International Journal of Ecology and Environmental Sciences
www.ecologyjournal.in
Online ISSN: 2664-7133; Print ISSN: 2664-7125; Impact Factor: RJIF 5.28
Received: 07-06-2020; Accepted: 21-06-2020; Published: 08-07-2020
Volume 2; Issue 3; 2020; Page No. 43-49

Evaluation of drought characteristics in Tonk district, Rajasthan

Rishi Pathak[1], Gaurav Sharma[2*], Lokesh Patel[3]
[1-3] Regional Centre, National Institute of Hydrology, Bhopal, Madhya Pradesh, India

Abstract
Drought characteristics were evaluated in the Tonk district along with the impact of climate change in the region. Statistical analyses reveal that there w4 as changing trends in rainfall during the years for the period spanning 23 years (1983-2008). The average annual rainfall in the region varies between 527.76 mm in Malpura block to 618.70 mm in the Todaraisingh block. The average annual rainfall in district was 568.92 mm. The coefficient of variability for the district was 32%. In order to assess the impact of climate change and its effect in the rainfall pattern, the 1-day maximum rainfall was computed and it indicates that in most of the block there was decrease in 1-day maximum rainfall which is a cause of concern for water resources management. The number of rainy days has been evaluated and it was observed that the average number of rainy days varies between 29 to 31 days and on an average about 28 days of rainfall occur which contributes to the average annual rainfall of 568.92 mm. Departure analysis indicates that in 1985, 1987, 1989, 2002, and 2006 the region was under widespread drought condition and the worst drought condition occurs in 1987 and 2002. Based on the departure analysis, the average drought frequency was once in every 3–6 years. Based on probability analysis using Weibull's plotting position formula block namely Todaraisingh, Tonk, Niwai and Malpura are drought-prone (Probability < 80 %) and facing regular water scarcity and droughts as compared to Uniara and Deoli which are not prone to droughts. Relative departure index (RDI) was computed in order to priorities block for immediate drought mitigation during its occurrences and it was evident that Malpura is at highest priority followed by Tonk and Todaraisingh.

Keywords: departure analysis, probability analysis, relative departure index, 1-day maximum rainfall, number of rainy day

Introduction

Drought is a natural phenomenon whose frequency of occurrences varies from region to region. Climatic parameters and human-induced activities lead to an increase in its magnitude, duration, and intensity. Water management, agriculture, and aquatic ecosystems are affected due to changes in the magnitude and frequency of droughts. Drought is classified into four categories, including meteorological, hydrological, agricultural, and socioeconomic droughts (Golmohammadi, Kamal, and Bovani 2011) [6]. Lack of precipitation for an extended period of time will results in Meteorological drought condition (Benitez and Domecq 2014) [3]. The hydrological drought resulted due to the inadequate surface and subsurface water (Al-Fattah *et al*. 2006; Hatmoko *et al*. 2015) [1, 7]. Agricultural drought usually refers to a period with declining soil moisture and consequent crop failure (Belal *et al*. 2014) [2]. Globally, droughts are the second most geographically extensive hazard after floods (UNESCO and FAO 2007) [13]. As per the analysis by the National Centre for Atmospheric Research (NCAR) the serious drought condition percentage over the earth surface has been more than doubled from the 1970s to the early 2000s (UNESCO and FAO 2007) [13]. Dai *et al*. (2004) using palmer drought index concluded that the fraction of global land experiencing very dry conditions rose from about 10–15 percent in the early 1970s to about 30 percent by 2002. Drought resulted due to inadequate water availability resulting either from due to erratic rainfall, higher water demands or a combination of both factors (Thomas *et al*. 2015) [12]. The impact of drought continues to appear even after the event is over because due to its occurrences the hydrologic cycle is destabilized and hence water availability in the region does not replenish immediately. Slow onset, varying durations, and large spatial coverage are some of the important features of drought which makes its different from other natural hazards. Therefore, in order to cope under such condition it is essential to understand this hazard so as to develop integrated drought early warning systems. The systems must incorporate each and every parameter which directly influence drought namely climate, soil, and all water supply functions. Drought characteristics namely onset, termination, frequency, severity and intensity are too complex to identify (Thomas *et al*. 2015) [12]. The initiation of drought resulted due to deficiency of rainfall. Surface and groundwater resources are affected due to drought and can lead to reduced water supply, deteriorated water quality, crop failure, reduced productivity (Mishra and Singh 2010) [9], diminished power generation, and suspended recreation activities, as well as affect a host of economic and social activities (Riebsame *et al*. 1991). Due to varying climatic condition the drought varies from place to place, available water resources, agricultural practices and various socio-economic attributes of the region (Thomas *et al*. 2015) [12]. It is believed that the arid and semi-arid regions are most vulnerable to drought. Drought is unavoidable but its impact can be rendered by adopting suitable measures. It is under this context the present study was conducted to identify drought-prone areas in Tonk district based on departure analysis and classification of which at various drought severity classes help in computing the drought frequency and prioritizes blocks for immediate drought mitigation planning.

Material and Methods

Description of Study area

Tonk district is located in North-Eastern part of the Rajasthan state between 75˚ 07' to 76˚ 19' E longitude and 25˚ 41' to 26˚ 34' N Latitude. The total geographical area of the district is 7194 sq km. A map of the district is presented in Figure 1. The climate of the area is semiarid type. The normal annual rainfall (1901-70) of the district is 598 mm whereas the average mean annual rainfall during the period 1983-2008 has been 568.92 mm. It is evident that the rainfall in the district has significantly decreased in the recent past. The district is drained by Banas River and its tributaries. It runs for roughly 135 km in the district. It is more than half a km in width and sometimes runs in 9 m deep channel. It is more or less perennial. It develops a dendritic pattern and forms a deep gorge at Rajmahal. Its left bank is stable and rocky while the right bank is covered by alluvium. The Mashi and Sohadra are the major tributaries of Banas in the district. Both are ephemeral in nature. The soil in the district varies from sandy loam to loam in Niwai block and parts of Tonk block and from clayey loam to loam in the remaining area.

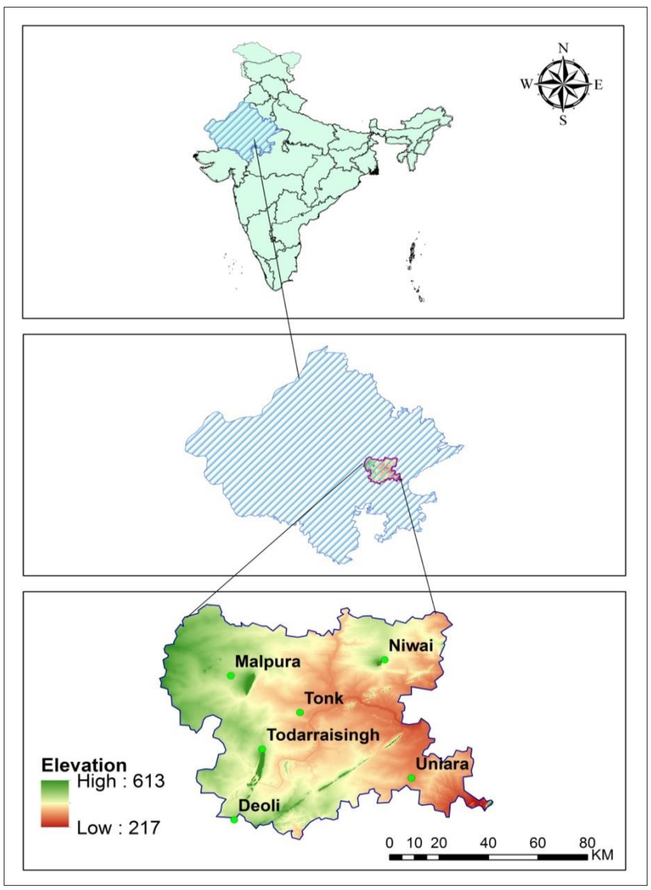

Fig 1: Location map of study area

Data Availability

The Daily rainfall records for 23 years (1983-2008) for various blocks in Tonk district has been obtained from the State Data Centre, Water Resource Department, Government of India and IMD, Pune.

Arithmetic Mean

It is generally used as the measure of central tendency of the given data. The arithmetic mean can be calculated by the formula in equation a.

$\bar{x} = \sum_i^n \frac{Xi}{N}$	....a

Where,
$\bar{x}$ = Arithmetic mean of given data
X_i = Daily rainfall data
N = Total number of rainfall data
n = Daily rainfall number (i^{th} order to n^{th})

Rainy Day

As per India Meteorological Department (IMD) a rainy day is defined as a day with rainfall of 2.5 mm or more rainfall (S. S. Nandargi and Gupta 2018) [11]. IMD further defines that rainfall for the station is called heavy if it is > 650 mm and 'very heavy' when it is > 1300 mm (S. Nandargi and Mulye 2012) [10].

Identification of drought prone areas

The drought-prone areas have been identified based on probability analysis of annual rainfall. An area has been considered to be drought-prone if the probability of occurrence of 75 % of mean annual rainfall is less than 80 % (Thomas *et al*. 2015; Sharma *et al*. 2020) [12, 4]. The annual rainfall series has been sorted in the descending order and ranks assigned from 1, 2 ……N, up to the last record and Weibull's distribution is fitted to the ranked data (Sharma *et al*. 2019) [4]. The probability of exceedance is given equation b.

$P = \frac{m}{N+1} * 100$……b

Where,
P = Probability of Exceedance of annual rainfall,
m = Rank of the particular record,
N = Total number of observations

Identification of drought years

The drought years can be identified based on the departure analysis of annual and seasonal rainfall time series. Since more than 90 % of the annual rainfall is received during the monsoon season, the seasonal rainfall departure analysis better represents the drought conditions in the study area (Thomas *et al*. 2015) [12]. To compute the seasonal rainfall departure (Di) the mean seasonal rainfall (Xm) fis subtracted from the seasonal rainfall series (Xi) given by equation c.

$Di = Xi - Xm$ …….c

The percentage departure (D %) is subsequently computed as given by Equation d.

$D\% = Di/Xm * 100$ …….d

An area or region is considered to be drought affected if it receives seasonal rainfall less than 75% of its normal value, as per the classification is given by India Meteorological Department (Appa Rao, 1986, Kumar *et al*. 2020). The year having annual or seasonal rainfall departure more than or equal to -20% is considered to be a drought year. In this study, the severity of drought has been categorized according to percentage deviations from the normal rainfall and grouped into four severity classes as given in Table 1. The departure analysis of annual and seasonal rainfall has been performed for different rain gauge station and subsequently, the drought years have been identified.

Table 1: Drought severity classification based on percentage of rainfall departure

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 %

Relative departure index

Relative departure index (RDI) is a ranking system, used to decide the relative drought proneness of various block in Tonk district based on rainfall departure analysis (Kar *et al*. 2016, Sharma *et al*. 2020) [4]. For this purpose, weights have been assigned to various drought years as follows, (1) mild drought, (2) moderate drought, (3) severe drought and (4) extreme drought. The relative departure index for the rain gauge stations has been decided by dividing the total cumulative weights obtained for the study period during drought years with the total number of years under consideration as given in equation e.

$$RDI = \frac{\sum_{i=1}^{n} W_i}{N} \quad \text{.....e}$$

Where,

N= Total number of a year under consideration

W_i= Weight for the i^{th} drought years

Greater the values of RDI more will be the severity of drought and based on that prioritization of stations is being carried out for the mitigation process.

Result and Discussion

Statistical Analysis

Statistical analysis was performed for various blocks of Tonk district using rainfall data spanning for 23 years (1983-2008). Statistical analyses were performed to assess any significant difference among the region and graphs were constructed to illustrate the changing trends during the years for the period. Average annual rainfall in the region varies between 527.76 mm in Malpura block to 618.70 mm in Todaraisingh block. The average annual rainfall in district was 568.92 mm. Figure 2 show the average annual rainfall for different blocks in Tonk district. Coefficient of variance was computed for annual rainfall in order to assess the variability in annual rainfall from its average. Coefficient of variability for the district was 32%. Maximum variability prevails in Malpura block (36.43%) and minimum in Deoli station (24%). Table 1 represents the statistical parameter computed for different station.

Table 1: Mean and coefficient of variance for different block of Tonk district

Station	Mean	CV (%)
Todaraisingh	618.70	35.47
Deoli	587.75	24.00
Tonk	583.21	33.46
Niwai	528.43	34.61
Malpura	527.76	36.43
Uniara	567.67	31.44

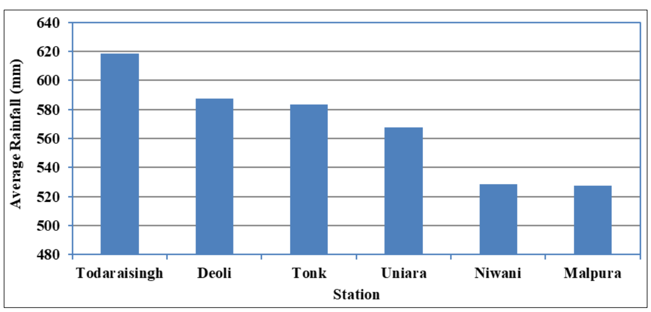

Fig 2: Average annual rainfall for different blocks in Tonk district

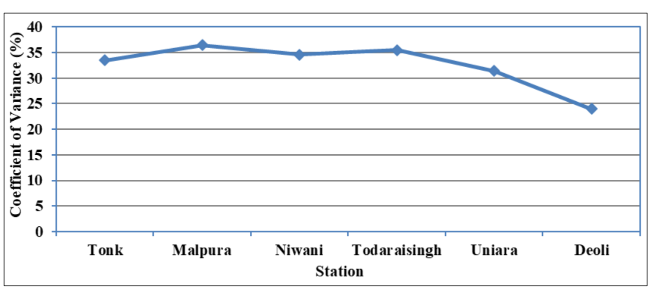

Fig 3: Coefficient of variance in Tonk district

1-day maximum rainfall

In order to assess the impact of climate change and its effect in the rainfall pattern, the 1-day maximum rainfall was computed. The scatter plot in Figure 4 and 5 show the 1-day maximum rainfall in Malpura and Uniara blocks and both are showing a decreasing pattern. Table 2 shows the status of 1-day maximum rainfall in various blocks of Tonk district. Analysis suggests that the 1-day maximum rainfall in blocks namely Tonk, Malpura, and Uniara there is decreasing and in block namely Todaraisingh and Deoli, there is an increasing pattern. The irregularity in maximum rainfall in the region is a cause of concern for the water resources management of this water-stressed region. The investigations through non-parametric trend analysis and hydrologic modelling will help to better understand these changes in more detail.

Table 2: status of 1-day maximum rainfall in various blocks of Tonk district

Block	Status
Tonk	Decreasing
Malpura	Decreasing
Niwai	Constant
Todaraisingh	Increasing
Uniara	Decreasing
Deoli	Increasing

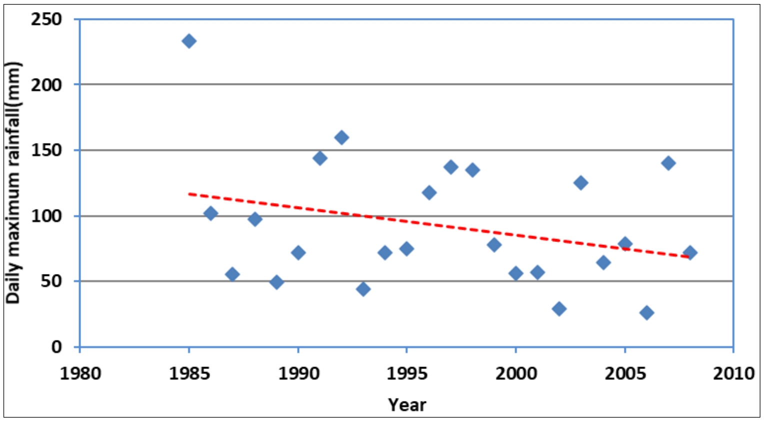

Fig 4: 1-day maximum rainfall Malpura Maximum Rainy Day

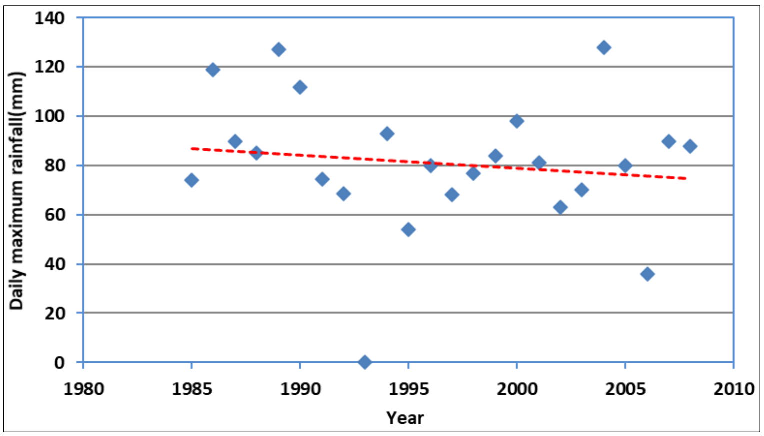

Fig 5: 1-day maximum rainfall Uniara Maximum rainfall

Number of rainy days

The number of rainy days has been evaluated on an annual basis for different blocks in Tonk district. It has been observed that the average number of rainy days varies between 29 to 31 days in different blocks of the study area. On an average, about 28 days of rainfall occur in the Tonk district which contributes to the average annual rainfall of 568.92 mm. Table 3 shows the number of rainy day in different block. The variation in the number of rainy days is given in Figure 6. The decrease in the number of rainy day indicates inadequate rainfall which further contributes to increasing the severity of drought situation in the region.

Table 3: number of rainy day in different block in the study area

Block	Number of Rainy Day
Tonk	30
Malpura	30
Niwai	29
Todaraisingh	29
Uniara	29
Deoli	31

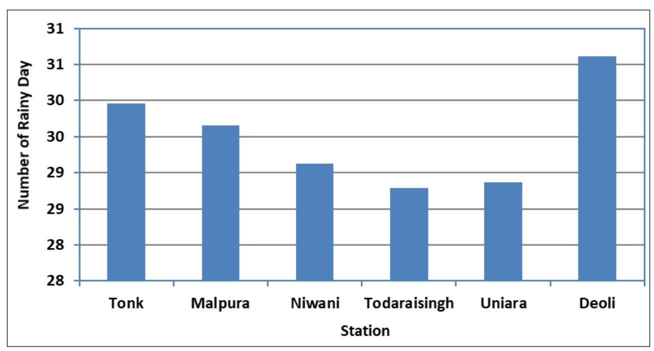

Fig 6: variation in the number of rainy days

Identification of drought year

Departure analysis of seasonal and annual rainfall was applied in order to identify drought year based on the rainfall data for the period from 1983-2008. The year having annual/seasonal rainfall deficiency more than or equal to 25 % is considered as a drought year/season. The departure analysis of seasonal rainfall has been performed for each block of the study area, and subsequently, the drought years have been identified. A summary of seasonal departure analysis is presented in Table 4.

Table 4: drought year which occurred in the study area

S.NO	Block	Drought Year
1	Todaraisingh	1985,1987,1993,1994,2002,2006,
2	Deoli	1985,1987,1998,2002,
3	Tonk	1985,1987,1989,1991,2000,2002,2005,
4	Uniara	1985,1987,2002,2006,
5	Niwai	1987,1989,2002,2006,2007,
6	Malpura	1987,1989,1993,2000,2001,2002,2006,

In 1985, 1987, 1989, 2002, and 2006 the region was under widespread drought condition and the worst drought condition prevails in 1987 and 2002. The drought assessment using departure analysis can help decision-makers in visualizing the impact of the hazard and in adopting the suitable strategies to deal with such a situation in future. This will help stakeholders, natural resource managers, agricultural producers and others to cope or to render the impact of drought. Figure 7 to 9 shows the seasonal departure for selected blocks in the study area.

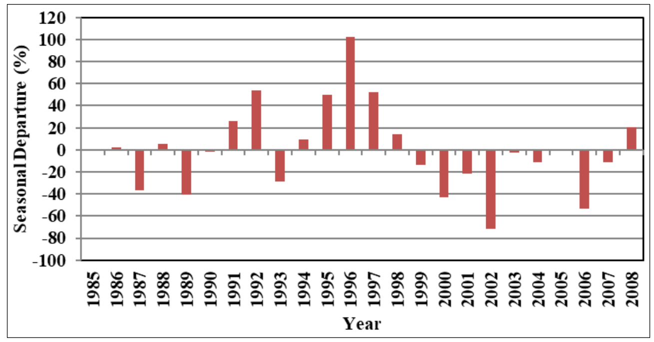

Fig 7: seasonal departure in Todaraisingh

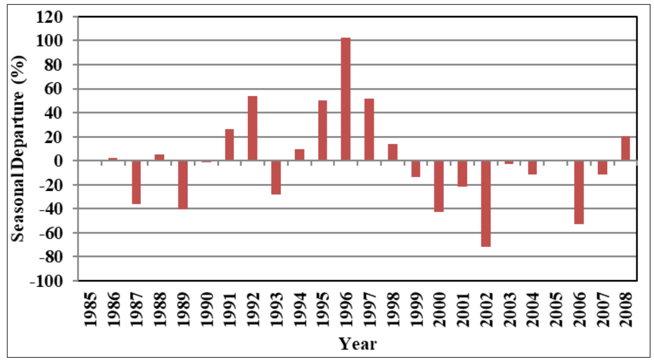

Fig 8: seasonal departure in Deoli

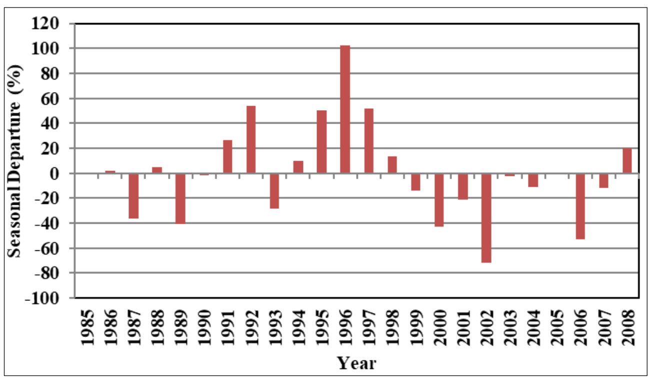

Fig 9: seasonal departure in Malpura

Evaluation of drought characteristics based on departure analysis

In this study, the drought severity has been classified on the basis of percentage deviations from the normal rainfall into four severity classes viz., mild drought for annual rainfall departures between -20 and -25 %; moderate drought for annual rainfall departure between -25 and -35 %; severe drought for annual rainfall departure between -35 and -50 %, and departure greater than -50 % is considered extreme drought. Table 5 represents drought characteristics evaluated using departure analysis. Based on the departure analysis, the average drought frequency is once in every 3–6 years. There were frequent occurrences of drought in the region and subsequent water stress, thereby adversely affecting the major agricultural operations.

Table 5: drought characteristics based on departure analysis

S.NO	Block	Mild	Moderate	Severe	Extreme	Drought Frequency
1	Malpura	1	1	3	2	1 in 3 year
2	Tonk	1	3	1	2	1 in 3 year
3	Todaraisingh	0	2	2	2	1 in 4 year
4	Niwai	0	1	3	1	1 in 5 year
5	Deoli	2	0	1	1	1 in 6 year
6	Uniara	0	1	2	1	1 in 6 year

Identification of drought prone areas

The probability analysis of annual rainfall is important to predict the relative frequency of occurrence of annual rainfall. The probability distribution of annual rainfall has been calculated using Weibull's plotting position formula, and plots between the probability of exceedance and the corresponding annual rainfall was prepared as given in Figure 10 and 11. From this plot, the probability corresponding to various rainfall amounts can be estimated. The 75 % dependable annual rainfall and the probability of occurrence for annual rainfall equivalent to 75 % of normal rainfall have been estimated and are given in Table 6. Block namely Todaraisingh, Tonk, Niwai and Malpura is drought-prone (Probability < 80 %) and facing regular water scarcity and droughts as compared to Uniara and Deoli which are not prone to droughts.

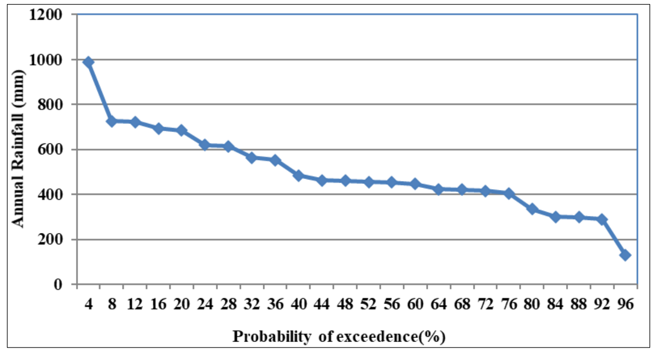

Fig 10: Probability distribution plots of annual rainfall at Uniara

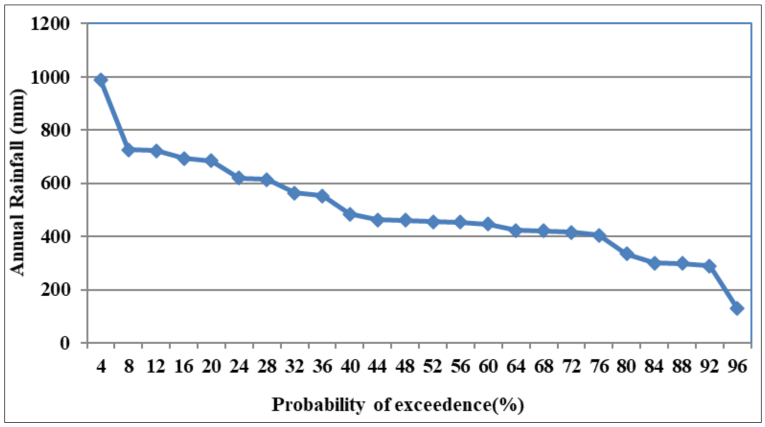

Fig 11: Probability distribution plots of annual rainfall at Niwai

Table 6: Probability distribution of annual rainfall

S. No.	Block	Mean rainfall (mm)	75% dependable rainfall (mm)	Probability of occurrence of rainfall equivalent to 75% of mean rainfall	Drought condition
1	Todaraisingh	590.67	443	75.53	Drought Prone
2	Deoli	549.83	412.38	88.44	No Drought Prone
3	Tonk	540.6	405.45	74.92	Drought Prone
4	Uniara	562.64	421.98	86.73	No Drought Prone
5	Niwai	497.18	372.88	77.84	Drought Prone
6	Malpura	492.98	369.73	74.03	Drought Prone

Relative departure index

The relative departure index (RDI) was computed each block of Tonk district. Prioritization of block based on RDI help in planning and adopting strategies to carried out mitigation measures for those blocks which are at the top in the ranking. Table 7 shows the ranking based on RDI. Malpura is at highest priority followed by Tonk and Todaraisingh.

Table 7: ranking based on RDI

Block	RDI
Malpura	0.83
Tonk	0.75
Todaraisingh	0.75
Niwai	0.63
Uniara	0.42
Deoli	0.38

Conclusion

The study presents an analysis of drought characteristics in Tonk district. The drought characteristics were studied by employing the departure analysis, as the area has a monsoon season limited to three months and has predominantly rain-fed agriculture. Departure analysis-based drought classification help to understand the frequency of drought occurrences and its characteristics will help in developing effective drought warning systems. Statistical trend analysis revealed that few blocks show a significant falling trend in rainfall and number of rainy days. Thus, indicating affects climate change phenomenon in the region. The large-scale groundwater exploitation and deforestation in the region has excavated the frequency of drought in the region. It is obvious that drought coupled with impending climate change will create a more vulnerable environment, particularly for the water resources and agricultural sector. Therefore, early warning systems need to be developed for the region based on the real-time monitoring of indicators based on rainfall, so as to improve the sustainability of agriculture and water-related sectors.

References

1. Al-Fattah SM, Dallag MM, Abdulmohsin RA, Al-Harbi WA, Issaka MB. "Intelligent Integrated Dynamic

Surveillance Tool Improves Field-Management Practices." 2006 SPE Intelligent Energy Conference and Exhibition, 2006; 1:233-43. https://doi.org/10.2523/99555-ms.
2. Belal Abdel Aziz, Hassan R El-Ramady, Elsayed S Mohamed, Ahmed M Saleh. "Drought Risk Assessment Using Remote Sensing and GIS Techniques." Arabian Journal of Geosciences. 2014; 7(1):35-53. https://doi.org/10.1007/s12517-012-0707-2.
3. Benitez Julián Báez, Roger Monte Domecq. "Analysis of Meteorological Drought Episodes in Paraguay." Climatic Change. 2014; 127(1):15-25. https://doi.org/10.1007/s10584-014-1260-7.
4. Gaurav Sharma, Chandra Kishor Kumar, Ankit Kumar. "Assessment of Meteorological Drought Characteristics Using Standardized Precipitation Index for Ajmer District, Rajasthan." International Journal of Current Microbiology and Applied Sciences. 2020; 9(2):1343-54. https://doi.org/10.20546/ijcmas.2020.902.157.
5. Gaurav Sharma, Chandra Kishor Kumar, Bhaskar Pratap Singh. 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(05):604-612.
6. Golmohammadi Maryam, Alireza Kamal, Alireza Massah Bovani. "The Investigation of Drought Values Fluctuation under the Effect of Climate Change (Case Study: Gharesou Basin): Case Study: Gharesou Basin." World Environmental and Water Resources Congress 2011: Bearing Knowledge for Sustainability - Proceedings of the 2011 World Environmental and Water Resources Congress, 2011, 1308-17. https://doi.org/10.1061/41173(414)136.
7. Hatmoko Waluyo, Radhika, Bayu Raharja, Daniel Tollenaar, Ronald Vernimmen. "Monitoring and Prediction of Hydrological Drought Using a Drought Early Warning System in Pemali-Comal River Basin, Indonesia." Procedia Environmental Sciences, 2015, 56-64. https://doi.org/10.1016/j.proenv.2015.03.009.
8. 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. https://doi.org/10.9734/cjast/2020/v39i830592
9. Mishra Ashok K, Vijay P Singh. "A Review of Drought Concepts." Journal of Hydrology. 2010; 391(1-2):202-16. https://doi.org/10.1016/j.jhydrol.2010.07.012.
10. Nandargi S, Mulye SS. "Relationships between Rainy Days, Mean Daily Intensity, and Seasonal Rainfall over the Koyna Catchment during 1961-2005." The Scientific World Journal 2012, 2012. https://doi.org/10.1100/2012/894313.
11. Nandargi SS, Gupta VK. "Spatial and Temporal Distribution of Rainfall and Rainy Days over the Goa State. 2018; 1(1):1-17.
12. 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):163-82. https://doi.org/10.1007/s00703-014-0361-1.
13. UNESCO, FAO. "Back Groud Paper on Drought – an Assessment Of." Regional Implementation Meeting for Asia and the Pacific for the Sixteenth Session of the Commission on Sustainable Development (CSD-16); 26-27 November 2007., no. November, 2007, 1-25.