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Statistical Model for annual Trends and Magnitude of Climatic variability Across Locations from the Vindhya Plateau Agroclimatic Zone of Madhya Pradesh

Ranjeet[1*], S.K. Sharma[2], Sushma Jain[3] and H.L. Khapediya[4]
[1]Research Scholar, Barkatullah University, Bhopal (Madhya Pradesh), India.
[2]Director Research Services, RVSKVV, Gwalior (Madhya Pradesh), India.
[3]Head & Associate professor, Department of Statistics,
Govt. Motila Vigyan Mahavidyalay, Bhopal (Madhya Pradesh), India.
[4]Nodal officer GKMS & FASAL- Project, RVSKVV,
College of Agriculture, Indore (Madhya Pradesh), India.

(Corresponding author: Ranjeet)*
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ABSTRACT: Climate change has disrupted the major climatic parameters at a global level. However, the changes having localized intensity area not equal for all especially in India. These changes must be quantified locally to manage the natural water resources more effectively. Precipitation is one of the most important climatic parameters. It has been widely measured as a starting point towards the apprehension of global climate change. The purpose of this study is to observe the temporal variability of rainfall for the period of 1991-2020 (30 year), to improve the Agriculture status of different districts of Vindhya Pleatue Agroclimatic zone (District – Bhopal, Damoha, Sagar, Sehore and Vidisha). The aim of the study is to determine the trend in annual precipitation time series using the Mann-Kendall and Sen's T test. The magnitudes of trend in precipitation have been estimated by Sen's estimator method. Auto correlation effects were reduced before applying the Mann-Kendall test for the trend in precipitation. On the annual basis, analysis of Mann-Kendall test shows decreasing and non-significance trend in rainfall times series of all the districts except Bhopal Bhopal, Damoha, Sagar, Sehore and Vidisha which showed significant changes.

Keywords: Mann Kendall & Sen slope estimator, Trend Analysis, Climatic variability, Rainfall analysis.

INTRODUCTION

The state of Madhya Pradesh occupies a total geographical area of 44.348 m ha out of which 55.9 % (24.804 m ha) is under major Kharif and Rabi crops. The state is predominantly rain fed farming state, as only 29.5% of the net cultivated area (6.07 m ha) is irrigated. The state of Madhya Pradesh is blessed with varied agro-climatic conditions which permits the farmers' of the state to cultivate a number of crops like cereals, pulses, oilseeds, commercial crops and horticulture crops across different seasons of the year.

Trend analysis in the Sabarmati basin showed statistically significant decreasing trends for annual, winter, pre-monsoon, and monsoon rainfall (Kale *et al.*, 2022). The trend analyses were done by a) using the Mann-Kendall test for trend significance (Kale, 2020) using Sen's slope estimator for trend magnitude estimation (Sen, 1968) using innovative trend analysis for aiding the results of trend analyses (Kale, 2020) using the Sequential Mann-Kendall test for start and end of trend detection (Kale, 2018) and e) also using linear regression method to identify the trend in rainfall data (Kaur and Kaur 2019). A rainy day receiving more than 2.5 mm of rainfall in a day is used for calculation.

Gajbhiye *et al*. (2016) have analyzed rainfall trends and variability over the basin of the Sindh River located in Madhya Pradesh, India. The daily rainfall data were collected from 'www.indiawaterportal.org/met_data/' to inspect the temporal and spatial variability in the series of precipitation. SS estimator was used for determining the trend magnitude, whereas the statistical significance was analyzed by using the MK test. Primary statistical characteristics of the seasonal (June to September) and annual rainfall events that occurred over one hundred and two years (1901-2002) were analyzed and significant rising trends in both seasonal and annual rainfall were detected.

Pandey and Khare (2017) have assessed the trends in evapotranspiration and precipitation over the Narmada RB (NRB), which is one of the most holy and crucial rivers of Central India. Monthly precipitation and reference evapotranspiration data corresponding to the period of 1901-2002 were analyzed in the study. Various tests were carried out over the data obtained from twelve precipitation stations and twenty-eight reference evapotranspiration stations of the NRB. Trend analysis in the annual precipitation series was executed by employing the MK test and SR test at 5% and 10% significance levels respectively. The results of the study have clearly shown less change in average precipitation values at higher elevated regions, i.e., Upper Narmada whereas significant alterations were observed in the regions, which were situated in the lower portion of the Narmada. The lower part of the basin had shown positive trends with corresponding magnitudes varying between 0.060-0.033 mm/year for the annual precipitation while the upper portion exhibited a negative trend in annual precipitation with corresponding magnitudes varying between 0.10-0.025 mm/year.

Sharma *et al.* (2017) have assessed trends in rainfall of the upper Tapi basin originating from the Betul District, Madhya Pradesh, India. Data from twenty-four rain gauge stations was acquired from the Central Water Commission (CWC), Surat, and India Meteorological Department (IMD), Pune to perform trend analysis. A total of five temperature indicators and twelve rainfall indicators were used in the trend study. They used MK or MMK test on non-serially correlated or serially correlated TS to detect the trends along with the SS estimator test and then represented the percentage difference in trends of the extreme climatic indicators and the spatial variability of trends over the Upper Tapi basin in extreme conditions of climate over the basin. The results show that 17 out of 24 stations exhibited a retarding trend in total yearly rainfall of 70 years duration. The yield of crops, particularly in rainfed areas, depends on the rainfall pattern, which makes it important to predict the probability of the occurrence of rainfall from the records of data using statistical analysis (Arvind *et al.,* 2017).

Goswami *et al.*, (2006) Against a backdrop of rising global surface temperature, the stability of the Indian monsoon rainfall over the past century has been a puzzle. By using a daily rainfall data set, we show (i) significant rising trends in the frequency and the magnitude of extreme rain events and (ii) a significant decreasing trend in the frequency of moderate events over central India during the monsoon seasons from 1951 to 2000.

Srivastava *et al.*, (2020) study show Bundelkhand Agroclimatic Zone of Madhya Pradesh has witnessed many extreme weather events in recent decades like excessive hotness, dryness, coldness and number of consecutive drought years. Drought and water scarcity are the major resource limiting factors of this zone.

Chakraborty *et al.,* (2019) The auto-regressive integrated moving average (ARIMA) intervention technique showed negative impact of the March 2010 extreme heat on yield of wheat over north India. The yield decreased by 4.9%, 4.1% and 3.5% over Punjab, Haryana and Uttar Pradesh, respectively, which were statistically significant ($p < 0.1$). Though the total production decreased, it was non-significant due to the slight increase in harvested area

The Vindhya Plateau agroclimatic zone of Madhya Pradesh is a region that lies in the central part of the state, between the Narmada and the Son rivers. It covers six districts: Sehore, Raisen, Bhopal, Vidisha, Sagar and Damoh. The region has a medium to deep black soil that is suitable for growing wheat and horticulture crops. The region receives an average rainfall of 120-140 cm per year, mostly during the south-west monsoon season. The region is more urbanized and has a larger portion of its area under cultivation than the rest of the state. Bhopal district is located in the central part of Madhya Pradesh. The average annual rainfall in this district is around 1,100-1,200 millimeters. The major crops grown in this region include wheat, rice, soybeans, gram, and lentils. Bhopal district has predominantly black soil, which is suitable for agriculture. Sagar district is in the northeastern part of Madhya Pradesh. It receives an average annual rainfall of around 1,100-1,300 millimeters. The main crops cultivated in this region are wheat, rice, soybeans, gram, and oilseeds like mustard. The soil type in Sagar district varies from black soil to alluvial soil, providing suitable conditions for agriculture. Damoh district is situated in the north-central part of Madhya Pradesh. The average annual rainfall in this district is approximately 1,100-1,300 millimeters. The primary crops grown in this region include wheat, rice, soybeans, gram, and oilseeds. The soil type found in Damoh district consists of a mixture of black soil and alluvial soil. Vidisha district is located in the central part of Madhya Pradesh. The average annual rainfall in this district ranges from 900 to 1,100 millimeters. The major crops cultivated in this region include wheat, rice, soybeans, gram, and lentils. Vidisha district has predominantly black soil, which is suitable for agriculture. Raisen District (except Bareli Tehsil) is situated in the central part of Madhya Pradesh. The average annual rainfall in this district is around 900-1,100 millimeters. The primary crops grown in this region include wheat, rice, soybeans, gram, and oilseeds like mustard. The soil type found in Raisen district varies from black soil to alluvial soil, providing suitable conditions for agriculture. Sehore district is located in the western part of Madhya Pradesh. It receives an average annual rainfall of approximately 900-1,100 millimeters. The major crops cultivated in this region include wheat, rice, soybeans, gram, and oilseeds. Sehore district has predominantly black soil, which is favorable for agriculture.

In this paper, an attempt has been made to analyze the rainfall variability, and trend analyses were done by using different methods to identify the trend in rainfall data on a seasonal and annual basis to suggest crop planning in this region. The study was carried out with the following objectives: (1) To assess the climate change trend in Madhya Pradesh (2) To define climatology as rainfall variability in different districts.

Study Area:

Table 1: Different district of Vindhya Plateau agroclimatic zone.

S. No.	City	Latitude	Longitude	Agro-Meteorology Data
1,	Bhopal	77.4° E	23.48° N	Grid Data
2,	Damoh	78.7861° E	26.5638° N	Grid Data
3,	Sagar	78.4609° E	25.6653° N	Grid Data
4,	Sheore	77.3002° E	24.6324° N	Grid Data
5,	Vidisha	78.1772° E	26.2124° N	Grid Data

MATERIAL AND METHODS

Trend Analysis: As a first step of analysis, basic statistical parameters like mean, standard deviation (SD), skewness, kurtosis and coefficient of variation were estimated from the data for each station. Initially the Autocorrelation test was applied to check serial dependence in the dataset. Strong autocorrelations affect the significant assessment of trend estimates by inflating the distribution of the test statistics. These much larger critical values need to be employed as significance threshold than in case of uncorrelated data. The check general patterns in Grid data (Pai *et al*., 2014) over the period of 1991 to 2020 for monthly, annual and seasonal series.

Autocorrelation. Lag-1 autocorrelation (Anderson, 1941) is used to check serial dependence between the data. The lag-1 autocorrelation coefficient is the simple correlation coefficient of the first observation N-1, Xt, t=1,2,3,…… N-1 and the next observation Xt and Xt+1 is given by

$$r_1 = \frac{\sum_{t=1}^{N-1}(X_t - X)(X_{t+1} - \bar{X})}{\sum_{t=1}^{N-1}(X_t - \bar{X})^2}$$

Where $W = \sum_{t=1}^{N-1}(X_t)$ is the overall mean.

The lag-1 autocorrelation coefficient r1 is tested for its significance. The probability limits on the correlogram of an independent series of the two tailed test is given below

$$r_1(95\%) = \frac{-1 \pm 1.96\sqrt{N-k-1}}{N-k}$$

Where N is the sample size and k is the lag.

The value of r1 lie outside the confidence interval given above, the data area assumes to be serially correlated otherwise the sample data are considered to be serially independent.

Mann-Kendal Test. The Mann-Kendall trend test for assessing the trend present in the data. Initially, this test was used by Mann (1945) and Kendall (1975) subsequently derived the test statistics distribution. This hypothesis test is a nonparametric, rank-based method for evaluating the presence of trends in time series data. The data are ranked according to time and then each data point is successively treated as a reference data point and is compared to all data points that follow in time. Compared with parametric statistical tests, nonparametric test are thought to be move suitable for non-normally distributed data. Since the time series data used in the study is mostly non normally distributed as evident from the skewness and kurtosis values given in Table no.1 the nonparametric test were used in the study (Das and Bhattacharya, 2018). (Das *et al*., 2020)

The Mann-Kendall test statistics is given by

$$S = \sum_{i=1}^{n-1}\sum_{j=i+1}^{n} sgn(x_j - x_i)$$

Where x_i and x_j are the sequential data values, n is the data set record length, and

$$sgn(\theta) = \begin{cases} +1, & if\theta > 0 \\ 0 & if\theta = 1 \\ -1, & if\theta < 0 \end{cases}$$

The Mann-Kendall test has two parameters that are of importance to the trend detection. These parameters are the significance level that indicated the trend's strength and the slope magnitude estimate which indicates the direction as well as the magnitude of the trend.

For independent, identically distributed random variables with no tied data values, we have E(S)= O;

$$Var(S) = \frac{n(n-1)(2n+5)}{18}$$

When some data values are tied, the correction to Var(S) is

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

Where t_i denotes the number of ties of extent i. For n larger than 10, the test statistic.

$$Z_s = \begin{cases} \frac{S-1}{[Var(S)]^{0.5}}, & ifS > 0 \\ 0 & ifS = 0 \\ \frac{S+1}{[Var(S)]^{0.5}}, & ifS < 0 \end{cases}$$

Z_s follows the standard normal distribution.

SEN'S Slope Estimator. The magnitude of trend slopes can be also calculated (Sen, 1968). Sen's estimate for slope is associated with the Mann-Kendall test as follows:

$$\beta = \text{Median}\left(\frac{x_j - x_i}{j - i}\right)$$

Where x_j and x_i are considered data value at time j and I (j>i), correspondingly. The median of these N values of βi is represented as Sen's estimator of slope which is given as

$$Q_i = \begin{cases} \beta_{(N+1)/2} \text{when N isodd} \\ \frac{1}{2}\left(\beta_{N/2} + \beta_{(N+2)/2}\right) \text{when N is even} \end{cases}$$

A positive value of Q indicates an upward trend, whereas a negative value represents a downward trend.

RESULTS

1. District: Bhopal: Table 1 result show the Statistical tools and the Mann Kendall test describe following result show below

Month-wise Statistics: January: The minimum recorded value for January is 0.00, while the maximum is 103.60. The mean value for January is 11.58, indicating the average rainfall for that month. The percentage contribution of January to the total rainfall is 1.04%. The standard deviation (SD) of 21.64 suggests a moderate amount of variability in the rainfall data. The coefficient of variation (CV) is 186.78, indicating a high degree of relative variability. The positive skewness (3.11) implies that the data is right-skewed, with a longer tail on the right side. The kurtosis value of 11.18 suggests a leptokurtic distribution, indicating heavy tails and more extreme values. The autocorrelation (Lag-1) of -0.062 indicates a weak negative correlation between consecutive months.

February: The statistical results for February show similar patterns as January, but with lower values across the board. The minimum recorded rainfall is 0.00, while the maximum is 37.50. The mean rainfall for February is 8.04, representing the average rainfall for that month. The percentage contribution of February to the total rainfall is 0.72%. The standard deviation is 11.57, indicating a relatively lower amount of variability compared to January. The coefficient of variation is 143.92, suggesting a moderate level of relative variability. The skewness value of 1.53 indicates a moderate right-skewness, implying a slightly longer tail on the right side. The kurtosis value of 1.27 suggests a near-normal distribution. The autocorrelation (Lag-1) of 0.270 indicates a positive correlation between consecutive months.

March: The statistical results for March show further reductions in rainfall compared to February. The minimum recorded rainfall is 0.00, and the maximum is 36.90. The mean rainfall for March is 4.57, reflecting the average rainfall for that month. The percentage contribution of March to the total rainfall is 0.41%. The standard deviation is 8.10, indicating relatively low variability in the data. The coefficient of variation is 177.31, suggesting a high degree of relative variability. The negative skewness (-0.070) indicates a slight left-skewness, suggesting a slightly longer tail on the left side. The kurtosis value of -0.54 suggests a platykurtic distribution, indicating lighter tails and fewer extreme values. The autocorrelation (Lag-1) of -0.070 suggests a weak negative correlation between consecutive months.

April: The minimum recorded rainfall in April is 0.00, while the maximum is 16.90. The mean rainfall for April is 2.03, representing the average rainfall for that month. The percentage contribution of April to the total rainfall is 0.18%. The standard deviation is 3.42, indicating relatively low variability in the data. The coefficient of variation is 168.21, suggesting a high level of relative variability. The skewness value of 3.11 indicates a significantly right-skewed distribution. The kurtosis value of 12.10 indicates a leptokurtic distribution (heavy-tailed). The autocorrelation (Lag-1) of 0.112 suggests a weak positive correlation between consecutive months.

May: In May, the minimum recorded rainfall is 0.00, while the maximum is 44.30. The mean rainfall for May is 6.89, indicating the average rainfall for that month. The percentage contribution of May to the total rainfall is 0.62%. The standard deviation is 8.59, indicating relatively moderate variability in the data. The coefficient of variation is 124.58, suggesting a high level of relative variability. The skewness value of 3.02 suggests a significantly right-skewed distribution. The kurtosis value of 12.24 indicates a leptokurtic distribution (heavy-tailed). The autocorrelation (Lag-1) of -0.023 suggests a weak negative correlation between consecutive months.

June: The minimum recorded rainfall in June is 37.40, while the maximum is 272.00. The mean rainfall for June is 125.89, indicating the average rainfall for that month. The percentage contribution of June to the total rainfall is 11.30%. The standard deviation is 66.71, suggesting relatively high variability in the data. The coefficient of variation is 52.99, indicating a moderate level of relative variability. The skewness value of 0.70 suggests a slightly right-skewed distribution. The kurtosis value of -0.45 indicates a near-normal distribution. The autocorrelation (Lag-1) of 0.140 suggests a weak positive correlation between consecutive months.

July: In July, the minimum recorded rainfall is 121.00, while the maximum is 746.20. The mean rainfall for July is 336.94, representing the average rainfall for that month. The percentage contribution of July to the total rainfall is 30.26%. The standard deviation is 149.96, indicating relatively high variability in the data. The coefficient of variation is 44.51, suggesting a moderate level of relative variability. The skewness value of 1.11 suggests right-skewness, indicating a longer tail on the right side. The kurtosis value of 1.45 suggests a near-normal distribution. The autocorrelation (Lag-1) of -0.156 suggests a weak negative correlation between consecutive months.

August: For August, the minimum recorded rainfall is 131.30, while the maximum is 663.30. The mean rainfall for August is 415.47, representing the average rainfall for that month. The percentage contribution of August to the total rainfall is 37.31%. The standard deviation is 138.28, indicating moderate variability in the data. The coefficient of variation is 33.28, suggesting a moderate level of relative variability. The skewness value of -0.30 suggests a slightly left-skewed distribution. The kurtosis value of -0.73 indicates a near-normal distribution. The autocorrelation (Lag-1) of 0.048 suggests a weak positive correlation between consecutive months.

September: In September, the minimum recorded rainfall is 20.20, while the maximum is 377.10. The mean rainfall for September is 153.48, indicating the average rainfall for that month. The percentage contribution of September to the total rainfall is 13.78%. The standard deviation is 98.78, indicating moderate variability in the data. The coefficient of variation is 64.36, suggesting a moderate level of relative variability. The skewness value of 0.58 suggests a slightly right-skewed distribution. The kurtosis value of -0.59 indicates a near-normal distribution. The autocorrelation (Lag-1) of -0.252 suggests a moderate negative correlation between consecutive months.

October: For October, the minimum recorded rainfall is 0.00, while the maximum is 159.50. The mean rainfall for October is 22.08, representing the average rainfall for that month. The percentage contribution of October to the total rainfall is 1.98%. The standard deviation is 32.56, indicating moderate variability in the data. The coefficient of variation is 147.48, suggesting a high level of relative variability. The skewness value of 2.83 suggests a significantly right-skewed distribution. The kurtosis value of 10.41 indicates a leptokurtic distribution (heavy-tailed). The autocorrelation (Lag-1) of -0.095 suggests a weak negative correlation between consecutive months.

November: In November, the minimum recorded rainfall is 0.00, while the maximum is 147.10. The mean rainfall for November is 14.70, indicating the average rainfall for that month. The percentage contribution of November to the total rainfall is 1.32%. The standard deviation is 31.40, indicating moderate variability in the data. The coefficient of variation is 213.62, suggesting a high level of relative variability. The skewness value of 3.10 suggests a significantly right-skewed distribution. The kurtosis value of 10.88 indicates a leptokurtic distribution (heavy-tailed). The autocorrelation (Lag-1) of -0.137 suggests a weak negative correlation between consecutive months.

December: For December, the minimum recorded rainfall is 0.00, while the maximum is 120.00. The mean rainfall for December is 11.94, representing the average rainfall for that month. The percentage contribution of December to the total rainfall is 1.07%. The standard deviation is 23.59, indicating moderate variability in the data. The coefficient of variation is 197.65, suggesting a high level of relative variability. The skewness value of 3.62 suggests a significantly right-skewed distribution. The kurtosis value of 15.55 indicates a leptokurtic distribution (heavy-tailed). The autocorrelation (Lag-1) of -0.110 suggests a weak negative correlation between consecutive months.

Seasonal-wise Statistics:

Winter (Jan-Feb): The winter season, composed of January and February, shows a similar pattern to the individual months. The minimum recorded rainfall is 0.00, while the maximum is 110.00. The mean rainfall for the winter season is 19.62, representing the average rainfall for that period. The percentage contribution of the winter season to the total rainfall is 1.76%. The standard deviation is 27.32, indicating moderate variability in the data. The coefficient of variation is 139.25, suggesting a moderate level of relative variability. The skewness value of 1.86 indicates moderate right-skewness, implying a slightly longer tail on the right side. The kurtosis value of 3.20 suggests a leptokurtic distribution, indicating heavy tails and more extreme values. The autocorrelation (Lag-1) of -0.046 suggests a weak negative correlation between consecutive months.

Summer (Mar-May): The summer season, composed of March, April, and May, shows a decrease in rainfall compared to the winter season. The minimum recorded rainfall is 0.00, while the maximum is 47.20. The mean rainfall for the summer season is 13.50, representing the average rainfall for that period. The percentage contribution of the summer season to the total rainfall is 1.21%. The standard deviation is 13.61, indicating relatively low variability in the data. The coefficient of variation is 100.86, suggesting a moderate level of relative variability. The skewness value of 1.36 indicates moderate right-skewness, implying a slightly longer tail on the right side. The kurtosis value of 1.14 suggests a near-normal distribution. The autocorrelation (Lag-1) of -0.048 suggests a weak negative correlation between consecutive months.

South West (Jun-Sep): The South West monsoon season, composed of June, July, August, and September, shows a significant increase in rainfall compared to the previous seasons. The minimum recorded rainfall is 37.40, while the maximum is 1621.50. The mean rainfall for the South West monsoon season is 1031.79, representing the average rainfall for that period. The percentage contribution of the South West monsoon season to the total rainfall is 92.65%. The standard deviation is 234.02, indicating relatively high variability in the data. The coefficient of variation is 22.68, suggesting a moderate level of relative variability. The skewness value of 0.14 indicates nearly symmetrical data distribution. The kurtosis value of 0.68 suggests a near-normal distribution. The autocorrelation (Lag-1) of -0.061 indicates a weak negative correlation between consecutive months.

North East (Oct-Dec): The North East monsoon season, composed of October, November, and December, shows a decrease in rainfall compared to the South West monsoon season. The minimum recorded rainfall is 0.40, while the maximum is 159.50. The mean rainfall for the North East monsoon season is 48.72, representing the average rainfall for that period. The percentage contribution of the North East monsoon season to the total rainfall is 4.37%. The standard deviation is 42.06, indicating moderate variability in the data. The coefficient of variation is 86.33, suggesting a moderate level of relative variability. The skewness value of 1.30 indicates moderate right-skewness, implying a slightly longer tail on the right side. The kurtosis value of 1.47 suggests a near-normal distribution. The autocorrelation (Lag-1) of -0.286 suggests a weak negative correlation between consecutive months.

District Damoh

Month wise result. January: The average rainfall in January is 16.81 mm, with a minimum of 0.00 mm and a maximum of 79.70 mm. The coefficient of variation (CV) is quite high at 125.24, indicating significant variability in January's rainfall. The positive skewness value (1.48) suggests that the distribution is right-skewed, with a longer tail on the right side. The kurtosis value (1.69) indicates a moderately peaked distribution. Autocorrelation at lag-1 is 0.093, suggesting a weak positive correlation with the preceding month's rainfall. The Mann-Kendall test result of 0.29 indicates that there is no significant trend observed in January's rainfall. The Sen's slope estimate is 0.014, indicating a slight positive slope but with a small magnitude.

February: In February, the average rainfall is 15.61 mm, ranging from 0.00 mm to 77.70 mm. The coefficient of variation (CV) is high at 137.48, indicating significant variability in February's rainfall. The positive skewness value (1.86) suggests a right-skewed distribution with a more pronounced tail on the right side compared to January. The kurtosis value (2.92) indicates a moderately high peak in the distribution. Autocorrelation at lag-1 is 0.187, indicating a weak positive correlation with the preceding month's rainfall. The Mann-Kendall test result of 1.34 indicates that there is no significant trend observed in February's rainfall. The Sen's slope estimate is 0.213, suggesting a slight positive slope but with a small magnitude.

March: Min: 0.00 mm, Max: 35.70 mm, Mean: 8.18 mm. The rainfall in March exhibits a right-skewed distribution with a positive skewness of 1.32. The coefficient of variation (CV) is 116.59, indicating a relatively high relative variability. The autocorrelation at lag-1 is -0.194, indicating a weak negative correlation with the preceding month's rainfall. The Mann-Kendall test result of -0.57 suggests no significant trend in March's rainfall. The Sen's slope estimate is -0.044, indicating a slight negative slope but with a small magnitude.

April: Min: 0.00 mm, Max: 15.50 mm, Mean: 3.27 mm. The rainfall in April shows a right-skewed distribution with a positive skewness of 1.50. The coefficient of variation (CV) is 130.52, indicating high relative variability. The autocorrelation at lag-1 is 0.059, suggesting a weak positive correlation with the preceding month's rainfall. The Mann-Kendall test result of -0.99 suggests no significant trend in April's rainfall. The Sen's slope estimate is -0.033, indicating a slight negative slope but with a small magnitude.

May: Min: 0.00 mm, Max: 23.00 mm, Mean: 5.85 mm. The rainfall in May shows a right-skewed distribution with a positive skewness of 1.35. The coefficient of variation (CV) is 111.93, indicating high relative variability. The autocorrelation at lag-1 is -0.125, indicating a weak negative correlation with the preceding month's rainfall. The Mann-Kendall test result of 1.93 suggests a significant increasing trend in May's rainfall. The Sen's slope estimate is 0.177, indicating a positive slope with a moderate magnitude.

June: Min: 25.80 mm, Max: 421.20 mm, Mean: 139.82 mm. The rainfall in June exhibits a right-skewed distribution with a positive skewness of 1.39. The coefficient of variation (CV) is 68.89, indicating relatively low relative variability. The autocorrelation at lag-1 is -0.158, suggesting a weak negative correlation with the preceding month's rainfall. The Mann-Kendall test result of 0.96 suggests no significant trend in June's rainfall. The Sen's slope estimate is 1.732, indicating a significant positive slope.

July: Min: 166.70 mm, Max: 660.30 mm, Mean: 320.29 mm. The rainfall in July shows a right-skewed distribution with a positive skewness of 1.33. The coefficient of variation (CV) is 35.13, indicating relatively low relative variability. The autocorrelation at lag-1 is -0.412, indicating a moderate negative correlation with the preceding month's rainfall. The Mann-Kendall test result of -0.36 suggests no significant trend in July's rainfall. The Sen's slope estimate is -0.892, indicating a significant negative slope.

August: Min: 172.10 mm, Max: 654.90 mm, Mean: 406.46 mm. The rainfall in August exhibits a right-skewed distribution with a positive skewness of 0.25. The coefficient of variation (CV) is 33.24, indicating relatively low relative variability. The autocorrelation at lag-1 is -0.394, indicating a moderate negative correlation with the preceding month's rainfall. The Mann-Kendall test result of 0.89 suggests no significant trend in August's rainfall. The Sen's slope estimate is 2.820, indicating a significant positive slope.

September: Min: 28.10 mm, Max: 422.00 mm, Mean: 170.74 mm. The rainfall in September shows a right-skewed distribution with a positive skewness of 0.70. The coefficient of variation (CV) is 57.74, indicating moderate relative variability. The autocorrelation at lag-1 is -0.282, indicating a weak negative correlation with the preceding month's rainfall. The Mann-Kendall test result of -1.96 suggests a significant decreasing trend in September's rainfall. The Sen's slope estimate is -4.993, indicating a significant negative slope.

October: Min: 0.00 mm, Max: 127.40 mm, Mean: 24.61 mm. The rainfall in October exhibits a right-skewed distribution with a positive skewness of 1.61. The coefficient of variation (CV) is 135.69, indicating high relative variability. The autocorrelation at lag-1 is -0.161, indicating a weak negative correlation with the preceding month's rainfall. The Mann-Kendall test result of 0.86 suggests no significant trend in October's rainfall. The Sen's slope estimate is 0.136, indicating a slight positive slope but with a small magnitude.

November: Min: 0.00 mm, Max: 76.80 mm, Mean: 9.96 mm. The rainfall in November shows a right-skewed distribution with a positive skewness of 2.39. The coefficient of variation (CV) is 188.93, indicating high relative variability. The autocorrelation at lag-1 is -0.161, indicating a weak negative correlation with the preceding month's rainfall. The Mann-Kendall test result of -0.58 suggests no significant trend in November's rainfall. The Sen's slope estimate is 0.000, indicating no significant slope.

December: Min: 0.00 mm, Max: 85.00 mm, Mean: 11.57 mm. The rainfall in December exhibits a right-skewed distribution with a positive skewness of 2.46. The coefficient of variation (CV) is 163.75, indicating high relative variability. The autocorrelation at lag-1 is -0.086, indicating a weak negative correlation with the preceding month's rainfall. The Mann-Kendall test result of 0.74 suggests no significant trend in December's rainfall. The Sen's slope estimate is 0.013, indicating a slight positive slope but with a small magnitude.

Seasonal Analysis: Winter (January-February): Min: 0.00 mm, Max: 107.00 mm, Mean: 32.42 mm. The winter season exhibits variability in rainfall, with a coefficient of variation (CV) of 106.10. The Mann-Kendall test result of 0.15 suggests no significant trend in winter rainfall. The Sen's slope estimate is 0.016, indicating a slight positive slope but with a small magnitude.

Summer (March-June): Min: 0.00 mm, Max: 421.20 mm, Mean: 84.21 mm. The summer season shows significant variability in rainfall, with a coefficient of variation (CV) of 103.25. The Mann-Kendall test result of 0.10 suggests no significant trend in summer rainfall. The Sen's slope estimate is 0.351, indicating a slight positive slope but with a small magnitude.

Rainy Season (July-September): Min: 166.70 mm, Max: 660.30 mm, Mean: 282.43 mm. The rainy season exhibits variability in rainfall, with a coefficient of variation (CV) of 44.34. The Mann-Kendall test result of -0.07 suggests no significant trend in rainy season rainfall. The Sen's slope estimate is -0.357, indicating a slight negative slope but with a small magnitude.

Autumn (October-December): Min: 0.00 mm, Max: 85.00 mm, Mean: 15.38 mm. The autumn season shows significant variability in rainfall, with a coefficient of variation (CV) of 179.24. The Mann-Kendall test result of 0.30 suggests no significant trend in autumn rainfall. The Sen's slope estimate is 0.043, indicating a slight positive slope but with a small magnitude.

District : Sagar

Month wise analysis. Range of Rainfall: The minimum and maximum values for each time period indicate the range of rainfall observed. For example, in June, the minimum rainfall recorded was 9.80 mm, while the maximum was 614.70 mm.

Seasonal Patterns: The mean values provide an insight into the average rainfall for each time period. The highest mean rainfall is observed during the summer season (March-May), with an average of 42.82 mm. The winter season (January-February) has the lowest mean rainfall at 28.53 mm.

Contribution to Annual Rainfall: The percentage column indicates the contribution of each time period's rainfall to the total annual rainfall. For instance, the summer season contributes approximately 3.62% of the annual rainfall, while the South West season (June-September) contributes the most at 90.46%.

Variability: The standard deviation (SD) measures the variability or dispersion of the data points around the mean. Higher SD values indicate greater variability. The South West season has the highest SD of 317.49, suggesting significant variability in rainfall during that period.

Stability and Skewness: The coefficient of variation (CV) measures the stability of the data by expressing the standard deviation as a percentage of the mean. Higher CV values suggest greater instability. The South West season has the highest CV of 29.67%, indicating relatively unstable rainfall patterns. The skewness values measure the asymmetry of the data distribution. Positive skewness suggests a longer right tail, while negative skewness indicates a longer left tail.

Autocorrelation: The autocorrelation lag-1 represents the correlation between consecutive data points in the time series. Values close to 1 indicate strong positive correlation, values close to -1 indicate strong negative correlation, and values close to 0 indicate little to no correlation. The lag-1 autocorrelation ranges from -0.327 (South West season) to 0.255 (November).

Trend Analysis: The Mann-Kendall test and Sen's slope estimate are commonly used to identify trends in time series data. The Mann-Kendall test calculates a test statistic (Z) to assess the presence of a trend, while Sen's slope estimate provides an estimate of the trend magnitude. A positive Sen's slope indicates an increasing trend, while a negative slope indicates a decreasing trend. The significance level (Signific.) determines whether the trend is statistically significant. In this case, several time periods have statistically significant trends (e.g., June, South West season, North East season).

Seasonal analysis. The overall annual rainfall for the dataset is 1182.70 mm, with a minimum of 648.70 mm and a maximum of 2019.30 mm. The mean annual rainfall is 1182.70 mm, indicating that it is close to the overall average. The coefficient of variation (CV) is 27.49%, suggesting moderate variability in the annual rainfall. The data distribution shows positive skewness, with a skewness value of 0.92. This means that the distribution has a longer right tail, indicating that extreme values and heavy rainfall events occur more frequently. The kurtosis value of 0.48 indicates that the distribution is relatively platykurtic, meaning it has lighter tails and fewer extreme values compared to a normal distribution. The autocorrelation at lag-1 is -0.315, indicating a weak negative correlation between consecutive annual rainfall values. The Mann-Kendall test Z statistic of -1.00 indicates a negative trend in the data, although it is not statistically significant at the 95% confidence level. The Sen's slope estimate of -6.304 suggests a negative slope in the data, indicating a decreasing trend in annual rainfall, but the significance level is not provided.

When considering the seasonal breakdown:

The winter season (Jan-Feb) has a mean rainfall of 28.53 mm, with a range from 0.00 mm to 134.60 mm. It shows a positive skewness, indicating a right-skewed distribution.

The summer season (Mar-May) has a higher mean rainfall of 42.82 mm, with a range from 0.00 mm to 115.60 mm. It also exhibits positive skewness.

The South West monsoon season (Jun-Sep) has the highest mean rainfall of 1069.92 mm, ranging from 589.10 mm to 1925.30 mm. It has positive skewness and a moderately high coefficient of variation (CV).

The North East monsoon season (Oct-Dec) has a mean rainfall of 41.43 mm, ranging from 0.00 mm to 267.80 mm. It exhibits positive skewness and higher kurtosis compared to other seasons.

District: Sehore

Monthly Statistics: January: The rainfall in January ranges from 0.00 to 87.30 with a mean of 9.71. The coefficient of variation (CV) is very high at 185.70, indicating a high degree of variability. The data is positively skewed (skewness = 3.18), indicating that the distribution has a long tail on the right side. The kurtosis value of 11.75 indicates a leptokurtic distribution, meaning it has heavy tails and a sharper peak compared to a normal distribution.

February: The rainfall in February ranges from 0.00 to 40.40 with a mean of 7.39. The CV is 144.82, indicating a high variability. The data is positively skewed (skewness = 2.04), but with a lower value compared to January. The kurtosis of 3.91 suggests a distribution closer to a normal distribution compared to January.

March: The rainfall in March ranges from 0.00 to 27.70 with a mean of 4.92. The CV is 135.91, indicating a high variability. The data is positively skewed (skewness = 1.85), but with a lower value compared to February. The kurtosis of 3.50 suggests a distribution closer to a normal distribution compared to both January and February.

April: The rainfall in April ranges from 0.00 to 8.70 with a mean of 1.48. The CV is 130.00, indicating a high variability. The data is positively skewed (skewness = 2.07), similar to February. The kurtosis of 5.62 indicates a leptokurtic distribution, similar to January.

May: The rainfall in May ranges from 0.00 to 40.70 with a mean of 6.45. The CV is 124.47, indicating a high variability. The data is slightly negatively skewed (skewness = -0.024), but still close to zero. The kurtosis of 11.21 suggests a leptokurtic distribution, similar to January.

June (Jun.): The rainfall in June ranges from 36.70 to 300.80 with a mean of 132.08. The CV is 52.59, indicating a moderate variability. The data is slightly negatively skewed (skewness = 0.64), but still close to zero. The kurtosis of -0.35 suggests a platykurtic distribution, meaning it has lighter tails compared to a normal distribution.

July: The rainfall in July ranges from 159.60 to 744.90 with a mean of 330.79. The CV is 42.53, indicating a moderate variability. The data is slightly positively skewed (skewness = 1.64). The kurtosis of 3.14 suggests a distribution closer to a normal distribution compared to January.

August: The rainfall in August ranges from 131.80 to 780.90 with a mean of 423.20. The CV is 32.46, indicating a moderate variability. The data is slightly positively skewed (skewness = 0.15). The kurtosis of 0.64 suggests a distribution closer to a normal distribution compared to January.

September: The rainfall in September ranges from 23.10 to 385.40 with a mean of 162.20. The CV is 63.04, indicating a high variability. The data is slightly negatively skewed (skewness = 0.43), but still close to zero. The kurtosis of -0.94 suggests a platykurtic distribution, similar to June.

October: The rainfall in October ranges from 0.00 to 141.50 with a mean of 21.43. The CV is 140.95, indicating a high variability. The data is slightly negatively skewed (skewness = 2.57), similar to February and April. The kurtosis of 8.01 suggests a leptokurtic distribution, similar to January.

November: The rainfall in November ranges from 0.00 to 132.00 with a mean of 15.25. The CV is 191.12, indicating a high variability. The data is slightly negatively skewed (skewness = 2.73), similar to February, April, and October. The kurtosis of 8.44 suggests a leptokurtic distribution, similar to January and October.

December: The rainfall in December ranges from 0.00 to 116.30 with a mean of 11.87. The CV is 192.57, indicating a high variability. The data is positively skewed (skewness = 3.57), similar to January and October. The kurtosis of 15.34 indicates a leptokurtic distribution, similar to January, October, and November.

Annual Rainfall: The annual rainfall ranges from 759.50 to 1769.40 with a mean of 1126.78. The CV is 19.27, indicating a moderate variability. The data is slightly negatively skewed (skewness = 0.64), but still close to zero. The kurtosis of 1.28 suggests a platykurtic distribution, meaning it has lighter tails compared to a normal distribution.

Seasonal Rainfall: Winter (Jan-Feb): The rainfall in winter ranges from 0.00 to 92.70 with a mean of 17.11. The CV is 133.52, indicating a high variability. The data is slightly negatively skewed (skewness = 1.85). The kurtosis of 3.15 suggests a distribution closer to a normal distribution compared to January.

Summer (Mar-May): The rainfall in summer ranges from 0.00 to 43.20 with a mean of 12.85. The CV is 86.25, indicating a moderate variability. The data is slightly negatively skewed (skewness = 1.07). The kurtosis of 0.67 suggests a distribution closer to a normal distribution compared to January and February.

South West (Jun-Sep): The rainfall in the southwest monsoon season ranges from 593.70 to 1722.80 with a mean of 1048.27. The CV is 21.26, indicating a moderate variability. The data is slightly positively skewed (skewness = 0.66). The kurtosis of 1.80 suggests a distribution closer to a normal distribution compared to January.

North East (Oct-Dec): The rainfall in the northeast monsoon season ranges from 2.30 to 141.50 with a mean of 48.55. The CV is 76.75, indicating a moderate variability. The data is slightly positively skewed (skewness = 1.08). The kurtosis of 0.93 suggests a distribution closer to a normal distribution compared to January.

District: Vidisha

Month wise analysis : Range: The range of values in the time series varies across the months, with minimum values ranging from 0.00 to 150.30 and maximum values ranging from 13.10 to 739.00.

Variability: The standard deviation (SD) and coefficient of variation (CV) provide information about the variability of the data. The SD values range from 2.65 to 241.27, indicating that the data points have a wide dispersion. The CV values range from 34.81 to 178.27, suggesting that the data has a relatively high degree of variation.

Skewness and Kurtosis: Skewness measures the asymmetry of the distribution, while kurtosis measures the shape of the distribution's tails. Positive skewness values indicate a longer tail on the right side of the distribution, while negative skewness values indicate a longer tail on the left side. The skewness values range from -0.298 to 3.50, suggesting some degree of asymmetry in the data. Kurtosis values range from -1.16 to 14.54, indicating that the data exhibits varying degrees of peakedness or flatness compared to a normal distribution.

Autocorrelation Lag-1: The autocorrelation lag-1 measures the correlation between consecutive observations in the time series. Values close to 0 indicate weak or no correlation, while values closer to 1 or -1 indicate strong positive or negative correlation, respectively. The lag-1 autocorrelation values range from -0.342 to 0.202, suggesting weak to moderate correlation between consecutive observations.

Mann-Kendall Test: The Mann-Kendall test is a non-parametric test used to detect trends in time series data. The test Z values range from -1.28 to 1.46, indicating the presence of both positive and negative trends, although some are statistically significant (e.g., $p < 0.05$) and others are not.

Sen's Slope Estimate: Sen's slope estimate provides an estimation of the slope or rate of change in the time series. Positive values indicate an increasing trend, while negative values indicate a decreasing trend. The Sen's slope estimate ranges from -3.168 to 1.638, indicating varying rates of change across the months.

Annual Rainfall: The annual rainfall data shows a minimum of 683.70 mm, a maximum of 1510.50 mm, and a mean of 1082.23 mm. The standard deviation is 241.27 mm, indicating a considerable amount of variability in annual rainfall. The coefficient of variation (CV) is 22.29%, suggesting a moderate level of variation relative to the mean. The skewness value is 0.12, indicating a slightly right-skewed distribution. The kurtosis value is -1.16, suggesting a relatively flat distribution compared to a normal distribution. The Mann-Kendall test for the annual rainfall data yields a test Z value of -0.14. Since the test Z value is not statistically significant ($|Z| < 1.96$), we can conclude that there is no significant trend in the annual rainfall data.

Seasonal Analysis. Winter (Jan-Feb): The winter season data shows a minimum rainfall of 0.10 mm, a maximum of 107.50 mm, and a mean of 21.59 mm. The standard deviation is 27.98 mm, indicating moderate variability in winter rainfall. The CV is 129.56%, suggesting a high level of variation relative to the mean. The skewness value is 1.64, indicating a right-skewed distribution. The kurtosis value is 1.97, suggesting a relatively peaked distribution. The Mann-Kendall test for the winter data (January to February) yields a test Z value of 0.59. Again, since the test Z value is not statistically significant (|Z| < 1.96), we can conclude that there is no significant trend in the winter data.

Summer (Mar-May): The summer season data shows a minimum rainfall of 0.30 mm, a maximum of 40.30 mm, and a mean of 12.23 mm. The standard deviation is 11.51 mm, indicating relatively low variability in summer rainfall. The CV is 94.10%, suggesting a moderate level of variation relative to the mean. The skewness value is 1.36, indicating a right-skewed distribution. The kurtosis value is 1.06, suggesting a relatively peaked distribution. The Mann-Kendall test for the summer data (March to May) yields a test Z value of -0.07. Similar to the previous cases, the test Z value is not statistically significant (|Z| < 1.96), indicating that there is no significant trend in the summer data.

South West (Jun-Sep): The South West monsoon season data shows a minimum rainfall of 470.80 mm, a maximum of 1468.10 mm, and a mean of 1001.39 mm. The standard deviation is 231.49 mm, indicating a considerable amount of variability in monsoon rainfall. The CV is 23.12%, suggesting a relatively moderate level of variation relative to the mean. The skewness value is -0.01, indicating a nearly symmetrical distribution. The kurtosis value is -0.23, suggesting a distribution close to normal. The Mann-Kendall test for the South West data (June to September) yields a test Z value of -0.32. Once again, the test Z value is not statistically significant (|Z| < 1.96), indicating that there is no significant trend in the South West data.

North East (Oct-Dec): The North East monsoon season data shows a minimum rainfall of 0.40 mm, a maximum of 205.60 mm, and a mean of 47.01 mm. The standard deviation is 44.18 mm, indicating moderate variability in monsoon rainfall. The CV is 93.98%, suggesting a relatively high level of variation relative to the mean. The skewness value is 1.86, indicating a right-skewed distribution. The kurtosis value is 4.70, suggesting a relatively peaked distribution. The Mann-Kendall test for the North East data (October to December) yields a test Z value of -0.25. Similar to the previous cases, the test Z value is not statistically significant (|Z| < 1.96), suggesting that there is no significant trend in the North East data.

DICUSSION

A study conducted by Subash and Sikka (2014) investigated the trends in rainfall and temperature in India. They found that annual maximum temperature shows an increasing trend in all the homogeneous temperature regions and corresponding annual rainfall also follows the same pattern in all the regions, except North East. As far as monthly analysis is concerned, no definite pattern has been observed between trends in maximum and minimum temperature and rainfall, except during October. Increasing trends of maximum and minimum temperature during October accelerate the water vapor demand and most of the lakes, rivers, ponds, and other water bodies with no limitation of water availability during this time fulfil the water vapor demand and shows an increasing trend of rainfall activity.

A study conducted Sharma *et al.,* (2018**)** the aim of the study is to determine the trend in annual precipitation time series using the Mann-Kendall and Sen's T test. The magnitudes of trend in precipitation have been estimated by Sen's estimator method. Auto correlation effects were reduced before applying the Mann-Kendall test for the trend in precipitation. On the annual basis, analysis of Mann-Kendall test shows decreasing and non-significance trend in rainfall times series of all the districts except Indore which showed significant changes.

Occurrence of Western Disturbance and Bay of Bengal Cyclonic Circulation. Madhya Pradesh state distance of Bya Bengal is 1040 km and the Arabian Sea is 1926 km. During the study period (the year 1991-2020) observed many cyclone arrivals of Bya Bangal 29 October 1999 Odisha cyclone was the strongest recorded tropical cyclone in the North Indian Ocean and among the most destructive in the region. Cyclone BOB 03 - 2002 Severe Cyclonic Storm impacted West Bengal on November 12. Cyclonic Storm Pyarr tracked a rare path from northeast to southwest in September 2005 in the Bay of Bengal. Cyclonic storm Phyan developed as a tropical disturbance to the southwest of Colombo in Sri Lanka on November 4, 2009. Cyclone Phyan caused heavy rainfall in Tamil Nadu, Maharashtra, and Gujarat. Cyclonic storm Nilam was the deadliest tropical cyclone to directly affect South India since Cyclone Jal in 2010. It made landfall near Mahabalipuram on October 31 as a strong cyclonic storm with peak winds of 85 km/h (50 mph). Extremely severe cyclonic storm Phailin was the most intense tropical cyclone to make landfall in India since the 1999 Odisha cyclone. Hudhud (Year 2014) was a strong tropical cyclone, which caused damage to Visakhapatnam in Andhra Pradesh. Visakhapatnam or Vizag along with Odisha was mostly affected by Hudhud. Ockhi was the most intense and one of the strongest tropical cyclones of the 2017 North Indian Ocean cyclone season. Ockhi from the Arabian Sea affected mainland India along with coastal areas of Kerala, Tamil Nadu, and Gujarat. Very Severe Cyclonic Storm Titli was a deadly and destructive tropical cyclone that made landfall on October 10, 2018, on the southwest coast of Gopalpur near Palasa in Andhra Pradesh. However, eight districts in Odisha such as Ganjam, Gajapati, Khordha, Puri, Jagatsinghpur, Kendrapara, Bhadrak, and Balasore were affected by the cyclone. Fani was termed an extremely severe cyclonic storm that hit the Indian state of Odisha in May 2019. It was equivalent to a high-end Category 4 major hurricane. Bulbul was the second cyclone in 2019. The Very Severe Cyclonic Storm Bulbul struck the eastern state on November 9, 2019, near Sagar Island in West Bengal. The storm caused extensive damage to agriculture and destroyed crops in around 490,000 acres of land statewide. The Super Cyclonic Storm Amphan was a powerful and deadly cyclone, that caused damage in

Eastern India and Bangladesh in May 2020. It made landfall near Bakkhali in West Bengal on May 20, 2020.

Table 1: Values of Descriptive statistics, Autocorrelation and Mann Kendall Test of the rainfall series in different district of Vindhya Plateau agroclimatic zone.

1. District: Bhopal

Time Series	Min	Max	Mean	Contribution %	SD	CV	Skewness	Kurtosis	Autocorrelation Lag-1	Mann-Kendall Test	Sen's slope estimate
										Test Z	Q
January	0.00	103.60	11.58	1.04	21.64	186.78	3.11	11.18	-0.062	0.23	0.000
February	0.00	37.50	8.04	0.72	11.57	143.92	1.53	1.27	0.270	0.84	0.043
March	0.00	36.90	4.57	0.41	8.10	177.31	2.72	8.32	-0.070	-0.54	0.000
April	0.00	16.90	2.03	0.18	3.42	168.21	3.11	12.10	0.112	0.36	0.000
May	0.00	44.30	6.89	0.62	8.59	124.58	3.02	12.24	-0.023	0.95	0.100
June	37.40	272.00	125.89	11.30	66.71	52.99	0.70	-0.45	0.140	1.82+	2.319
July	121.00	746.20	336.94	30.26	149.96	44.51	1.11	1.45	-0.156	-1.25	-3.550
August	131.30	663.30	415.47	37.31	138.28	33.28	-0.30	-0.73	0.048	0.46	1.048
September	20.20	377.10	153.48	13.78	98.78	64.36	0.58	-0.59	-0.252	-1.55	-2.975
October	0.00	159.50	22.08	1.98	32.56	147.48	2.83	10.41	-0.095	0.84	0.225
November	0.00	147.10	14.70	1.32	31.40	213.62	3.10	10.88	-0.137	-0.83	0.000
December	0.00	120.00	11.94	1.07	23.59	197.65	3.62	15.55	-0.110	-0.04	0.000
Annual Rainfall (mm)	698.10	1663.30	1113.63	100.00	233.54	20.97	0.24	-0.48	-0.096	0.00	-0.037
Winter (Jan-Feb)	0.00	110.00	19.62	1.76	27.32	139.25	1.86	3.20	-0.046	0.80	0.073
Summer (Mar-May)	0.00	47.20	13.50	1.21	13.61	100.86	1.36	1.14	-0.048	0.29	0.075
South West (Jun-Sep)	463.60	1621.50	1031.79	92.65	234.02	22.68	0.14	0.68	-0.061	-0.21	-1.475
North East (Oct-Dec)	0.40	159.50	48.72	4.37	42.06	86.33	1.30	1.47	-0.286	0.14	0.032

*** if trend at α=0.001, ** if trend at α= 0.01, * if trend at α= 0.05, + if trend at α= 0.1 level of significance,
Min= Minimum, Max= Maximum, SD= Standard Deviation, CV = Coefficient of Variation

2. District Damoh

Time Series	Min	Max	Mean	Contribution %	SD	CV	Skewness	Kurtosis	Autocorrelation Lag-1	Mann-Kendall Test	Sen's slope estimate
										Test Z	Test Z
January	0.00	79.70	16.81	1.48	21.05	125.24	1.48	1.69	0.093	0.29	0.014
February	0.00	77.70	15.61	1.38	21.46	137.48	1.86	2.92	0.187	1.34	0.213
March	0.00	35.70	8.18	0.72	9.54	116.59	1.32	1.04	-0.194	-0.57	-0.044
April	0.00	15.50	3.27	0.29	4.26	130.52	1.50	1.72	0.059	-0.99	-0.033
May	0.00	23.00	5.85	0.52	6.55	111.93	1.35	1.21	-0.125	1.93+	0.177
June	25.80	421.20	139.82	12.34	96.33	68.89	1.39	2.00	-0.158	0.96	1.732
July	166.70	660.30	320.29	28.26	112.52	35.13	1.33	2.67	-0.412	-0.36	-0.892
August	172.10	654.90	406.46	35.87	135.09	33.24	0.25	-0.69	-0.394	0.89	2.820
September	28.10	422.00	170.74	15.07	98.59	57.74	0.70	0.32	-0.282	-1.96*	-4.993
October	0.00	127.40	24.61	2.17	33.40	135.69	1.61	2.08	-0.161	0.86	0.136
November	0.00	76.80	9.96	0.88	18.82	188.93	2.39	5.51	-0.161	-0.58	0.000
December	0.00	85.00	11.57	1.02	18.95	163.75	2.46	7.08	-0.086	0.74	0.013
Annual Rainfall (mm)	625.90	1768.30	1133.17	100.00	260.92	23.03	0.18	0.09	-0.274	0.14	0.608
Winter (Jan-Feb)	0.00	107.00	32.42	2.86	34.39	106.10	1.05	-0.42	0.142	0.86	0.481
Summer (Mar-May)	1.20	43.90	17.30	1.53	13.07	75.54	0.56	-0.74	-0.092	0.36	0.058
South West (Jun-Sep)	450.50	1553.80	1037.31	91.54	245.77	23.69	-0.16	0.22	-0.315	-0.07	-0.300
North East (Oct-Dec)	1.90	147.70	46.15	4.07	36.26	78.57	1.08	1.08	-0.094	0.29	0.165

*** if trend at α=0.001, ** if trend at α= 0.01, * if trend at α= 0.05 ,+ if trend at α= 0.1 level of significance,
Min= Minimum, Max= Maximum, SD= Standard Deviation, CV = Coefficient of Variation

3. District: Sehore

Time Series	Min	Max	Mean	Contribution %	SD	CV	Skewness	Kurtosis	Autocorrelation Lag-1	Mann-Kendall Test	Sen's slope estimate
										Test Z	Test Z
January	0.00	87.30	9.71	0.86	18.04	185.70	3.18	11.75	-0.126	-0.32	-0.004
February	0.00	40.40	7.39	0.66	10.71	144.82	2.04	3.91	0.138	1.05	0.054
March	0.00	27.70	4.92	0.44	6.69	135.91	1.85	3.50	0.000	-1.04	-0.078
April	0.00	8.70	1.48	0.13	1.93	130.00	2.07	5.62	0.132	-0.52	-0.004
May	0.00	40.70	6.45	0.57	8.02	124.47	2.92	11.21	-0.024	0.88	0.080
June	36.70	300.80	132.08	11.72	69.46	52.59	0.64	-0.35	0.104	1.89+	2.614
July	159.60	744.90	330.79	29.36	140.70	42.53	1.64	3.14	-0.245	-1.07	-2.411
August	131.80	780.90	423.20	37.56	137.38	32.46	0.15	0.64	0.108	0.25	1.067
September	23.10	385.40	162.20	14.40	102.25	63.04	0.43	-0.94	-0.168	-1.82+	-3.829
October	0.00	141.50	21.43	1.90	30.20	140.95	2.57	8.01	-0.030	1.32	0.355
November	0.00	132.00	15.25	1.35	29.15	191.12	2.73	8.44	-0.060	-0.72	0.000
December	0.00	116.30	11.87	1.05	22.86	192.57	3.57	15.34	-0.101	0.13	0.000
Annual Rainfall (mm)	759.50	1769.40	1126.78	100.00	217.08	19.27	0.64	1.28	-0.031	0.00	-0.278
Winter (Jan-Feb)	0.00	92.70	17.11	1.52	22.84	133.52	1.85	3.15	-0.101	0.66	0.100
Summer (Mar-May)	0.00	43.20	12.85	1.14	11.08	86.25	1.07	0.67	-0.044	-0.36	-0.108
South West (Jun-Sep)	593.70	1722.80	1048.27	93.03	222.91	21.26	0.66	1.80	-0.007	-0.29	-1.386
North East (Oct-Dec)	2.30	141.50	48.55	4.31	37.26	76.75	1.08	0.93	-0.285	0.14	0.062

*** if trend at α=0.001, ** if trend at α= 0.01, * if trend at α= 0.05 ,+ if trend at α= 0.1 level of significance,
Min= Minimum, Max= Maximum, SD= Standard Deviation, CV = Coefficient of Variation

4. District: Sagar

Time Series	Min	Max	Mean	Contribution %	SD	CV	Skewness	Kurtosis	Autocorrelation Lag-1	Mann-Kendall Test	Sen's slope estimate
										Test Z	Test Z
January	0.00	54.80	12.60	1.07	18.64	148.01	1.31	0.22	0.218	0.40	0.000
February	0.00	132.40	15.93	1.35	30.22	189.68	2.75	7.75	0.068	0.07	0.000
March	0.00	64.00	14.12	1.19	18.94	134.08	1.28	0.46	0.115	0.83	0.033
April	0.00	86.40	7.58	0.64	16.30	214.94	4.27	20.12	-0.136	-0.63	-0.032
May	0.00	115.60	21.12	1.79	25.14	119.04	2.04	5.72	0.059	-0.64	-0.200
June	9.80	614.70	174.49	14.75	158.70	90.95	1.48	1.48	-0.265	1.75+	3.314
July	72.30	1081.50	369.63	31.25	210.00	56.81	1.73	3.57	-0.104	0.04	0.105
August	141.70	624.80	364.46	30.82	124.55	34.17	0.27	-0.44	0.132	-0.71	-2.713
September	9.70	678.10	161.34	13.64	145.55	90.21	1.93	4.27	-0.029	-0.86	-1.520
October	0.00	120.30	23.62	2.00	33.22	140.62	1.83	2.55	-0.095	-0.91	-0.112
November	0.00	118.40	10.88	0.92	27.42	252.13	3.06	9.09	0.255	-0.26	0.000
December	0.00	75.60	6.93	0.59	15.45	223.10	3.43	13.70	-0.149	0.63	0.000
Annual Rainfall (mm)	648.70	2019.30	1182.70	100.00	325.09	27.49	0.92	0.48	-0.315	-1.00	-6.304
Winter (Jan-Feb)	0.00	134.60	28.53	2.41	34.99	122.66	1.77	2.87	0.156	0.21	0.038
Summer (Mar-May)	0.00	115.60	42.82	3.62	29.07	67.88	1.02	0.87	0.243	-1.91+	-0.764
South West (Jun-Sep)	589.10	1925.30	1069.92	90.46	317.49	29.67	1.05	0.51	-0.327	-1.14	-4.500
North East (Oct-Dec)	0.00	267.80	41.43	3.50	63.05	152.19	2.60	6.87	0.119	-0.77	-0.477

*** if trend at α=0.001, ** if trend at α= 0.01, * if trend at α= 0.05, + if trend at α= 0.1 level of significance,
Min= Minimum, Max= Maximum, SD= Standard Deviation, CV = Coefficient of Variation

5. District: Vidisha

Time Series	Min	Max	Mean	Contribution %	SD	CV	Skewness	Kurtosis	Autocorrelation Lag-1	Mann-Kendall Test	Sen's slope estimate
										Test Z	Test Z
January	0.00	98.30	12.64	1.17	20.94	165.63	2.81	9.26	-0.081	-0.11	0.000
February	0.00	53.90	8.95	0.83	13.65	152.50	1.97	3.49	0.185	1.25	0.072
March	0.00	36.30	5.07	0.47	7.78	153.44	2.68	8.50	-0.112	-0.95	-0.041
April	0.00	13.10	1.63	0.15	2.65	162.48	3.06	11.78	0.202	-0.05	0.000
May	0.00	33.60	5.52	0.51	6.88	124.58	2.60	8.86	-0.180	0.84	0.055
June	31.00	266.40	119.48	11.04	70.78	59.24	0.78	-0.47	0.023	1.46	1.638
July	117.30	664.50	328.23	30.33	135.26	41.21	1.14	1.13	-0.227	-0.82	-2.070
August	150.30	739.00	396.64	36.65	138.06	34.81	0.19	-0.16	-0.144	0.14	0.260
September	34.60	469.70	157.04	14.51	98.09	62.46	1.04	1.89	-0.298	-1.28	-3.168
October	0.00	205.60	23.10	2.13	41.18	178.27	3.38	13.49	-0.124	0.66	0.110
November	0.00	121.50	13.02	1.20	27.27	209.45	2.81	8.57	-0.170	-0.06	0.000
December	0.00	104.60	10.89	1.01	20.77	190.65	3.50	14.54	-0.103	0.39	0.010
Annual Rainfall (mm)	683.70	1510.50	1082.23	100.00	241.27	22.29	0.12	-1.16	-0.204	-0.14	-1.275
Winter (Jan-Feb)	0.10	107.50	21.59	2.00	27.98	129.56	1.64	1.97	-0.038	0.59	0.119
Summer (Mar-May)	0.30	40.30	12.23	1.13	11.51	94.10	1.36	1.06	-0.181	-0.07	-0.024
South West (Jun-Sep)	470.80	1468.10	1001.39	92.53	231.49	23.12	-0.01	-0.23	-0.158	-0.32	-0.829
North East (Oct-Dec)	0.40	205.60	47.01	4.34	44.18	93.98	1.86	4.70	-0.342	-0.25	-0.123

*** if trend at α=0.001, ** if trend at α= 0.01, * if trend at α= 0.05, + if trend at α= 0.1 level of significance,
Min= Minimum, Max= Maximum, SD= Standard Deviation, CV = Coefficient of Variation

CONCLUSIONS

In the district Bhopal months of June, July, and August have the highest rainfall amounts, with significant variability and positive trends. September shows a significant decreasing trend in rainfall. Winter and autumn seasons exhibit high variability in rainfall, while summer and the rainy season show moderate variability. No significant trends are observed in winter, summer, rainy season, or autumn rainfall. The analysis provides insights into the statistical properties and trends in rainfall for each month and season, aiding in understanding the patterns and variability in the region's precipitation.

Sagar district In conclusion, the data suggests that there is a decreasing trend in annual rainfall, although it is not statistically significant. The South West monsoon season (Jun-Sep) receives the highest amount of rainfall, while the winter season (Jan-Feb) receives the least. The data also shows a positive skewness, indicating a higher occurrence of heavy rainfall events. However, further analysis and significance testing are necessary to make more definitive conclusions.

Sehore district the provided data shows the monthly rainfall statistics for each month of the year, as well as the statistics for different seasonal and annual periods. The data exhibits varying degrees of variability, skewness, and kurtosis throughout the months and seasons. Some months, such as January, October, and November, show higher variability and leptokurtic distributions, indicating heavy tails and sharper peaks. Overall, the annual rainfall demonstrates moderate variability and a platykurtic distribution. It's important to note that these conclusions are based on the provided data, and further analysis and consideration of other factors may be required for a comprehensive understanding of the rainfall patterns.

it can be observed that the relationship between the number of rainy days and the independent variable varies across different districts or regions. Some regions exhibit a weak relationship, while others show a moderate relationship. The growth rates indicate either a slight positive or negative change in the number of rainy days with an increase in the independent variable. It's important to note that the significance level is not provided in the given data, so we cannot make any conclusions based on it.

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