Original Research Article

Statistical Model for annual trends and Magnitude of climatic variability across Locations from the Malwa Plateau agroclimatic zone of Madhya Pradesh

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 hydrological status of different districts of Malwa Agroclimatic Zone. 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 and Sens's slope estimator shows district wise Indore (Z 1.21 & Q 7.86), Mandsaur (Z 0.82 & Q 3.697), Neemuch (Z 1.03 & Q 3.488), Rajgarh (Z 0.93 & 0.5658), Ratalm (Z 0.64 & Q 3.525), Shajapur (Z = 0.57 & Q 3.164) and Ujjain (Z 0.11 & Q 0.692) was increasing trend not statically significance only one district Dewas result show decreasing (Z-0.07 and Q -0.189) non-significance trend in rainfall times series..

Comment [H1]: Conclusion and r ecommendation not stated, conclude the work based on the findings of the work and also state the recommendation

Keywords: Rainfall analysis, non-parametric tests, trend analysis, auto correlation, Mann-Kendall and Sen's T tests.

1. INTRODUCTION

Climate change has begun to mark itself worldwide as scientific facts in the form of increased downpours and stroms, diminishing glaciers, rising temperature and sea level etc. US EPA studies identify the global temperature patter from 1901 to the present help of using data by National Oceanic and Atmospheric Administration's National Climatic Data Centre (NCDC). This report state the average global warming in the late 1970's was -17.58 ^{0}C to -17.49 ^{0}C per decade and the global average surface temperature has risen at an average rate of -17.70 ^{0}C per decades since 1901.

Comment [H2]: Patter or pattern?

Comment [H3]: Check the grammar

Comment [H4]: ? querry the figure, please check again and add citation to it

Temperature and precipitation are essential element of climate and changes in them can affect human health, ecosystems, plants and animals. An increase in temperature can result in heat wave incidents and cause illness and death and also cause alter in species of animals and plants. Kothawale and Rupa Kumar 2005, found that precipitation trends increase can results in an increase in the floods frequency and a decade could increase in instances of drought [1]. An increasing trend of temperature leads to more evaporation, which in turn, increase precipitation. It is found that over 1901-2003, mean annual temperature of all India has raised at the rate of 0.05 ^{0}C/decades, which mostly due to the rise of maximum temperature (0.07 ^{0}C/decades) and minimum temperature (0.02 ^{0}C/decades).

Comment [H5]: Consider restricting the grammar to bring out clear meaning of the sentence

Goswami et al. 2006, in their study carried out by several investigators found that the trend and magnitude of temperature rise over the Indian sub-continent is broadly constant with the worldwide over the last century. Pant and Kumar 1997, found that an increasing trend of mean annual temperature, at the rate of 0.57 ^{0}C per 100 years in the annual air

Comment [H6]: Update your in-text citation to the last five years, temperature from 1881-1997. Similar changes in precipitation form and its timing can have widespread effect on the availability of water and can cause a shift in animal and plant species. The average temperature is increasing in the Upper Ganga Canal command area with level of non-significant trend. Increasing trend in rainfall was predicted in the upper ganga canal command area and it was concluded that there may be an impact of climatic change which is contributing to the prolonged and heavy rainfall that is rising with time.

Comment [H7]: Add mor flesh to your background information the need of modeling Climate variability, which buttress the importance of the study

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.

Malwa plateau agro climatic zone comprises 8 entire districts (Indore, Dewas, Mandsore, Neemuch, Raigarh, Ratlam, Shajapur, and Ujjain) and part of Dhar (Dhar, Badnawar, Sardarpur Tehsil) and Jhabua (Petlawad Tehsil) districts of Madhya Pradesh. Malwa agroclimatic zone is average rainfall 977 mm. the average rainfall in Malwa agroclimatic zone in the different districts Indore (985.2 mm), Ujjain (866.7mm), Dewas (1219.7 mm), Rajgarh (971.3 mm), Neemuch (872.5 mm), Ratlam (982.7 mm), Mandsoure (1014.9 mm) and Shajapur (957.6 mm) [ ]. The soils of the area are medium, deep and shallow black and contain 40-60% clay. pH ranges from 7-8, CEC 33-55 c mol kg^{-1} and bulk density varies from 1.2-1.6 Mgm^{-3}, low in N, medium to high in P and high in K, S and Zn deficiency are very common. Infiltration: 1.55-3.66 cm / hr (Low-Medium). Major crops are soybean (Kharif); chickpea and wheat (Rabi).Other crops are maize, sorghum, pigeon pea (Kharif) and spices, opium, medicinal crops (Rabi).

Comment [H8]: This should be in study area

2. MATERIAL AND METHOD

Study Area:

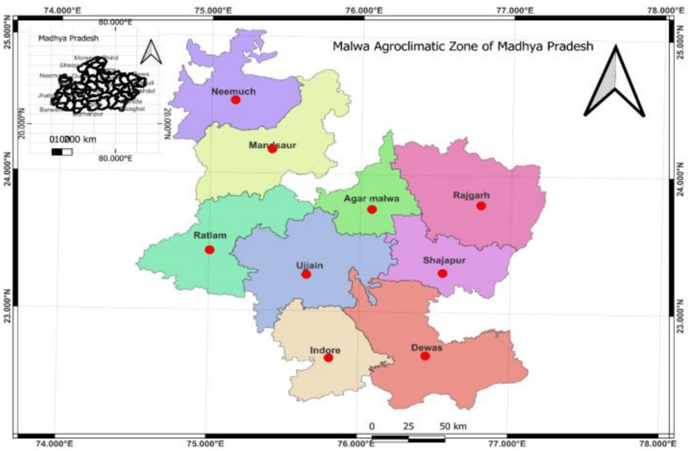
Data collection: -

The Monthly precipitation data was download form the website of the Indian Meteorological Department (IMD) through the India water-portal website (https://www.imdpune.gov.in/cmpg/Griddata/Rainfall_25_Bin.html) 1991 to 2020 for the time period. IMD has define four seasons, namely winter (January-February), Summer (March-May), South-West (June-September) and North-East (October-November) so using monthly rainfall data/ seasonal and annual rainfall series were prepared. After that, statistical analysis and trend detection has been done using Microsoft office excel 2013.

Table no. 1: Study Area

S. No.	City	Latitude	Longitude	**Agro-Meteorology Data**	**Year**
1	Indore	75.8577° E	22.7196° N	Observatory Data	1991-2020
2	Dewas	76.0508° E	22.9623° N	Grid Data	1991-2020
3	Ujjain	75.7849° E	23.1793° N	Grid Data	1991-2020
4	Shajapur	76.2730° E	23.4273° N	Grid Data	1991-2020
5	Neemuch	74.8624° E	24.4764° N	Grid Data	1991-2020
6	Ratlam	75.0376° E	23.3342° N	Grid Data	1991-2020
7	Mandsaur	75.0693° E	24.0768° N	Grid Data	1991-2020
8	Rajgarh	76.7337° E	23.8509° N	Grid Data	1991-2020

STUDY AREA MAP



Pic 1. Study area on map

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. apart form this, Loess **regression curve** was used to plot an check general patterns in data over the period of 1991 to 2020 for monthly, annual and seasonal series.

AUTOCORRELATION

Lag-1 autocorrelation 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, X_t , t=1,2,3,…… N-1 and the next observation X_t and X_{t+1} is given by

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

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

The lag-1 autocorrelation coefficient r_1 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 r_1 lie outside the confidence interval given above, the data area assumes to be serially correlated otherwise the sample data are 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 and Kendall and 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 nonnormally distributed data. Since the time series data used in the study is mostly nonnormally distributed as evident from the skewness and kurtosis values given in Table no.1 the nonparametric test were used in the study.

The Mann-Kendall test statistics is given by

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

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

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

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;

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

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

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

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

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

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:

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

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 β_i is represented as Sen's estimator of slope which is given as

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

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

3. RESULTS AND DISCUSSION

Trend analysis of rainfall for the period of 1991 to 2020 (30 years) in Malwa Agroclimatic zone has been done in the present study. Mann-Kendall and Sen's Slope Estimator has been used for the determination of the rainfall trend detection.

Indore: - Rainfall (mm) Trend analysis shows the (Fig. 1 and Table 2a) in Indore district south west monsoon 92.22 per cent contribution and the annual rainfall average 1006.76 (mm) per year. (Table 2.) the R^2 value is 0.0717 which means that only 7.17% of the variance in the dependent variable can be explained by the independent variable. Annual Autocorrelation lag-1 Show 0.077. The Mann Kendall Test and Sen's Slope estimator on annual basis rainfall trend result show the increasing trend with non- significance level annual growth in Z statistics 1.21. in the other hand, seasonal basis South-West trend with increasing positive (Z-1.07) non- significance level. South-West Monsoon increasing decades wise increasing Q statistics positive 7.591 (Table No.2). Summer, North-East and winter series show the decreasing trend with non-significance. On the monthly basis, the month of May, June, July, August, September and December increasing trend (Z-0.13 to 0.94) , decades wise trend positive (Q- 7.862) non significance level. Month of January, February, March, April and November show the Negative trend (Z- - 1.24 to 1.27) .

Dewas :- In Dewas district result show in (fig 2 and Table 2b) the annual average rainfall (mm) in 1015 per year the south west monsoon contribution 93.10 per cent. The skewnes and kurtosis of annual rainfall (mm) 1.141 and 4.81 was positive and autocorrelation lag-1 was showing negative correlation (-0.143). Mann Kendall test baed on annual basis rainfall trend result shows the increasing trend with no-significance level. On the hand, South-West, summer, and winter show decreasing trend (-0.07 and -0.04) and North-East (0.04) show positive with non-significance. On the monthly basis, the month of October show increasing positive trend (1.71) with 0.1% significance level and Sen's slope estimator (Q 0.145) positive. September shows the decreasing trend (-1.71) with 0.1% significant level of confidence and the Sen's slope estimator negative (Q -3.895).

Ujjain :- the result was show in (fig.2 and Table 2c)The annual average rainfall (mm) 914.82 mm , In Ujjain district on annual basis rainfall trend result show the increasing trend (0.11) with non-significance level. On the other hand, the mankendall test and sens slope estimate show seasonal basis southwest monsoon series shows the increasing trend (0.25). the month wise rainfall increasing trend August (Z-= 2.36 & Q= 4.492) with 0.05 level of significance and October was (Z-= 1.72 & Q 0.250) increasing trend at 0.1% level of significance. The other month of decreasing trend September (Z statistics -2.18 & Q statistic -3.556) (0.05%), March (Z Statistics -1.82 & Q Statistics = -0.43) (90%), Z-values and level of significance and the rest of month February, May, June Increasing trend and the Month of January, April, July November and December decreasing trend.

Shajapur: - in Shajapur district (Fig.1 and Table 2g) result show on the basis annual rainfall (mm) 957.06 mm and the highest rainfall 1675.20 mm and the minimum rainfall 538.30 mm. basis rainfall trend result show Autocorrelation lag-1 decreasing trend (--0.024) with non-significance level. On the Mann –Kendall test and Sen's slope estimator was show , seasonal basis of Summer , monsoon decreasing trend (Z= -0.14) with non-significance level and other winter season little increasing trend (1.04) with non-significant. On monthly basis the month decreasing trend of March, July, September , November and December was decreasing trend and the January, February, April , May , June and October was increasing trend.

Neemuch:- in Neemuch district (fig.2 and Table 2d) Mann-Kendall Test and Sen's Slope estimator result show on annual basis rainfall trend result show increasing trend (Z= 1.03 & 4.625) with non-significance. On the other hand, seasonal basis Winter, Summer , South-West and North- East monsoon increasing rainfall trend with non- significance. On monthly basis the month of August (Z= 1.91, Q= 4.625) with 0.1 % level of significance trend. Month of September (Z= -1.70 & Q -2.821) with 0.1 % significance level. .

Ratlam :- in Ratlam district (Fig.2 and Table 2f) on the basis of result show annual average rainfall (mm) 895 mm and the minimum rainfall (mm) 480 mm, maximum rainfall 1700 mm the Skewness (1.16) and Kurtosis(2.51). based on Autocorrelation Lag-1 -0.097 was result show decreasing trend per year . The Mann-Kendall test and Sen's slope estimate show annual basis rainfall trend increasing trend (Z= 0.64 & Q = 3.525) with non-significance and Q= 3.525 decades wise increase trend. On the other hand, seasonal basis monsoon increasing trend in Z-0.23 and Q- 0.039 with non-significance and Winter, South-West and North-East was increasing trend and sen's slope was non-significance. On monthly basis of the month of June (Z= 2.25 & Q= 0.25) and October (Z= 1.88 & Q= 0.250) increasing trend with 0.1% significance trend. March and August decreasing trend with 0.1% level of significance with Z statistics (- 1.69 and -2.11).

Mandsaur:-in Mandsour district (Fig. 2 and Table 2c) result show average annual rainfall (mm) 823.27 mm (30 years average) the skwness and kurtosis wash show positive (0.89 & 1.04). the Autocorrelation lag-1 show negative correlation (-0.052). Mann-Kendal Test & Sen's slope estimator show Z = 0.82 & Q= 3.967 on annual basis rainfall trend result show increasing trend with non-significance. On the other hand, seasonal basis of rainfall trend winter , summer, South-West and Nort-East (Z 0.46 to 1.23 & Q 0.075 to 2.867) increasing trend with non-significance trend. On monthly basis of the month of August (Z = 2.07 & Q= 5.403) increasing trend with 0.1 % level of significance trend. Month of September (Z -1.59 & Q -2.073) decreasing trend with 0.1 % level of significance trend.

Rajgarh :- in Rajgarh district (Fig.2 and Table 2e) on annual basis rainfall trend Mann-Kendall test and Sen's slope estimator result show increasing trend (Z 0.93 & Q 5.658) with non-significance trend. On the other hand, seasonal basis of rainfall trend Winter, Summer, South-West and North-East monsoon was increasing trend (Z= 0.32 to 1.25 & Q = 0.067 to 4.40) with non-significance. Based on Z Statistics month wise January, February, May, June, August and October was increasing trend (Z 0.20 to 1.59) with non-significance trend. Month of March, April July November and December decreasing trend non- significance trend.

4. CONCLUSION

Indore district on annual basis rainfall trend result show the increasing trend with non-significance level annual positive growth in Z statistics 1.21. in the other hand , seasonal basis South-West monsoon trend with increasing positive (Z= 1.07) non- significance . In Dewas district on annual basis rainfall trend result shows the decreasing (Z- 0.07) trend with no-significance level. On the hand, seasonal basis the show decreasing trend with non-significance. In Ujjain district on annual basis rainfall trend result show the increasing trend (Z= 0.11) with non-significance. On the other hand, seasonal basis the month of August shows the decreasing trend (Z= 2.36 and Q 3.492) with 0.10 % level of confidence . in Shajapur district on annual basis rainfall trend result show incrasing trend (0.57) with non-significance level. On the other hand, seasonal basis of Winter, South-West and North-East monsoon increasing trend (Z= 0.37 to 1.04) with non-significance level. in Neemuch district on annual basis rainfall trend result show increasing trend (Z 1.03 and Q 3.488) with non-significance. On the other hand, seasonal basis increasing trend all seasonal winter, summer, South-West, and North-East monsoon (Z 0.86 to 1.40, Q 0.067 to 3.086) with non- significance in Ratalm district on annual basis rainfall trend result show decreasing trend (Z 0.84) with non-significance and Q 3.525 decades wise increase trend. On the other hand, seasonal basis winter , Sout-West and North-East monsoon increasing trend in (Z 0.09 to 0.95) and Q- 0.8 to

2.98 with non-significance. . in Mandsour district on annual basis rainfall trend result show increasing trend (0.82) with non-significance. On the other hand, seasonal basis of rainfall trend winter (Z1.23), summer (Z= 0.46), South-West (0.86) and North-East (0.91) increasing trend with non-significance trend. in Rajgarh district on annual basis rainfall trend result show increasing trend (Z= 0.93 & Q = 5.658) with non-significance trend. On the other hand, seasonal basis of rainfall trend winter, summer, South-West and North-East monsoon was increasing trend (0.04 to 1.25) with non-significance

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Table no. 2: Values of Descriptive statistics, autocorrelation, Mann-Kendall Test and Sen's slope estimate of the rainfall series in different district of Malwa agroclimatic zone.

2a. District Indore

Time Series	Min	Max	Mean	% Contribution	SD	CV	skewness	Kurtosis	Auto Correlation Lag-1	Mann - Kendall Test	Sen's slope estimate
										Test Z	Q
Jan.	0.00	60.60	8.09	0.80	16.03	198.12	2.39	5.20	0.287	-1.24	0.000
Feb.	0.00	57.80	5.75	0.57	13.40	233.11	2.93	8.68	0.059	-0.38	0.000
Mar.	0.00	39.20	2.73	0.27	7.34	268.74	4.53	22.54	0.033	-0.56	0.000
Apr.	0.00	30.40	2.00	0.20	5.82	290.82	4.35	20.81	0.069	-1.04	0.000
May.	0.00	83.70	16.13	1.60	20.49	127.02	1.57	2.63	-0.116	0.13	0.000
Jun.	11.00	372.45	156.31	15.53	88.45	56.58	0.65	0.17	-0.298	0.11	0.300
Jul.	49.20	676.90	318.71	31.66	160.41	50.33	0.39	-0.59	0.282	0.29	0.916
Aug.	91.10	772.00	283.21	28.13	153.15	54.08	1.30	2.27	0.095	1.57	4.645
Sep.	7.70	398.00	170.24	16.91	100.38	58.97	0.46	-0.06	0.015	0.46	1.305
Oct.	0.00	164.10	30.63	3.04	37.92	123.81	1.90	4.30	-0.174	-0.72	-0.175
Nov.	0.00	124.00	10.47	1.04	29.07	277.70	3.29	10.36	0.414	-1.27	0.000
Dec.	0.00	34.20	2.48	0.25	6.93	279.04	3.75	15.68	-0.048	0.94	0.000
Annual Rainfall (mm)	487.70	1656.14	1006.76	100.00	298.57	29.66	0.52	-0.07	0.077	1.21	7.862
Winter (Jan-Feb)	0.00	97.20	13.84	1.37	22.88	165.37	2.32	5.70	0.313	-0.98	0.000
Summer (Mar-May)	0.00	83.70	20.87	2.07	22.74	108.96	1.53	2.09	0.137	0.57	0.130
South West (Jun-Sep)	435.30	1560.30	928.47	92.22	283.61	30.55	0.60	-0.04	0.103	1.07	7.591
North East (Oct-Dec)	0.00	223.00	43.58	4.33	52.09	119.52	1.91	4.24	0.039	-0.73	-0.223

*** 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

2b. District Dewas

Time Series	**Min**	**Max**	**Mean**	**Contribution %**	**SD**	**CV**	**skewness**	**Kurtosis**	**Auto Correlation Lag-1**	**Mann-Kendall Test**	**Sen's slope estimate**
										Test Z	**Test Z**
Jan.	0.00	50.60	6.20	0.61	11.00	177.43	2.78	8.78	-0.162	-0.24	0.000
Feb.	0.00	32.70	4.95	0.49	8.08	163.16	2.39	5.91	0.086	0.22	0.000
Mar.	0.00	23.80	3.53	0.35	5.32	150.58	2.24	6.24	0.148	-1.18	-0.022
Apr.	0.00	10.30	1.38	0.14	2.42	175.35	2.65	7.30	0.043	-0.36	0.000
May.	0.00	38.60	6.68	0.66	9.32	139.53	2.53	6.51	0.036	0.54	0.058
Jun.	36.30	299.30	125.93	12.40	64.58	51.28	0.63	0.44	0.137	1.64	2.567
Jul.	139.10	762.10	297.02	29.24	136.68	46.02	2.02	5.03	-0.358	-1.43	-3.011
Aug.	140.10	734.30	375.63	36.98	118.90	31.65	0.67	2.02	0.182	0.43	1.468
Sep.	16.20	357.10	147.18	14.49	98.74	67.09	0.44	-0.96		-1.93+	-3.895
Oct.	0.00	107.10	20.92	2.06	28.32	135.36	1.96	3.53	0.037	1.71+	0.415
Nov.	0.00	114.50	15.98	1.57	27.80	173.92	2.17	4.79	0.011	-0.41	0.000
Dec.	0.00	108.80	10.45	1.03	21.30	203.88	3.70	16.15	-0.103	-0.47	0.000
Annual Rainfall (mm)	601.60	1801.00	1015.86	100.00	218.19	21.48	1.41	4.81	-0.143	-0.07	-0.189
Winter (Jan-Feb)	0.00	55.70	11.15	1.10	15.51	139.07	1.74	2.35	-0.105	0.00	0.000
Summer (Mar-May)	0.00	40.50	11.59	1.14	11.52	99.40	1.31	0.86	0.009	-0.43	-0.078
South West (Jun-Sep)	573.90	1743.20	945.76	93.10	222.94	23.57	1.45	4.46	-0.118	0.00	0.033
North East (Oct-Dec)	1.70	124.10	47.35	4.66	35.12	74.17	0.56	-0.57	-0.176	0.04	0.018

*** 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

2c. District Mandsaur

Time Series	Min	Max	Mean	Contribution %	SD	CV	skewness	Kurtosis	Auto Correlation Lag-1	Mann-Kendall Test	Sen's slope estimat
										Test Z	Test Z
Jan.	0.00	19.50	3.34	0.41	5.09	152.51	1.83	2.73	-0.072	1.01	0.013
Feb.	0.00	17.20	2.36	0.29	4.37	185.42	2.31	5.18	0.018	0.37	0.000
Mar.	0.00	77.40	3.67	0.45	14.04	382.99	5.34	28.91	-0.024	-0.42	0.000
Apr.	0.00	18.80	2.51	0.30	5.30	211.45	2.25	3.96	0.103	0.17	0.000
May.	0.00	31.50	6.77	0.82	7.66	113.15	1.64	2.71	-0.21	0.00	0.000
Jun.	12.70	186.00	83.16	10.10	50.25	60.42	0.36	-0.74	0.027	0.70	0.591
Jul.	76.50	655.30	244.99	29.76	128.56	52.48	1.53	2.73	-0.355	-0.61	-1.867
Aug.	103.50	603.30	316.28	38.42	110.19	34.84	0.45	0.14	0.137	2.07+	5.463
Sep.	6.50	357.90	116.53	14.15	84.87	72.83	0.92	0.70	-0.186	-1.89+	-2.973
Oct.	0.00	174.10	22.29	2.71	42.07	188.78	2.64	6.88	0.000	1.55	0.152
Nov.	0.00	137.90	17.17	2.09	37.47	218.17	2.50	5.32	0.001	0.20	0.000
Dec.	0.00	43.20	4.22	0.51	9.76	231.40	3.01	9.25	-0.143	0.00	0.000
Annual Rainfall (mm)	504.60	1398.00	823.27	100.00	199.39	24.22	0.89	1.04	-0.052	0.82	3.967
Winter (Jan-Feb)	0.00	26.90	5.70	0.69	7.38	129.64	1.63	1.93	-0.019	1.23	0.075
Summer (Mar-May)	0.10	77.70	12.94	1.57	14.94	115.42	2.99	11.92	-0.269	0.46	0.091
South West (Jun-Sep)	440.30	1367.30	760.95	92.43	200.47	26.34	1.17	1.79	-0.089	0.86	2.867
North East (Oct-Dec)	0.00	176.20	43.68	5.31	51.99	119.03	1.21	0.32	-0.107	0.91	0.455

*** 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

2d. District Neemuch

Time Series	Min	Max	Mean	Contribution %	SD	CV	Skewness	Kurtosis	Auto Correlation Lag-1	Mann-Kendall Test	Sen's slope estimate
										Test Z	Test Z
Jan.	0.00	18.70	2.49	0.32	4.36	174.89	2.49	6.44	-0.079	0.82	0.000
Feb.	0.00	17.10	2.51	0.32	4.60	183.13	2.07	3.71	0.052	0.26	0.000
Mar.	0.00	81.90	3.83	0.49	14.85	387.30	5.36	29.09	-0.022	-0.26	0.000
Apr.	0.00	21.60	2.91	0.37	6.19	212.97	2.25	3.82	0.120	1.53	0.000
May.	0.00	38.00	7.99	1.02	9.47	118.56	1.61	2.50	-0.231	0.02	0.000
Jun.	11.00	189.40	76.64	9.83	46.48	60.65	0.46	-0.31	0.048	0.87	0.788
Jul.	65.10	587.30	236.48	30.32	111.14	47.00	1.33	2.33	-0.380	-0.64	-1.300
Aug.	108.90	506.10	297.86	38.19	100.66	33.79	0.08	-0.89	0.088	1.91+	4.625
Sep.	5.60	340.50	109.23	14.00	80.86	74.03	0.94	0.78	-0.188	-1.70+	-2.821
Oct.	0.00	151.40	19.17	2.46	36.50	190.41	2.76	7.58	0.002	1.33	0.124
Nov.	0.00	142.00	17.07	2.19	39.46	231.18	2.64	6.00	-0.027	0.08	0.000
Dec.	0.00	32.70	3.86	0.49	8.52	220.84	2.62	6.01	-0.157	0.21	0.000
Annual Rainfall (mm)	516.00	1283.30	780.04	100.00	170.70	21.88	0.87	1.21	-0.071	1.03	3.488
Winter (Jan-Feb)	0.00	22.30	5.01	0.64	6.66	132.99	1.37	0.81	0.002	1.40	0.067
Summer (Mar-May)	0.20	82.10	14.73	1.89	16.51	112.11	2.55	8.85	-0.254	0.89	0.169
South West (Jun-Sep)	449.70	1259.30	720.21	92.33	171.46	23.81	1.12	2.09	-0.102	0.86	3.086
North East	0.00	154.70	40.09	5.14	49.79	124.19	1.29	0.37	-0.082	0.87	0.386

(Oct-Dec)											

*** 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

2e. District Rajgarh

Time Series	**Min**	**Max**	**Mean**	**Contribution %**	**SD**	**CV**	**Skewness**	**Kurtosis**	**Auto Correlation Lag-1**	**Mann-Kendall Test**	**Sen's slope estimate**
										Test Z	**Test Z**
Jan.	0.00	61.20	8.00	0.82	13.46	168.17	2.71	8.14	-0.033	0.20	0.009
Feb.	0.00	43.30	5.50	0.57	9.79	178.04	2.70	7.93	0.157	0.63	0.011
Mar.	0.00	43.00	3.73	0.38	8.09	217.03	4.22	20.31	0.065	-1.12	-0.025
Apr.	0.00	14.20	2.18	0.22	3.82	175.42	2.31	5.02	-0.033	-0.51	0.000
May.	0.00	33.90	6.59	0.68	7.34	111.40	2.10	5.86	-0.142	0.88	0.095
Jun.	24.10	223.30	104.59	10.75	58.53	55.96	0.43	-0.89	0.010	1.59	1.728
Jul.	111.20	714.20	291.68	29.97	146.86	50.35	1.64	3.08	-0.299	-0.61	-1.495
Aug.	120.10	625.90	371.80	38.20	132.09	35.53	0.36	-0.46	0.047	1.39	3.836
Sep.	9.90	321.40	133.50	13.72	92.42	69.23	0.54	-1.01	-0.284	-1.50	-2.300
Oct.	0.00	199.70	21.54	2.21	39.34	182.63	3.51	14.76	-0.049	1.04	0.200
Nov.	0.00	105.70	15.93	1.64	27.99	175.72	2.06	3.75	-0.094	-0.48	0.000
Dec.	0.00	88.90	8.18	0.84	17.69	216.31	3.70	15.53	-0.116	-0.07	0.000
Annual Rainfall (mm)	534.80	1624.80	973.22	100.00	234.14	24.06	0.48	0.76	-0.007	0.93	5.658
Winter (Jan-Feb)	0.00	64.10	13.50	1.39	18.42	136.39	1.69	1.79	0.043	1.02	0.067
Summer (Mar-May)	0.00	48.60	12.50	1.28	11.68	93.42	1.50	2.20	-0.199	0.04	0.014
South West	476.50	1585.9	901.57	92.64	224.19	24.87	0.66	1.86	-0.005	1.25	4.400

(Jun-Sep)		0									
North East (Oct-Dec)	0.20	199.70	45.65	4.69	43.40	95.07	1.65	4.10	-0.279	0.32	0.214

*** 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

2f. District Ratlam

Time Series	**Min**	**Max**	**Mean**	**Contribution %**	**SD**	**CV**	**skewness**	**Kurtosis**	**Auto Correlation Lag-1**	**Mann-Kendall Test**	**Sen's slope estimat**
										Test Z	**Test Z**
Jan.	0.00	23.40	3.66	0.41	5.94	162.53	2.22	4.49	-0.068	0.24	0.000
Feb.	0.00	11.30	1.79	0.20	3.20	178.69	1.89	2.51	0.236	-0.32	0.000
Mar.	0.00	58.90	2.97	0.33	10.76	362.67	5.18	27.65	0.081	-1.69+	0.000
Apr.	0.00	14.40	1.48	0.17	3.19	215.34	3.00	9.66	0.102	-0.70	0.000
May.	0.00	33.90	4.88	0.55	7.07	144.92	2.73	9.32	-0.165	-0.57	-0.022
Jun.	4.00	265.30	105.11	11.74	65.09	61.93	0.45	-0.13	0.147	0.43	0.518
Jul.	79.50	600.40	264.84	29.59	129.27	48.81	1.13	1.08	-0.348	-0.29	-0.947
Aug.	141.60	661.80	336.62	37.61	126.40	37.55	0.78	0.15	0.015	2.25+	4.477
Sep.	5.60	426.00	126.84	14.17	98.51	77.66	1.07	1.27	-0.036	-2.11+	-3.883
Oct.	0.00	139.10	23.88	2.67	37.42	156.71	2.01	3.47	0.050	1.88+	0.250
Nov.	0.00	107.30	17.78	1.99	32.28	181.54	2.07	3.34	0.064	0.19	0.000
Dec.	0.00	59.80	5.17	0.58	11.69	226.04	3.86	17.12	-0.111	-0.75	0.000
Annual Rainfall (mm)	480.40	1700.20	895.00	100.00	249.84	27.92	1.16	2.51	-0.097	0.64	3.525
Winter (Jan-Feb)	0.00	28.10	5.45	0.61	7.38	135.53	1.79	2.72	0.026	0.09	0.000
Summer	0.00	61.50	9.33	1.04	12.49	133.88	2.92	10.39	-0.152	-0.52	-0.100

(Mar-May)											
South West (Jun-Sep)	465.80	1657.00	833.40	93.12	254.61	30.55	1.19	2.41	-0.117	0.75	2.986
North East (Oct-Dec)	0.00	139.10	46.83	5.23	44.37	94.75	0.69	-0.84	-0.097	0.95	0.800

*** 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

2g. District Shajapur

Time Series	**Min**	**Max**	**Mean**	**Contribution %**	**SD**	**CV**	**Skewness**	**Kurtosis**	**Auto Correlation Lag -1**	**Mann-Kendall Test**	**Sen's slope estimate**
										Test Z	**Test Z**
Jan.	0.00	49.90	6.93	0.72	11.28	162.67	2.58	7.04	-0.063	0.50	0.020
Feb.	0.00	34.30	4.70	0.49	8.05	171.32	2.53	6.83	0.152	0.41	0.000
Mar.	0.00	46.20	3.76	0.39	8.63	229.81	4.39	21.50	0.083	-0.92	-0.031
Apr.	0.00	14.30	2.29	0.24	3.75	163.63	2.06	3.83	-0.048	0.43	0.000
May.	0.00	31.10	6.63	0.69	6.92	104.45	1.73	4.08	-0.149	0.84	0.085
Jun.	23.60	225.40	106.03	11.08	57.85	54.56	0.33	-0.91	0.030	1.36	1.517
Jul.	114.60	708.60	283.38	29.61	143.89	50.78	1.73	3.39	-0.301	-0.96	-2.141
Aug.	124.50	617.80	365.11	38.15	121.86	33.38	0.37	-0.16	0.124	1.39	3.986
Sep.	9.00	297.80	132.68	13.86	88.89	67.00	0.45	-1.16	-0.232	-1.52	-2.690
Oct.	0.00	177.40	21.67	2.26	36.64	169.13	3.01	10.99	-0.029	1.63	0.200
Nov.	0.00	108.80	16.06	1.68	27.95	174.06	2.01	3.63	-0.053	-0.13	0.000
Dec.	0.00	88.20	7.82	0.82	17.27	220.76	3.87	16.92	-0.123	-0.09	0.000
Annual Rainfall (mm)	538.30	1675.20	957.06	100.00	226.01	23.62	0.81	2.29	-0.024	0.57	3.164
Winter	0.00	54.60	11.63	1.22	15.59	134.00	1.76	2.15	0.015	1.04	0.067

(Jan-Feb)											
Summer (Mar-May)	0.00	51.60	12.67	1.32	11.57	91.27	1.60	3.24	-0.213	-0.14	-0.029
South West (Jun-Sep)	494.80	1632.20	887.21	92.70	222.36	25.06	1.06	3.26	-0.016	0.50	2.395
North East (Oct-Dec)	0.20	177.80	45.55	4.76	41.36	90.79	1.23	2.03	-0.262	0.37	0.239

*** 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

2h. District Ujjain

Time Series	**Min**	**Max**	**Mean**	**Contribution %**	**SD**	**CV**	**Skewness**	**Kurtosis**	**Auto Correlation Lag-1**	**Mann-Kendall Test**	**Sen's slope estimate**
										Test Z	**Test Z**
Jan.	0.00	36.50	5.29	0.58	8.72	164.70	2.54	6.29	-0.109	-0.18	0.000
Feb.	0.00	20.50	2.92	0.32	5.28	180.46	2.47	6.08	0.093	0.15	0.000
Mar.	0.00	46.10	3.34	0.36	8.62	258.25	4.53	22.46	0.183	-1.82+	-0.043
Apr.	0.00	11.60	1.53	0.17	2.87	187.59	2.42	5.67	-0.020	-0.43	0.000
May.	0.00	28.10	5.68	0.62	6.85	120.60	1.90	3.72	-0.192	0.18	0.013
Jun.	14.70	244.00	110.74	12.11	61.13	55.20	0.32	-0.43	0.016	0.71	0.959
Jul.	118.80	704.10	266.65	29.15	136.25	51.10	1.69	3.14	-0.347	-1.36	-2.011
Aug.	136.40	642.50	340.57	37.23	115.40	33.88	0.75	0.50	0.140	2.36*	4.492
Sep.	8.90	367.20	130.34	14.25	92.47	70.95	0.71	-0.13	-0.116	-2.18*	-3.556
Oct.	0.00	132.00	22.81	2.49	34.07	149.33	2.05	3.86	0.020	1.72+	0.250
Nov.	0.00	99.70	17.62	1.93	29.22	165.81	1.67	1.65	0.031	-0.04	0.000
Dec.	0.00	88.00	7.32	0.80	16.88	230.76	4.09	18.95	-0.115	-0.20	0.000
Annual Rainfall	489.80	1779.00	914.82	100.00	233.28	25.50	1.66	5.65	-0.142	0.11	0.692

(mm)											
Winter (Jan-Feb)	0.00	48.30	8.22	0.90	11.56	140.74	2.21	4.95	-0.030	0.14	0.006
Summer (Mar-May)	0.00	53.90	10.54	1.15	11.43	108.40	2.10	6.07	-0.164	-0.75	-0.133
South West (Jun-Sep)	473.60	1727.90	848.31	92.73	234.97	27.70	1.82	5.78	-0.122	0.00	0.060
North East (Oct-Dec)	0.70	132.00	47.75	5.22	39.67	83.08	0.45	-1.06	-0.204	0.32	0.311

*** 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