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# **Indicator-Based Assessment of Drought in Bhilwara District, Rajasthan**

**Gaurav Sharma<sup>1</sup>, Chandra Kishor Kumar<sup>2\*</sup> and Rishi Pathak<sup>1</sup>**

<sup>1</sup>Regional Centre, National Institute of Hydrology, Bhopal-462016, Madhya Pradesh, India.

<sup>2</sup>Department of Farm Engineering, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi-221 005, Uttar Pradesh, India.

### **Authors' contributions**

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## **ABSTRACT**

Management of water resources helps to sustain even in drastic conditions resulted due to unprecedented disruption in rainfall patterns. Change and irregularity in the pattern of the Indian monsoon are the outcomes of human-induced activities. Inadequate water availability affecting various sectors namely domestic, industrial, and agricultural sectors that are dependent upon it. To cope under such drastic conditions adaptability and planning prior to its occurrence plays a significant role. It is under this context, the present study investigated drought characteristics which include drought frequency and severity caused by prolonged dry spells in Bhilwara district, Rajasthan. The district falls in the water-scarce regions with arid to semi-arid conditions and with an average annual rainfall of 658.03 mm. Due to high rainfall variability, the region is frequently subsumed under drought-like conditions. Comprehensive analysis using daily rainfall data from 1973-2018 for 12 rain gauge stations in Bhilwara district has been carried out. Most of the stations were drought-prone assessed by probability analysis using Weibull's plotting position formula. The departure analysis showed that Kotri station has a maximum drought frequency of 1 in 2 years while other stations were having a drought frequency of 1 in 3 to 4 years. Prioritization of drought-prone stations based on rainfall departure analysis helps to initiate an immediate mitigation process based on the ranking of its proneness. Asind and Bhilwara station with RDI 0.91 has

\*Corresponding author: E-mail: [chandra.kishor@bhu.ac.in](mailto:chandra.kishor@bhu.ac.in);

maximum proneness and its calls for effective planning for drought management. Based on seasonal departure analysis it is found that 1980, 1981, 1985, 1987, 2000, 2002, 2008, 2015, and 2017 are drought years. The result has been supplemented using NDVI so that the vegetation condition can also be assessed during water stress conditions. The study highlighted that the frequency of drought has increased owing due to climate change and thus, poses serious challenges if not tackle adequately.

*Keywords: Drought; rainfall departure; Relative departure Index; NDVI; Bhilwara.*

## 1. INTRODUCTION

Drought occurred due to insufficient or below-average rainfall over an extended period which causes a considerable hydrologic imbalance and as a result, water scarcity, crop damage, reduced river flow, and depletion of groundwater and soil moisture occurred [1]. The extent or magnitude of drought is further escalated when evaporation and transpiration rate exceed precipitation for a considerable period. Droughts cannot be avoided, but they can be predicted and monitored to mitigate their negative impacts. Inadequate water availability due to deficient moisture supply resulting in drought either from sub-normal or erratic rainfall distribution, higher water demands, or a combination of both factors [2-4].

Wilhite [5] stated that droughts are the world's costliest natural disaster (6–8 billion dollars annually), affecting more people than any other form of a natural disaster. A drought invariably occurs when the links in the hydrologic cycle are broken or destabilized and its impact continues to appear even after the event is over. Most of the natural hazards are somewhat predictable but drought due to its slow onset, varying durations, and large spatial coverage with modest structural damages can cause greater damage and can only be mitigated using area-specific planning. To equip with appropriate mitigation strategies it is crucial that the measures including the temporal and spatial extent of drought.

Evaluation of drought characteristics includes onset, termination, frequency, severity, and intensity are complex but the assessment of which is important for implementing recreation activities by involving hydrologic and hydraulic structures including ponds, tanks, dams, and rain-water harvesting to render its impact. The deficiency of rainfall is always responsible for the initiation of a drought. Assessing a drought scenario based on its impact on water resources availability help to classify it into three main types

i.e., meteorological, agricultural, and hydrological drought [6,7].

Drought impacts both surface and groundwater resources and can lead to reduced water supply, deteriorated water quality, and crop failure [8,9]. Inadequate water availability acts as a host which depletes economic as well as social activities involves with it [10]. The various drought-affecting parameters differ from place to place depending upon climatic conditions, available water resources, agricultural practices, and various socio-economic attributes of the region [11]. It is believed that the arid and semi-arid regions are most vulnerable to drought. Identifying drought-prone areas using the Geographical Information System (GIS) approach is suitable that takes into consideration the surface features i.e. the slope which influences runoff and inadequate accumulation of water and subsequent occurrence of the drought-like situation [12].

For vegetation monitoring one of the most suitable indices that have been reported by many researchers is the NDVI [13,14]. The importance of this index can be highlighted with the facts that it can be used for assessing the crop cover, drought monitoring, and agricultural drought assessment [15-17]. NDVI based vegetation condition is an effective measurement technique which is used to indicate the surface vegetation covers and crops growth status [18].

The impact of the drought is prolonged and its effect prevails for a longer period and thus severely affecting the socio-economic activities. The present study aims to understand the drought characteristics over the Bhilwara district of Rajasthan which lies in the semi-arid region and had many issues pertaining water resources availability and which subsequently resulted in a drought-like situation. The evaluation helps to develop area-oriented drought mitigation strategies that help to render its impacts.

## 2. MATERIALS AND METHODS

Bhilwara district lies between 25.35°N and 74.65°E and has an area of 10,455 Km<sup>2</sup>. It has an average elevation of 421 m. The mean annual rainfall in the study area is 658.05 mm. Bhilwara district falls in the Banas (9157.2 sq km), Chambal (1164.9 sq km) & Luni basins (133.0 sq km). The soil of the district varies from Sandy Loam to Heavy loams. Soils of the district are classified as follows [19].

- Clay Loam or medium black: This type of soil is found in the hilly areas in the central parts of the district.
- Loam: this type of soil is found in the entire district.
- Sand and sandy loam: This type of soil is found mostly near the banks of rivers and nalas.
- Loam pebbly and stony: These types of soils are met within the hilly areas of the eastern blocks of the district.

The climate in the district has a hot dry summer and bracing cold winter. The cold season is from December to February and is followed by hot summer from March to the last week of June, the southwest monsoon season which follows, last till mid-September. The period from mid-September to about the end of November constitutes the post-monsoon season.

### 2.1 Data Availability

The daily rainfall data for the period of 47 years (1973-2018) has been utilized to investigate drought episodes in the Bhilwara district, Rajasthan. The rainfall data were obtained from an online published report by the government of Rajasthan. Vegetation condition has been assessed using Landsat 8 OLI satellite imagery which was downloaded from United States Geological Survey (USGS) Earth Explorer database for the normal year (2013) and drought year (2015 and 2017), the data also incorporate Shuttle Radar Topography Mission (SRTM) digital elevation map (90 m resolution). For preparing the map ArcGIS 10.1 software has been used. The baseline map of the study area is shown in Fig. 1.

### 2.2 Identification of Drought Prone Station

Most of the studies related to drought foremost require the identification of drought-prone

blocks/stations. The identification of drought-prone blocks helps to investigate circumstances that cause proneness to drought due to inadequate rainfall as compared to normal. Several studies have been published in a different research paper in which drought prone blocks has been identified using probability analysis of annual rainfall [20-24]. The analysis identified the region or area as drought-prone if the probability of occurrence of 75 % of mean annual rainfall is less than 80 % [25]. The probability of exceedance in the given studies has been computed based on Weibull's distribution wherein the annual rainfall series has been sorted in the descending order and ranks are assigned in increasing order 1, 2 .....N, up to the last record and distribution are fitted to the ranked data. The probability of exceedance is given by equation 1:

$$P = \frac{m}{N+1} * 100 \quad \dots\dots (1)$$

Where,  
P = Probability of Exceedance of annual rainfall,  
m = rank of a particular record, N = total number of observation

### 2.3 Identification of Drought Year

Investigating drought years helps to unveil the circumstances that induce drought. Identification of drought year helps to investigate deficit in the rainfall amount which resulted into the drought-like situation due to insufficient soil moisture condition. In the present study, drought years have been identified to ascertain the situation (deficit in rainfall amount as compared to normal) which if not taken care will lead to drought. Departure analysis of annual and seasonal rainfall has been adopted to investigate drought years which has been synthesis in several other studies as well [26,21,23,12]. The present studies identified drought years based on seasonal rainfall, as it is the major contributor i.e., 90 % of the annual rainfall in the region. The seasonal rainfall departure (Di) is computed by subtracting the mean seasonal rainfall (Xm) from the seasonal rainfall series (Xi) as given in equation 2:

$$[Di = Xi - Xm] \quad \dots\dots (2)$$

The percentage departure (D %) is subsequently computed by equation 3:

$$[D \% = Di / Xm * 100] \quad \dots\dots (3)$$

IMD criterion has been adopted to consider years as drought years wherein total seasonal rainfall is less than 75 % of the normal. Most of the studies in the semi-arid and arid regions suggested that even a deficit of 20% of normal rainfall can causes huge impacts and leads to lesser crop yields and crop productivity. Therefore while differentiating drought severity during drought years, four drought severity classes have been defined viz., (a) mild drought (b) moderate drought (c) severe drought (d) extreme drought. The seasonal rainfall departure based on drought severity class has been shown in Table 1.

weights are assigned which are as follows: 1 for mild drought, 2 for moderate drought, 3 for severe drought, and 4 for extreme drought. The proneness has been decided by dividing the total cumulative weights obtained during drought years with the total number of years under consideration as given in equation 4:

$$RDI = \frac{\sum_{i=1}^n W_i}{N} \dots\dots\dots (4)$$

Where,  
N= Total number of the year under consideration,  
W<sub>i</sub>= Weight for the i<sup>th</sup> drought years

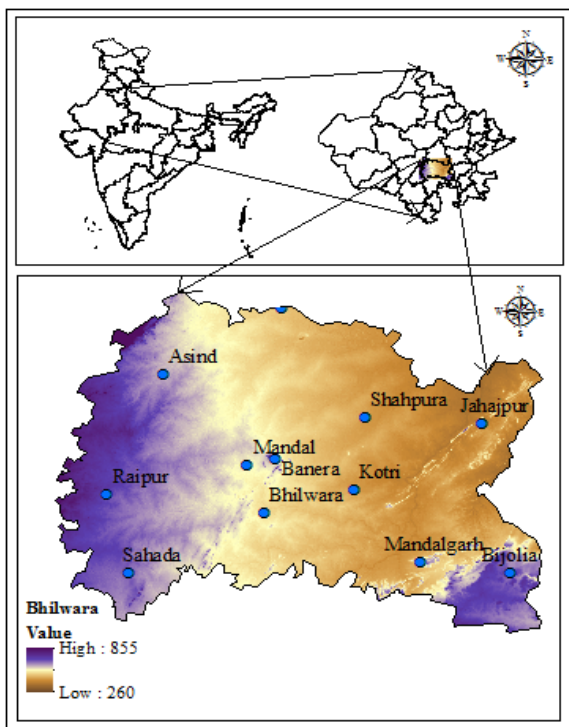


Fig. 1. Base Map for Bhilwara District

#### 2.4 Prioritizing Drought Prone Station Based on Relative Departure Index (RDI)

Distribution of Indian monsoon due to spatial variability and irregularity causes a complex circumstance wherein different blocks in the same region may face drought and wet conditions at the same time, therefore prioritization of block is foremost important to subsidize the adverse condition occurred due to drought with immediate mitigation responses. RDI can be synthesis for ranking and for identify relative drought proneness of various blocks. This indicator involves weighing systems wherein

#### 2.5 Normalized Difference Vegetation Index

An approach has been applied to investigate the vegetation condition during water stress conditions using satellite imagery-based indicator viz., NDVI. This indicator is most widely used for extracting biophysical conditions and delineating the distribution of vegetation and soil based on the characteristic reflectance patterns of green vegetation. The NDVI is a simple numerical indicator that helps in observing the status of crops based on vegetation and soil moisture conditions. In the present study, Landsat 8 OLI satellite imagery has been used to assess NDVI using equation 5:

$$NDVI = \frac{NIR - Red}{NIR + Red} \dots\dots\dots (5)$$

Where, RED is visible red reflectance, and NIR is near infrared reflectance.

The range of NDVI lies between -1 to +1 wherein very low-value NDVI (0.1 and below) correspond to barren areas of rock, sand, or snow. Moderate values represent shrub and grassland (0.2 to 0.3), while high value indicates temperate and tropical rainforests (0.6 to 0.8). Bare soil is represented with NDVI values, which are closest to 0, and water bodies, are represented with negative NDVI values.

#### 2.6 Inverse Distance Weighted (IDW)

In the present study, the IDW method of interpolation technique is used for the representation of the spatial distribution of annual rainfall and coefficient of variance in the study area. This method is based on the assumption that things that are close to one another are more alike than those that are farther apart

([http://www.gisresources.com/types-interpolation-methods\\_3/](http://www.gisresources.com/types-interpolation-methods_3/)). To predict the value for any unmeasured location, IDW will use the measured values surrounding the prediction location (<http://webhelp.esri.com>). IDW weight the point closer to the prediction location greater than those farther away, hence the name Inverse distance weighted. The weight of each sample point is an inverse proportion to the distance. IDW is given by equation 6:

$$\bar{x} = \frac{\sum_{i=1}^n \frac{1}{d_i} (x_i)}{\sum_{i=1}^n \frac{1}{d_i}} \dots\dots\dots (6)$$

Where,  $\bar{x}$  = value to be estimated;  $x_i$  = known value;  $d_1, d_2, d_3, \dots, d_n$  = distance from the  $n$  data points to the point estimated  $n$ .

### 3. RESULT AND DISCUSSION

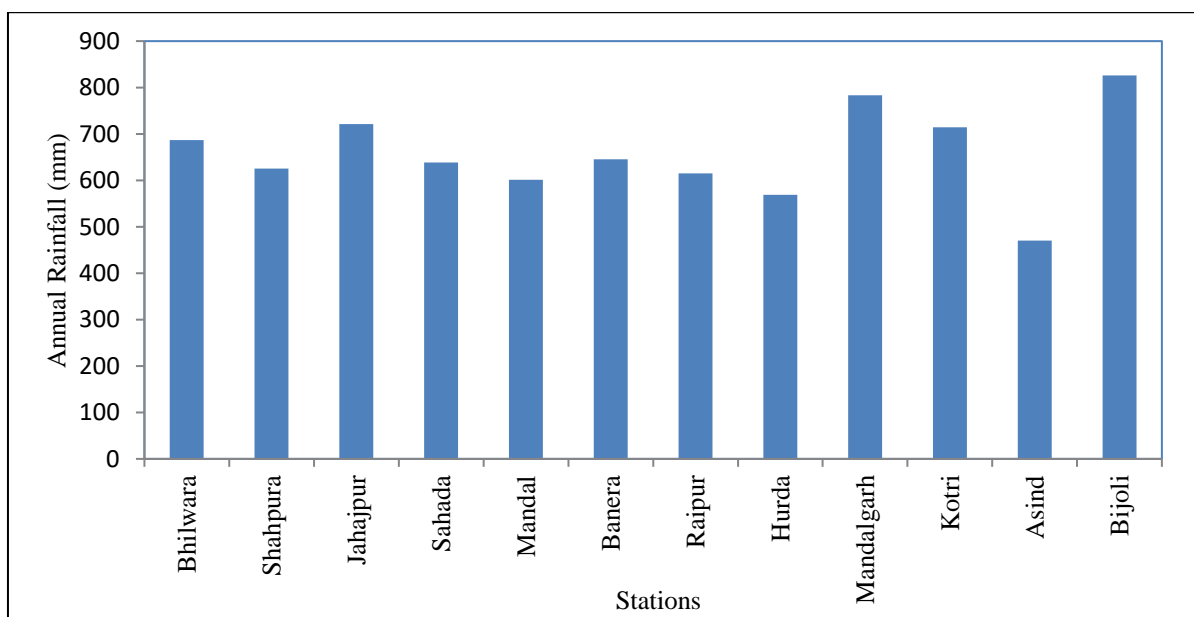
The major factors which influence drought are spatial and temporal variability of rainfall and investigation of its characteristics is important. The statistical approach is the simplest and widely used technique while investigating rainfall

patterns in any region [27]. Table 2 reveals the rainfall characteristics assessed using statistical parameters. The average annual rainfall for the district is 658.03 mm with a standard deviation of 196.26 mm and CV of 30.94 percent. Bijolia station receives the highest average annual rainfall (813.43 mm) followed by Mandaligarh station (775.79) whereas Asind station receives the least average annual rainfall (431.91 mm). The variation of the average annual rainfall in different stations in the Bhilwara district is shown in Fig. 2.

The spatial distribution of annual rainfall is examined based on IDW in ArcGIS 10.1 and it showed an increase in rainfall while moving from moving west to east. The spatial variation of annual rainfall is shown in Fig. 3. The distribution of rainfall in the region is very much erratic and thus may act as a constraint for agricultural practices. Therefore suitable measures need to be adopted in the region as means of adjusting to drought, including shifting of varieties, changes in types of crops, irrigation, and input use.

**Table 1. Standard Range of Departure values and their classification**

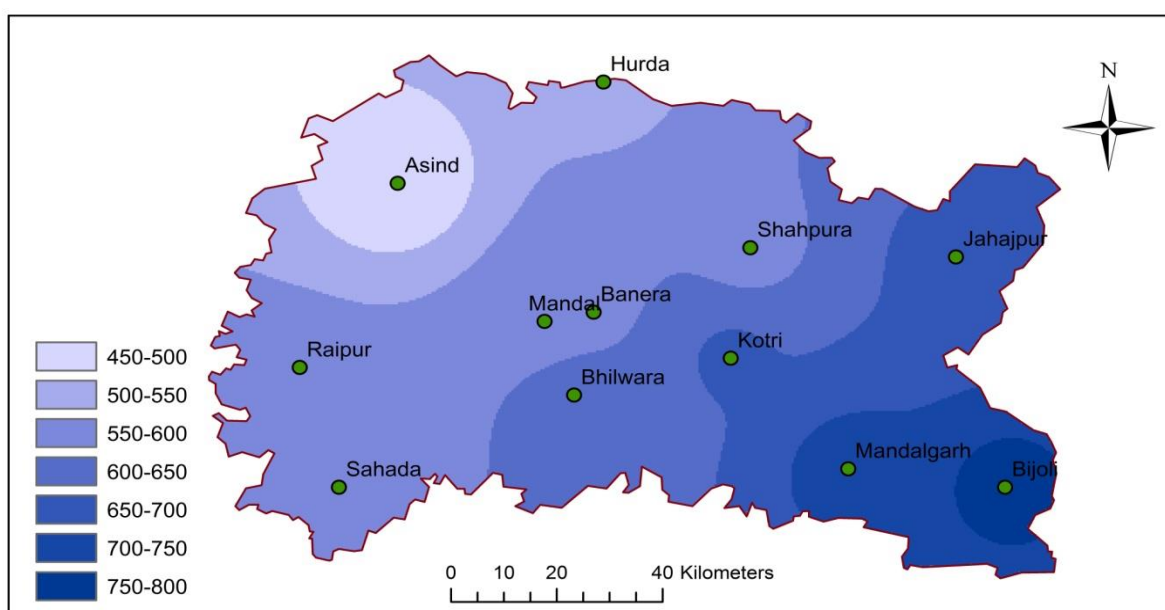
| S.No. | Drought Classes  | Range (%)         |
|-------|------------------|-------------------|
| 1.    | Mild Drought     | -20 % < D < -25 % |
| 2.    | Moderate Drought | -25 % < D < -35 % |
| 3.    | Severe Drought   | -35 % < D < -50 % |
| 4.    | Extreme Drought  | D > -50 %         |



**Fig. 2. Average annual rainfall for different station of Bhilwara district**

**Table 2. Rainfall characteristics computed using statistical parameter**

| Station     | Mean   | SD     | CV (%) |
|-------------|--------|--------|--------|
| Bhilwara    | 691.19 | 222.94 | 32.25  |
| Shahpura    | 615.51 | 168.10 | 27.31  |
| Jahajpur    | 718.71 | 175.55 | 24.43  |
| Sahada      | 623.78 | 187.90 | 30.12  |
| Mandal      | 579.04 | 187.42 | 32.37  |
| Banera      | 646.47 | 214.26 | 33.14  |
| Raipur      | 579.72 | 203.78 | 35.15  |
| Hurda       | 541.13 | 182.73 | 33.77  |
| Mandaligarh | 775.79 | 206.10 | 26.57  |
| Kotri       | 706.91 | 232.35 | 32.87  |
| Asind       | 431.91 | 159.62 | 36.96  |
| Bijolia     | 813.43 | 214.35 | 26.35  |



**Fig. 3. Spatial variation of Annual Rainfall for Bhilwara district of Rajasthan**

There is a considerable difference between point rainfalls i.e., the rainfall at a single station. The mean annual rainfall of rain gauge stations is calculated by the arithmetical average of the annual rainfall of several consecutive years. The average of all the rain gauge stations gives the average annual rainfall for the Bhilwara district. The spatial variability of rainfall suggesting adaptation of soil and water conservation measure in the west portion of the district to adhere maximum soil moisture during monsoon period which otherwise lost as runoff without much utility. Adaptation of area-oriented crops helps in better utilization of availed water resources in the region.

In order to unveil the stations that are prone to drought, a probability analysis of seasonal rainfall

has been carried out. The identified drought-prone stations in the study area are shown in Fig. 4.

It has been observed that most of the stations in the study area are drought-prone except Shahpura and Jahajpur. These two stations are located in the northeast region of the district. Identification of drought-prone stations helps in understanding the distribution of rainfall that leads to circumstances wherein drought prevails in one region while the other remains unaffected. The spatial variability of rainfall is clearly unveiled in the above Fig.4 wherein the overall distribution of rainfall in the northeast region is comparatively more as compared to the rest of the region in the study area. Hence while suggesting and planning mitigation strategies the evaluation of drought-



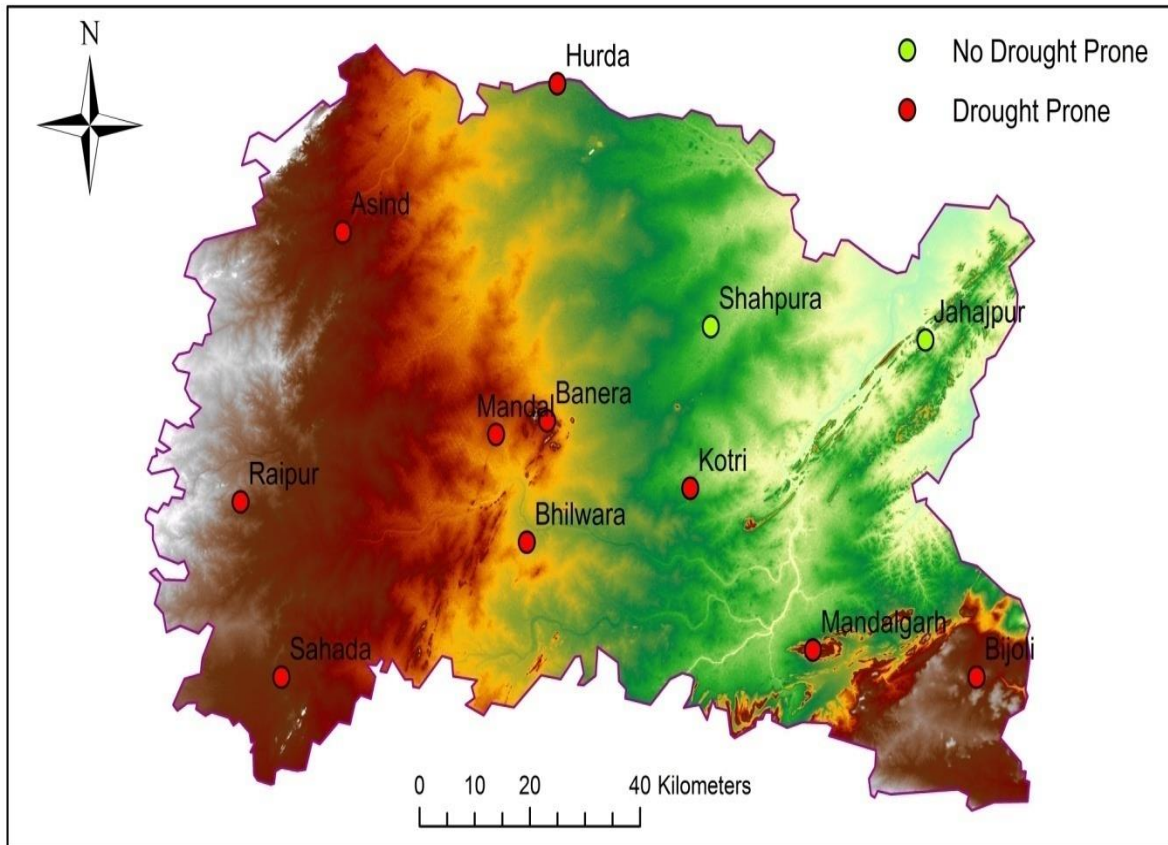
prone environments helps to fill the remaining gap in the understanding of the location and area-specific adaptation capacities. The management based on the above results will help to foster resilience.

Drought years have been identified in the region based on seasonal rainfall departure, but in several other studies annual rainfall departure has also been applied. Since the present study mainly concern to deals with the impact of seasonal rainfall wherein a large portion of the annual rainfall is received and also the existing soil moisture due to adequate rainfall after the harvest of Kharif crop sufficient to meet the demand of Rabi crop thereby depicting the lesser influence of annual rainfall as compared to the seasonal rainfall. The identified drought years in various stations are given in Table 3.

It is observed that most of the stations are under the grip of drought during the years 1980, 1981, 1985, 1987, 2000, 2002, 2008, 2015, and 2017. The study reveals that 2000 and 2002 are the

major drought years wherein most of the regions were severely affected wherein the livelihood of farmers dependent on agricultural practices are hit hard due to decreased crop productivity and crop yield. The monitoring of drought years is important in order to be able to foresee a possible drought event in the future and to be better prepared to mitigate the anticipated damages of such an event if occurred. The seasonal rainfall departure of drought-affected stations in the Bhilwara district is given in Fig. 5 to Fig. 9.

Based on the departure analysis of seasonal and annual rainfall, drought of different severity classes has been evaluated. Since the region is located in the arid and semi-arid regions the drought has been classified into four severity classes viz., mild drought, moderate drought, severe drought, and extreme drought. The analysis reveals the occurrence of a frequent drought of varying severity classes. Table 4 shows drought severity and frequency in the Bhilwara district of Rajasthan.



**Fig. 4. Drought-prone stations in Bhilwara district of Rajasthan**  
**Table 3. Drought year for the various station of Bhilwara district**

| Station    | Year   |
|------------|--|
| Bhilwara   | 1979/1980/1981/1985/1987/1993/1998/2000/2002/2003/2005/2007/2009/2015/2017 |
| Shahpura   | 1978/1980/1981/1985/1987/1995/1998/2000/2002/2010/2015/2017                |
| Jahajpur   | 1980/1981/1985/1987/1995/1998/2002/2008/2009/2017                          |
| Sahada     | 1974/1981/1985/1987/1992/1993/1995/1998/1999/2000/2002/2008/2015           |
| Mandal     | 1974/1980/1981/1985/1987/1993/1998/1999/2000/2002/2005/2007/2008/2015      |
| Banera     | 1974/1979/1980/1985/1987/1988/1993/1995/1998/2002/2003/2007/2009/2015/2017 |
| Raipur     | 1974/1981/1984/1985/1987/1993/1998/1999/2000/2002/2007/2008/2015/2017      |
| Hurda      | 1977/1981/1984/1985/1989/1995/1997/1998/1999/2000/2002/2008/2015/2017      |
| Mandaliarh | 1979/1980/1981/1985/1987/1998/2000/2002/2015                               |
| Kotri      | 1978/1979/1980/1981/1985/1987/1993/1995/1997/1998/1999/2000/2002/2005      |
| Asind      | 1974/1977/1979/1982/1985/1986/1987/1993/1999/2000/2002/2003/2008/2015/2017 |
| Bijoli     | 1974/1979/1980/1981/1985/1988/2002/2005/2007/2008/2015/2017                |

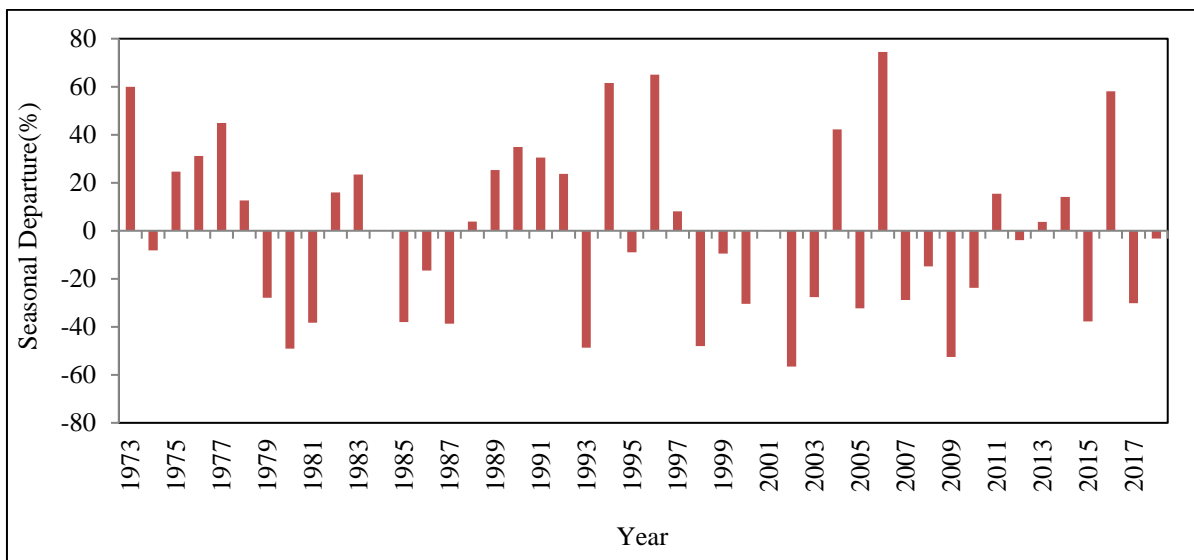


Fig. 5. Departure of seasonal rainfall at Bhilwara station of Bhilwara district

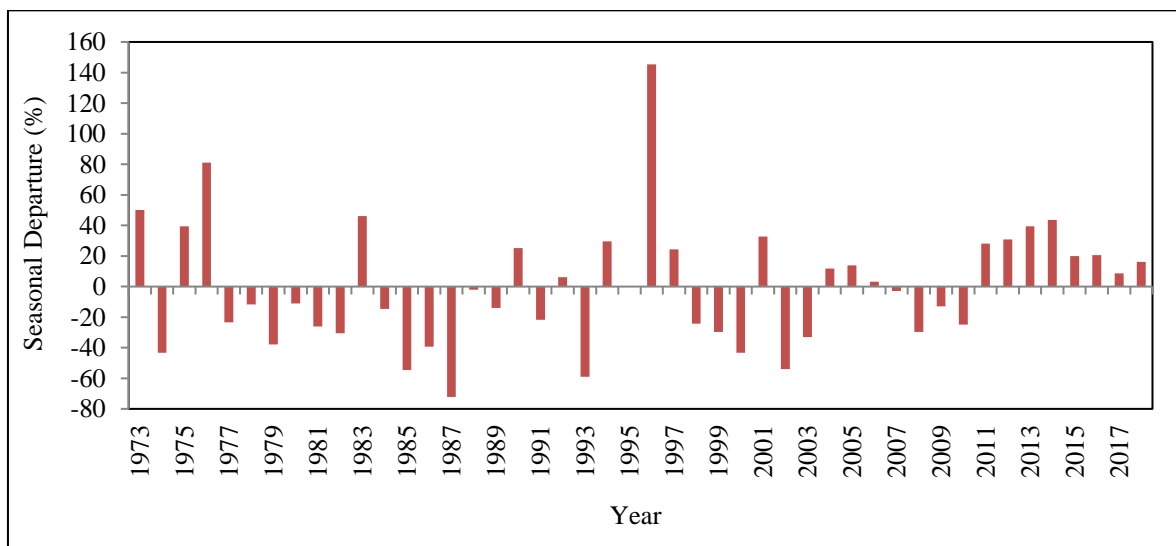
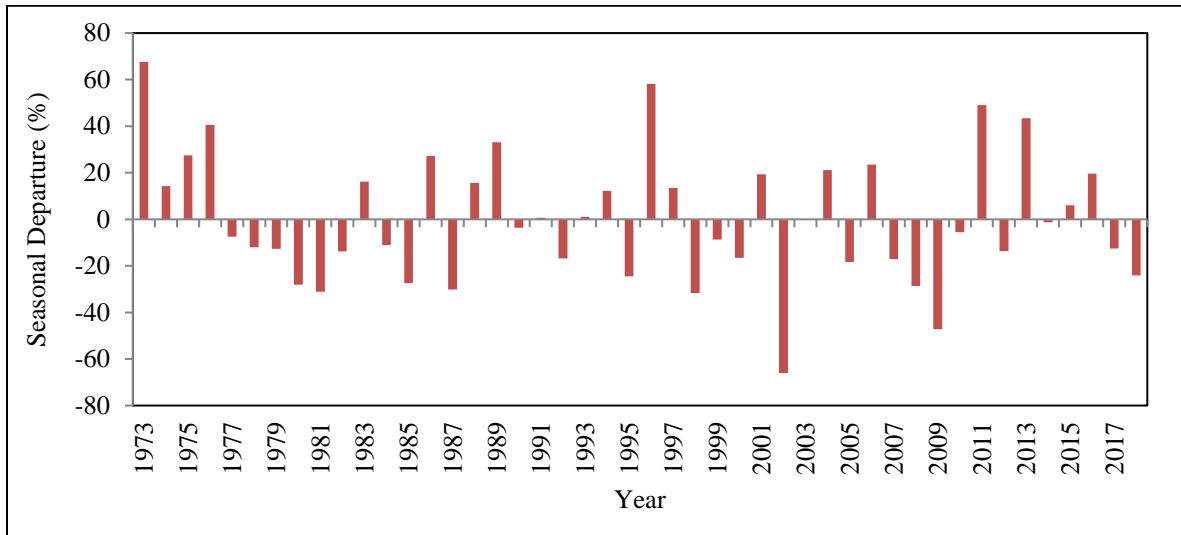
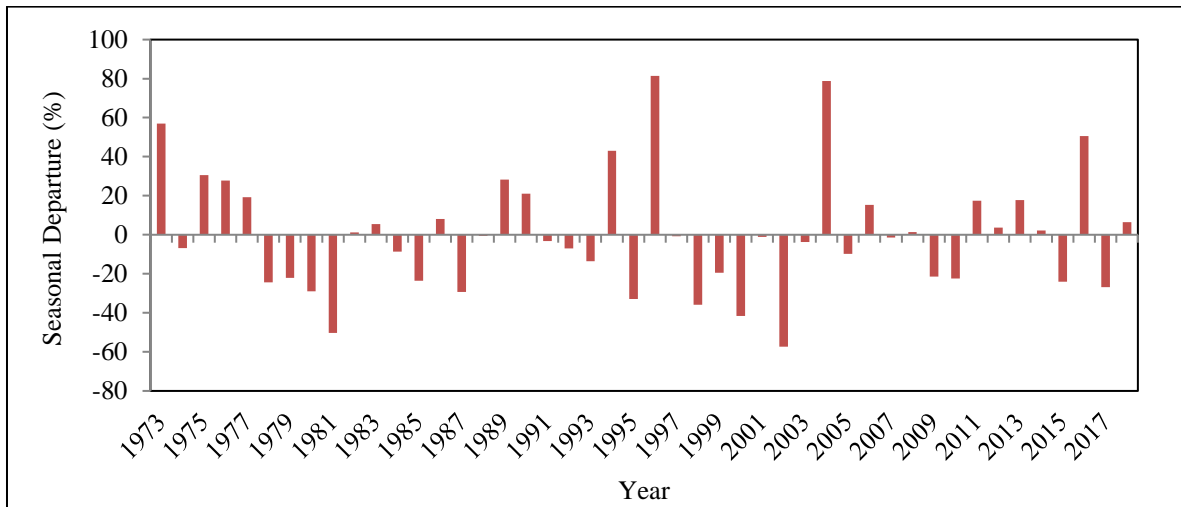


Fig. 6. Departure of seasonal rainfall at Asind station of Bhilwara district

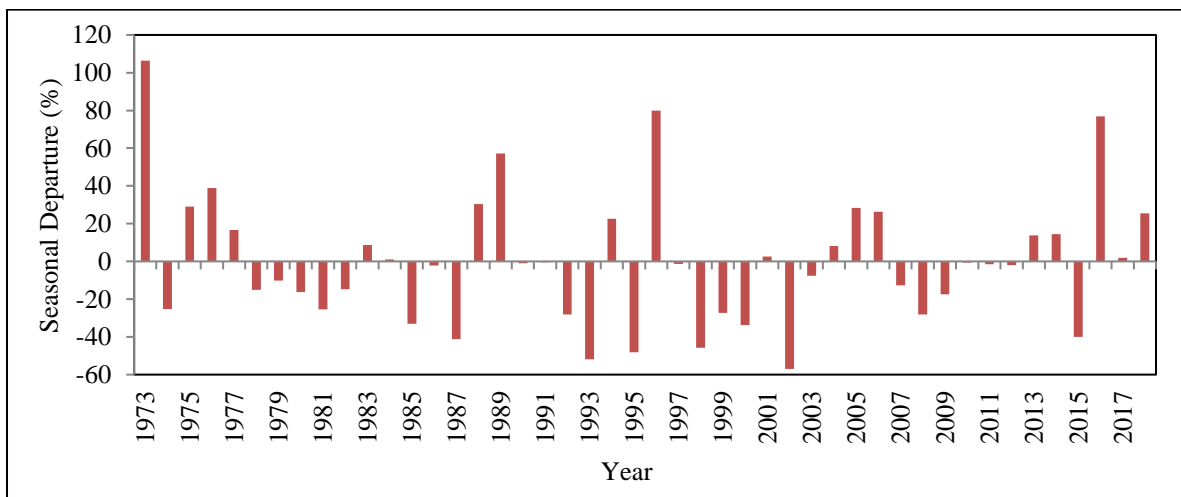




**Fig. 7. Departure of seasonal rainfall at Jahajpur station of Bhilwara district**



**Fig. 8. Departure of seasonal rainfall at Shahpura station of Bhilwara district**



**Fig. 9. Departure of seasonal rainfall at Sahada station of Bhilwara district**

**Table 4. Drought severity classes and drought frequency for various stations in Bhilwara district**

| Station    | Mild | Moderate | Severe | Extreme | Drought frequency |
|------------|------|----------|--------|---------|-------------------|
| Bhilwara   | 1    | 6        | 7      | 2       | 1 in 3 Year       |
| Shahpura   | 6    | 4        | 2      | 2       | 1 in 3 Year       |
| Jahajpur   | 2    | 6        | 1      | 1       | 1 in 5 Year       |
| Sahada     | 0    | 7        | 4      | 2       | 1 in 3 Year       |
| Mandal     | 3    | 5        | 5      | 1       | 1 in 3 Year       |
| Banera     | 2    | 7        | 4      | 2       | 1 in 3 Year       |
| Raipur     | 3    | 4        | 6      | 3       | 1 in 3 Year       |
| Hurda      | 3    | 5        | 3      | 4       | 1 in 3 Year       |
| Mandalgarh | 0    | 6        | 5      | 0       | 1 in 4 Year       |
| Kotri      | 3    | 8        | 6      | 1       | 1 in 2 Year       |
| Asind      | 4    | 5        | 4      | 4       | 1 in 3 Year       |
| Bijoli     | 3    | 3        | 6      | 0       | 1 in 4 Year       |

**Table 5. Priorities station based on Relative departure index (RDI)**

| Station    | Relative Departure Index (RDI) |
|------------|--------------------------------|
| Bhilwara   | 0.91                           |
| Shahpura   | 0.61                           |
| Jahajpur   | 0.46                           |
| Sahada     | 0.74                           |
| Mandal     | 0.70                           |
| Banera     | 0.78                           |
| Raipur     | 0.89                           |
| Hurda      | 0.83                           |
| Mandalgarh | 0.59                           |
| Kotri      | 0.89                           |
| Asind      | 0.91                           |
| Bijoli     | 0.59                           |

Generally, most of the stations in the study area face drought once in 3 years. Only Asind station faces drought once in 2 years indicating severe stress to water resources availability. The occurrence of drought events in the region is frequent and thus urges an agricultural adaptation in response to acute drought conditions to avoid or to alleviate related risks involved. Since most stations are drought-prone hence prioritization needs to be carried out to determine stations that need to be mitigated first prior to order station. The relative departure index has been used for this purpose which helps to prioritize the drought-prone stations so that the drought relief and mitigation efforts can be directed initially to these worst affected stations which are on the highest priority. This index helps to identify the higher-ranked stations in the study area. The station priorities based on the relative departure index are given in Table 5. It can be observed that Asind and Bhilwara stations is having the highest priority (0.91) followed by Kotri and Raipur stations (0.89)

respectively. Jahajpur station has the lowest priority (0.46). Prioritization of station help in adaptation strategies oriented to area-specific condition with measures in the context of region ability to attain sustainability in water resources management.

### 3.1 NDVI Based Investigation of Water Stress Condition

In the present study, NDVI has been used to examine the results that have been computed based on the rainfall analysis using seasonal and annual rainfall departure and relative departure index. The average NDVI for the normal years (2013) and drought years i.e., 2015 and 2017 has been prepared. NDVI has been widely used to examine the vegetation vigor or growth rate and can help to determine the production of green vegetation as well as to detect vegetation changes over the region during the normal and water stress condition. Fig. 10 a, b, c showed the NDVI for normal years (2013) and drought years (2015 and 2017) respectively.

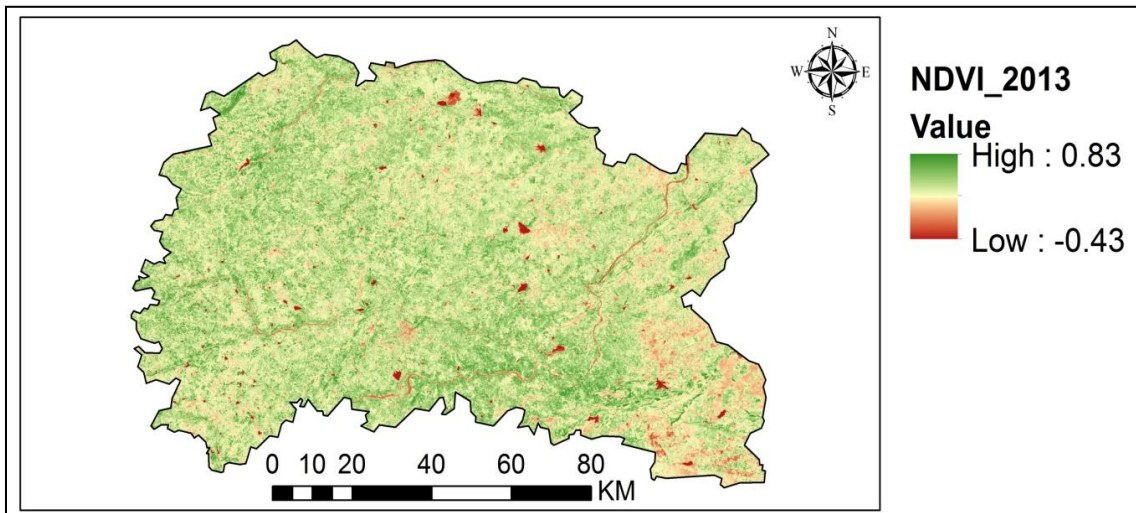


Fig. 10a. NDVI during normal years (2013)

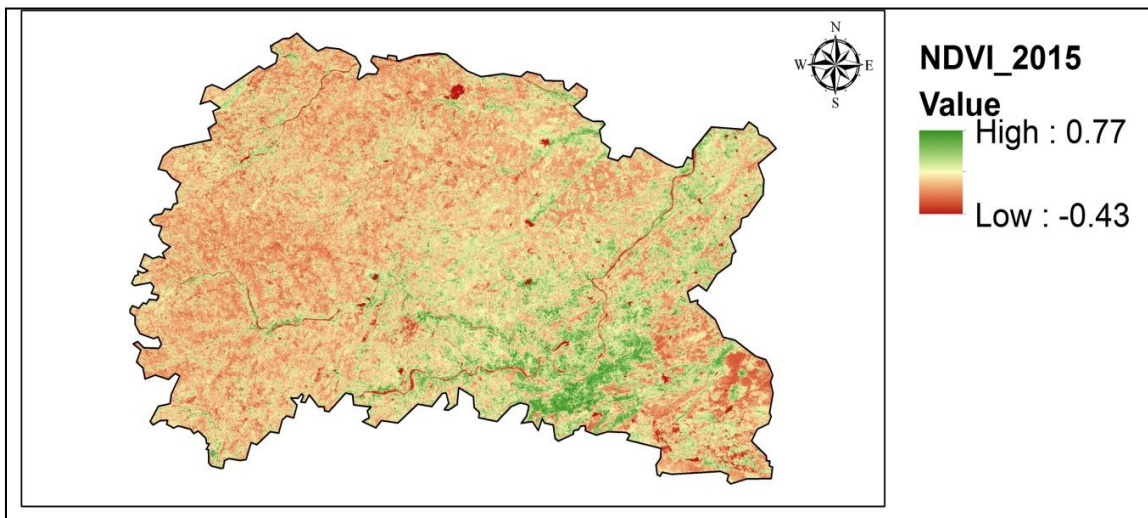


Fig. 10b. NDVI during drought years (2015)

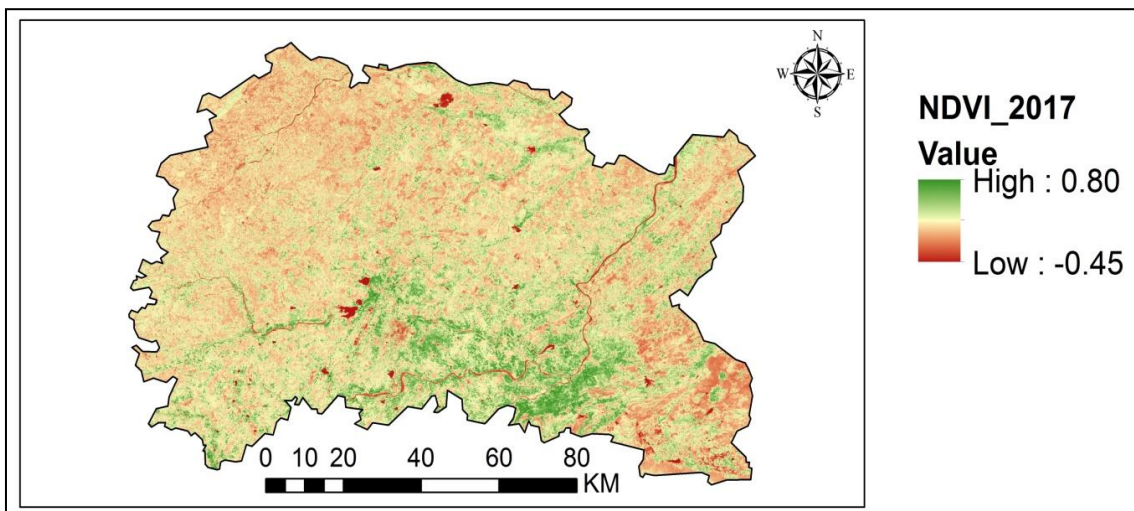


Fig. 10c. NDVI during drought years (2017)

The NDVI represents the vegetation condition that has been extracted from the satellite imagery. During the normal years, it is clearly evident that most of the region of the Bhilwara district showed higher values of NDVI thus vegetation remains green due to the availability of water in the soil. On the contrary during drought years when soil water availability decreases, due to stress by water deficit; the green vegetation tends to disappear, then the values of NDVI decrease. The lowest values are found on the less vegetated soils and presumably because the reflection from the soil is high, and produce low values in the NIR band and high values in the red band; hence the NDVI values are low.

#### 4. CONCLUSION

Human induces activities causes a change in the natural regime of a various important phenomenon which helps to maintain environment sustainably. Such intervention causes unpredictable and unpredicted changes in form of erratic rainfall, frequent drought, and flood, and therefore understanding these substantial changes helps to adhere to suitable adaptation. In this context, meteorological drought characteristics in the Bhilwara district of Rajasthan have been evaluated which provides an insight into the prevailing drought features that occurred in the region. The drought characteristics have been evaluated based on the seasonal and annual rainfall departure analysis and prioritization of station was also carried out using the relative departure index (RDI). The analysis indicates that most of the stations are identified as drought-prone stations except Shahpura and Jahajpur. The region was under the grip of widespread drought during 1980, 1981, 1985, 1987, 2000, 2002, 2008, 2015, and 2017. The drought frequency in the region was quite high i.e., once in every 2 to 3 years. The results have been supplement with NDVI, so that the vegetation condition can also be extracted during normal and drought years. Adaptation of drought mitigation strategies based on preliminary investigation help in area-oriented strategies which may acts as complementary responses identified helps to address vulnerability to drought. Strengthen design with an integrated plan of action through appropriate measures viz., use of new crop varieties and livestock species, crop, and livelihood diversification, changing planting dates, planting trees, irrigation, soil and water conservation, and

migration are suitable measures in agriculture to render drought impacts and future adaptability.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

#### REFERENCES

1. Gaiha R, Hill K, Thapa G, Kulkarni VS. Have Natural Disasters Become Deadlier? Sustainable Economic Development, 2015; 415–444. DOI:10.1016/b978-0-12-800347-3
2. Dracup JA, Lee KS, Paulson EG. On the statistical characteristics of drought events. *Water Resources Research*. 1980;16(2): 289-296.
3. Redmond KT. The depiction of drought: A commentary. *Bulletin of the American Meteorological Society*. 2002;83(8):1143-1147.
4. Thomas T, Jaiswal RK, Nayak PC, Ghosh NC. Comprehensive evaluation of the changing drought characteristics in Bundelkhand region of Central India. *Meteorology and Atmospheric Physics*. 2015;127(2):163-182.
5. Wilhite DA. *Drought: A Global Assessment*. Routledge, New York. 2000; 1(2):89-104.
6. Wilhite DA, Glantz MH. Understanding: the drought phenomenon: the role of definitions. *Water International*. 1985; 10(3):111-20.
7. Payano-Almanzar R, Rodriguez J. Meteorological, Agricultural and Hydrological Drought in the Dominican Republic: A Review. *Current World Environment*. 2018;13(1):124.
8. Riebsame WE, Changnon SA, Karl TR. Drought and natural resources management in the United States: impacts and implications of the 1987-89 droughts. Routledge; 2019.
9. Mishra AK, Singh VP. A review of drought concepts. *Journal of Hydrology*. 2010; 391(1-2):202-216.
10. Mishra SK, Singh VP. SCS-CN Method. In *Soil conservation service curve number (SCS-CN) methodology*, Springer, Dordrecht; 2003;84-146.
11. Sharma G, Kumar CK, Singh BP. Assessment of Meteorological Drought for Ujjain District of Madhya Pradesh, India

- Using Effective Drought Index and ArcGIS. Int. J. Curr. Microbiol. App. Sci. 2019; 8(5):604–612.
12. Sharma G, Kumar CK, Kumar A. Assessment of Meteorological Drought characteristics using Standardized precipitation Index for Ajmer district, Rajasthan, India. Int. J. Curr. Microbiol. App. Sci. 2020;9(02):1343-1354.
  13. Nageswara Rao PP, Shobha SV, Ramesh KS, Somashekhar RK. Satellite-based assessment of agricultural drought in Karnataka state. Journal of the Indian society of remote sensing. 2005;33(3): 429-434.
  14. Tucker CJ. Red and photographic infrared linear combinations for monitoring vegetation. Remote Sensing of Environment. 1979;8(2):127-150.
  15. Ayyangar RS, Rao PN, Rao KR. Crop cover and crop phenological information from red and infrared spectral responses. Journal of the Indian Society of Photo-Interpretation and Remote Sensing. 1980;8(1):23-29.
  16. Rao PN, Rao VR. An approach for agricultural drought monitoring using NOAA/AVHRR and Landsat imagery. In proceeding of international geoscience and remote sensing symposium. 1984;1:225-229.
  17. Singh RP, Roy S, Kogan F. Vegetation and temperature condition indices from NOAA AVHRR data for drought monitoring over India. International Journal of Remote Sensing. 2003; 24(22):4393-4402.
  18. Bhandari AK, Kumar A, Singh GK. Feature extraction using Normalized Difference Vegetation Index (NDVI): A case study of Jabalpur city. Procedia Technology. 2012;6:612-21.
  19. Central Ground Water Board. Ground Water Scenario, Bhilwara District, Rajasthan; 2013. Available: [http://www.cgwb.gov.in/District\\_Profile/Rajasthan/Bhilwara.pdf](http://www.cgwb.gov.in/District_Profile/Rajasthan/Bhilwara.pdf).
  20. Central Water Commission. on identification of drought prone areas for 99 districts. (Report), New Delhi, India; 1982.
  21. Thomas T, Jaiswal RK, Galkate R, Nayak PC, Ghosh NC. Drought indicators-based integrated assessment of drought vulnerability: a case study of Bundelkhand droughts in central India. Natural Hazards. 2016;81(3):1627-52.
  22. Kar SK, Thomas T, Singh RM. Identification of drought prone areas and trend analysis of rainfall phenomenon in Dhasan Basin. Indian Journal of Dryland Agricultural Research and Development. 2016;31(2):09-14.
  23. Kumar A, Panda KC, Nafil M, Sharma G. Identification of Meteorological Drought Characteristics and Drought Year Based on Rainfall Departure Analysis. Current Journal of Applied Science and Technology. 2020;39(8):51–59.
  24. Pathak R, Sharma G, Patel L. Evaluation of drought characteristics in Tonk district, Rajasthan. International Journal of Ecology and Environmental Sciences. 2020;2:43-49.
  25. Appa Rao G. Drought climatology. Jal Vigyan Samiksha, Publication of high-level technical committee on hydrology, National Institute of Hydrology, Roorkee; 1986.
  26. Pandey RP, Pandey A, Galkate RV, Byun HR, Mal BC. Integrating hydro-meteorological and physiographic factors for assessment of vulnerability to drought. Water resources management. 2010; 24(15):4199-4217.
  27. Praveen B, Talukdar S, Shahfahad et al. Analyzing trend and forecasting of rainfall changes in India using non-parametrical and machine learning approaches. 2020; Sci Rep 10: 10342. Available: <https://doi.org/10.1038/s41598-020-67228-7>

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