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Statistical Model for Annual Trends and Magnitude of Climatic Variability across Locations from the Malwa Plateau Agroclimatic Zone of Madhya Pradesh, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Global climate change has affected the local weather patterns in different regions, especially in India. To manage the water resources effectively, it is important to quantify the local changes in the climatic variables. One of the key variables is precipitation, which is often used as an indicator of

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climate change. This study aims to examine the temporal variability of rainfall in the Malwa Agroclimatic Zone from 1991 to 2020 (30 years) and to assess its impact on the hydrological status of the districts in this zone. The Mann-Kendall and Sen's tests are used to detect the trend and magnitude of change in the annual precipitation time series. The autocorrelation effects are removed before applying the Mann-Kendall test. The results show that on an annual basis, 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 & Q 0.5658), Ratalm (Z 0.64 & Q 3.525), Shajapur (Z = 0.57 & Q 3.164) and Ujjain (Z 0.11 & Q 0.692) have an increasing but not statistically significant trend in rainfall, while Dewas (Z -0.07 and Q -0.189) has a decreasing but not statistically significant trend in rainfall. The annual and monthly maximum temperature decreased in the Indore district, while the minimum temperature showed an increasing and decreasing trend. Dewas district also had a decreasing maximum temperature and an increasing minimum temperature. Ujjain district had a decreasing trend for maximum temperature and a significant annual increasing trend for minimum temperature. Shajapur district had a significant annual decreasing trend for maximum temperature and a significant annual and monthly (January and September) increasing trend for minimum temperature. Neemuch district had a significant annual increasing trend for both maximum and minimum temperature, as well as a significant monthly (January) increasing trend for minimum temperature. Ratlam district had a significant annual and monthly (January and September) increasing trend for minimum temperature. Mandsaur and Rajgarh districts had non-significant increasing trends for both maximum and minimum temperature, except for significant monthly (January and September) increasing trends.

Keywords: Rainfall analysis; non-parametric tests; trend analysis; autocorrelation; Mann-Kendall and Sen's tests.

1. INTRODUCTION

Climate change has significant impacts on the global hydrological cycle, altering the characteristics and variability of precipitation events. This has profound implications for the availability and quality of water resources, agricultural productivity, food security, and human health. For example, climate change can increase the risk of droughts and floods in different regions, affecting crop yields, irrigation systems, water supply, sanitation, and disaster management. Therefore, it is essential to understand how precipitation patterns are changing under different scenarios of greenhouse gas emissions and global warming, and how this affects different sectors and regions. The manuscript's objective is aligned with the current state of scientific knowledge and policy relevance, as reflected by the recent publications of the IPCC Sixth Assessment Report and the World Meteorological Organization's Statement on the State of the Global Climate in 2022, which both highlight the importance of studying the effects of climate change on precipitation. The occurrence of extreme weather events like droughts, cyclones, high-intensity precipitation, cold day & cold nights, and warm days & warm nights, etc. has changed a lot during past decades throughout India [1]. As the patterns of these extremes are highly variable over space and time, the study of the extremes at a local scale using the information stored in the historical climate datasets may provide crucial information in this regard. Goswami *et al.* [2] have reported an increase in the rainfall extremes (both > 100 and >150 mm/day) and a decrease in the moderate rainfall events during the monsoon season over central India. Rainfall trend analysis studies have been carried out by many researchers worldwide and in India (Gao *et al*., 2019).

Trend analysis in the Sabarmati basin showed statistically significant decreasing trends for annual, winter, pre-monsoon, and monsoon rainfall [3]. The trend analyses were done by a) using the Mann-Kendall test for trend significance [4] using Sen's slope estimator for trend magnitude estimation [5] using innovative trend analysis for aiding the results of trend analyses [4] using the Sequential Mann-Kendall test for start and end of trend detection [6] and e) also using linear regression method to identify the trend in rainfall data [7]. A rainy day receiving more than 2.5 mm of rainfall in a day is used for calculation.

Gajbhiye *et al*. [8] 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 [9] 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.*[10] 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 [11].

In Madhya Pradesh, agriculture supports nearly 70 percent of the rural population. With 72 percent area under rainfed cultivation and a predominance of smallholders with low adaptive capacity, the agriculture sector is highly vulnerable to climatic change. Though 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 a 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 permit the farmers of the state to cultivate several crops like cereals, pulses, oilseeds, commercial crops, and horticulture crops across different seasons of the year. During 2021-22, MP recorded an area of 15.01 million hectares, 11.57 % to All India, production of 32.84 million tonnes contribution to All India 10.57 per cent (Agriculture Statistics Glance 2022). are the effects

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 an average rainfall of 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).

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 (3) To estimate the maximum & minimum temperature anomaly.

2. MATERIALS AND METHODS

Data collection: The Monthly precipitation data was downloaded from 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) from 1991 to 2020 for the period. IMD has defined 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.

Trend Analysis: As a first step of the analysis, basic statistical parameters like minimum, maximum, and average 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 the case of uncorrelated data.

Table 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

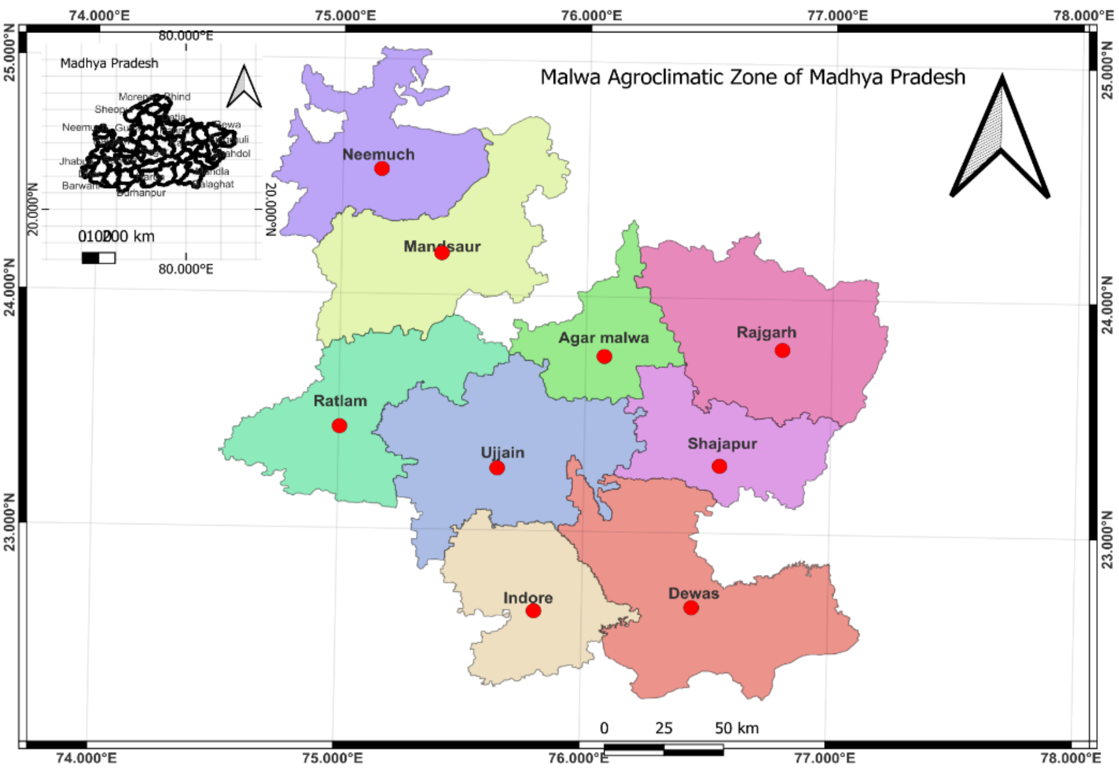

Fig. 1. Study area on the map

Autocorrelation: Lag-1 autocorrelation is used to check serial dependence between the data. The lag-1 autocorrelation [12] 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 lies 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 [13, 14] 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 tests are thought to be more 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 are given by

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

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

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

The Mann-Kendall test has two parameters that are of importance to 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;

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

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

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

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

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

Z_s follows the standard normal distribution.

SEN'S Slope Estimator: The magnitude of trend slopes can be also calculated [5]. 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 values 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

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

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

3. RESULTS AND DISCUSSION

The present study examines the trend of rainfall in the Malwa Agroclimatic zone from 1991 to 2020 (30 years). It uses Mann-Kendall and Sen's Slope Estimator methods to detect the changes in rainfall patterns and minimum & maximum temperatures.

3.1 Variability of Rainfall (mm) District-wise:

Indore: - The annual rainfall in the Indore district is 1006.76 mm, of which 92.22 per cent is contributed by the southwest monsoon (Table 2). The autocorrelation lag-1 of the annual rainfall is 0.077. The Mann-Kendall test and Sen's slope estimator show that the annual rainfall has an increasing but not statistically significant trend, with Z statistics of 1.21 and Q statistics of 7.86. On a seasonal basis, only the southwest monsoon has an increasing but not statistically significant trend, with Z statistics of 1.07 and Q statistics of 7.591 (Table No.2a). The other seasons (summer, northeast, and winter) have decreased but not statistically significant trends. Every month, the months of May, June, July, August, September and December have increasing but not statistically significant trends, with Z statistics ranging from 0.13 to 0.94 and Q statistics of 7.862. The months of January, February, March, April, and November have decreased but not statistically significant trends, with Z statistics ranging from -1.24 to -1.27.

Dewas: The annual rainfall data for the Dewas district is presented in (Table 3). The average annual rainfall (mm) was 1015, with 93.10 per cent of it coming from the southwest monsoon. The annual rainfall (mm) had a positive skewness of 1.141 and a positive kurtosis of 4.81. The autocorrelation lag-1 was negative (-0.143), indicating no significant temporal dependence. The Mann-Kendall test showed an increasing trend in annual rainfall, but it was not statistically significant. The seasonal rainfall trends were also not significant, except for October, which had a positive and significant trend (1.71) at a 0.1% level of confidence, with a Sen's slope estimator of 0.145. The month of September had a negative and significant trend (-1.71) at the same level of confidence, with a Sen's slope estimator of -3.895. The other months and seasons showed no significant trends in rainfall.

Ujjain: The annual average rainfall in Ujjain district was 914.82 mm, as shown in (Table 4). The rainfall trend analysis on an annual basis showed an increasing trend (0.11) with a non-significant level. On a seasonal basis, the southwest monsoon series showed an increasing trend (0.25) according to the Mann-Kendall test and Sen's slope estimate. The month-wise rainfall analysis revealed that August had an increasing trend (Z = 2.36 and Q = 4.492) with a significance level of 0.05, and October had an increasing trend (Z = 1.72 and Q = 0.250) with a significance level of 0.1. On the other hand, September had a decreasing trend (Z = -2.18 and Q = -3.556) with a significance level of 0.05, and March had a decreasing trend (Z = -1.82 and Q = -0.43) with a significance level of 0.9. The rest of the months showed either increasing or decreasing trends without any significance level.

Shajapur: The annual rainfall (mm) in Shajapur district (Table 5) was 957.06 mm, with a maximum of 1675.20 mm and a minimum of 538.30 mm. The autocorrelation lag-1 of the rainfall trend showed a decreasing trend (-0.024) with a non-significant level. The Mann–Kendall test and Sen's slope estimator showed a decreasing trend (Z = -0.14) with a non-significant level for the summer and monsoon seasons, and a slight increasing trend (1.04) with a non-significant level for the winter season. Every month, the rainfall trend was decreasing for March, July, September, November, and December, and increasing for January, February, April, May, June, and October.

Neemuch:- According to the Mann-Kendall Test and Sen’s Slope estimator results for the Neemuch district (Table 6), the annual rainfall trend shows a non-significant increase (Z= 1.03 & Q= 4.625). Similarly, the seasonal rainfall trends for Winter, Summer, South-West, and North-East monsoon are also non-significantly increasing. However, the monthly rainfall trend for August shows a significant increase at 0.1 % level (Z= 1.91, Q= 4.625), while the monthly rainfall trend for September shows a significant decrease at 0.1 % level (Z= -1.70 & Q= -2.821).

Ratlam: The annual average rainfall in Ratlam district was 895 mm, with a minimum of 480 mm and a maximum of 1700 mm (Table 7). The rainfall distribution was positively skewed (1.16) and leptokurtic (2.51). The autocorrelation lag-1 was -0.097, indicating a decreasing trend per year. However, the Mann-Kendall test and Sen's slope estimate showed an increasing trend (Z= 0.64 & Q = 3.525) on an annual basis, but it was not statistically significant. The same trend was observed for the decade-wise analysis (Q= 3.525). On a seasonal basis, the monsoon rainfall showed an increasing trend (Z-0.23 and Q- 0.039), but it was also not significant. The winter, southwest, and northeast seasons also had increasing trends, but none of them were significant. Every month, only June (Z= 2.25 & Q= 0.25) and October (Z= 1.88 & Q= 0.250) had significant increasing trends at 0.1% level. March and August had significant decreasing trends at 0.1% level with Z statistics of - 1.69 and -2.11, respectively.

Mandsaur:-in Mandsour district (Table 8) results show average annual rainfall (mm) of 823.27 mm (30 years average) the skewness 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 an annual basis rainfall trend results show an increasing trend with non-significance. On the other hand, the 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 the non-significance trend. Every month August (Z = 2.07 & Q= 5.403) increasing trend with a 0.1 % level of significance trend. Month of September (Z -1.59 & Q -2.073) decreasing trend with a 0.1 % level of significance trend.

Rajgarh:- According to the Mann-Kendall test and Sen's slope estimator, the annual rainfall trend in Rajgarh district (Table 9) shows a non-significant increase (Z = 0.93 and Q = 5.658). The same is true for the seasonal rainfall trends of Winter, Summer, South-West, and North-East monsoon, which also show a non-significant increase (Z = 0.32 to 1.25 and Q = 0.067 to 4.40). The monthly rainfall trends reveal that January, February, May, June, August, and October have a non-significant increasing trend (Z = 0.20 to 1.59), while March, April, July, November, and December have a non-significant decreasing trend.

3.2 Variability of Maximum & Minimum Temperature

The temperature data (maximum and minimum) for the annual, monthly, and seasonal periods show significant trends. Tables 2-9 shows the Mann-Kendall test value and the Theli-Sen slope for the maximum temperature.

Indore - The maximum temperature in the Indore district shows a statistically significant decreasing trend in December (-2.37) at the 0.001% level, with a slope of -0.086 per year. The maximum temperature also shows significant decreasing trends in January (-1.93), July (-1.75), and August (-2.00) at the 0.1% level, with slopes of -0.077, -0.067, and -0.05 per month, respectively. The seasonal analysis shows that the South-West monsoon (Z -2.25) and the North-East monsoon (Z -2.14) have significant decreasing trends in the maximum temperature, with slopes of -0.045 and -0.051 per month, respectively. The minimum annual temperature shows an increasing but non-significant trend (Z 0.46) with a slope of 0.010 ^{o}C per month. The monthly analysis shows that May, June, July, September, October, and December have increasing but non-significant trends in the minimum temperature. The other months (January, February, March, April, August, and November) have decreasing trends in the minimum temperature. The seasonal analysis also shows an increasing but non-significant trend in the minimum temperature.

Dewas: There is a clear annual pattern in the maximum temperature of the Dewas district, as the trend test shows a negative but insignificant result (Z = -0.96) and a small downward slope (Q = -0.013 per year) (Table 3). The monthly analysis reveals that only January (Z = -1.65, Q = -0.02 per month) and April (Z = -1.72, Q = -0.018 per month) have a significant downward trend in the maximum temperature. The rest of the months have a slight or downward trend, with Z values between -0.05 to -1.43 and Q values between -0.02 and 0.01. The seasonal analysis indicates that the winter (January to February) and the monsoon (June to September) seasons have a notable downward trend at a 0.1% significance level (Z = -1.73), while the other seasons have a negligible or no downward trend, with Z values between -1.16 and -0.43. The minimum temperature has an annual upward trend that is not significant (Z = 0.62, Q = 0.008). All the months have an upward trend in the minimum temperature, with Z values between 0.05 and 1.40 and Q values between 0.006 and 0.017. The seasonal analysis shows that the South-West monsoon season has an upward trend (Z = 1.04, Q = 0.011), while the other seasons have a slight or no upward trend, with Z values between 0.068 and 0.68.

Table 2. Values of Autocorrelation, Mann-Kendall Test, Sen's slope estimate of the rainfall (mm), maximum & minimum temperature (^{o}C) series in Indore district of Malwa agroclimatic zone

Time Series	Rainfall (mm)						Temperature (^{o}C)			
							Maximum		Minimum	
	Min	Max	Mean	Auto Correlation Lag-1	Mann-Kendall Test	Sen's slope estimate	Mann-Kendall Test	Sen's slope estimate	Mann-Kendall Test	Sen's slope estimate
					Test Z	Q	Test Z	Q	Test Z	Q
January	0.00	60.60	8.09	0.287	-1.24	0.000	**-1.93+**	-0.077	-0.88	-0.030
February	0.00	57.80	5.75	0.059	-0.38	0.000	-0.36	-0.011	-0.14	0.000
March	0.00	39.20	2.73	0.033	-0.56	0.000	-1.38	-0.053	-0.70	-0.025
April	0.00	30.40	2.00	0.069	-1.04	0.000	-0.39	-0.014	-0.04	0.000
May	0.00	83.70	16.13	-0.116	0.13	0.000	-1.00	-0.037	1.61	0.059
June	11.00	372.45	156.31	-0.298	0.11	0.300	-0.73	-0.035	0.91	0.029
July	49.20	676.90	318.71	0.282	0.29	0.916	**-1.75+**	-0.067	0.48	0.008
August	91.10	772.00	283.21	0.095	1.57	4.645	**-2.00***	-0.050	-0.39	-0.005
September	7.70	398.00	170.24	0.015	0.46	1.305	-1.04	-0.022	1.36	0.030
October	0.00	164.10	30.63	-0.174	-0.72	-0.175	-0.48	-0.021	1.02	0.040
November	0.00	124.00	10.47	0.414	-1.27	0.000	-0.80	-0.025	-0.77	-0.027
December	0.00	34.20	2.48	-0.048	0.94	0.000	**-2.73****	-0.086	0.00	0.000
Annual	487.70	1656.14	1006.76	0.077	1.21	7.862	-2.59	-0.044	0.46	0.010
Winter (Jan-Feb)	0.00	97.20	13.84	0.313	-0.98	0.000	-1.43	-0.043	-0.41	-0.019
Summer (Mar-May)	0.00	83.70	20.87	0.137	0.57	0.130	-1.20	-0.031	0.14	0.003
South West (Jun-Sep)	435.30	1560.30	928.47	0.103	1.07	7.591	**-2.25***	-0.045	0.54	0.007
North East (Oct-Dec)	0.00	223.00	43.58	0.039	-0.73	-0.223	**-2.14***	-0.051	0.50	0.013

**** 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*

Table 3. Values of Autocorrelation, Mann-Kendall Test, Sen's slope estimate of the rainfall (mm), maximum & minimum temperature (^oC) series in Dewas district of Malwa agroclimatic zone

Time Series	Rainfall (mm)						Temperature (^oC)			
							Maximum		Minimum	
	Min	Max	Mean	Auto Correlation Lag-1	Mann-Kendall Test	Sen's slope estimate	Mann-Kendall Test	Sen's slope estimate	Mann-Kendall Test	Sen's slope estimate
					Test Z	Q	Test Z	Q	Test Z	Q
January	0.00	50.60	6.20	-0.162	-0.24	0.000	**-1.65+**	-0.020	-0.47	0.000
February	0.00	32.70	4.95	0.086	0.22	0.000	-1.43	-0.020	0.45	0.006
March	0.00	23.80	3.53	0.148	-1.18	-0.022	-1.61	-0.023	0.05	0.000
April	0.00	10.30	1.38	0.043	-0.36	0.000	**-1.72+**	-0.018	0.88	0.011
May	0.00	38.60	6.68	0.036	0.54	0.058	-0.57	-0.006	0.93	0.014
June	36.30	299.30	125.93	0.137	1.64	2.567	-0.05	0.000	0.30	0.000
July	139.10	762.10	297.02	-0.358	-1.43	-3.011	-0.07	0.000	0.97	0.011
August	140.10	734.30	375.63	0.182	0.43	1.468	-0.59	-0.006	1.40	0.017
September	16.20	357.10	147.18		-1.93+	-3.895	-0.63	-0.011	0.95	0.012
October	0.00	107.10	20.92	0.037	1.71+	0.415	-0.88	-0.013	0.75	0.011
November	0.00	114.50	15.98	0.011	-0.41	0.000	-1.02	-0.017	0.48	0.008
December	0.00	108.80	10.45	-0.103	-0.47	0.000	-0.47	-0.009	0.70	0.008
Annual	601.60	1801.00	1015.86	-0.143	-0.07	-0.189	-0.96	-0.013	0.62	0.008
Winter (Jan-Feb)	0.00	55.70	11.15	-0.105	0.00	0.000	**-1.73+**	-0.020	0.00	0.000
Summer (Mar-May)	0.00	40.50	11.59	0.009	-0.43	-0.078	-1.16	-0.015	0.68	0.007
South West (Jun-Sep)	573.90	1743.20	945.76	-0.118	0.00	0.033	-0.43	-0.006	1.04	0.011
North East (Oct-Dec)	1.70	124.10	47.35	-0.176	0.04	0.018	-1.04	-0.015	0.62	0.009

**** 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*

Table 4. Values of Autocorrelation, Mann-Kendall Test, Sen's slope estimate of the rainfall (mm), maximum & minimum temperature (^oC) series in Ujjain district of Malwa agroclimatic zone

Time Series	Rainfall (mm)						Temperature (^oC)			
							Maximum		Minimum	
	Min	Max	Mean	Auto Correlation Lag-1	Mann-Kendall Test	Sen's slope estimate	Mann-Kendall Test	Sen's slope estimate	Mann-Kendall Test	Sen's slope estimate
					Test Z	Q	Test Z	Q	Test Z	Q
January	0.00	36.50	5.29	-0.109	-0.18	0.000	**-1.68+**	-0.024	**2.04***	0.060
February	0.00	20.50	2.92	0.093	0.15	0.000	**-1.66+**	-0.023	0.57	0.010
March	0.00	46.10	3.34	0.183	-1.82+	-0.043	-1.38	-0.020	0.97	0.017
April	0.00	11.60	1.53	-0.020	-0.43	0.000	-1.29	-0.013	0.00	0.000
May	0.00	28.10	5.68	-0.192	0.18	0.013	-0.45	-0.005	1.43	0.029
June	14.70	244.00	110.74	0.016	0.71	0.959	-0.09	0.000	0.56	0.009
July	118.80	704.10	266.65	-0.347	-1.36	-2.011	0.07	0.000	1.05	0.007
August	136.40	642.50	340.57	0.140	2.36*	4.492	-0.43	0.000	0.75	0.007
September	8.90	367.20	130.34	-0.116	-2.18*	-3.556	-0.74	-0.009	**1.82+**	0.022
October	0.00	132.00	22.81	0.020	1.72+	0.250	-0.90	-0.010	0.38	0.005
November	0.00	99.70	17.62	0.031	-0.04	0.000	-0.72	-0.010	0.20	0.008
December	0.00	88.00	7.32	-0.115	-0.20	0.000	-0.48	-0.008	0.14	0.004
Annual	489.80	1779.00	914.82	-0.142	0.11	0.692	-0.96	-0.009	**1.78+**	0.017
Winter (Jan-Feb)	0.00	48.30	8.22	-0.030	0.14	0.006	**-1.73+**	-0.020	1.59	0.033
Summer (Mar-May)	0.00	53.90	10.54	-0.164	-0.75	-0.133	-1.14	-0.014	1.05	0.018
South West (Jun-Sep)	473.60	1727.90	848.31	-0.122	0.00	0.060	-0.21	-0.002	1.29	0.009
North East (Oct-Dec)	0.70	132.00	47.75	-0.204	0.32	0.311	-0.79	-0.010	0.27	0.008

**** 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*

Table 5. Values of Autocorrelation, Mann-Kendall Test, Sen's slope estimate of the rainfall (mm), maximum & minimum temperature (^oC) series in Shajapur district of Malwa agroclimatic zone

Time Series	Rainfall (mm)						Temperature (^oC)			
							Maximum		Minimum	
	Min	Max	Mean	Auto Correlation Lag-1	Mann-Kendall Test	Sen's slope estimate	Mann-Kendall Test	Sen's slope estimate	Mann-Kendall Test	Sen's slope estimate
					Test Z	Q	Test Z	Q	Test Z	Q
January	0.00	49.90	6.93	-0.063	0.50	0.020	-0.73	-0.013	**2.18***	0.064
February	0.00	34.30	4.70	0.152	0.41	0.000	-1.13	-0.042	0.84	0.020
March	0.00	46.20	3.76	0.083	-0.92	-0.031	-0.34	-0.009	1.07	0.024
April	0.00	14.30	2.29	-0.048	0.43	0.000	0.00	0.000	0.55	0.013
May	0.00	31.10	6.63	-0.149	0.84	0.085	0.54	0.017	1.25	0.034
June	23.60	225.40	106.03	0.030	1.36	1.517	-0.34	-0.010	0.25	0.004
July	114.60	708.60	283.38	-0.301	-0.96	-2.141	-0.45	-0.008	1.13	0.011
August	124.50	617.80	365.11	0.124	1.39	3.986	0.05	0.000	0.72	0.006
September	9.00	297.80	132.68	-0.232	-1.52	-2.690	1.57	0.044	**1.83+**	0.023
October	0.00	177.40	21.67	-0.029	1.63	0.200	0.11	0.000	0.64	0.012
November	0.00	108.80	16.06	-0.053	-0.13	0.000	-0.73	-0.017	0.39	0.019
December	0.00	88.20	7.82	-0.123	-0.09	0.000	-0.09	0.000	0.66	0.017
Annual	538.30	1675.20	957.06	-0.024	0.57	3.164	-0.16	-0.001	**1.84+**	0.020
Winter (Jan-Feb)	0.00	54.60	11.63	0.015	1.04	0.067	-0.93	-0.025	**1.91+**	0.041
Summer (Mar-May)	0.00	51.60	12.67	-0.213	-0.14	-0.029	0.57	0.007	1.30	0.022
South West (Jun-Sep)	494.80	1632.20	887.21	-0.016	0.50	2.395	0.37	0.007	1.30	0.010
North East (Oct-Dec)	0.20	177.80	45.55	-0.262	0.37	0.239	-0.32	-0.008	0.66	0.017

**** 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*

Table 6. Values of Autocorrelation, Mann-Kendall Test, Sen's slope estimate of the rainfall (mm), maximum & minimum temperature (^oC) series in Neemuch district of Malwa agroclimatic zone

Time Series	Rainfall (mm)						Temperature (^oC)			
							Maximum		Minimum	
	Min	Max	Mean	Auto Correlation Lag-1	Mann-Kendall Test	Sen's slope estimate	Mann-Kendall Test	Sen's slope estimate	Mann-Kendall Test	Sen's slope estimate
					Test Z	Q	Test Z	Q	Test Z	Q
January	0.00	18.70	2.49	-0.079	0.82	0.000	-0.59	-0.014	**2.07***	0.055
February	0.00	17.10	2.51	0.052	0.26	0.000	-0.77	-0.036	0.07	0.000
March	0.00	81.90	3.83	-0.022	-0.26	0.000	-0.39	-0.010	1.07	0.026
April	0.00	21.60	2.91	0.120	1.53	0.000	0.11	0.000	0.07	0.000
May	0.00	38.00	7.99	-0.231	0.02	0.000	0.82	0.023	1.32	0.036
June	11.00	189.40	76.64	0.048	0.87	0.788	0.68	0.012	1.08	0.017
July	65.10	587.30	236.48	-0.380	-0.64	-1.300	-0.59	-0.012	0.99	0.011
August	108.90	506.10	297.86	0.088	**1.91+**	4.625	0.21	0.000	0.99	0.008
September	5.60	340.50	109.23	-0.188	**-1.70+**	-2.821	1.59	0.057	1.61	0.023
October	0.00	151.40	19.17	0.002	1.33	0.124	0.34	0.010	0.34	0.006
November	0.00	142.00	17.07	-0.027	0.08	0.000	-0.47	-0.008	0.00	0.000
December	0.00	32.70	3.86	-0.157	0.21	0.000	-0.36	-0.008	0.99	0.013
Annual	**516.00**	**1283.30**	**780.04**	**-0.071**	**1.03**	**3.488**	**0.18**	**0.002**	**1.62**	**0.017**
Winter (Jan-Feb)	0.00	22.30	5.01	0.002	1.40	0.067	-0.80	-0.025	1.55	0.025
Summer (Mar-May)	0.20	82.10	14.73	-0.254	0.89	0.169	0.52	0.008	1.13	0.022
South West (Jun-Sep)	449.70	1259.30	720.21	-0.102	0.86	3.086	0.55	0.015	1.59	0.015
North East (Oct-Dec)	0.00	154.70	40.09	-0.082	0.87	0.386	-0.20	-0.003	0.39	0.009

**** 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*

Table 7. Values of Autocorrelation, Mann-Kendall Test, Sen's slope estimate of the rainfall (mm), maximum & minimum temperature (°C) series in Ratlam district of Malwa agroclimatic zone

Time Series	Rainfall (mm)						Temperature (°C)			
							Maximum		Minimum	
	Min	Max	Mean	Auto Correlation Lag-1	Mann-Kendall Test Test Z	Sen's slope estimate Q	Mann-Kendall Test Test Z	Sen's slope estimate Q	Mann-Kendall Test Test Z	Sen's slope estimate Q
January	0.00	23.40	3.66	-0.068	0.24	0.000	-0.48	-0.010	**1.86+**	0.054
February	0.00	11.30	1.79	0.236	-0.32	0.000	-1.18	-0.039	0.34	0.009
March	0.00	58.90	2.97	0.081	**-1.69+**	0.000	-0.23	-0.008	0.82	0.017
April	0.00	14.40	1.48	0.102	-0.70	0.000	0.09	0.000	-0.16	0.000
May	0.00	33.90	4.88	-0.165	-0.57	-0.022	0.79	0.017	1.45	0.029
June	4.00	265.30	105.11	0.147	0.43	0.518	0.09	0.000	0.72	0.014
July	79.50	600.40	264.84	-0.348	-0.29	-0.947	-0.64	-0.015	1.42	0.012
August	141.60	661.80	336.62	0.015	**2.25+**	4.477	-0.09	0.000	0.79	0.006
September	5.60	426.00	126.84	-0.036	**-2.11+**	-3.883	**1.77+**	0.050	**1.92+**	0.026
October	0.00	139.10	23.88	0.050	**1.88+**	0.250	0.21	0.008	0.04	0.000
November	0.00	107.30	17.78	0.064	0.19	0.000	-0.73	-0.021	0.07	0.004
December	0.00	59.80	5.17	-0.111	-0.75	0.000	-0.41	-0.006	-0.04	0.000
Annual	480.40	1700.20	895.00	-0.097	0.64	3.525	0.00	0.000	**1.68+**	0.014
Winter (Jan-Feb)	0.00	28.10	5.45	0.026	0.09	0.000	-1.02	-0.025	1.45	0.023
Summer (Mar-May)	0.00	61.50	9.33	-0.152	-0.52	-0.100	0.48	0.013	0.95	0.015
South West (Jun-Sep)	465.80	1657.00	833.40	-0.117	0.75	2.986	0.55	0.012	1.50	0.014
North East (Oct-Dec)	0.00	139.10	46.83	-0.097	0.95	0.800	-0.30	-0.005	0.11	0.006

**** 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*

Table 8. Values of Autocorrelation, Mann-Kendall Test, Sen's slope estimate of the rainfall (mm), maximum & minimum temperature (^oC) series in Mandsaur district of Malwa agroclimatic zone

Time Series	Rainfall (mm)						Temperature (^oC)			
							Maximum		Minimum	
	Min	Max	Mean	Auto Correlation Lag-1	Mann-Kendall Test Test Z	Sen's slope estimate Q	Mann-Kendall Test Test Z	Sen's slope estimate Q	Mann-Kendall Test Test Z	Sen's slope estimate Q
January	0.00	19.50	3.34	-0.072	1.01	0.013	-0.66	-0.014	**2.04***	0.058
February	0.00	17.20	2.36	0.018	0.37	0.000	-0.95	-0.033	0.21	0.006
March	0.00	77.40	3.67	-0.024	-0.42	0.000	-0.21	-0.009	1.00	0.020
April	0.00	18.80	2.51	0.103	0.17	0.000	0.18	0.004	0.00	0.000
May	0.00	31.50	6.77	-0.21	0.00	0.000	0.79	0.017	1.36	0.033
June	12.70	186.00	83.16	0.027	0.70	0.591	0.48	0.009	1.16	0.015
July	76.50	655.30	244.99	-0.355	-0.61	-1.867	-0.52	-0.014	1.10	0.009
August	103.50	603.30	316.28	0.137	2.07+	5.463	0.14	0.000	1.00	0.009
September	6.50	357.90	116.53	-0.186	-1.89+	-2.973	**1.73+**	0.056	**2.08***	0.031
October	0.00	174.10	22.29	0.000	1.55	0.152	0.27	0.010	0.39	0.008
November	0.00	137.90	17.17	0.001	0.20	0.000	-0.64	-0.017	0.11	0.008
December	0.00	43.20	4.22	-0.143	0.00	0.000	-0.47	-0.007	0.18	0.000
Annual	504.60	1398.00	823.27	-0.052	0.82	3.967	0.07	0.001	1.53	0.018
Winter (Jan-Feb)	0.00	26.90	5.70	-0.019	1.23	0.075	-0.87	-0.025	1.61	0.025
Summer (Mar-May)	0.10	77.70	12.94	-0.269	0.46	0.091	0.68	0.011	1.09	0.017
South West (Jun-Sep)	440.30	1367.30	760.95	-0.089	0.86	2.867	0.61	0.014	1.55	0.015
North East (Oct-Dec)	0.00	176.20	43.68	-0.107	0.91	0.455	-0.39	-0.010	0.36	0.013

**** 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*

Table 9. Values of Autocorrelation, Mann-Kendall Test, Sen's slope estimate of the rainfall (mm), maximum & minimum temperature (°C) series in Rajgarh district of Malwa agroclimatic zone

Time Series	Rainfall (mm)						Temperature (°C)			
							Maximum		Minimum	
	Min	Max	Mean	Auto Correlation Lag-1	Mann-Kendall Test	Sen's slope estimate	Mann-Kendall Test	Sen's slope estimate	Mann-Kendall Test	Sen's slope estimate
					Test Z	Q	Test Z	Q	Test Z	Q
January	0.00	61.20	8.00	-0.033	0.20	0.009	-0.80	-0.013	**2.23***	0.064
February	0.00	43.30	5.50	0.157	0.63	0.011	-1.14	-0.045	0.82	0.020
March	0.00	43.00	3.73	0.065	-1.12	-0.025	-0.36	-0.010	0.98	0.024
April	0.00	14.20	2.18	-0.033	-0.51	0.000	0.00	0.000	0.66	0.018
May	0.00	33.90	6.59	-0.142	0.88	0.095	0.61	0.017	1.16	0.033
June	24.10	223.30	104.59	0.010	1.59	1.728	-0.52	-0.013	0.11	0.000
July	111.20	714.20	291.68	-0.299	-0.61	-1.495	-0.34	-0.008	1.06	0.011
August	120.10	625.90	371.80	0.047	1.39	3.836	0.05	0.000	0.57	0.006
September	9.90	321.40	133.50	-0.284	-1.50	-2.300	1.61	0.050	**1.69+**	0.019
October	0.00	199.70	21.54	-0.049	1.04	0.200	0.04	0.000	0.59	0.010
November	0.00	105.70	15.93	-0.094	-0.48	0.000	-0.93	-0.017	0.39	0.022
December	0.00	88.90	8.18	-0.116	-0.07	0.000	-0.05	0.000	0.66	0.018
Annual	534.80	1624.80	973.22	-0.007	0.93	5.658	-0.30	-0.004	**1.82+**	0.019
Winter (Jan-Feb)	0.00	64.10	13.50	0.043	1.02	0.067	-1.07	-0.025	**2.00***	0.039
Summer (Mar-May)	0.00	48.60	12.50	-0.199	0.04	0.014	0.54	0.007	1.43	0.023
South West (Jun-Sep)	476.50	1585.90	901.57	-0.005	1.25	4.400	0.27	0.007	1.25	0.008
North East (Oct-Dec)	0.20	199.70	45.65	-0.279	0.32	0.214	-0.41	-0.008	0.62	0.014

**** 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*

Ujjain: - The maximum temperature of Ujjain district has a clear annual pattern, as shown by the trend test. The result is negative but not significant (Z = -0.96) and the slope is small (Q - 0.009 per year) (Table 4). The monthly analysis shows that only January (Z = -1.68, Q = -0.024 per month) and February (Z = -1.66, Q = -0.023 per month) have a significant trend at a 0.1 % level. Only July has a slight upward trend (Z = 0.07, Q = 0.001 per month). The other months have a slight or no downward trend, with Z values ranging from -1.38 to - 0.09. The seasonal analysis of the time series data shows that the winter monsoon has a decreasing trend at a 0.1 % level of significance (Z value -1.73 and Q value -0.02 per season), while the other seasons have a slight or no upward trend, with Z values ranging from -0.21 to -1.14. The minimum temperature of Ujjain district also has a clear annual pattern, as shown by the trend test. The result is positive and significant at 0.1 % level (Z value -1.78, Q value 0.017 per year). The month of January has a significant trend at 0.05 level (Z value 2.04 and Q value 0.06 per month) and the month of September has a significant trend at 0.1 % level (Z value 1.28 and Q value 0.022). The other months have an increasing trend, with Z values ranging from 0.14 to 1.43 and Q values ranging from 0.007 to 0.29 per month. The seasonal time series data shows that the minimum temperature of the North-West monsoon has an increasing trend, with Z values ranging from 0.27 to 1.59 and Q values ranging from 0.008 to 0.033 per season.

Shajapur: - The trend test shows that the maximum temperature of the Shajapur district varies throughout the year, but the change is not significant (Z -0.16) and the rate is low (Q -0.001 per year) (Table 5). The Mann-Kendall test for each month reveals that May, August, and September have a positive but non-significant trend (Z value 0.54 to 1.57), while the other months have a negative trend (Z value -0.09 to - 1.13). The minimum temperature has a significant annual increase of 0.020 per year (Z value 1.84). The monthly analysis shows that January and September have significant positive trends of 0.064 and 0.023 per month respectively (Z value 2.18 and 1.83). The other months have positive but non-significant trends (Z value 0.25 to 1.25 and Q value 0.004 to 0.03). The seasonal analysis indicates that winter (January, February), summer, and South-West monsoon have significant positive trends of 0.041, 0.022, and 0.022 per season respectively (Z value 1.91 and 1.30). North-East monsoon has a positive but non-significant trend.

Neemuch:- The analysis of the maximum temperature of the Neemuch district reveals that it fluctuates throughout the year, but the variation is not significant (Z 0.18) and the rate is low (Q 0.002) (Table 6). The positive trend indicates that the maximum temperature has been rising over time. The monthly maximum temperature data shows that May, June, July, August, September, and October have an increasing trend with Z values ranging from 0.11 to 1.56 and Q values ranging from 0.10 to 0.05 per month. The months of January, February, March, July, November, and December have a decreasing trend. The minimum temperature data shows that the annual trend is positive with a Z value of 1.62 and a Q value of 0.017 per year (Table 6). The month of January has a significant increasing trend at a 5 % level with a Z value of 2.07 and a Q value of 0.055 per month. The rest of the months have an increasing trend with Z values from 0.07 to 1.61 and Q values from 0.001 to 0.023.

Ratlam: The maximum temperature of the Ratlam district shows a non-significant increasing trend with a Z value of 0.001 and a Q value of 0.001 (Table 7). The monthly trend analysis reveals that September has a significant increasing trend with a Z value of 1.77 and a Q value of 0.05, while April, May, June, and October have non-significant increasing trends. The seasonal trend analysis indicates that the maximum temperature increases in Summer and South-West monsoon, but decreases in Winter and North-East monsoon. The minimum temperature of Ratlam district shows a significant increasing trend with a Z value of 1.68 and a Q value of 0.014 (Table 7). The monthly trend analysis shows that January and September have significant increasing trends with Z values of 1.86 and 1.92, and Q values of 0.054 and 0.026, respectively. Only April has a decreasing trend with a Z value of -0.16 and a Q value of 0.001, while the rest of the months have increasing trends. The seasonal trend analysis shows that the minimum temperature increases in all seasons, with Z values ranging from 0.11 to 1.50 and Q values ranging from 0.006 to 0.023.

Mandsaur:- The analysis of the maximum temperature data for the Mandsaur district reveals that there is no significant change in the annual trend, with a Z value of 0.07 and a Q value of 0.001 per year (Table 8). However, when looking at the monthly data, the month of September shows a significant increase in the maximum temperature, with a Z value of 1.73 and a Q value of 0.056 per month at a 0.1% level of significance. The months of April, May, June, August, and October also show an increasing trend, with Z values ranging from 0.18 to 0.79 and Q values ranging from 0.004 to 0.017. The remaining months (January, February, March, July, November, and December) show a decreasing trend in the maximum temperature. The seasonal analysis shows that the summer and southwest monsoon seasons have an increasing trend in the maximum temperature, with Z values of 0.68 and 0.61 and Q values of 0.011 and 0.014 per season respectively. The winter and northeast monsoon seasons have a decreasing trend in the maximum temperature. The annual minimum temperature data shows a non-significant increase in the trend, with a Z value of 1.53 and a Q value of 0.018 per year. The months of January and September have a significant increase in the minimum temperature, with Z values of 2.04 and 2.08 and Q values of 0.058 and 0.031 per month respectively at a 0.05% level of significance. The rest of the months and seasons have an increasing trend in the minimum temperature.

Rajgarh: The analysis of the maximum temperature data for the Rajgarh district reveals that there is no significant change in the decreasing annual trend, with a Z value of -0.30 and a Q value of -0.004 per year (Table 9). However, when looking at the monthly data. The months of April, May, August, September, October, and December also show an increasing trend, with Z values ranging from 0.001 to 0.017 and Q values ranging from 0.001 to 0.050. The remaining months (January, February, March, June, July, November, and December) show a decreasing trend in the maximum temperature. The seasonal analysis shows that the summer, southwest, and monsoon seasons have an increasing trend in the maximum temperature, with Z values of 0.68 and 0.61 and Q values of 0.011 and 0.014 per season respectively. The winter and northeast monsoon seasons have a decreasing trend in the maximum temperature. The annual minimum temperature data shows a 0.1 % level of a significant increase in the trend, with a Z value of 1.82 and a Q value of 0.019 per year. The months of January and September have a significant increase in the minimum temperature, with Z values of 2.23 & 1.69 and Q values of 0.064 & 0.019 per month respectively at a 0.05% level of significance. The rest of the months and seasons have an increasing trend in the minimum temperature. The seasonal trend was observed in time series data winter seasonal Z value 2.00 and Q value 0.039 magnitude 0.05 % level of significance increasing trend. Summer, South-West monsoon, and North-East monsoon were observed to increase the minimum temperature trend.

3.3 Discussion

A study conducted by N. Subash and A. K. Sikka [15] 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 fulfill the water vapor demand and shows an increasing trend of rainfall activity [16,17].

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.

4. CONCLUSION

Indore district shows an increasing trend in annual rainfall with a non-significant level of Z statistics (1.21). On the other hand, the South-West monsoon season shows a positive but non-significant trend (Z= 1.07). Dewas district shows a decreasing trend in annual rainfall with a non-significant level of Z statistics (-0.07). Similarly, all the seasons show a decreasing but non-significant trend. Ujjain district shows an increasing trend in annual rainfall with a non-significant level of Z statistics (0.11). However, the month of August shows a decreasing trend with a 0.10% level of confidence (Z= -2.36 and Q = -3.492). Shajapur district shows an increasing trend in annual rainfall with a non-significant level of Z statistics (0.57). All the seasons, namely winter, South-West, and North-East monsoon, also show an increasing but non-significant trend (Z= 0.37 to 1.04). Neemuch district shows an increasing trend in annual rainfall with a non-significant level of Z statistics (1.03) and Q statistics (3.488). All the seasons, namely Winter, Summer, South-West, and North-East monsoon, also show an increasing but non-significant trend (Z= 0.86 to 1.40 and Q= 0.067 to 3.086). Ratlam district shows a decreasing trend in annual rainfall with a non-significant level of Z statistics (-0.84) and Q statistics (3.525), but the decade-wise analysis shows an increasing trend. All the seasons, except Summer, show an increasing but non-significant trend (Z= 0.09 to 0.95 and Q= -0.8 to 2.98). Mansour district shows an increasing trend in annual rainfall with a non-significant level of Z statistics (0.82). All the seasons, namely Winter, Summer, South-West, and North-East monsoon, also show an increasing but non-significant trend (Z= 0.46 to 1.23). Rajgarh district shows an increasing trend in annual rainfall with a non-significant level of Z statistics (0.93) and Q statistics (5.658). All the seasons, namely Winter, Summer, South-West, and North-East monsoon, also show an increasing but non-significant trend (Z= 0.04 to 1.25).

Indore district shows the annual and monthly maximum temperature was decreased and minimum temperate increased and decreasing trend. Also, District Dewa's maximum temperature decreased and the minimum temperature also show an increasing trend. Ujjain district shows maximum temperature was also decreasing trend and minimum temperature increasing annual significant trend. District Shajapur showed an annual maximum trend observed the decreasing and the significantly and minimum temperature was increasing annually (Z1.84) 0.1% level of significance, monthly January (Z 2.18) & September (Z 1.83) each month was statically significant increasing trend was observed. Neemuch district observed an annual increasing trend of Z 0.18 and Q value of 0.002 and minimum temperature also observed an increasing trend of Z value 1.62. January month minimum temperature increasing significant trend (Z 2.07) 0.05 level of significance. Ratalm district's annual minimum temperature was Z 01.68 0.1 % level of significance increasing trend observe. The month of January and September both are a significant increasing trend. Mandsaur and Rajgarh district maximum and minimum temperature observed an increasing trend but non-significance and months January & September observed a 0.05 % level of significance increasing trend.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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