Meteorological Drought Assessment in Banaskantha, Gujarat

[1]Pranav B. Mistry [2]T. M. V. Suryanarayana
[1]Research Scholar [2]Associate Professor
[1,2]Department of Water Resources Engineering and Management Institute
[1,2]The Maharaja Sayajirao University of Baroda, Samiala-391410, India

Abstract

Drought assessment is very important to manage water resources in lean period. It plays vital role in managing water demands especially in agriculture sector. In the present study, monthly rainfall and potential evapotranspiration data for 102 years (i.e., 1901 to 2002) were collected and analysed for drought assessment. The dry periods were calculated using meteorological drought indices i.e. Reconnaissance Drought Index for various time scales of RDI-3, RDI-6, RDI-9 and RDI-12. The outcomes of the study shows that RDI-12 gives finest results as compared to other time scales because it considers all 12-month of hydrologic year for calculation. Amongst the period considered, the normal dry, moderate drought, severe drought and extreme drought conditions occurred for 29%, 6%, 6% and 4% respectively. Considering only the drought years i.e. (46 Years) normal dry, moderate drought, severe drought and extreme drought conditions exists for 65%, 13%, 13% and 9% respectively. It is recommended that more accurate predictions are achieved using longer duration of RDI-12 index in drought monitoring systems for water resources planning and water management in the present study.Based on the findings of this research, it is recommended that the RDI index should be used as the proper drought index in drought monitoring systems for water resources planning and management in Banaskantha.

Keyword- Drought Assessment, Reconnaissance Drought Index

I. INTRODUCTION

Drought is a complex and least understood phenomenon which generally occurs due to the below normal availability of water for a considerable period which can extend to regions, countries or continents. Even though drought is a recurring phenomenon and affects all geographical areas, but its impacts are more severe in arid and semi-arid regions where there already exists high natural variability in the rainfall pattern. The main characteristics include severity, intensity, areal extent, progression and withdrawal of droughts. Drought severity, duration and its spatial extent are some of the important characteristics (Thomas et al. 2015).

Drought indices are important elements of drought monitoring and assessment since they simplify complex interrelationships between many climate and climate-related parameters. Indices make it easier to communicate information about climate anomalies to diverse user audiences and allow scientists to assess quantitatively climate anomalies in terms of their intensity, duration, frequency and spatial extent (Wilhite et al. 1985).

II. LITERATURE REVIEW

Tigkas et al. (2013) studied the Reconnaissance Drought Index (RDI) (initial or normalized expressions) as a single climatic index for the detection of possible climatic changes. Using data for various reference periods (12, 6, 3 months).Similarly, Thomas et al. (2015) considered RDI by considering Penman-Monteith method used to estimate PET to analyse the climate change impacts on the drought scenario in Bundelkhand region. Also, spatio-temporal variation of drought has been investigated and it was found that every drought events has its own characteristics in terms of its areal extent, its progression, withdrawal and severity. Tigkas et al. (2015) presented a summary of the RDI theory with some practical applications and RDI can be calculated for any time step, and effectively related with agricultural drought and directly linked to the climate conditions of the area. Mistry and Suryanarayana (2018) studied SPI in Banaskantha and shown that 6%, 15% and 15% of Extreme dry years, severe dry years and Moderate dry years occur amongst drought years considered, which means 36% years are categorized into moderate to extreme drought years out of the total drought years.

Lunagaria and Suryanarayana (2015) estimated dry periods using analysis of RDI-3, RDI-6, RDI-9 and RDI 12.and concluded that it was better to use RDI of 12 months' index for analysis of drought for Sabarkantha district. Patel et al. (2017) had calculated SPI for 4, 6, 12, 24 and 48 months' time scales in Surat District. The area experienced more than 20% years of dry and wet events for the 20th Century. It is observed that the years 1942, 1945 and 1959 are identified as severe wet events for the time

scale considered. Malakiya and Suryanarayana (2016) developed SPI and RDI for assessment of the drought for Amreli district, wherein they concluded that it is better to use SPI and RDI of 12 months' index for analysis of drought for this study.

Numerous drought indices with various intricacy have been utilised in several climatic regions. Presently, the Reconnaissance Drought Index (RDI), which is considered as a powerful index of meteorological drought, is acquisitioning approval primarily in semi-arid and arid climatologic areas. Because RDI is based on precipitation (P) and potential evapotranspiration (PET), it assesses the PET estimation effects on the characterisation of drought severity computed by RDI.

III. STUDY AREA AND DATA COLLECTION

Banaskantha is one among the thirty three districts of the Gujarat state of India. The administrative headquarters of the district is Palanpur. The main rivers in the district are Banas, Saraswati River and Sipu. Banaskantha District includes the area around the Bank of Banas River.

The District is situated between 23°33' to 24°45' North Latitude and 72°15' to 73°87' East Longitude. The climate of this district is characterized by a hot summer and dryness in the non-rainy seasons. The cold season starts from December to February is followed by the hot season from March to May. The south-west monsoon season is from June to September and post monsoon season from October and November. The annual rainfall varies between 214 mm to 1,801 mm. The annual average rainfall of Banaskantha district is 863.01 mm and average temperature of is 26.97° C. For the present analysis of drought calculation 102 years (i.e., 1901 to 2002) precipitation and potential evapotranspiration data has been collected from website of Indian Water Portal.

Fig. 1: Taluka Map of Banaskantha

IV. METHODOLOGY

A. Reconnaissance Drought Index

A new reconnaissance drought identification and assessment index was first presented by (Tsakiris, 2004) while a more comprehensive description was presented in (Tsakiris et al. 2006). The index, which is referred to as the Reconnaissance Drought Index, RDI, may be calculated by the following equations. For illustrative purposes the yearly expressions are presented first. The first expression, the initial value (α0), is presented in an aggregated form using a monthly time step and may be calculated for each month of the hydrological year or a complete year. The α0 is usually calculated for the year i in an annual basis as follows:

$$\alpha_0^{(i)} = \frac{\sum_{j=1}^{12} P_{ij}}{\sum_{j=1}^{12} PET_{ij}} \quad i = 1 \text{ to } N, \text{and } j = 1 \text{ to } 12 \qquad (1)$$

In which P_{ij} and PET_{ij} are the precipitation and potential evapotranspiration of the month j of the year i. A second expression, the Normalized RDI, (RDIn) is computed using the following equation for each year, in which it is evident that the parameter $\bar{\alpha}_0$ is the arithmetic mean of α_0 values calculated for the N years of data.

$$RDI_n^{(i)} = \frac{a_0^{(i)}}{\overline{a_0}} - 1 \qquad (2)$$

The third expression, the Standardized RDI (RDIst), is computed following similar procedure to the one that is used for the calculation of the SPI. The expression for the Standardized RDI is:

$$RDI_{st}^{(i)} = \frac{y^{(i)} - \bar{y}}{\widehat{a_y}} \quad (3)$$

In which $y^{(i)}$ is the in $a_0^{(i)}$, is its arithmetic mean and $\widehat{a_y}$ is its standard deviation. Below Table 1 shows RDI values range and corresponding drought classification.

RDI Values	*Drought classification*
2.00 or more	*Extremely wet*
1.5 to 1.99	*Severely wet*
1.00 to 1.49	*Moderately wet*
0 to 0.99	*Normal Conditions-wet*
0 to -0.99	*Normal Conditions-dry*
-1 to -1.49	*Moderate drought*
-1.5 to -1.99	*Severe drought*
-2 or less	*Extreme drought*

Table 1: Classification of RDI

V. RESULTS AND ANALYSIS

The rainfall of Banaskantha is shown in below figure 1 which shows between rainfall and time. The coefficient of determination (r^2) shows that 0.28% variation in rainfall is explained by time. The total rainfall received in a given period at a location is highly variable from one year to another year. The variability depends on the type of climate and length of the considered period. In general it can be stated that the drier the climate, the higher the variability of rainfall in time. The same hold for the length the period: the shorter the period the higher the annual variability of rainfall in that period.

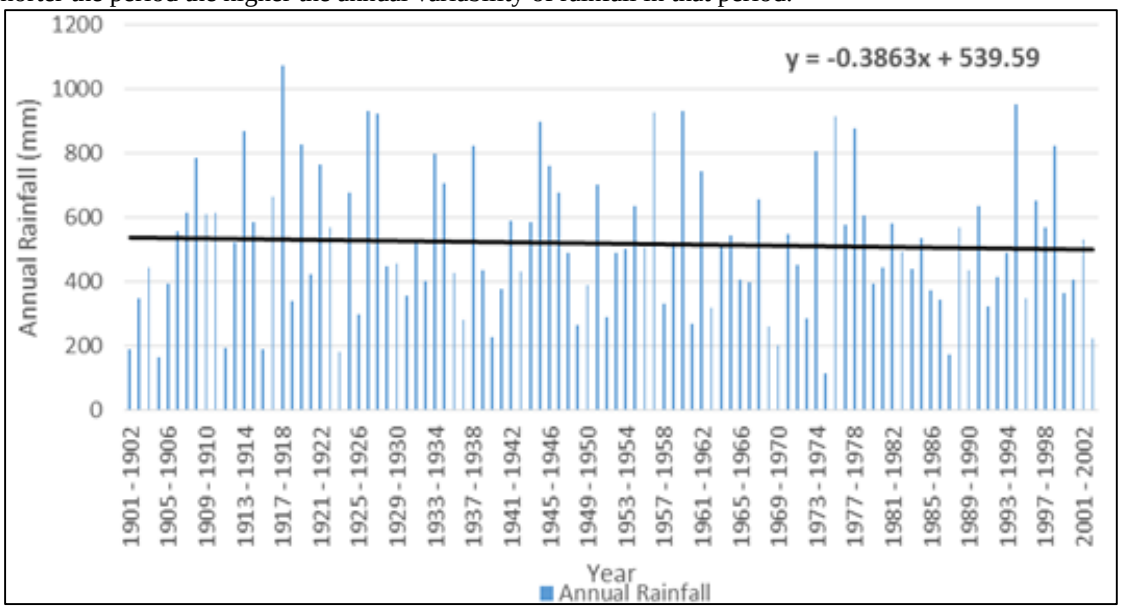


Fig. 2: Annual Rainfall over Banaskantha district

A. Analysis of Reconnaissance Drought Index

The computation for RDI was carried out for drought assessment using DrinC tool. DrinC gives the ability to formulate a drought analysis that suits better the needs or the purpose of this study.

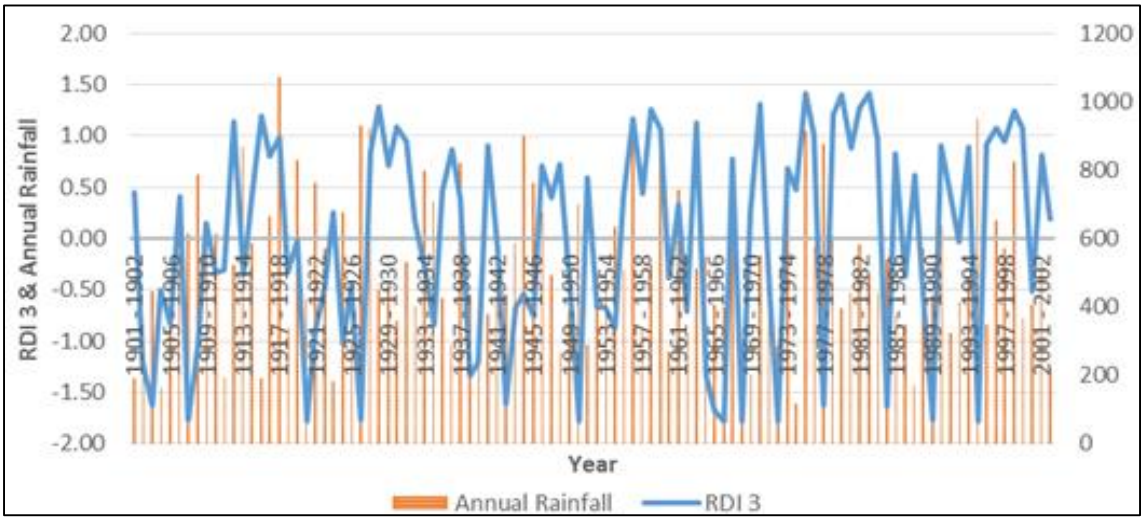


Fig. 3: Variation of Annual Rainfall and RDI 3

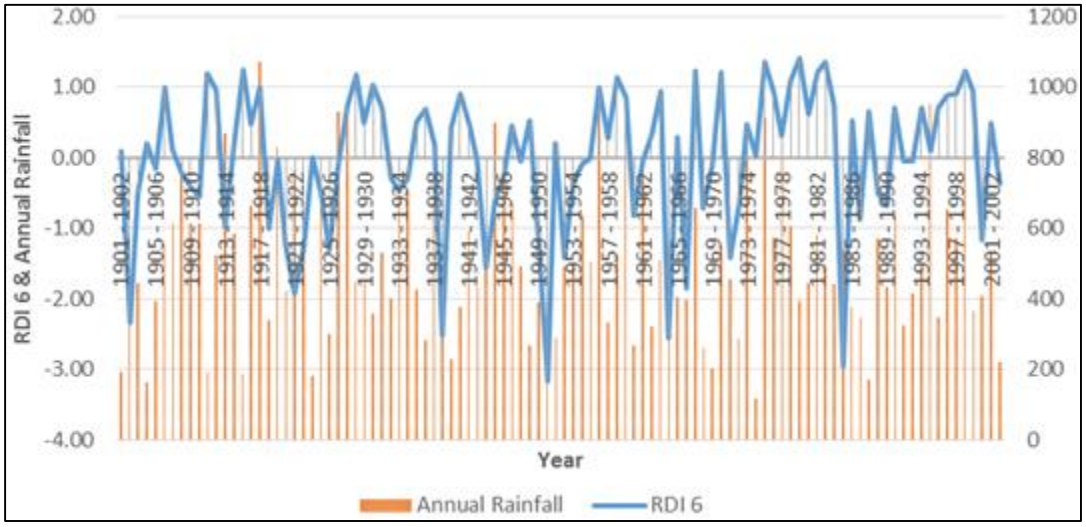


Fig. 4: Variation of Annual Rainfall and RDI 6

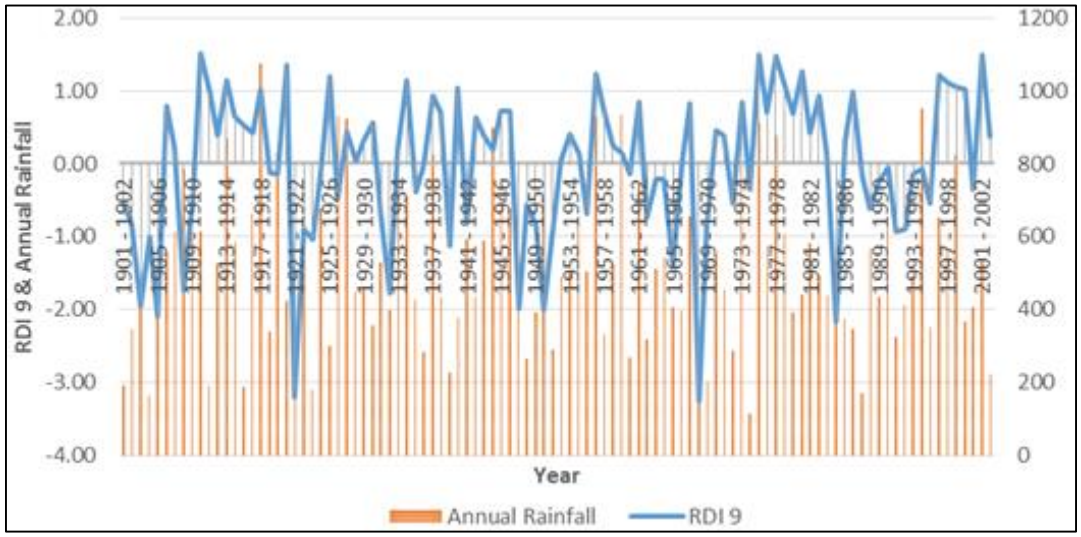


Fig. 5: Variation of Annual Rainfall and RDI 9

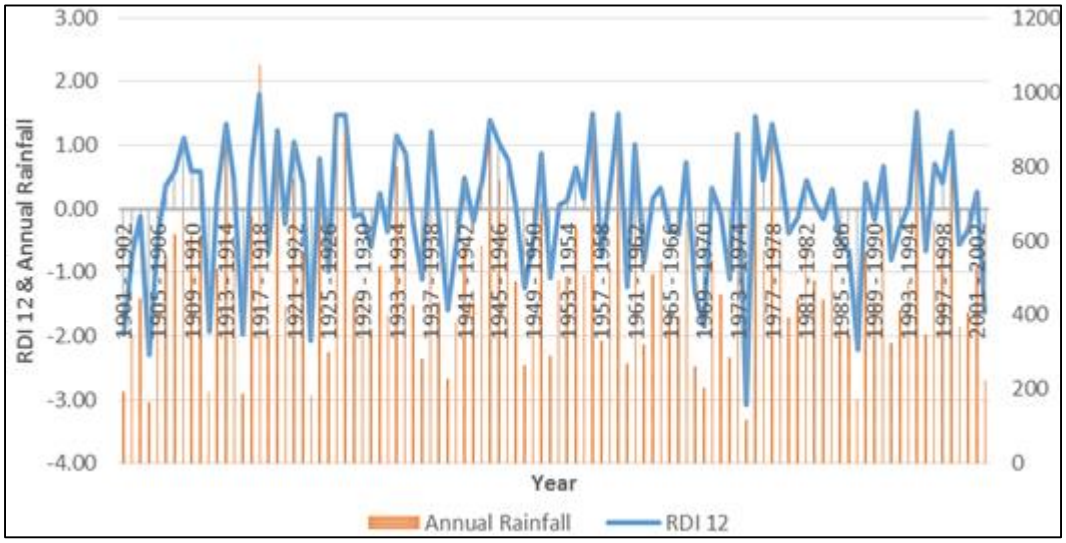
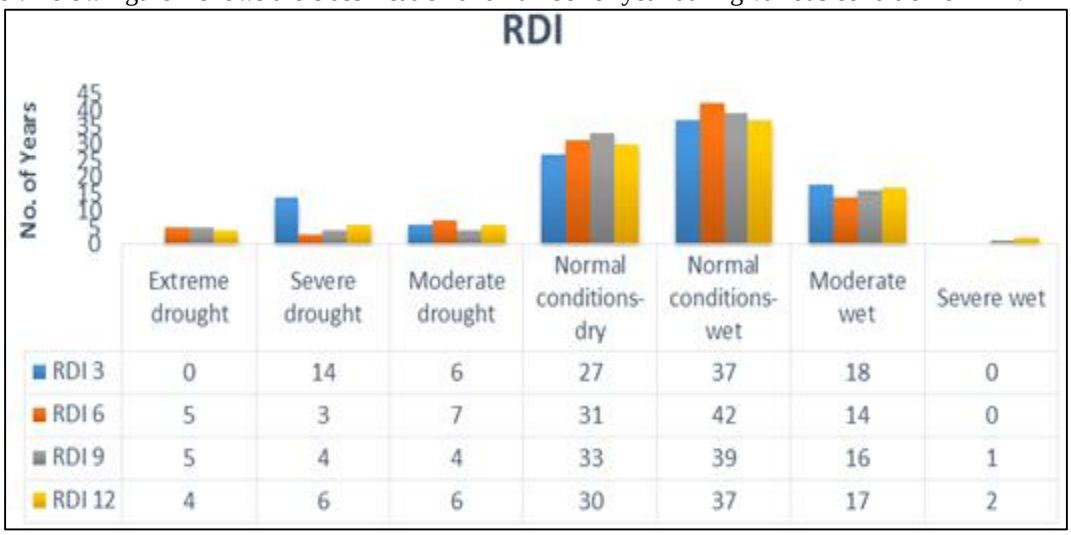


Fig. 6: Variation of Annual Rainfall and RDI 12

The Figures 3, 4, 5 and 6 shows annual rainfall and deviation of computed RDI values for different time scales RDI 3, RDI 6, RDI 9 and RDI 12 respectively. When the period of analysis is short, the variation between positive and negative values are seen more frequently and when the period of analysis increases, it is observed that the variation between positive and negative values are fewer. Below figure 7 shows the classification and number of year during various condition of RDI.



	Extreme drought	Severe drought	Moderate drought	Normal conditions-dry	Normal conditions-wet	Moderate wet	Severe wet
RDI 3	0	14	6	27	37	18	0
RDI 6	5	3	7	31	42	14	0
RDI 9	5	4	4	33	39	16	1
RDI 12	4	6	6	30	37	17	2

Fig. 7: Number of Years under various conditions during 20th Century

RDI	*Extreme Drought*	*Severe Drought*	*Moderate Drought*
RDI 3	*No events*	*1903, 1907, 1920, 1926, 1942, 1950, 1965, 1966, 1968, 1972, 1977, 1984, 1989, 1994*	*1902, 1908, 1924, 1938, 1939, 1964,*
RDI 6	*1902, 1938, 1950, 1964, 1984,*	*1921, 1943, 1966*	*1920, 1922, 1925, 1949, 1952, 1971, 2000*
RDI 9	*1905, 1921, 1950, 1968, 1984*	*1903, 1908, 1932, 1947*	*1904, 1923, 1939, 1965*
RDI 12	*1904, 1923, 1974, 1987*	*1901, 1911, 1915, 1939, 1969, 2002*	*1936, 1948, 1951, 1960, 1968, 1972*

Table 2: Number of Drought Affected Year for various time scales

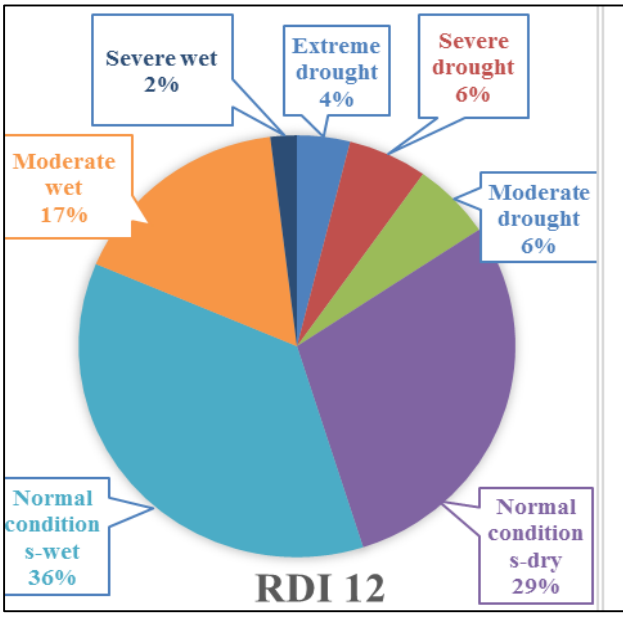


Fig. 8: Distributions of Wet and Dry period (RDI 12)

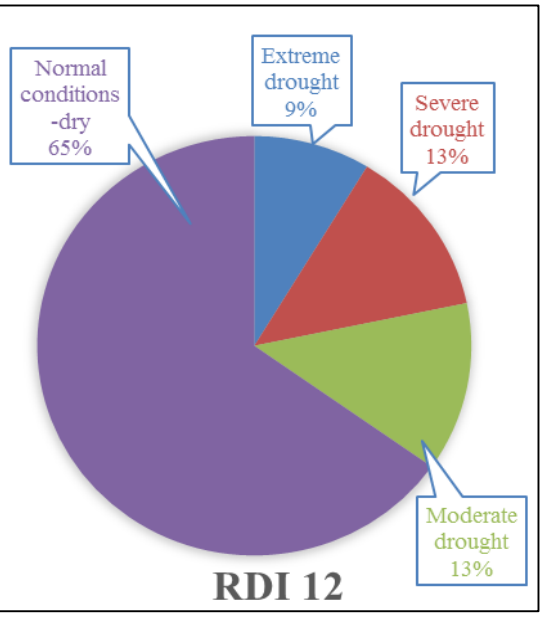


Fig. 9: Frequency of Drought Condition

Figure 8 shows frequency RDI 12 indicator, where figure 9 shows only frequency of drought years it is shown that extreme wet conditions is never occurred in the last 102 years. Only severe conditions occurred only 2% amongst 102 years so it is indicating that Banaskantha Taluka falls under scarcity rainfall for the period of time in the last 102 years, because the average annual rainfall of Banaskantha is only 520 mm which is very low. Also, from the above figure it shows that amongst the period considered, the normal dry, moderate drought, severe drought and extreme drought conditions occurred for 29%, 6%, 6% and 4% respectively. Considering only the drought years i.e. (46 Years) normal dry, moderate drought, severe drought and extreme drought conditions exists for 65%, 13%, 13% and 9% respectively.

VI. Conclusions

The RDI method gives best results without other climatic parameters like minimum and maximum temperature, humidity and sun hours as it uses only Precipitation data and Potential evapotranspiration gives accurate results. From the results and analysis it is concluded that extreme drought condition occurred in 1904, 1923, 1974 and 1987 years. Severe drought condition occurred in 1901, 1911, 1915, 1939, 1969 and 2002 years and Moderate drought conditions occurred in the year 1936, 1948, 1951, 1960, 1968, and 1972. The outcomes of the study shows that RDI-12 gives finest results as compared to other time scales because it considers all 12-month of hydrologic year for calculation. Amongst the period considered, the normal dry, moderate drought, severe drought and extreme drought conditions occurred for 29%, 6%, 6% and 4% respectively. Considering only the drought years i.e. (46 Years) normal dry, moderate drought, severe drought and extreme drought conditions exists for 65%, 13%, 13% and 9% respectively.

In general, the present results have shown that the most part of Banaskantha has been affected by drought. So, there is a need to undergo future researches on these region so as to improve the water resource management and development programs and to resolve the socio-economic and agricultural problems faced by the people in these parts of the country.

References

[1] Lunagaria N and Suryanarayana TMV (2017). Assessment of Drought in Sabarkantha District Using Reconnaissance Drought Index (RDI). International Journal of Science and Research (IJSR) ISSN (Online): 2319-7064, Volume 6 Issue 1,970-974.

[2] Malakiya, A.D. and Suryanarayana, T.M.V.: Assessment of Drought Using Standardized Precipitation Index (SPI) and Reconnaissance Drought Index (RDI): A Case Study of Amreli District. International Journal of Science and Research (IJSR), 5(8) (2016) 1995-2002.

[3] Mistry PB, Suryanarayana TMV (2019) Categorization of Drought During Twentieth Century Using Precipitation in Banaskantha District, Gujarat, India. Innovations in Infrastructure. Advances in Intelligent Systems and Computing, vol. 757. PP 267-274.

[4] Patel NR. Suryanarayana, TMV and Shete DT. Analyzing Extreme Events Using Standardized Precipitation Index during the 20th Century for Surat District, India. Application of Geographical Information Systems and Soft Computation Techniques in Water and Water Based Renewable Energy Problems. Eds. M. Majumder, Springer Verlag, Singapore, (2017) 41-50.

[5] Thomas T, Jaiswal RK, Galkate RV and Nayak TR (2015). Reconnaissance drought index based evaluation of meteorological drought characteristics in Bundelkhand, International Conference on Emerging Trends in Engineering, Science and Technology, Procedia Technology 24, 23 – 30.
[6] Tigkas D, Vangelis H and Tsakiris G (2013). The RDI as a composite climatic index", European Water 41: 17-22.
[7] Wilhite DA and Glantz MH (1985). Understanding the drought phenomenon: The role of definitions. Water International, 10, 111–120.