Maharashtra, northern Karnataka, Jharkhand, Andhra Pradesh Orissa, Gujarat and Rajasthan. Different sectors of area have different water requirements, which make it impossible for generating general drought conditions that are predominant over the whole sector at once. Defining drought in terms of agricultural, meteorological, socio-economic and hydrological conditions is not possible because defining drought in one field is not appropriate for implementation in other fields.

Meteorological drought is defined on the basis of degree of dryness (with respect to some “normal” or average amount) and duration of dry period. Different countries use different definitions for meteorological drought. Agricultural drought refers to the situation when rainfall and soil moisture are insufficient during crop growing season to support healthy crop to maturity, causing crop stress and wilting. Depletion of surface water occurring due to decrease in precipitation, very low stream flow and drying of lakes, reservoirs, rivers etc. result in hydrological drought. Hisdal and Tallaksen (2003) found that hydrological droughts are often lagged compared to Meteorological droughts. When the water resource system fails to fulfil the demands associated with socio-economic conditions such as water supply and demand for economic goods then the condition is termed as socio-economic drought. Drought has negative impact on various sectors of the society e.g., economy, energy, recreation, agriculture, water resources, ecosystems and human health (Dai et al., 2004, Watson et al., 1997). Various research studied on land management, crop suitability and vegetation cover stated that drought is that phenomenon that affects it (Warwade et al., 2014; Jha et al., 2022). A prolonged Drought can crumble the economy of the affected region as well as causing devastating impacts on that environment and on the society, the effect can be greater for developing countries. The assessment of the drought is done by combining the quantitative indices such as SPI, PDSI etc. and various drought indicators like wildfires, lake levels etc. with on-the-ground report to have a clear picture of the actual drought conditions. Each drought monitoring tool has some sort of its limitation and therefore to cope up with the limitations of that tool, it is advised to use at least two or more drought indices to create a more comprehensive drought forecast. The drought also adds additional burden on the

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government exchequer. There are a variety of remotely sensed data acquired from the space by the sensors like MODIS, ASTER, AMSR-E, AVHRR, SMOS, AWiFS, LISS-III, ETM+ etc. which serves as input for the various methods throughout the electromagnetic spectrum which are capable for the identification, locating and analysing severity of the Agricultural drought. National Agricultural Drought Assessment and Monitoring System (NADAMS) is very successful from the very beginning of the project since 1989 under ISRO (Indian Space Research Organization) in India which effectively utilizes the drought information from satellite products for contingency planning and for drought declaration process. Aghakouchak et al., (2015) had reviewed the existing as well as emerging drought monitoring methods particularly those that use satellite based data to analyse the drought conditions over a specific region. The advantage of using satellite based data is that it provides real time data over a wide region and some disadvantages associated with the satellite data are that of Data continuity, short length of records, changes in sensors, acceptability by the community etc. India is a country with diverse flora and fauna and with over 1.33 billion of population (World Bank) dwelling in a landmass of 3.287 million Sq. KMs and are highly dependent on the agriculture. Jharkhand is a region in eastern India where 75% of its workforce relies on agriculture for their livelihood. Since, almost all the people are dependent on the mercy of the monsoon the required data regarding the monitoring, assessment and prediction of Agricultural drought collected during Rabi and kharif seasons. Dutta et al., (2015) attempted to assess the efficiency of the remote sensing and Geographic Information System (GIS) techniques for monitoring the spatial and temporal extent of agricultural drought for whole Rajasthan. Jin et al., (2016) assessed ecological vulnerability in western China based on time-integrated NDVI data from 1982 to 2013. Hazaymeh et al., (2017) studied about a remote sensing –based agricultural drought indicator and its implementation over a semi-arid region, Jordan Kenawy et al., (2019) had used the normalized difference vegetation index (NDVI) to precisely portray the potential water suppliers for the western Arabian Peninsula. The author had extracted different time series NDVI data from the Moderate Resolution Imaging Spectroradiometer (MODIS) which were further used to develop a robust estimate of rainstorm intensity and frequency. The Meteorological drought may not always result in Agricultural drought, since some regions might be having a good irrigation network for the crops which can obviously hinder the results of the drought assessment, but the rain-fed crops are always affected by the meteorological drought.

Vicente Serrano et al., (2010) studied the Standardized precipitation evapotranspiration index (SPEI). Drought conditions were determined through Standardized Precipitation Index (SPI) and cumulative deviation curve techniques. Chanda et al., (2015) had proposed a new index called Standardized Precipitation Anomaly Index (SPAI) which can be used to quantify the meteorological drought in those regions where precipitation is strongly seasonal and periodic. They had demonstrated this by using a non-periodic precipitation series from Kansas, USA and a strongly periodic precipitation series from India. Weng et al., (2015) studied and investigated that with the expanding effect of environmental change and anthropogenic exercises, dry season occurs in more zones with higher recurrence. Chang et al., (2016) had acquired the precipitation data of 1960-2010 from 21 meteorological stations to analyse the short, medium and long term drought

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on 3, 6 and 12 months timescales respectively using the Standardised Precipitation Index (SPI) with the analysis of the trends of the drought characteristics by modified Mann-Kendall (MMK) test method. Ramkar et al., (2018) had studied the spatial and temporal variation of the drought associated to semi-arid region of the Tapi river basin in Central India. The temporal analysis of the drought was conducted using SPI, Rainfall Decile (RD), and Reconnaissance Drought Index (RDI). Mohammad et al., (2018) Investigated and examined the dry season status in the Yarmouk Basin (YB), in northern Jordan, utilizing the Standardized Precipitation Index (SPI), the Standardized Water-Level Index (SWI), and the Percent Departure from Normal precipitation (PDNP) during the years 1993–2014. Evaluation of a seasonal drought assessment and prediction model for Agricultural drought with different approaches for rain-fed and irrigated areas would help the government in better planning and taking necessary steps to mitigate the impacts of Drought.

Keeping the basic knowledge of the Agricultural, meteorological and Hydrological drought as well as keeping in mind the future challenges associated with the drought, the present study focus on Drought monitoring. First, we monitored drought using the Standardized Precipitation Index from 1950 to 2002. Second, we assessed drought using NDVI and VCI. Finally, we compared the results getting from using NDVI and VCI with results of the meteorological based SPI.

2. METHODOLOGY

Present area is conducted under Jharkhand state, India. “The land of Forests” which is located in the eastern region of India and is spatially located between north latitudes 21º-58´ – 25º-18´ and east longitudes 83º-22´ – 87º-57´. It has geographical area of 79,714 km^2 out of which 38 lakh hectares is cultivable land and 2239481 hectares is forest area which accounts for approximately 23% of the total land coverage. The state is endowed with five main rivers namely Barakar, Swarnrekha, Damodar, Koyal, and Shankh which are used for irrigation purposes at many of places. The average elevation above sea level of Jharkhand is 1000 ft. and Parasnath being the highest point of Jharkhand with an elevation of around 4400 ft. Jharkhand is an entirely land locked state which shares its boundary with Bihar in the north, Odisha at its south, West Bengal at its East, and Chhattisgarh and the Uttar Pradesh in the west. The state has some of the most spectacular natural wonders in the form of Waterfalls, luxuriant forests and undulating hills and mountain ranges that boosts ecotourism.

The plains of the Jharkhand are moderate fertile in nature and are composed of different types of soil. The red soil is common along the Damodar valley and Rajmahal area. Sandy soil are found in Dhanbad and Hazaribagh regions, while Laterite soil is found in abundance in the western part of Ranchi, Palamu and in some regions of Santhal Paragana and Singhbhum areas. The regions of Koderma and Jhumri Tilaiya are rich in micacious soil (Having Mica). The soil of Jharkhand in general have very low amount of Phosphorous and Sulphur, the availability of Nitrogen and Potassium is medium in the soil and Boron is almost absent from the soil. The state is bequeathed with large deposits of minerals such as coal, bauxite, iron, manganese, mica, limestone, copper etc. The

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presence of abundant minerals has led to the setting up of many industries which in turn had employed a number of people. Location map of study area is shown in Figure 1.

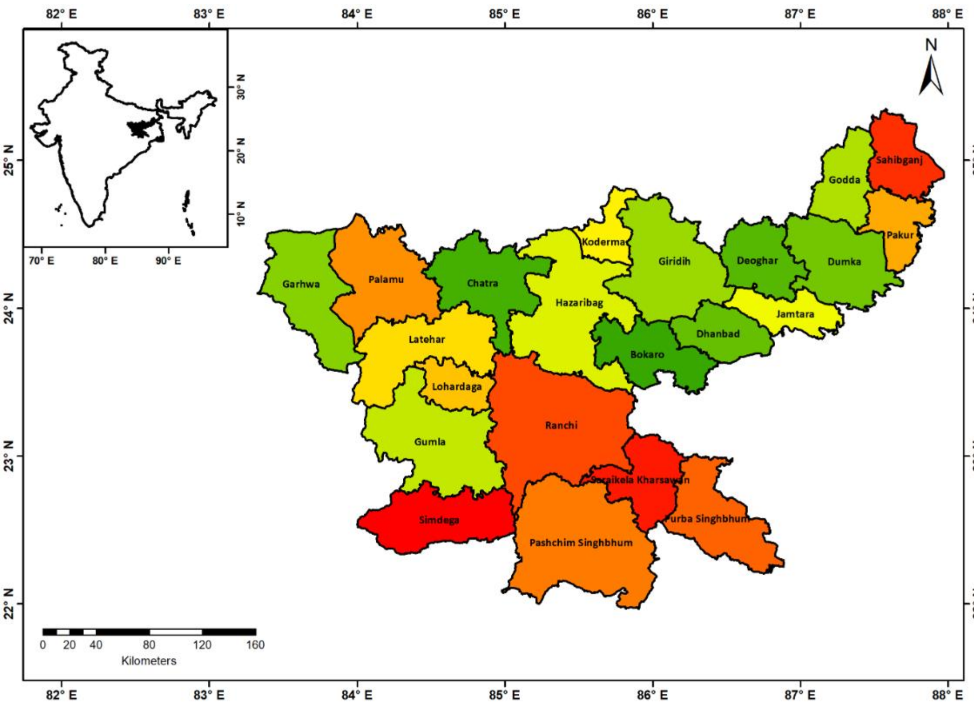

Fig 1: Location map of districts of Jharkhand in India

Agriculture is one of the major modes of earning livelihood in Jharkhand. Going by the demographics of Jharkhand, 82.20% people lives in the villages and totally depend on the primary sector i,e., agriculture. Merely 14% of the total sown area in Jharkhand is equipped with the irrigation facilities and hence most of the farmers are fully dependent on the mercies of monsoon for agricultural yield. Rice is the leading crop in Jharkhand. Other major crops that are produced in Jharkhand are Millet, Maize, Wheat, Barley, oilseeds etc.

The Terra Moderate Resolution Imaging Spectro-radiometer (MODIS) vegetation indices (MOD13A3) data is used for this work to find NDVI response and VCI values. These data have been acquired from U.S. Geological Survey (earthexplorer.usgs.gov).The Meteorological data related to Monthly mean data was used to find out the Meteorological drought year, Normal year and for the assessment of the drought using Standardized Precipitation Index (SPI) for Jharkhand has been procured from India Meteorological Department (IMD).

2.1 Standardized Precipitation Index (SPI)

SPI values were estimated for all the stations for different time scales 3, 6 and 12 months. The drought begins when the SPI first falls below zero and ends with the positive value of SPI following a value -1 or less. It is a dimensionless Index whose negative value indicates drought while positive value indicates wet condition. Calculation of any station

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is based on the long term precipitation record (at least 30 years) of desired time steps (Edwards and McKee, 1997). In this study SPI is calculated for 3, 6 and 12 months for considering the agricultural and hydrologists point of view. The gamma distribution is defined by its probability density function, which is given as below (Eq. 1):

$$g(x)=\frac{1}{\tau(\alpha)\beta^{\alpha}}x^{\alpha-1}e^{\frac{-x}{\beta}} \quad (1)$$

Where

$\alpha = ShapeParameter, \alpha > 0$

$\beta = ScaleParameter, \beta > 0$

The maximum likelihood method is used here to optimally estimate the parameters of gamma function (Eq. 2, Eq. 3, Eq. 4).

$$\alpha=\frac{1}{4A}\left(1+\sqrt{1+\frac{4A}{3}}\right) \quad (2)$$

$$\beta=\frac{\bar{x}}{\alpha} \quad (3)$$

Where

$$A=\ln\bar{x}-\frac{\sum \ln x}{n} \quad (4)$$

$N = Number of\ precipitation\ observation$

The cumulative probability density function is given by (Eq. 5):

$$G(x)=\int_0^x g(x)d(x)=\frac{1}{\tau(\alpha)\beta^{\alpha}}\int_0^x x^{\alpha-1}e^{\frac{-x}{\beta}}d(x) \quad (5)$$

Mathematically gamma distribution is undefined for zero value and the monthly precipitation may have zeroes, so the cumulative probability function becomes (Eq. 6)

$$H(x)=q+(1-q)G(x) \quad (6)$$

Where, q is the probability of a zero and its value is obtained by dividing the no of zeroes to the total no. of precipitation data. For longer time scales such as 3, 6, 12, 24 months

The graphical method of equi-probability transformation from fitted gamma distribution standard normal distribution is the general method of Z transformation (Eq. 7, Eq. 8, Eq. 9 and Eq. 10).

$$Z=SPI=\left(t-\frac{c_0+c_1t+c_2t^2}{1+d_1t+d_2t^2+d_3t^3}\right) \quad (7)$$

$for\ 0 < H(x) \leq 0.5$

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$$Z = SPI = -\left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}\right) \quad (8)$$

$for\, 0.5 < H(x) \leq 1.0$

Where

$c_0 = 2.515517; c_1 = 0.802583; c_2 = 0.010328; d_1 = 1.432788; d_2 = 0.189269; d_3 = 0.001308$

$$t = \sqrt{\ln \frac{1}{(H(x))^2}} \quad (9)$$

$for\, 0 < H(x) \leq 0.5$

$$t = \sqrt{\ln \frac{1}{(1 - H(x))^2}} \quad (10)$$

$for\, 0.5 < H(x) \leq 1.0$

Drought characteristics: The specification of a time scale in the definition of drought leads to several basic characteristics of drought like severity, intensity, duration and frequency. Two of the most important characteristics are frequency and duration. *Severity* of a drought event is given as Drought Magnitude (Eq. 11)

$$DM = \sum_{j=1}^{x} SPI_{ij} \quad (11)$$

Where, j starts with the first month of a drought and continues to increase until the end of the drought (x) for any of the i time scales. The DM has units of months and would be numerically equivalent to drought duration if each month of the drought has SPI = -1.0.

Intensity of a drought event is given as DM divided by no. of months between first negative SPI value and last negative SPI value. Frequency is the no. of events in a time period which is dependent on different time scales.

2.2 Normalized Difference Vegetation Index (NDVI)

The Satellite data MODIS (MOD13A3) have been used to estimate the NDVI values of October month for both the normal and drought years which can reflect the vegetation scenario of monsoon season of the said years.

NDVI is suitable for monitoring drought, estimating healthy status of vegetation, crop growth conditions and crop yields (Logan, 1987; Dabrowska-Zielinska et al., 1987; Singh et al., 2003). The basic concept of NDVI is based on the fact that internal mesophyll structure of healthy green leaves reflect Near-Infrared (NIR) radiation whereas the leaf chlorophyll and other pigments absorb a large proportion of the red visible (VIS) radiation. This function of internal leaf structure becomes reversed in case of unhealthy or water stressed vegetation (Eq. 12).

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$$NDVI = \frac{(NIR - VIS)}{(NIR + VIS)} \quad (12)$$

NDVI is calculated using the difference between reflectance in Near-Infrared (NIR) and red band (VIS) of electromagnetic spectrum. The NDVI value ranges between -1 and +1. It may range from 0.6 to 0.8 in the temperate and tropical rainforests and can go below 0.1 in the areas with barren rocks, sand and snow cover. The effectiveness of NDVI for studying vegetation and related issues may be restricted by several sources of error that usually occur due to atmospheric nuisances and many other reasons like sensor degradations, satellite orbit drift and change of satellite. (Kogan, 1995).

2.3 Vegetation Condition Index (VCI)

Since, weather related NDVI fluctuations cannot be detected easily, the ecological component must be separated from the impact of weather for estimating the actual condition of vegetation health. In this context, Kogan (1995) suggested Vegetation Condition Index for identifying drought related vegetation stress and measuring the intensity, time of onset, duration, dynamics and impacts of drought on overall vegetation condition. The following equation is applied on the final NDVI database (Eq. 13):

$$VCI = \frac{(NDVI_j - NDVI_{min})}{(NDVI_{max} - NDVI_{min})} \times 100 \quad (13)$$

Where, $NDVI_{max}$ and $NDVI_{min}$ represent maximum and minimum NDVI of each pixel calculated for each month and j represents the index of current month. VCI value is being measured in percentage ranging from 1 to 100. The range between 50% and 100% indicates above normal condition of vegetation whereas the values ranging from 50% to 35% indicate the drought condition and below 35% indicates severe drought condition (Kogan, 1995). This index normalizes NDVI and separates the long-term ecological signal from the short term climate signal and in this sense it proves to be a better indicator for monitoring water stress condition as compared to NDVI (Kogan and Sullivan, 1993). The resulted images of Vegetation Condition Index (VCI) were classified on the basis of drought severity classification proposed by Kogan (1995).

3. RESULTS AND DISCUSSIONS

3.1 Drought monitoring through SPI

The SPI is a very powerful tool which is frequently used by decision makers to assess and monitor the intensity of meteorological drought events over the globe. In present study, SPI index was used to identify the incidence, intensity and temporal variation of meteorological drought then results have been compared with agricultural drought index i.e., VCI and NDVI. Month of September has been chosen for the calculation as negative SPI value in wet season will indicate drought throughout the year. Value of SPI of different districts during 1951-2002 are depicted in Figure 2.

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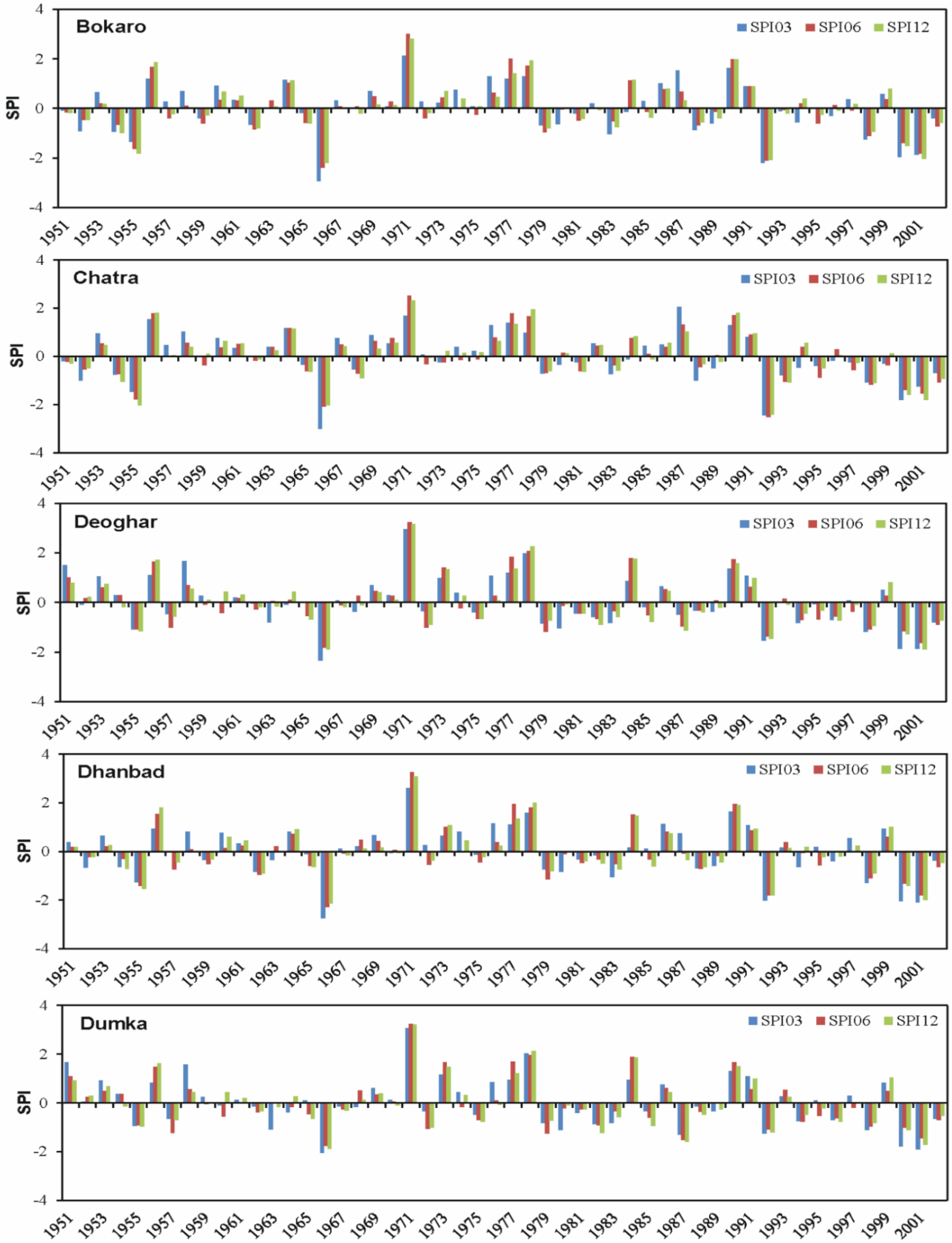

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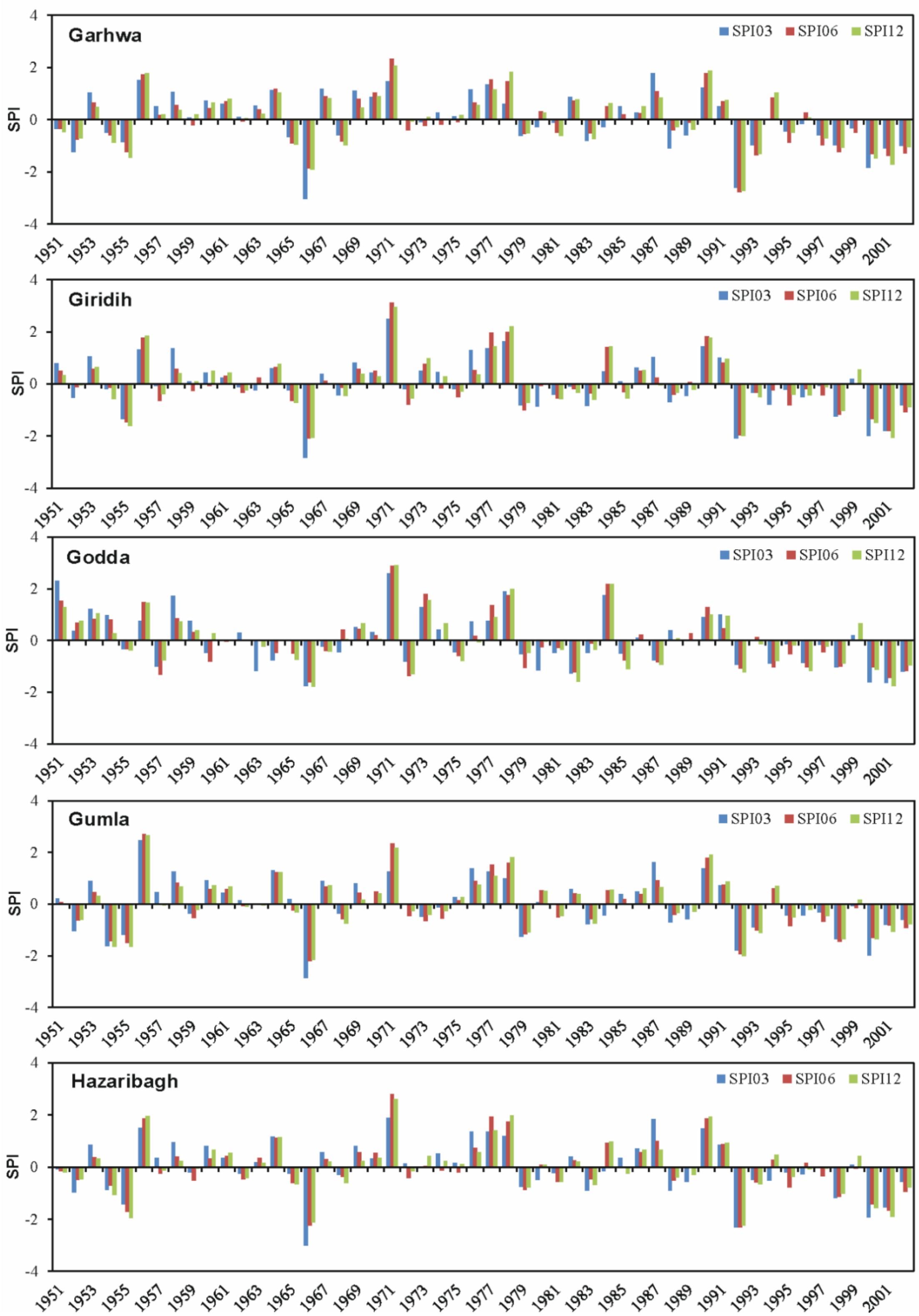

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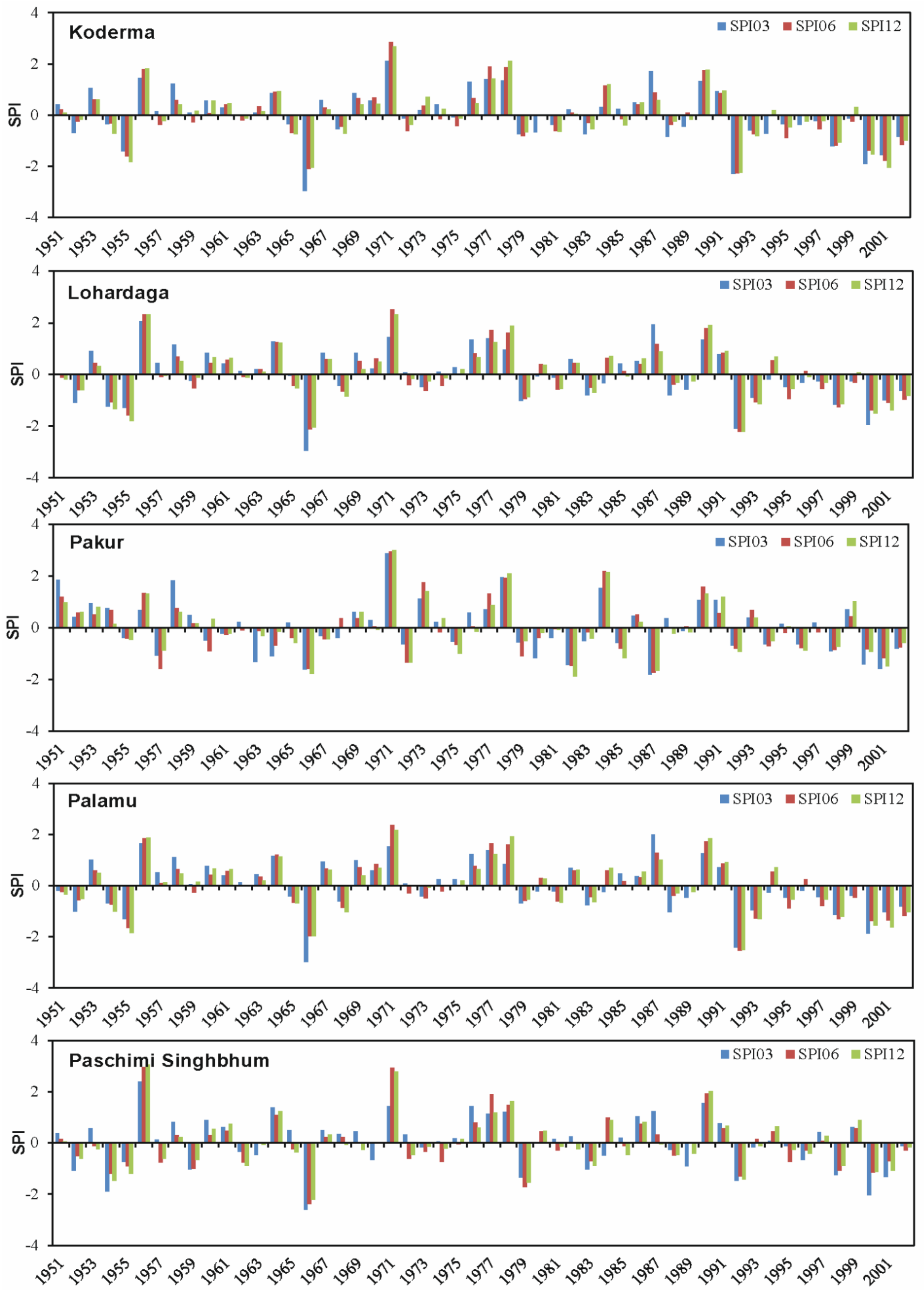

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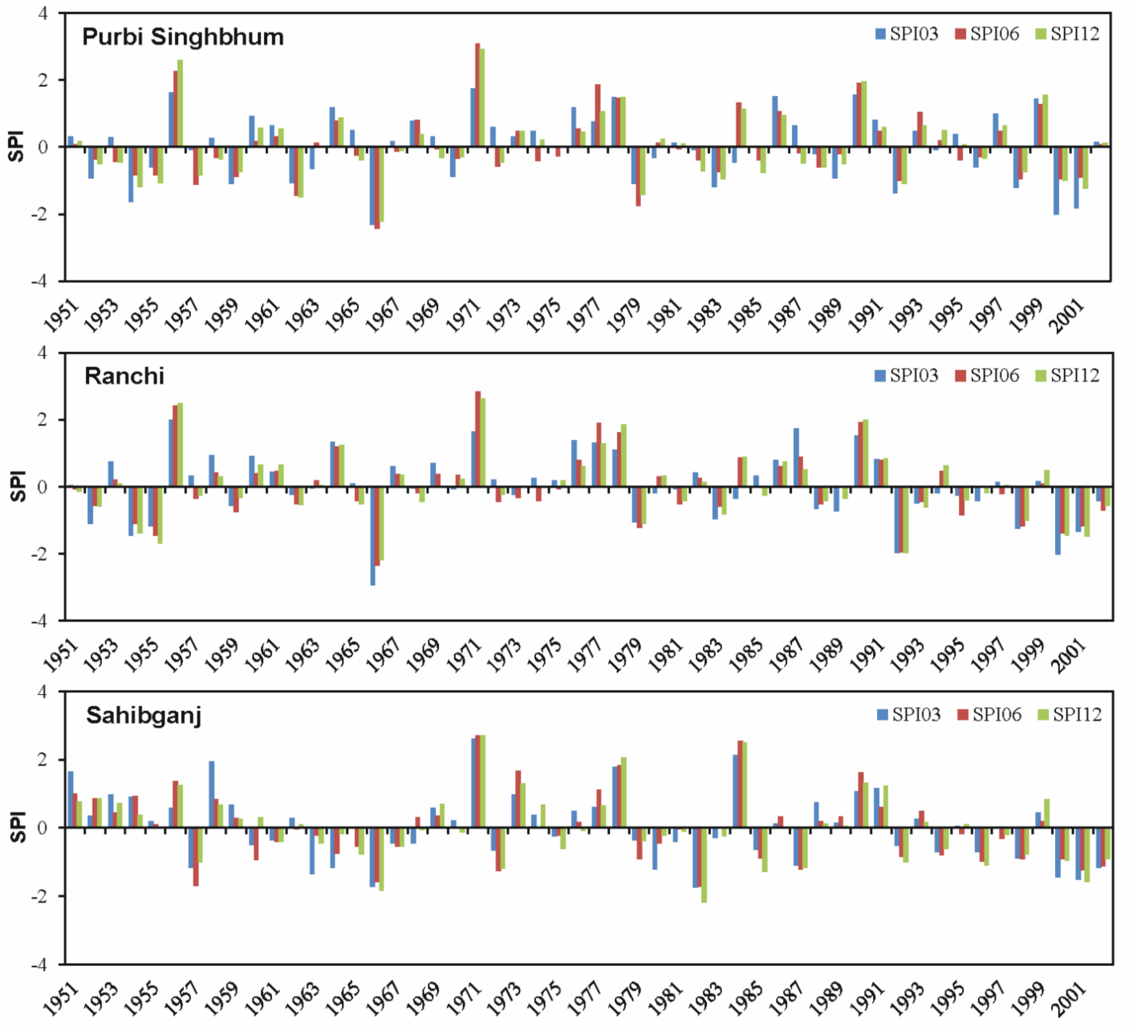

Fig 2: District wise variations of SPI values of September during 1951-2002 in Jharkhand

As above mentioned figure clearly showing the three scale i.e., 3-montly, 6-monthly and 12-monthly variability of SPI values during 1951 to 2002 in different districts of Jharkhand. From this study it was noticed that the 78% data has been indicated an extreme drought events during year 1966 except Deoghar, Dhanbad, Garhwa and Palamu (SPI-6 and SPI-12 showing Severe Drought). In the same year 1966, the SPI values of all the three time scales showed severe drought for Godda, Lohardaga, Pakur and Sahibganj. As per the results, year 1966 declared as an extreme dry year during the study period 1951-2002while the state experienced an extreme wet condition in year 1971. Similarly in the year 1992, ten stations namely Bokaro, Chatra, Dhanbad, Garhwa, Giridih, Gumla, Hazaribagh, Koderma, Lohardaga and Palamu exhibited extreme dry condition. Further 56% stations were experienced extreme drought condition in year 1992 in the state. During 1992-1998, there was a continuous trend of negative values of SPI of all the three time scales at most of the stations shows the prolonged dry condition in the region from

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1992 to 1998. It can also be stated that as the time scale increases from 3 monthly to 12 monthly, the frequency decreases and SPI value's fluctuation is more frequent at 3 monthly time scale as compared to 12 month time scale. District wise 3-Monthly, 6-Monthly and 12- Monthly SPI in normal (2002) and dry (2000) year are shown in Table 1, Table 2 and Table 3 respectively.

Table 1: District wise 3-Monthly SPI in normal (2002) and dry (2000) year

S. No.	Station	Normal Year (2002)				Dry Year (2000)		
		SPI-Jul	SPI-Aug	SPI-Sep		SPI-Jul	SPI-Aug	SPI-Sep
1	Bokaro	-1.27	-0.65	-0.40		-1.11	-1.90	-1.97
2	Chatra	-1.79	-1.05	-0.69		-1.25	-1.97	-1.81
3	Deoghar	-1.21	-0.83	-0.80		-1.00	-1.62	-1.87
4	Dhanbad	-1.09	-0.54	-0.37		-0.98	-1.81	-2.05
5	Dumka	-0.94	-0.62	-0.65		-0.81	-1.44	-1.77
6	Garhwa	-1.96	-1.22	-1.01		-0.84	-1.76	-1.83
7	Giridih	-1.58	-1.01	-0.81		-1.22	-1.93	-1.98
8	Godda	-1.26	-1.06	-1.20		-1.03	-1.42	-1.61
9	Sahebganj	-1.16	-0.97	-1.17		-0.98	-1.25	-1.44
10	Gumla	-1.56	-0.79	-0.59		-0.75	-1.41	-1.97
11	Hazaribagh	-1.55	-0.88	-0.57		-1.21	-1.94	-1.92
12	Kodarma	-1.80	-1.13	-0.84		-1.3	-2.01	-1.91
13	Lohardaga	-1.65	-0.92	-0.62		-1.01	-1.69	-1.95
14	Pakur	-0.90	-0.67	-0.81		-0.79	-1.19	-1.42
15	Palamu	-1.91	-1.13	-0.82		-1.09	-1.85	-1.87
16	West Singhbhum	-0.75	-0.28	-0.13		-0.42	-1.15	-2.05
17	East Singhbhum	-0.35	0.07	0.15		-0.21	-1.11	-2.01
18	Ranchi	-1.28	-0.66	-0.41		-0.92	-1.63	-2.03

Table 2: District wise 6-Monthly SPI in normal (2002) and dry (2000) year

S. No.	Station	Normal Year (2002)				Dry Year (2000)		
		SPI_Jul	SPI_Aug	SPI_Sep		SPI_Jul	SPI_Aug	SPI_Sep
1	Bokaro	-1.29	-0.74	-0.73		-0.88	-1.69	-1.40
2	Chatra	-1.79	-1.11	-1.08		-1.12	-1.96	-1.39
3	Deoghar	-1.23	-0.89	-0.91		-0.89	-1.50	-1.17
4	Dhanbad	-1.12	-0.63	-0.63		-0.78	-1.54	-1.32
5	Dumka	-0.94	-0.67	-0.70		-0.71	-1.25	-1.02
6	Garhwa	-1.95	-1.28	-1.28		-0.81	-1.80	-1.32
7	Giridih	-1.59	-1.08	-1.07		-1.08	-1.81	-1.35
8	Godda	-1.24	-1.10	-1.19		-1.01	-1.38	-1.04
9	Gumla	-1.60	-0.82	-0.91		-0.55	-1.45	-1.30
10	Hazaribagh	-1.56	-0.95	-0.93		-1.02	-1.85	-1.43
11	Kodarma	-1.79	-1.19	-1.16		-1.19	-1.95	-1.38
12	Lohardaga	-1.66	-0.96	-0.97		-0.81	-1.71	-1.39
13	Pakur	-0.86	-0.70	-0.77		-0.73	-1.03	-0.84
14	Palamu	-1.90	-1.18	-1.18		-0.97	-1.87	-1.38
15	West Singhbhum	-0.85	-0.29	-0.29		-0.08	-1.04	-1.15
16	East Singhbhum	-0.43	0.03	0.07		0.10	-0.74	-0.94
17	Ranchi	-1.33	-0.71	-0.66		-0.64	-1.56	-1.39
18	sahebganj	-1.10	-0.99	-1.11		-0.96	-1.18	-0.91

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Table 3: District wise 12-Monthly SPI in normal (2002) and dry (2000) year

S. No	Districts	Normal year (2002)				Dry year (2000)		
		SPI_July	SPI_Aug	SPI_Sep		SPI_July	SPI_Aug	SPI_Sep
1	Bokaro	-1.77	-1.27	-0.57		-0.40	-1.25	-1.51
2	Chatra	-1.75	-1.49	-0.94		-1.29	-2.03	-1.58
3	Deoghar	-1.71	-1.34	-0.73		-0.45	-1.21	-1.27
4	Dhanbad	-1.77	-1.18	-0.48		-0.04	-0.94	-1.42
5	Dumka	-1.53	-1.13	-0.54		-0.05	-0.85	-1.12
6	Garhwa	-1.72	-1.48	-1.04		-1.17	-1.92	-1.49
7	Giridih	-1.88	-1.50	-0.88		-0.84	-1.59	-1.48
8	Godda	-1.60	-1.44	-0.97		-0.72	-1.38	-1.13
9	Gumla	-1.47	-1.16	-0.77		-0.48	-1.67	-1.34
10	Hazaribagh	-1.78	-1.40	-0.77		-0.89	-1.69	-1.57
11	Kodarma	-1.86	-1.57	-0.99		-1.15	-1.86	-1.54
12	Lohardaga	-1.59	-1.29	-0.82		-1.00	-1.95	-1.50
13	Pakur	-1.29	-1.04	-0.59		-0.07	-0.77	-0.92
14	Palamu	-1.69	-1.48	-1.02		-1.25	-2.04	-1.54
15	West Singbhum	-1.24	-0.70	-0.18		0.39	-0.95	-1.14
16	East Singhbhum	-1.11	-0.45	0.14		1.12	-0.17	-1.01
17	Ranchi	-1.56	-1.12	-0.56		-0.50	-1.56	-1.46
18	Sahebganj	-1.45	-1.28	-0.90		-.0.48	-1.10	-0.97

Further, as we know that the average annual rainfall of Jharkhand is 1250 mm and as per the results the year 1965, 1966, 1972, 1992 and 2000 have been detected as the meteorological drought years.

For spatial analysis using VCI and NDVI, year 2000 has been chosen as the dry year while 2002 is the normal year. The normal year and drought years were monitored using SPI and compared with the results obtained from NDVI derived Vegetation Condition Index (VCI).

From the Table 1, Table 2 and Table 3, it can be seen that in the normal year (2002), all the districts indicate near normal to moderate drought condition for all the three time scales.

Most of the stations indicated moderate to extreme dry condition for all three time scales in the months of July, August and September in 2000.

Fluctuation of SPI value in year 2000 and 2022 for SPI-3, SPI-6 and SPI-12 are illustrated in Figure 3.

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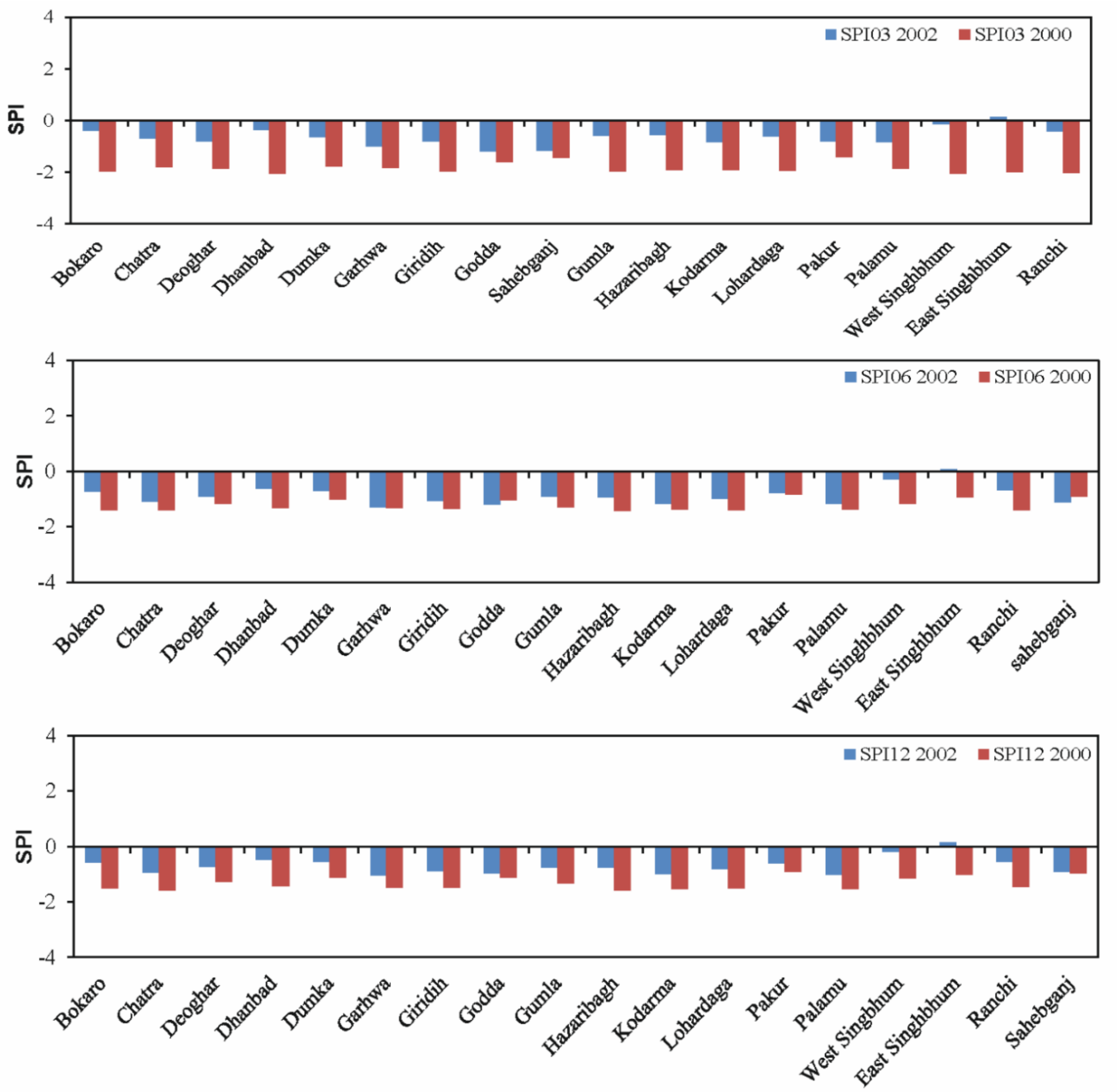

Fig 3: Comparison of drought and normal year for the month of September using SPI03, SPI06 and SPI12

3.2 NDVI and drought monitoring

Though NDVI has been used by many authors for studying drought, it has been recommended by a number of studies to use VCI rather than using NDVI alone. In the present study, the stacked NDVI layers were visualized to identify differences in vegetation health during normal (2002) and dry year (2000) shown in Figure 4. In order to assess the performance of MODIS derived NDVI, two non-consecutive years, 2000 and 2002 were chosen for their distinct NDVI characteristics.

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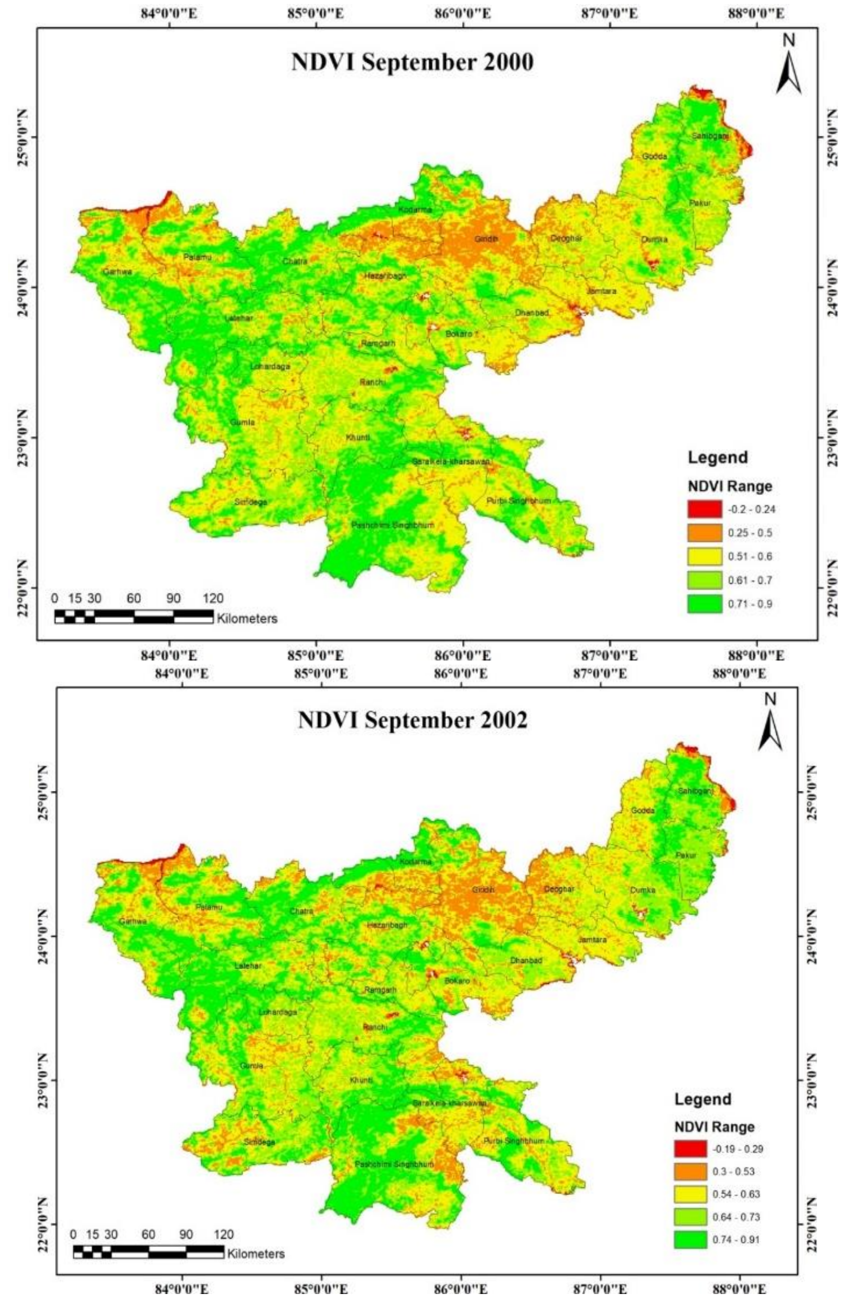

Fig 4: Comparison of drought (2000) and normal year (2002) using NDVI

Further NDVI maps are prepared during the month of October for the year of 2008, 2009, 2015, 2016 and 2018. However, 2016 year is chosen as normal year which are also indicated the NDVI values depicted in Figure 5.

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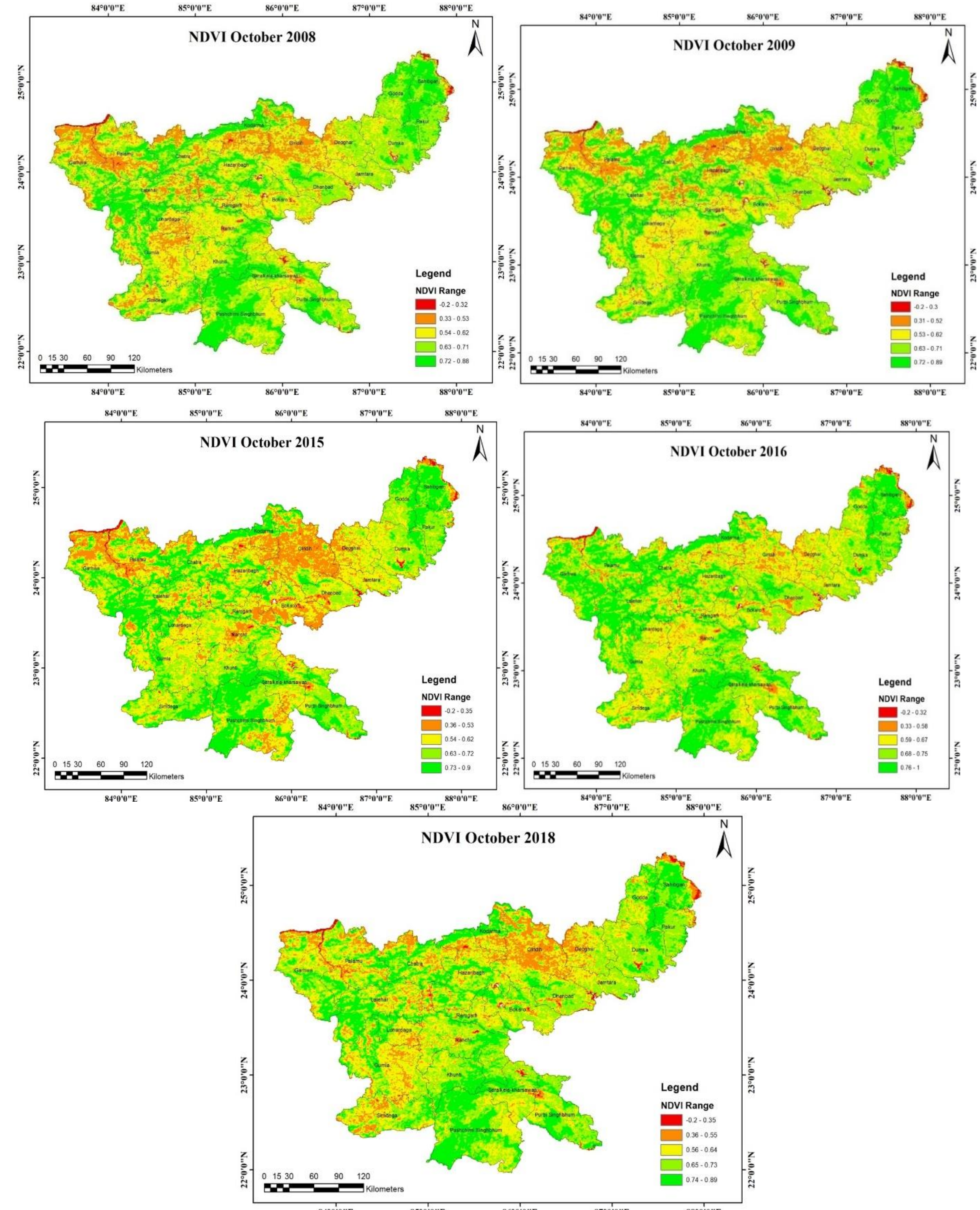

Fig 5: NDVI response during October 2015, October 2016 and October 2018

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3.3 Drought monitoring through VCI

While monitoring drought with VCI, it was found that most of the parts are above normal condition in 2002. The value of VCI observed in 2002 was much greater than the VCI value of 2000 which indicates year 2000 as drought year which means year 2000 was in more stressed condition than year 2002.

In year 2000, even some parts in Jharkhand are indicating more greenness due to particular days rainfall as similar pattern obtained in NDVI image which was also reflected in VCI variation map. Results shows that VCI declared the year 2000 was a drought year and 2002 was a normal year which indicates that MODIS data can be successfully used for the drought assessment in absence of meteorological data. Both the maps are shown in Figure 6.

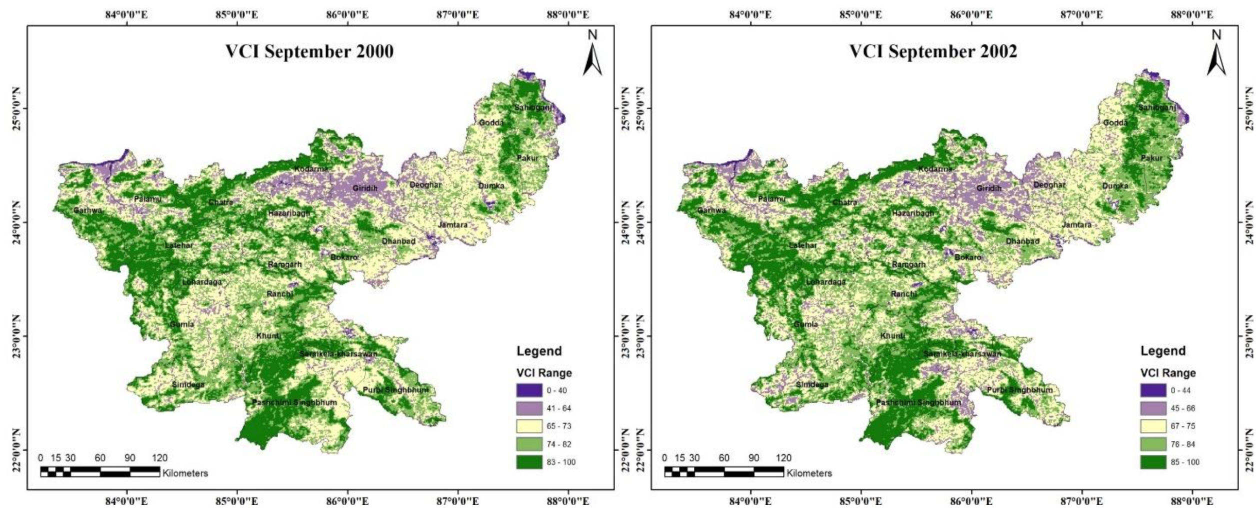

Fig 6: Spatial variation of Vegetation Condition Index (VCI) during normal year (2002) and dry year (2000).

Further, the recent drought years of 2008, 2009, 2015, 2016 and 2018 were examined using the Vegetation Condition Index (VCI) responses during the October month. VCI responses of the drought years 2008, 2009, 2015, 2016 and 2018 respectively. Whereas the year 2016 is chosen as normal year which are also shown in Figure 7.

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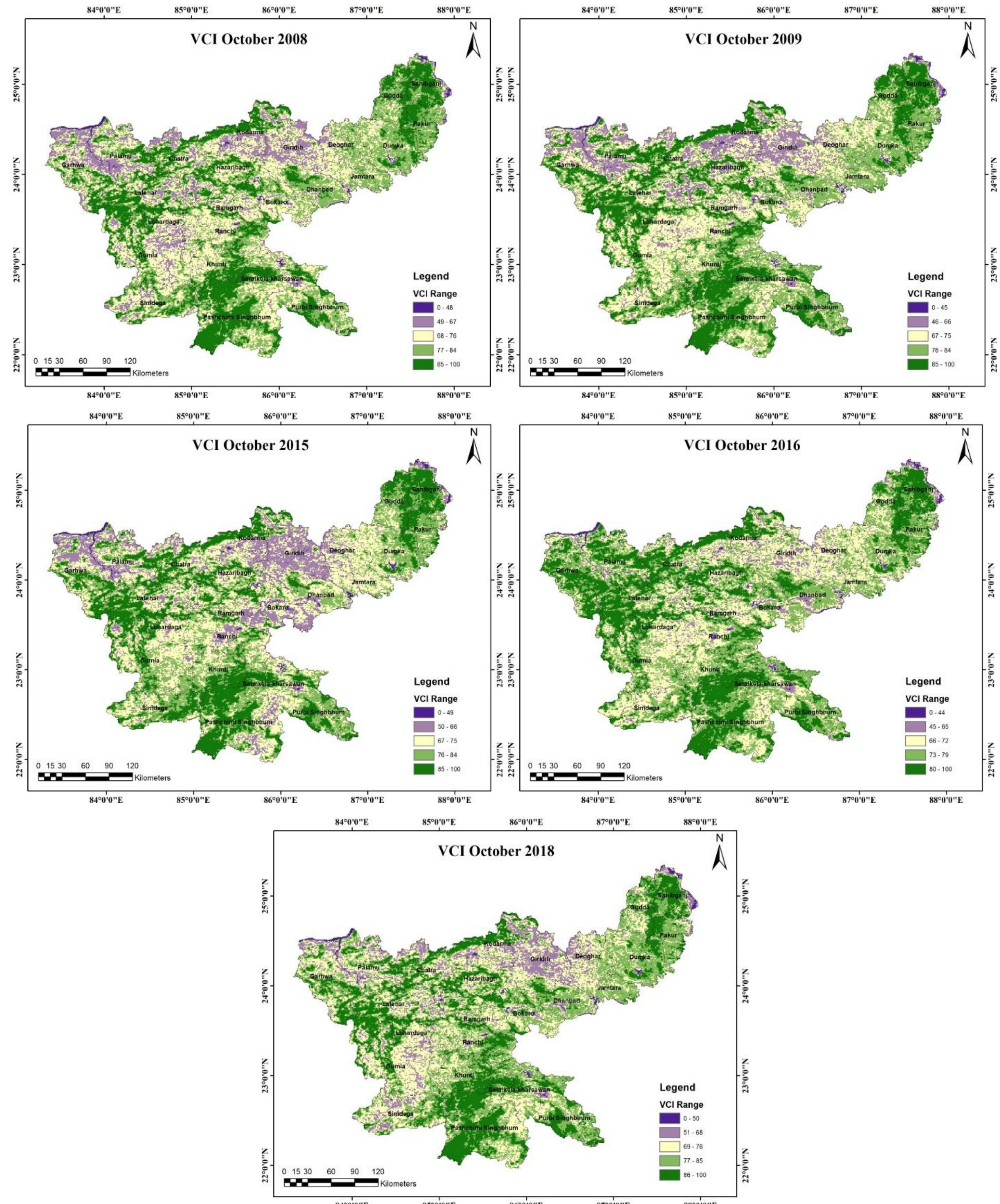

Fig 7: VCI response during October 2015, October 2016 and October 2018

4. CONCLUSIONS

The present study was aimed to assess the agricultural drought from 1951 to 2002 using Standardized Precipitation Index (SPI). Using SPI it was found that there was an extreme drought in the year 1966 during 1951 to 2002. 78% stations (14 out of 18 stations) indicated year 1966 as the extreme dry year for all the time scales vis 3, 6, and 12 months. It was also observed that almost all the stations were facing an extreme wet condition in the year 1971. A prolonged period of dry condition was also observed for most of the stations from 1992 to 1998. Similarly in the year 1992, ten stations namely Bokaro, Chatra, Dhanbad, Garhwa, Giridih, Gumla, Hazaribagh, Koderma, Lohardaga and Palamu exhibited extreme dry condition. That is 56% stations (10 out of 18 stations) indicated 1992 as the extreme dry condition for all the three time scales. Year 1992 was the second severest drought in the history of Jharkhand after 1966 during 1951 to 2002. It was also noticed that SPI value fluctuation is more frequent for 3 month time scale as compared to 12 month time scale. For smaller time scale like 3 months, the duration of drought occurrence was low and this duration is more for greater time scales which indicates that with the decrease in time scale, the duration of drought also decreases.

While comparing the estimates of NDVI and VCI with SPI for the year 2000 and the year 2002, it was found that the results were in resonance with each other i,e., the results showed 2000 as the dry year whereas 2002 as the normal year. The VCI values showed that the vegetation was in stressed condition for the drought year and relatively less stressed for normal year. On further assessment of the drought using NDVI and VCI responses from 2000 to 2018, it was found that the year 2008, 2009, 2015 and 2018 were severely hit by drought. Hence, it is concluded that MODIS data may be used in absence of meteorological data to assess the drought. Drought studies using different drought indices could help in designing early warning systems and also to provide mitigation measures.

References

1) AghaKouchak A, Farahmand A, Melton FS, Teixeira J, Anderson MC, Wardlow BD, Hain CR (2015) Remote sensing of drought: progress, challenges and opportunities. Rev Geophys 53(2):452–480

2) Chang J, Li Y, Ren Y, Wang Y (2016) Assessment of precipitation and drought variability in the Weihe River Basin, China. Arab J Geosci 9(14):633

3) Dabrowska-Zielinska, K. (1987). Inferring evapotranspiration from remotely sensed thermal radiation data.

4) Dai, A., Trenberth, K. E., & Qian, T. (2004). A global dataset of Palmer Drought Severity Index for 1870–2002: Relationship with soil moisture and effects of surface warming. Journal of Hydrometeorology, 5(6), 1117-1130.

5) Dutta, D., Kundu, A., Patel, N. R., Saha, S. K., & Siddiqui, A. R. (2015). Assessment of agricultural drought in Rajasthan (India) using remote sensing derived Vegetation Condition Index (VCI) and Standardized Precipitation Index (SPI). The Egyptian Journal of Remote Sensing and Space Science, 18(1), 53-63.

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6) Edwards, D. C., & McKee, T. B. (1997). Characteristics of 20th Century Droughts in the United States at Multiple Time Scales; Climatology Report, 97–2; Department of Atmospheric Sciences. Colorado State University: Fort Collins, Colorado, 155.

7) El Kenawy, A. M., Hereher, M. E., & Robaa, S. M. (2019). An assessment of the accuracy of MODIS land surface temperature over Egypt using ground-based measurements. Remote Sensing, 11(20), 2369.

8) Gibbs WJ, Maher JV (1967) Rainfall deciles as drought indicators. In: Bureau of Meteorology, Bulletin No. 48, Melbourne. Australia

9) Hazaymeh K, Hassan QK (2017) A remote sensing-based agricultural drought indicator and its implementation over a semi-arid region, Jordan. J Arid Land 9(3):319–330

10) Hisdal, H., & Tallaksen, L. M. (2003). Estimation of regional meteorological and hydrological drought characteristics: a case study for Denmark. Journal of Hydrology, 281(3), 230-247.

11) Jha, A., Singh, A., & Warwade, P. (2021). Impact of Pre-Monsoonal Rainfall Trend on Vegetation for Ranchi Plateau, Jharkhand, India, Indian Journal of Ecology, 48(6): 1621-1626.

12) Jin J, Wang Q (2016) Assessing ecological vulnerability in western China based on time-integrated NDVI data. J Arid Land 8(4):533–545

13) Karabulut, M. (2015). Drought analysis in Antakya-Kahramanmaraş Graben, Turkey. Journal of Arid Land, 7(6), 741-754.

14) Kogan, F. N. (1997). Global drought watch from space. Bulletin of the American Meteorological Society, 78(4), 621-636.

15) Kogan, F., & Sullivan, J. (1993). Development of global drought-watch system using NOAA/AVHRR data. Advances in Space Research, 13(5), 219-222.

16) Logan, J. (1987). Bibliography of Agricultural Climatology: Part II.

17) Maity, R., & Chanda, K. (2015). Potential of genetic programming in hydroclimatic prediction of droughts: An Indian perspective. In Handbook of genetic programming applications (pp. 381-398). Springer, Cham.

18) McKee TB, Doesken NJ, Kleist J (1993) the relationship of drought frequency and duration to time scales. In: Proceedings of the 8th Conference on Applied Climatology (Vol. 17, No. 22). American Meteorological Society, Boston, MA, pp 179–183

19) Mohammad AH, Jung HC, Odeh T, Bhuiyan C, Hussein H (2018) Understanding the impact of droughts in the Yarmouk Basin, Jordan: monitoring droughts through meteorological and hydrological drought indices. Arab J Geosci 11(5):103

20) Palmer, W. C. (1965). Meteorological drought (Vol. 30). US Department of Commerce, Weather Bureau.

21) Ramkar, P., & Yadav, S. M. (2018). Spatiotemporal drought assessment of a semi-arid part of middle Tapi River Basin, India. International Journal of Disaster Risk Reduction, 28, 414-426.

22) Shafer, B. A., & Dezman, L. E. (1982, January). Development of surface water supply index (SWSI) to assess the severity of drought condition in snowpack runoff areas. PROCEEDING OF THE WESTERN SNOW CONFERENCE.

23) Singh, R. P., Roy, S., & Kogan, F. (2003). Vegetation and temperature condition indices from NOAA AVHRR data for drought monitoring over India. International journal of remote sensing, 24(22), 4393-4402.

24) Warwade, p., Hardaha, M.K., Kumar, D., &Chandniha, S.K. (2014) "Estimation of soil erosion and crop suitability for a watershed through remote sensing and GIS approach". In The Indian Journal of Agricultural Sciences 84 (1), 18-23.

25) Warwade, P., Tiwari, S., Ranjan, S., Chandniha, S.K. & Adamowski, J. 2018. Spatio-temporal variation of rainfall over Bihar State, India. Journal of water and land development, (36), 183-197.

26) Warwade,p., Sharma, N., Paney, A., & Ahrens, B. 2017. Analysis of climate variability in a part of Brahmaputra River basin in India, In River System Analysis and Management. Pp 113-142, Springer.

27) Watson, I. W., Westoby, M., & McR, A. (1997). Continuous and episodic components of demographic change in arid zone shrubs: models of two Eremophila species from Western Australia compared with published data on other species. Journal of Ecology, 833-846.

28) Weng B, Zhang P, Li S (2015) Drought risk assessment in China with different spatial scales. Arab J Geosci 8(12):10193–10202

29) Wilhite DA (2005) Drought and water crises: Science, Technology, and Management Issues. CRC Press, USA

30) Wilhite DA (2009) the role of monitoring as a component of preparedness planning: delivery of information and decision support tools. In: Coping with drought risk in agriculture and water supply systems: Drought Management and Policy Development in the Mediterranean.

31) Wilhite DA, Glantz MH (1985) Understanding: the drought phenomenon: the role of definitions. Water Int 10(3):111–120

32) Wu, H., Hayes, M. J., Weiss, A., & Hu, Q. I. (2001). An evaluation of the Standardized Precipitation Index, the China-Z Index and the statistical Z-Score. International Journal of Climatology: A Journal of the Royal Meteorological Society, 21(6), 745-758.