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Climate Change Impact Studies on Historical Rainfall Records: A Case Study of Dindori District, Madhya Pradesh, India

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ABSTRACT
Climate change is worldwide but its impacts are feeling local. Dindori district is uniquely known for rich forest wealth and tribal communities in Madhya Pradesh India. People derive their livelihood and nutrition security from forest resources. Climate change is likely to impact the distribution of these natural resources by altering their phenology and production. In the present study, long-term rainfall (1901-2018) time series has been applied for rainfall analysis using parametric (Regression) and non-parametric (Mann-Kendal and Sen's slope estimator) tests. The negative trends have been found in Dindori district, Madhya Pradesh, India. A detailed study has been carried out for rainfall behavior identification of the district. The present study is used for forest, agricultural, water resources development, planning, and mitigation.

KEYWORDS: *Climate change, Dindori district, Rainfall, Regression, and Mann-Kendall test*

INTRODUCTION

Climate change is one of the most serious challenges facing the world today, which is expected to have long-term impacts on sustainable living. Climate change is considered to impact the water resources, rainfall, environment, agriculture, and other allied sectors that are a vital role in the survival of mankind. Climate change, science not only demonstrates that climate change is taking place, but that its cause is mostly the result of human activities. It can also respond to the challenges that will proceed. Global and regional climate models project the likely scenarios for the coming decades and century. The changes in average temperature of the earth can transform into large shifts in the climate and weather. These changes are now being witnessed by the changes in rainfall pattern and distribution, resulting in frequent events of floods and droughts with higher severities, extreme precipitation, as well as more frequent and severe heat waves. In the

Indian context, it is reported that the land surface temperature has increased at a rate of 0.2°C per decade during 1971-2007 (Kothawale et al., 2010). An enhanced hydrological cycle is therefore expected due to a global increase in average water vapor, evaporation, and precipitation as a result of the temperature increase. While there is an increase in rainfall intensity at many places, the change in climate makes some other areas, especially semi-arid regions, vulnerable to drought occurrences. It is widely understood that changes in runoff are the result of the combined effects of climate, land cover, and human activities in a basin. In recent decades, increasing shortages of water resources in most of the river basins are mainly due to human activities and climate change (Vorosmarty et al., 2000).

The southwest monsoon, which brings about 80% of the total precipitation over the country, is critical for the availability of freshwater for drinking and irrigation. Changes in climate over the Indian region particularly the southwest monsoon would have a significant impact on agriculture production, water resources management, and the overall economy of the country. The changing pattern of precipitation deserves urgent and systematic attention as it will affect the availability of food supply (Dore, 2005). According to IPCC (2013), future climate change is likely to affect agriculture, increase the risk of hunger and water scarcity, and would lead to more rapid melting of the glacier. Freshwater availability in many river basins in Asia is likely to decrease due to climate change. This reduction along with population growth and rising living standards could adversely affect more than a billion people in Asia by the 2050s.

Madhya Pradesh (MP) was one of the first states to begin work on a State Action Plan on Climate Change (SAPCC, 2009) and to expect future climate change scenarios study state's need to plan how greenhouse gases (GHGs) will change in the future. A range of emissions scenarios has been developed by the Intergovernmental Panel on Climate Change (IPCC) to project how the global economy might develop. Each scenario uses different assumptions for population and economic growth, energy use, and technology (MPSAPCC, 2014). More than half of Madhya Pradesh faces the threat of adverse weather conditions on account of global warming and climate change, a new study has revealed. To predict the impact of global warming and climate change on Madhya Pradesh, a study on vulnerable zones and the risk involved was carried out by Environmental Planning and Coordination Organization (EPCO). Dindori is the most vulnerable district regarding the environmental and socio-economic aspects. The Dindori district will be more susceptible to climate extremities like frequent droughts, floods, and rises in diurnal temperature among others (TOI, 2014).

Sushant (2013) has been reported case studies in eastern Madhya Pradesh - a central Indian province on community adaptation strategies for sustainable livelihood options. With about 90% of the region being rain-fed, erratic rainfalls in the last fifteen years have caused up to a 60% decrease in crop yields, directly impacting the food security of the region. The System of Rice Intensification (SRI) and horticultural expansion are adaptation measures for tackling climate change.Global average precipitation is projected to increase, but both increases and decreases are expected at the regional and continental scales (IPCC, 2007). Similar trends were reported in rainfall by various authors in India (Thapliyal and Kulshrestha 1991; Kumar et al., 1992; Sinha ray and De 2003 Singh et al.,2008) Available literature associated with global warming effects strongly indicates that at global scale there are significant changes in rainfall pattern (Diz et al., 1989; Hulme et al., 1998). Various other authors (Rind et al., 1989; Mearns et al., 1996) have also highlighted the future climate change and its influence on rainfall trends. Studies analyzing rainfall characteristics, variability, and trends have reported that there will be extreme variations in precipitation intensity, spatial and temporal rainfall patterns in most regions of India (Goswami et al., 2006; Kumar et al., 2010).

Various authors (Mirza 2002, Goswami et al., 2006; Dash et al., 2007) reported that many parts of Asia would witness an increase in intense rainfall events, while a reduction in the total rainy days and total annual rainfall. Studies based on daily values of rainfall from 1951to 2000 reported the rising trends in magnitude and frequency of extreme events of precipitation, as well as a noticeably, decrease in the frequency of the usual occurrences

(Goswami et al., 2006) during the monsoon over central India. A study of the annual rainfall of nine river basins of central India and northwest (Singh et al., 2008) indicated an increasing trend in annual rainfall in the majority of the basins. Sinha Ray and Srivastava (1999) established that the frequency of heavy rainfall events during the southwest monsoon shows an increasing trend over certain parts of India. However, a decreasing trend has been observed during the winter, pre-monsoon, and post-monsoon seasons. Mondal et al. (2012) have found a rising and decreasing trend of precipitation in months in Cuttak District, Odisha.

Based on mathematical tools/methods, the works reported for rainfall trend analysis may be grouped into two types (Zhang et al., 2006; Kundzewicz and Robon 2004). The first method is named as a parametric method (linear), while the second is termed as a nonparametric method (Mann, 1945; Kendal, 1975), viz. Mann-Kendal (MK) and Sen's slop estimator (1968). Out of these methods, the use of a nonparametric approach (Kalumba et al., 2013 and Sabzevari et al., 2015) is more appropriate for an analysis of distributed data involving uncertainty, which is observed in hydrometeorological time series. Several researchers (Chinchorkar et al., 2015, Sarkar and Garg, 2018; Thakral et al., 2018; Prabhakar et al., 2019, Panda and Sahu, 2019, Yadav et al., 2019, Rajani et al., 2020 and Shrivastava et al., 2020) reported their works regarding detecting a hydrological and hydrometeorological trend in the time series by MK test and Sen's slope estimator. In this study MK test method and Sen's slope estimator for Dindori district of Madhya Pradesh have been selected for trend analysis of the long-term historical rainfall records of Dindori Madhya Pradesh, India, available from the year 1901 to 2018 on the monthly, seasonal, and annual variability and statistical analysis have been also carried out for the time series.

Location of the study area

Dindori is a district of Madhya Pradesh state of central India. The town of Dindori is the district headquarters. It was created on 25thMay 1998 with a total of 927 villages. The district is a part of the Jabalpur Division. The district covers an area of 7470 sq.km. and is located in the eastern part of Madhya Pradesh, bordering the state of Chhattisgarh. Dindori District is located between Latitude 80°.35′ to 80°.58′ and Longitude 22°.17′ to 23°.22′. It has an average elevation of 640 meters (The highest elevation at 1100mamsl). It is surrounded by Shahdol in the east, Mandla in the west, Umaria in the north, and Bilaspur district of the state of Chhattisgarh in the south (Fig. 1). It is divided into seven blocks namely Dindori, Shahpura, Mehadwani, Amarpur, Bajaj, Karanjiya, and Sambalpur. According to the 2011 census, Dindori District has a population of 704218. The district has a population density of 94 inhabitants per square kilometer. The Baiga are a predominant tribe in this district. They are very vulnerable tribal groups that can only be found in the district. The Baigas are also known as the "National Human". Around 64% of the total population belongs to the ST groups. 65 million old plant fossils are found in this district and attempts are made to protect the fossils at Ghughua Fossil Park.

Objective of the study

1. To collect the rainfall data from 1901 to 2018 from IMD and District Land Record Department District- Dindori (M.P.) and determine various statistical parameters such as Mean, Median, Mode, Coefficient of Dispersion, and Co-efficient of Skewness.
2. To prepare rainfall data for monthly, seasonal and annual time series analysis
3. To determine Parametric (regression) test and Non-Parametric (Mann-Kendal) test analysis for Climate Change Impact study on historical rainfall data in the region.

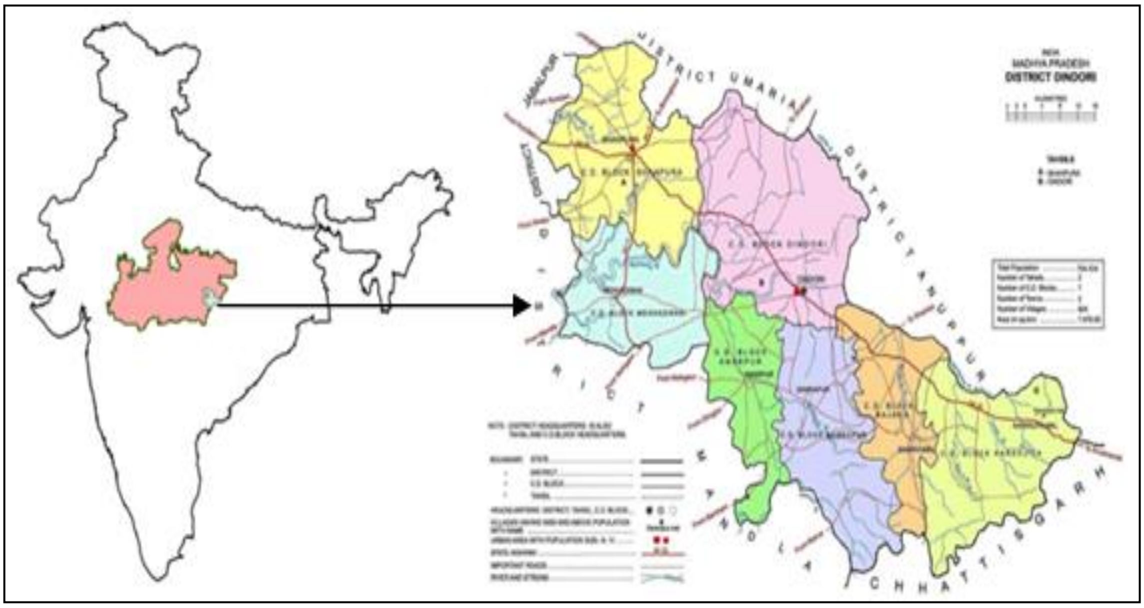

Figure 1: Location map of the study area

MATERIALS AND METHODS

In the present study, records on rainfall data have been collected from the IMD, New Delhi and land record department District- Dindori, Madhya Pradesh and were further used for analysis. Moreover, the rainfall records at Dindori station were selected for 118th years (1901-2018) having continuous rainfall data. The meteorological station Dindori district Madhya Pradesh used in this study of changes in rainfall pattern at deferent time scales, a year was divided into four principal sections:

1. The pre-monsoon season prevailing from March to May.
2. Monsoon season prevailing from June to September.
3. Post-monsoon season prevailing from October to November.
4. Winter season prevailing from December to February.

For the evaluation of trends in rainfall, daily data have been used from monthly totals. Monthly data of rainfall were further used to compute the seasonal and annual time series, which were in turn used for the investigation of trends on the seasonal and annual time scales. Trends in data can be identified by using either parametric or non-parametric methods, and both methods are widely used. The non-parametric methods are extensively used for analyzing the trends in several hydrologic series (Chattopadhay et al., 2011; Dinpanshoh et. al., 2011; Fu et al., 2004; Hirsch et al., 1982; Jhajharia and Singh 2011; Jhjharia et al., 2009, 2011; Tebakari et al., 2005; Yu et al., 1993). In the present study, two methods viz. Parametric (regression) and Non-Parametric (Mann-Kendal) test and Sens's slope estimator have been used. These are described in the following sections.

Regression Model

One of the most useful parametric models to detect the trend is the "Simple Linear Regression" model. The method of linear regression requires the assumptions of normality of residuals, constant variance, and true linearity of relationship (Helsel and Hirsch 1992a, b). The model for Y (e.g., precipitation) can be described by an equation of the form:

$$Y = at + b \quad (1)$$

Where

t - time (year)

a - slope coefficient; and

b - least-squares estimate of the intercept

The slope coefficient indicates the annual average rate of change in the hydrometeorological characteristic. If the slope is significantly different from zero statistically, it is entirely reasonable to interpret that there is a real change occurring over time. The sign of the slope defines the direction of the trend of the variable: increasing if the sign is positive, and decreasing if the sign is negative.

Mann-Kendall (MK) Test

The non-parametric Mann-Kendal (MK) test, which is commonly used for meteorological data namely rainfall, temperature, pan evaporation, wind speed, etc. analysis and trends detection that are monotonic but not necessarily linear. The MK test does not require the assumption of normality, and only indicates the direction but not the magnitude of significant trends (Dennis et al., 2005). The trend in the data if any was quantified using Mann-Kendall's S-statistic (Mann 1945; Kendall 1955).The MK method assumes that the time series under research is stable, independent, and random with an equal probability distribution(Zhang et al., 2005). The MK test is applied to uncorrelated data because it was reported that the presence of serial correlation might lead to an erroneous rejection of the null hypothesis (Helsel and Hirsch 1992a, b; Kulkarni and von Storch 1995; Yue et al., 2002; Yue and Wang 2002; Yue and Pilon 2003; Adamowski and Bougadis, 2003).

The MK statistical test required sample data that should be serially independent (Yue and Wang 2004). The MK statistic, S is defined as:

$$S = \sum_{j=1}^{m-1} \sum_{k=j+1}^{m} \mathrm{sign}(x_k - x_j), \tag{2}$$

Where x_k and x_k are the jth and kth in the sequential of data sample size m and for$x_k - x_j = \theta$

$$\mathrm{sign}(\theta) = \begin{cases} 1 & \text{if } \theta > 1 \\ 0 & \text{if } \theta = 0 \\ -1 & \text{if } \theta < 1 \end{cases} \tag{3}$$

Assuming independent data with identically scattered, the variance and mean of the S statistic in Eq.(2) may be calculated as given by (Kendall 1975a;Dinpashoh et al., 2011),

$$E[S] = 0, \quad \mathrm{Var}(S) = \frac{m(m-1)(2m+5)}{18} \tag{4}$$

However, forties in the data set the expression for Var(S) becomes:

$$\mathrm{Var}(S) = \frac{m(m-1)(2m+5) - \sum_{i=1}^{m} t_i(t_i-1)(2t_i+5)}{18} \tag{5}$$

Where m is the number of tied (zero difference between compared values) group and t_i is the number of data points in the i^{th} tied group. The standard normal deviate (z statistics) is then computed,

$$Z = \begin{cases} \frac{S-1}{\sqrt{\mathrm{Var}(S)}} & \text{if } S > 1 \\ 0 & \text{if } S = 0 \\ \frac{S+1}{\sqrt{\mathrm{Var}(S)}} & \text{if } S < 1 \end{cases} \tag{6}$$

The Z values greater than ± 1.96 represent a 5% level of significant positive/negative trend in the time series, respectively.

Theil-Sen's Slope estimator:

Sen (1968) gave a nonparametric procedure for linear trends in time series in terms of slopes. The slope estimation (Q_i) of m pairs of data are calculated using the following expression,

$$Q_i = \frac{x_j - x_k}{j-k} \quad \text{for } i=1,2,3,\ldots\ldots,m \tag{7}$$

The median of Q_i is derived from:

$$\beta = \begin{cases} \frac{Q(m+1)}{2} & \text{m is odd} \\ \frac{1}{2}\left(\frac{Qm}{2} + \frac{Q(m+2)}{2}\right) & \text{m is even} \end{cases} \tag{8}$$

The results are compared with threshold levels at 5%, and the β values above ±1.96 are significant (increasing/decreasing) trends.

RESULT AND DISCUSSION

In this study, monthly, seasonal and annual rainfall data were analyzed for Dindori district Madhya Pradesh (Figure 2, Figure 3, and Figure 4).The linear regression analysis has been carried out for the Dindori Meteorological station and graphical presentations are depicted (Figure 5, Figure 6, Figure 7, Figure 8 and Figure 9) for the trend in seasonal and annual rainfall of the area. The descriptive statistics of rainfall such as the maximum and minimum, mean, median, standard deviation, coefficient of variation, kurtosis, and skewness are depicted in Table 1. The monthly rainfall trends for the Dindori district over the last one hundred eighteen years are comprised of January to May and September to December are shows significantly decreasing trends of the area. Only one significant increasing trend appears in the area towards June-August (Figure 2). The yearly rainfall (Figure 3) and trend detection of the seasonal and annual rainfall of the study area show that during the years of 1901 to 2018 and also given linear regression equation (Figure 5 to Figure 9).The average rainfall of the Dindori district has been calculated and found to be 1305.7 mm. Hence, this year's rainfall data was above the average line which years were favourable for groundwater recharge of the area and these years' rainfall data found below the line of average were not favorable for groundwater recharge of the area.

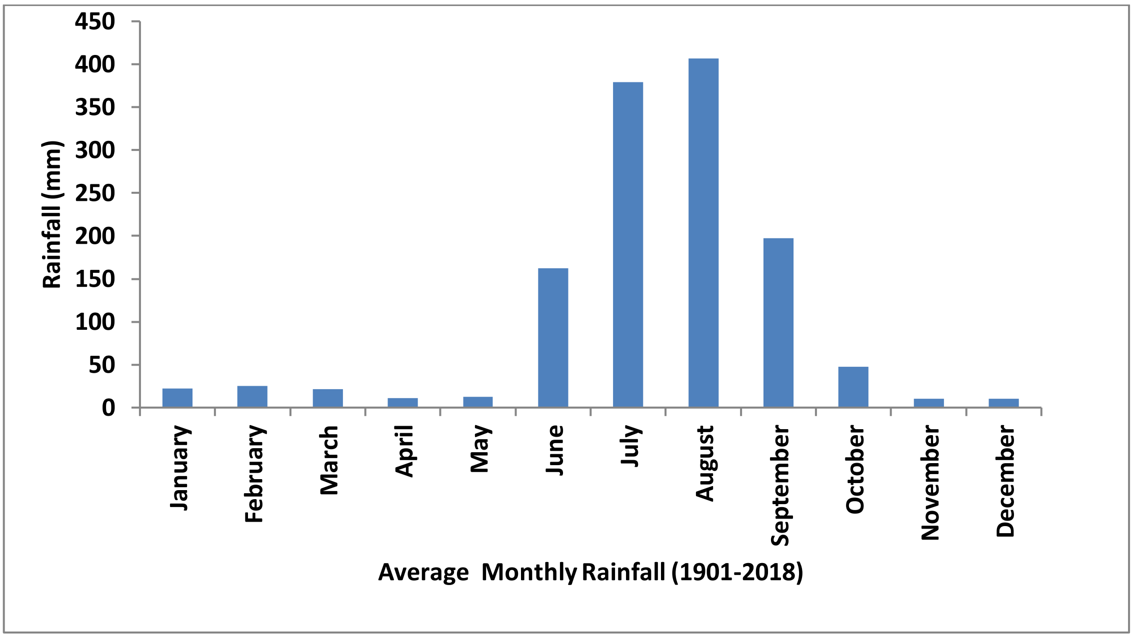

Figure 2: Average monthly rainfall of the study area (1901-2018)

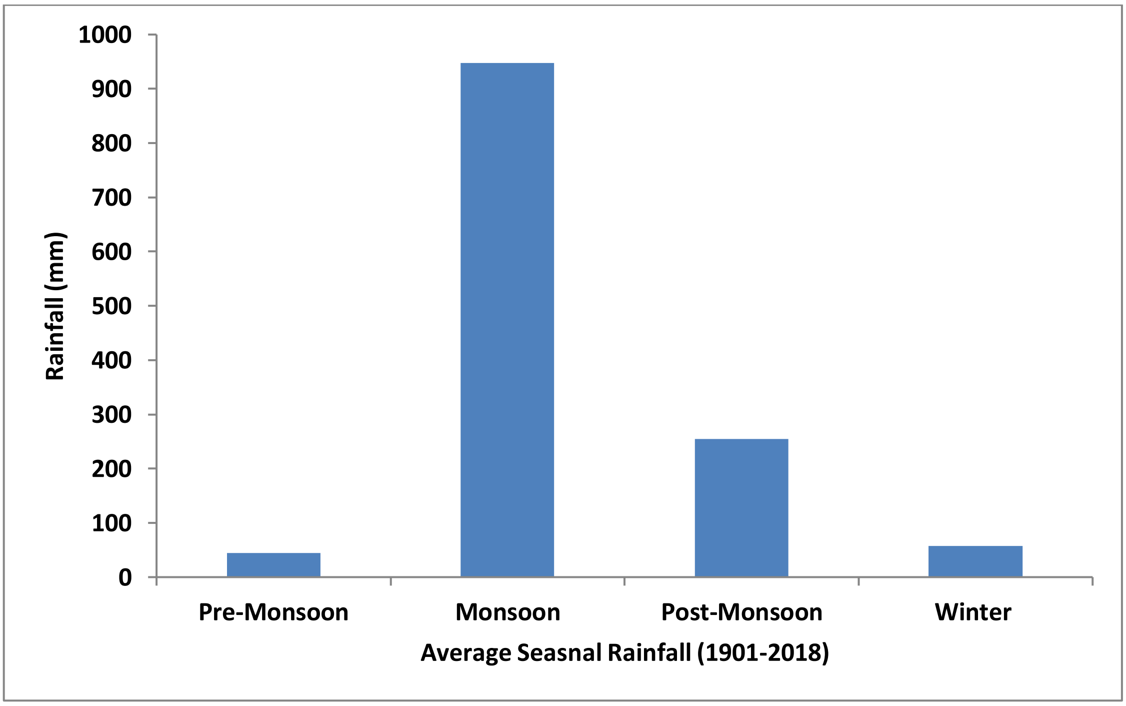

Figure 3: Average Seasonal rainfall of the study area (1901-2018)

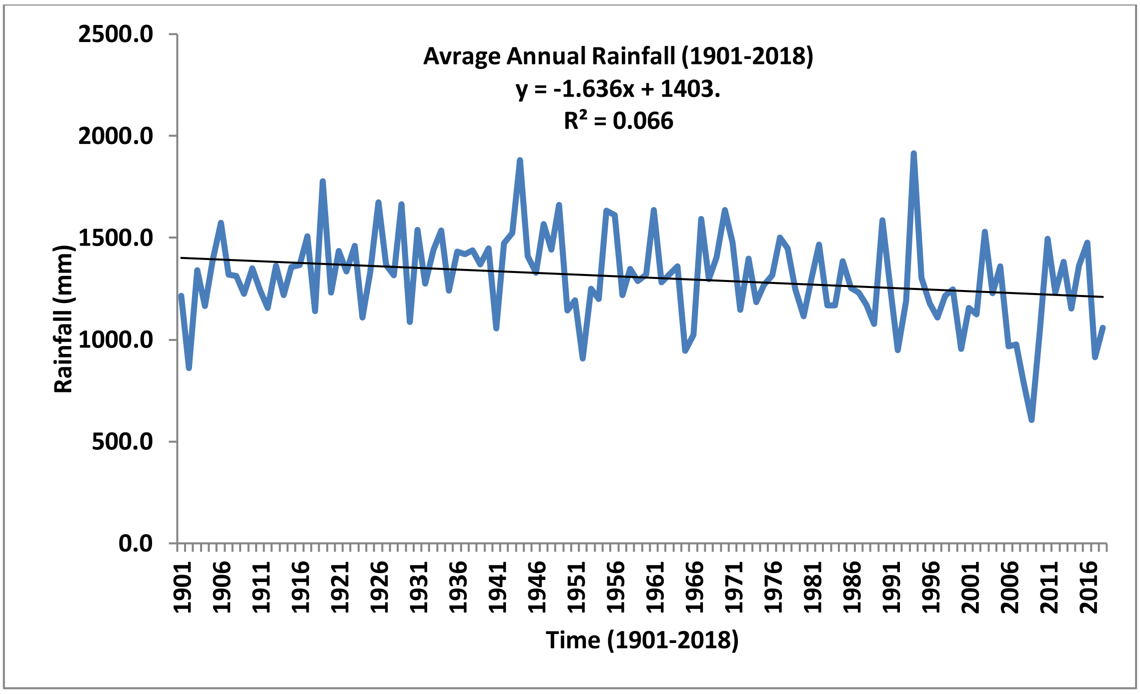

Figure 4: Average annual rainfall of the study area (1901-2018)

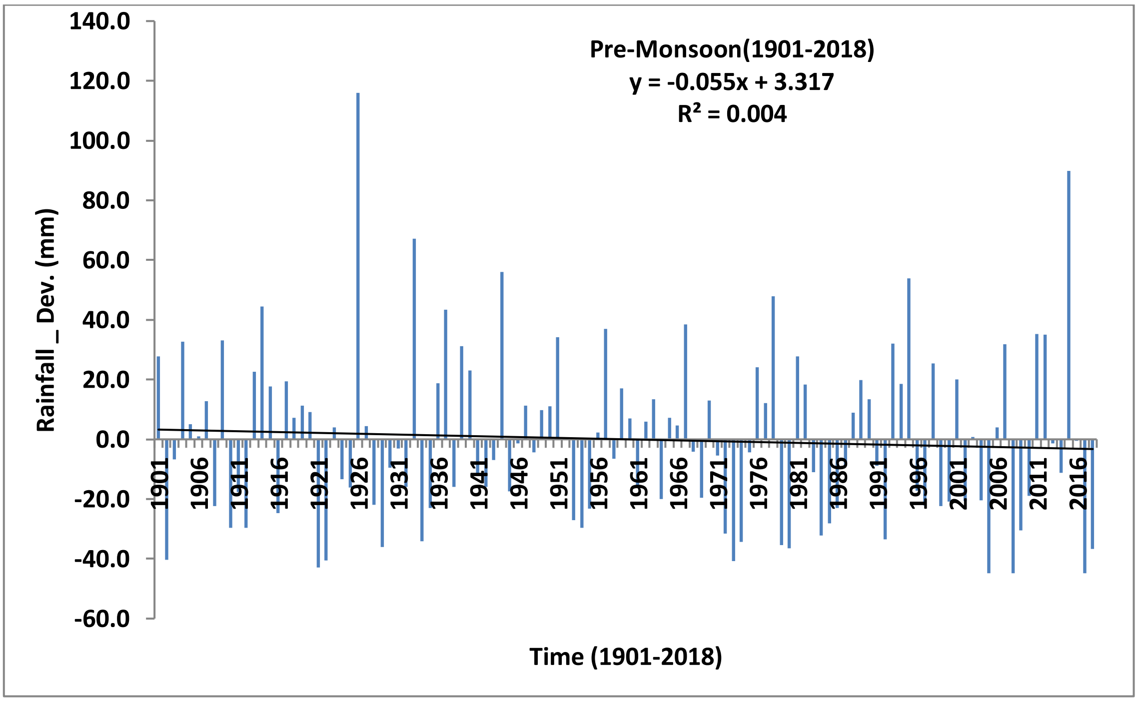

Figure 5: The trends of pre monsoon rainfall of the study area (1901-2018)

Trend analysis in the various study shows that there are generally non-parametric (Hollander and Wolfe, 1973) methods were used, M-K test (Mann, 1945 Kendall, 1975) is one of the best methods among them, which is preferred by the various researcher (Jain and Kumar, 2012).

The Mann-Kendal (MK) test has been employed by several researchers (Yu et al., 1993, Singh et al., 2008a, b). The MK method is used for a trend in a time series without specifying whether the trend is linear or non-linear. The MK test was also applied in the present study. The MK test result is fined by using Programme 'AUTO_MK_Sen.exe'. This program was developed for calculating Sen's Slope, Mann-Kendall Test by Dr. Vijay Kumar, Scientist, NIH, Roorkee. The Mann-Kendall (MK) test has been used for the identification of the statistical significance of the trend at a confidence interval of 95%.

The Sen's slope estimator was then applied to estimate the magnitude of the trend over the study period. The Sen's slope was applied to verify the outcome of the simple regression analysis. Analysis of monthly, seasonal and annual rainfall trends using Mann-Kendal test and Sen's slope estimator are shows (Table 2).

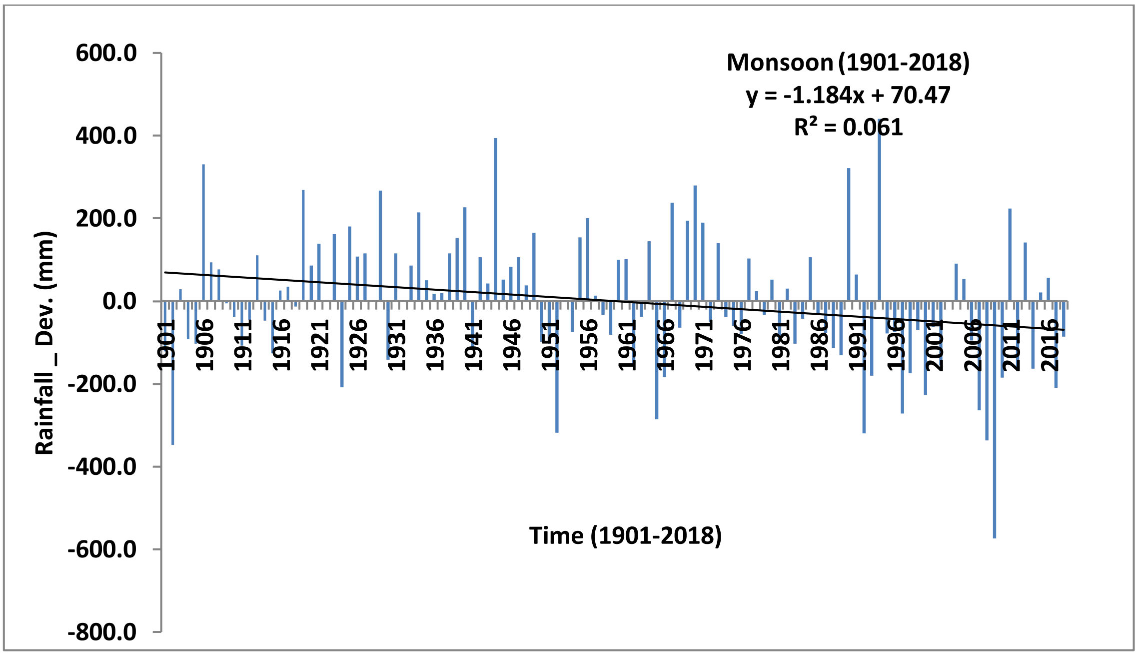

Figure 6: The trends of monsoon season rainfall of the study area (1901-2018)

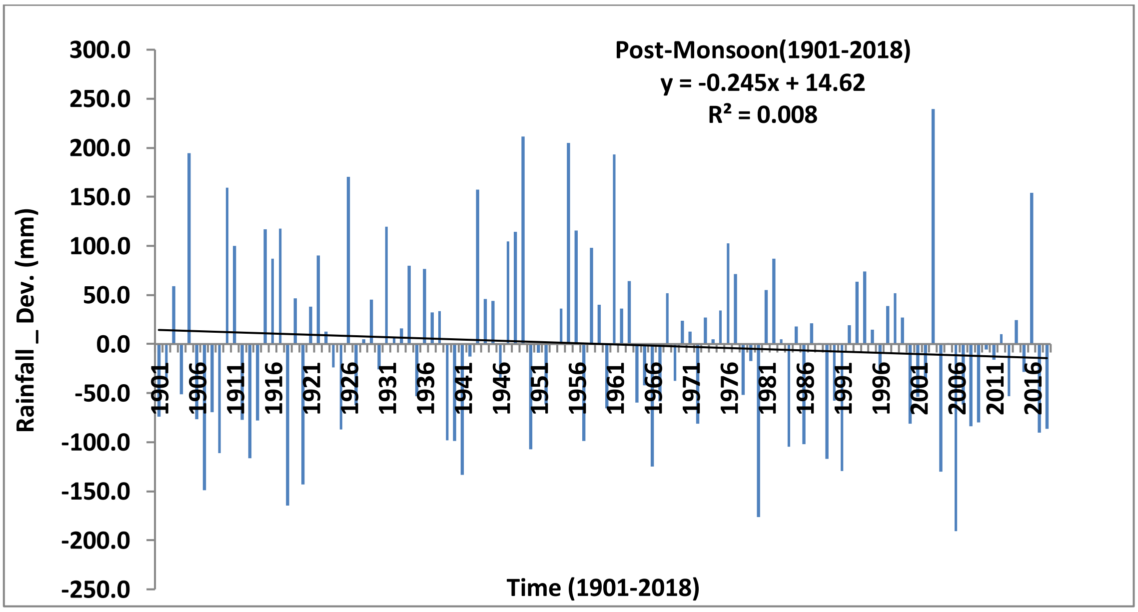

Figure 7: The trends of post monsoon rainfall of the study area (1901-2018)

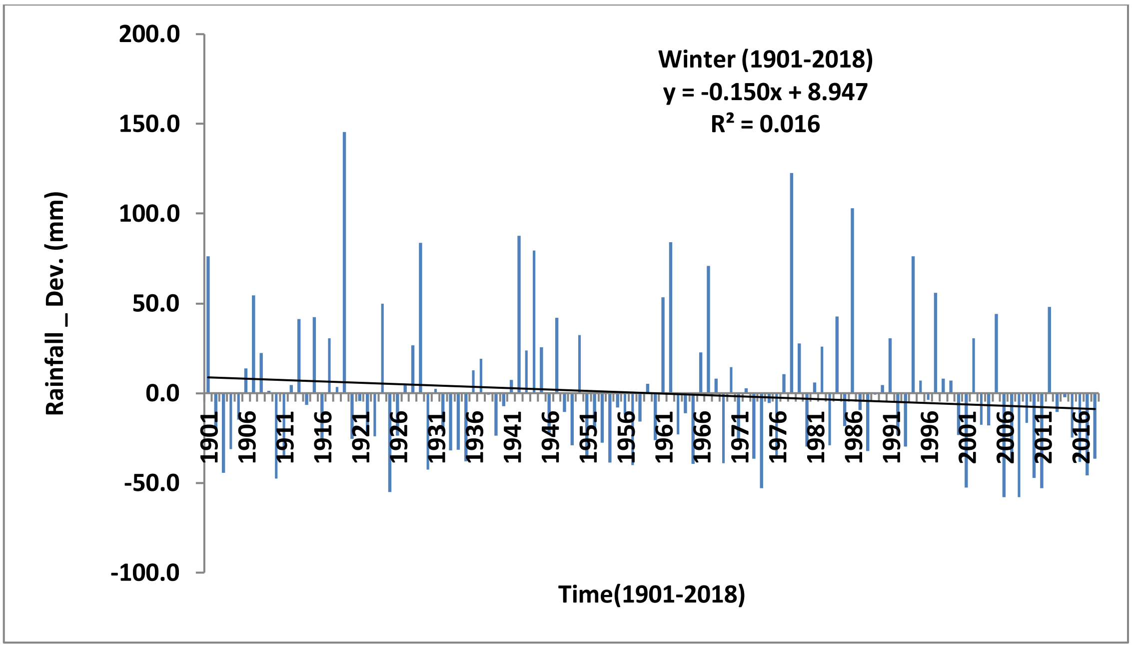

Figure 8: The trends of winter season rainfall of the study area (1901-2018)

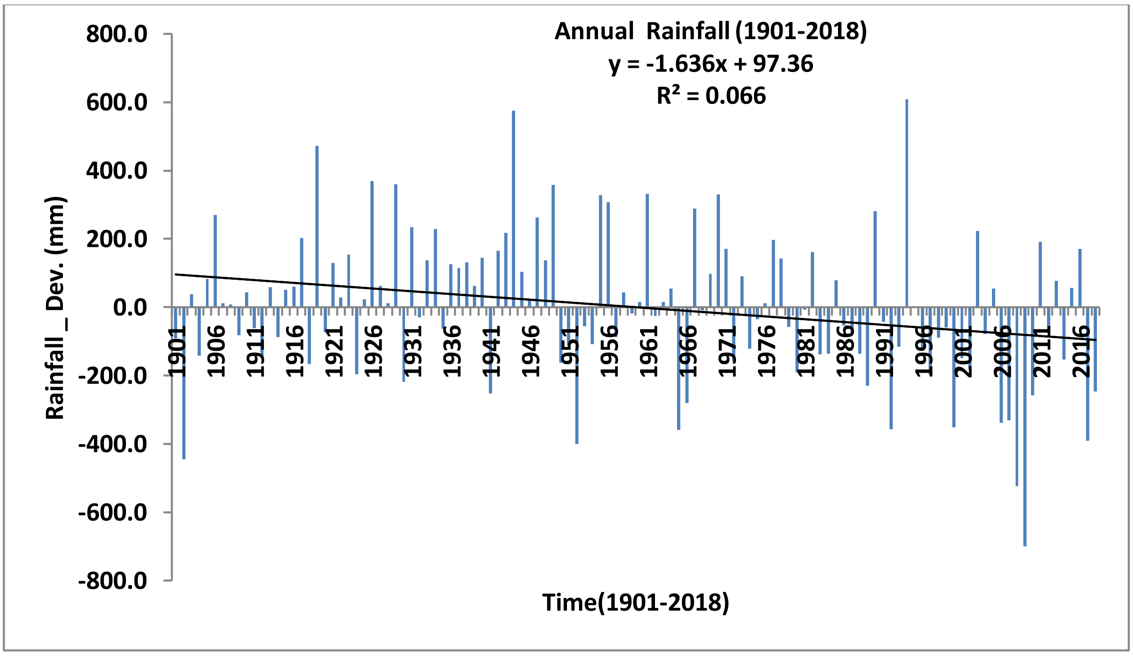

Figure 9: The trends of annual rainfall of the study area (1901-2018)

The Months (April, May, June, July, and August), Seasonal (Pre-monsoon and Monsoon), and Annual rainfall trends are found a statistically significant increasing trend (at 5% significance level) and also remains are found in decreasing trends of the study area. Besides the above trends, the regression analysis shows an increasing trend as well as decreasing trend of rainfall in the Monthly, Seasonal and Annual during the different periods, but such trend is not statistically significant.

Table 1: Statistical information of monthly/seasonal rainfall data of study area (1901 to 2018)

Month/Seasons	Max.	Min.	Mean	Median	SD	CD	CV (%)	Skew.	Kurt.
January	114.3	0	22.1	15.8	23.1	1.045	104.525	1.4	2.2
February	108.3	0	25.2	18.4	24.7	0.980	98.016	1.3	1.6
March	100.8	0	21.2	14.2	22.4	1.057	105.660	1.3	1.7
April	58.1	0	10.7	6.7	11.8	1.103	110.280	1.9	3.5
May	79.8	0	12.8	8.9	13.7	1.070	107.031	1.8	4.5
June	460.8	24.6	162	142.4	83.2	0.514	51.358	0.9	0.9
July	674.8	108.7	379.4	374.1	108.8	0.287	28.677	0.3	0.2
August	556.6	156.8	406.5	405.2	100.7	0.248	24.772	0.1	-0.1
September	482.2	51.9	197.3	190.9	76.9	0.390	38.976	0.8	1.2
October	186	0	47.8	35.7	42.5	0.889	88.912	0.9	0.1
November	66.1	0	10	1.7	15	1.500	150.000	1.7	2.1
December	126.6	0	10.6	2.2	19.5	1.840	183.962	3.2	12.7
Pre- Monsoon	160.8	0	44.8	42.5	28.7	0.641	64.063	0.9	1.7
Monsoon	1388.7	374.5	947.9	949.3	163.6	0.173	17.259	-0.2	0.8
Post Monsoon	494.6	64.5	255.1	258.1	90.4	0.354	35.437	0.3	-0.2
Winter	203.4	0	57.9	49.1	40.2	0.694	69.430	1.1	1.2
Annual	1915	605.3	1305.7	1315	216.8	0.166	16.604	-0.1	0.8

Table 2: Mann-Kendal test and Sen's slope estimator for monthly, seasonal, and annual rainfall of the study area

Month/Seasons	S	VAR(S)	Z	Trend at 95% level	Sen's Slope
January	-96	184680.70	-0.22	No trend	-0.002
February	-143	184551.70	-0.33	No trend	-0.005
March	-344	184443.30	-0.80	No trend	-0.010
April	210	184417.30	0.49	No trend	0.005
May	142	184331.30	0.33	No trend	0.001
June	1265	180205.00	2.98	Positive trend	0.989
July	120	180206.00	0.28	No trend	0.089
August	69	184847.00	0.16	No trend	0.046
September	-1360	180206.00	-3.20	Negative trend	-1.217
October	-996	180206.00	-2.34	Negative trend	-0.635
November	-598	179937.30	-1.41	No trend	-0.038
December	-304	182251.30	-0.71	No trend	0.000
Pri- Monsoon	1254	180189.30	2.95	Positive trend	0.269
Monsoon	752	180206.00	1.77	No trend	0.733
Post Monsoon	-504	180206.00	-1.18	No trend	-2.191
Winter	-1310	180206.00	-3.08	Negative trend	-0.740
Annual	626	180206.00	1.47	No trend	1.167

CONCLUSION

The statistical parameters as average annual rainfall (1305.7mm), median (1315), stander deviation (216.8) coefficient of dispersion (0.166), and coefficient of variation (16.604), Skewness (-0.1), and Kurtosis (0.8) of the district is found. The year 1958 is the most likely change point year in the time series for the study are due to the beginning of the current warming period. It observed that the rainfall trend is having decreasing trend beyond this year. The present study is based on the analysis of the trend in rainfall data using parametric (linear regression) and nonparametric (Mann-Kendal and Sen's slope estimator tests) methods on monthly, seasonal, and annual scale for the Dindori district, Madhya Pradesh, It demonstrates statistically significant changes in rainfall of the study area during the last 118years.The analysis shows a significantly increasing trend in Months

(April, May, June, July, August), Seasonal (Pre-monsoon and Monsoon), and Annual rainfall trend has been observed in the area. The analysis shows these years' rainfall data above the average line which years were favourable for groundwater recharge of the area and these years rainfall data found below the line of average were not favorable for groundwater recharge of the area and indicate for climate change impact of rainfall of the area.This study is an encouragement to explore the impact of climate change on the local scale, the govt. authorities and policy. Also this type of study is required to understand the rainfall regime of the area and its impacts on climate change.

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