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Variability and Trend Analysis of the Rainfall of the Past 119 (1901-2019) Years using Statistical Techniques: A Case Study of Uttar Dinajpur, India

Ajit Sarkar, Sunil Saha, Debabrata Sarkar and Prolay Mondal*
Department of Geography, Raiganj University, Raiganj, West Bengal
✉ mon.prolay@gmail.com

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Abstract: The present study aims to identify and measure the impact of climate change on rainfall patterns in the Uttar Dinajpur district of West Bengal. The hydro-meteorological time series rainfall data was collected from the IMD and CHRS data portals and subsequently analysed using various statistical methods. Agriculture in this district is the main economic activity, but the rainfall propensity is very unpredictable and sporadic that has a significant impact on agriculture. The rainfall results (1901-2019) were examined and assessed using statistical techniques for Mann-Kendall's Z-statistic and Sen's slope estimators. From the estimation, it is understood that the pre-monsoon, monsoon, and winter seasons have positive trends in rainfall, whereas the post-monsoon rainfall shows a negative trend and both Mann-Kendall and Sen's slope projections depict the same. Likewise, January, February, April, May, June, July, August, and December reflect upward positive change, while a downward trend (decline trend) was recorded in March, September, and October. The winter Kharif crops are more impacted by this negative or decreasing pattern of seasonal rainfall than other crops. The maximum average monthly rainfall in July (892.1 mm) and January showed the lowest average monthly rainfall of 63.3 mm. The results revealed that during the monsoon season the maximum rainfall (75.2%) occurred and the coefficient of variance value is 20.4 %. In the winter season, the minimal rainfall (2.87%) with a coefficient of variance (CV) is 72.9%. The rainfall forecast using SMOreg and linear regression methods has been calculated. This research contributes greatly to adopting different strategies by the planners, researchers, numerous government institutions, and NGOs for the overall development of the study area. This study may also be effective in the management of water resources in the study region.

Keywords: Rainfall Variability; M-K Test; SMOreg.; Linear regression.

Introduction

Rainfall is a significant natural event, and several credible evidences support the effect of climate change on rainfall intensities (Degefu and Bewket, 2013; Muthoni, 2018). Climate change is a significant and diverse challenge to our living and physical ecosystems (Malik et al., 2020). Rainfall is part of the world's hydrological cycle (Castino et al., 2016). The hostile impact on the global hydrological cycle of climate change has gradually modified the pattern, frequency, severity, trend, and duration of rainfall (Groisman et al., 2005). The constant rainfall alteration contributes to many hydro-meteorological hazards such as floods, (Roy et al., 2020), drought, landslides (Chowdhuri et al., 2021), soil erosion (Pal et al., 2019; Chakrabortty et al., 2020; Pal et al., 2021), etc (White and Haas, 1975; Caine, 1980; Castino et al., 2016), which often cost poorly to

*Corresponding Author

any nation. Rainfall is the foremost factor that controls the growth of vegetation and agricultural productivity (Lobell et al., 2011; Shang et al., 2011) together with the socio-economic improvement of a region (Saha et al., 2020). So it is essential to search the evidence of the changes in rainfall and its pattern (Conway, 2000; Berbery & Barros, 2002; Gloor et al., 2013). An area with optimal temperatures and precipitation is increasingly becoming a developed region. The rate of precipitation has changed steadily but surely because of the global impact of climate change (Meze-Hausken, 2004; Hagdu et al., 2013; Cheung et al., 2008). Climate change has risen global catastrophes in the recent few decades, which are harmful to agricultural productivity, the economy, and the ecosystem (Gajbhiye, 2016). Due to global shifts in the climate, local factors in the atmosphere have often changed. The increasingly declining trend in precipitation in the last few decades shows that the amount of rainfall has decreased and it varies over the region (Javari, 2001; Willems et al., 2014; Soltani et al., 2015). Water is a key resource for a region's growth. The production of agriculture and industrial development of an area is closely linked to water resources accessibility. It is estimated by the Intergovernmental Panel on Climate Change (IPCC) that the average global land surface temperature increased by 0.74°C ± 0.18°C in the period from 1906 to 2005. Due to this increment, the availability of freshwater has decreased rapidly. It is estimated that in the mid-twenty-first century the average annual runoff and availability of water will reduce by 10–30%. Humid and warm air can move vertically and reach a saturated level with a relative humidity of 100%. Thereafter, the condensation process will be accelerated and rainfall will occur. It calculated that the global annual average earth surface precipitation increased by nearly 1.1 mm per decade from the period of 1901 to 2005 (uncertainty ±1.5 mm). During the past few decades, a trend of increment in rainfall was discovered in the latitudinal zone of 30°N to 85°N, and a noticeable decreasing trend was observed between 10°S and 30°N latitudinal zone (Basistha et al., 2009) in during last 30–40 years. As per the IPCC report (2007), the rainfall decreased by 7.5% in South Asia and West Africa and it increased by 20% in northwest India from 1900 to 2005.

During the recent decades, the association between climate change and rainfall intensity is a leading topic for researchers (Sharma, 2017). The essence of local and regional precipitation (Malik et al., 2016) is highly important for assessing hydrological impacts in the context of climate change such as flooding and drought (Huang et al., 2015), and it is noted that area with optimal precipitation are fertile and vice versa (Saha et al., 2020). Dore (2005) found out that rainfall scale and severity were increased globally but decreased on a regional scale. El-Nino Southern Oscillation (ENSO) is a critical factor for global climatic instability that influences the distribution of rainfall in tropical areas (Nicholls, 1998). The frequency and strength of the monsoonal precipitation are also calculated by the upper air atmospheric circulation that regulates the South-East trade wind. In India, about 85 million hectares of land (60%) depends on summer rainfall out of a total of 141 million hectares of agricultural land, i.e. about 40% of the total population still depends on monsoon rainfall for farming, and about 54% (75.5 million ha) net sown area is affected by summer rainfall (Clark et al., 2000). The Indian Ocean is the warmest and the smallest ocean among the tropical oceans. The global (Schott et al., 2009), as well as regional variability (Chowdary et al., 2015) of the climate, have a momentous relationship with the sea surface temperature (SST) of the Indian Ocean. The characteristics of summer and winter monsoon rain are in changing form and it is emphasized from the analysis of the trend of the Indian winter (North-East Monsoon) and summer monsoon (South-Western Monsoon) rainfall variability (Guhathakurta and Rajeevan 2008). Scientist has already looked around the globe for the pattern and trend in climate variability (Serrano, 1999; Gallant, 2007; Philandras, 2011; Zhang, 2015; Lyra, 2017). India's economy is strongly dependent on timely rainfall (Kumar, 2010). A pattern of rainfall has been observed over the Central Peninsula, North-West India, and the west coast of June, although rainfall has been significantly reduced over Madhya Pradesh, North-West peninsula, and North-East India in July (Kumar, 1992; Guhathakurta, 2008).

The majority of rainfall in India was caused by the South-West Monsoon Wind (Pal et al., 2019). Rainfall is the primary water supply for developing numerous economic activities. Like other areas of India, the district of Uttar Dinajpur also has a seasonal rainfall (June – September) caused by S-W Monsoon. In Uttar Dinajpur, rainfall affects the area in two ways such as actively and passively. The major effect is to mean the physical loss of resources which involves damage to farmland, bridges, buildings, the sewerage system, roads, and channels (Hussain, 2015), while the indirect effects include water contamination that spreads diseases such as cholera, dengue, typhoid, and fever, etc.

This research work is an analysis of the annual and seasonal trend of rainfall variability of the Uttar Dinajpur from 1901 to 2019 by applying non-parametric Mann-Kendall (M-K test) and Sen's slope estimator method. The M-K test is a famous non-parametric test to analyze the data and discovering the monotonic dependence (Salmi et al., 2002) from the data. To examine the true slope of the trend, Sen's linear method was used.

Objectives

The major objectives of the present study are given below:

1. To analyse the rainfall trends and variability in the study area.
2. Try to assess the future rainfall intensity in the study area.

Study Area

The study area, Uttar Dinajpur, came into existence after the division of West Dinajpur into Dakshin and Uttar Dinajpur on 1st April 1992. Uttar Dinajpur District has occupied an area of 3,140 sq. km and its geographic location lies between latitude 25°11′ N and 26°49′ N and longitude between 87°49′ E and 90°00′ E. The district has two subdivisions as Raiganj and Islampur. The northern front of the district is enclosed by Darjeeling and Jalpaiguri district, on the south Malda district is situated, the eastern edge is bounded by Bangladesh, and the western frontier is bounded by the state of Bihar. The district is divided into nine assembly constituencies as Chopra, Islampur, Goalpokhar-I, Chakulia, Karandighi, Raiganj, Hemtabad, Kaliyaganj and Itahar. The total population of the district is 30,07,134, and the population density is 958 persons /sq. km. (Census, 2011). Generally, the topography of Uttar Dinajpur district is a plain type with a gentle southerly slope. The flood plain region of the river Kulik, Nagaur, Gamari, Sooin, (Saha et al., 2020), etc deposit sediments thus making the study area rich in fluventic soil. The district is a region of humid subtropical climate with an annual average rainfall of 1,605.93 mm. The Uttar Dinajpur district received about 75.92% rainfall (Table 1) due to the south-west monsoon during the summer season. The annual average temperature of the district ranges from 9°C to 41°C, respectively. Consequently, paddy, jute, mesta, sugarcane, etc. are the major crops in this district. NH-31 and NH-34 are the major roadways of the district that joins with several other state highways.

Materials and Methods

The interior objective of the study is to measure the variability of rainfall patterns within a period. To satisfy the objectives, the Mann-Kendall (M-K test) was used to analyse the data, the Sen's slope estimator method (Eq. 6) was applied to explore the magnitude of variability in the rainfall frequency and the Z-test technique was used to analyse the significance of the rainfall time series data. The linear Regression method and Sequential Minimal Optimization (SMO) have been used to estimate the prediction of future (2020-2025) rainfall. The rainfall data were collected from the Indian Meteorological Department (IMD) of the period from 1901 to 2019. This data consists of information about the day-wise minimum and maximum quantity of rainfall, Intensity of the rainfall, duration of the rainfall, etc. The time series rainfall data were explained on a monthly, seasonally, and yearly basis. All the statistical calculations have been estimated using MS Excel and XLSTAT software. ArcGIS-10.5 software was used to produce the location map of the study area (Figure 1).

Data Sources

Rainfall data has been collected from IMD and CHRS data portal for 119 years (1901-2019) to evaluate the tendency and the intensity of the rainfall using various statistical techniques.

Data Analysis

Analysis of the Trend

Trend analysis is a significant tool that helps in the measurement of the efficient planning and managing of water resources. This also gives information about the precipitation variability, direct runoff, and river discharge in any area by which we can presume the future that may be possibly changed due to the climate or rainfall (Dinpashoh, 2013). However, the statistical implications of the trend are analysed by using the Mann-Kendall test (significance of trend) while the degree of the trend is analysed by Sen's slope estimated method.

Analysed the Significance of the Trend (M-K Statistical Method)

The non-parametric M-K test is applied to detect the

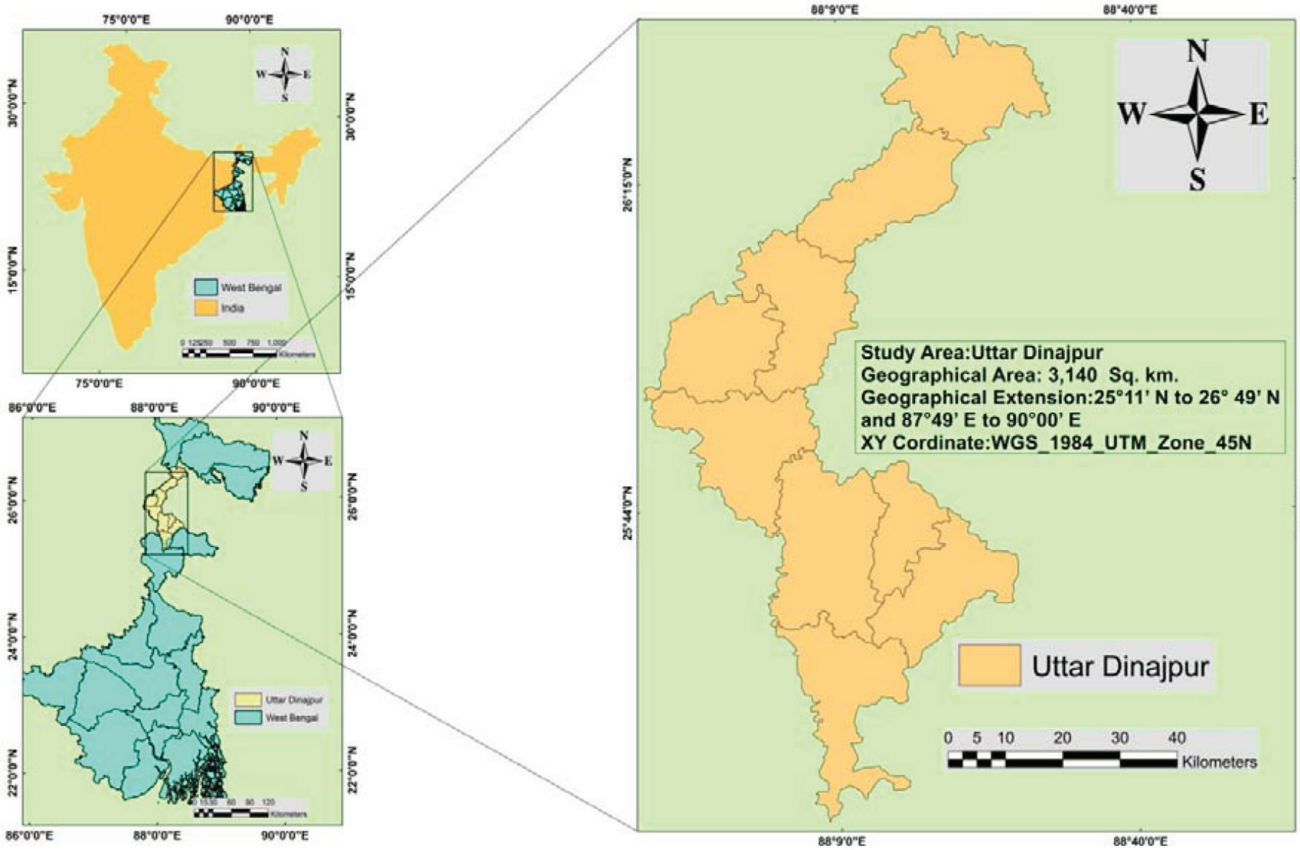

Figure 1: Location map of the study area.

trends of rainfall tendency that are monotonic or not but it is not necessarily linear. The null hypothesis is independent and randomly ordered, but it indicates only the direction. It is a well-circulated method to assess the trend of rainfall. The M-K Z-value is always indicating either a positive value or a negative value (+ or -) (Helsel, 1992; Birsan, 2005).

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sign}(Xj - Xk) \qquad (1)$$

$$\operatorname{Sign}(Xj - Xk) = \begin{cases} +1, & \text{if } xj - xk > 1 \\ 0, & \text{if } xj - xk = 0 \\ -1, & \text{if } xj - xk < 1 \end{cases} \qquad (2)$$

where, '*n*' is the number of the points; '*Xj*' *is the annual value of j year;* '*Xk*' is the annual value in year *k*, *j>k* respectively,

$$E(S) = 0 \qquad (3)$$

$$\operatorname{Var}(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{k=1}^{p} tk(tk-1)(2tk+5) \right] \qquad (4)$$

$$Z_{\mathrm{MK}} = \begin{cases} \frac{s-1}{\sqrt{\operatorname{var}(s)}} ..if\, s>0 \\ 0..if\, s=0 \\ \frac{s+1}{\sqrt{\operatorname{var}(s)}} ..if\, s<0 \end{cases} \qquad (5)$$

where 'p' is the number of tied values (zero difference between compared values), *tk* is the number of ties for *k*th value. A positive *Z* value represents an increasing trend, while a negative *Z* value indicates a decreasing trend. When $|Z| > Z-\alpha/2$, (H0) is not accepted, that is, if Z value is larger than +1.96, it indicates a significant upward trend at the level of 0.05 significance, while negative M-K Z value is lesser than -1.96, it indicates a decreasing significant trend.

Analysis Magnitude of the trend (Sen's Estimator Method)

Sen's non-parametric method was developed for determining the vastness or magnitude of the slope of the hydro-meteorological time series data. This method is a model of linearity for the trend analysis of rainfall data. As with the M-K test, a positive value indicates an upward trend and a negative value signifies a downward trend (Karpouzos, 2010; Xu, 2007). Sen's slope of the estimator can be defined as–

$$Ti = \frac{xj - xk}{j - k} \tag{6}$$

where, xj and xk are data values at time j and k $(j>k)$, respectively. The median of these n values of Ti is determined by using Sen's slope estimation method which is defined as–

$$Q_i = \begin{cases} T_{\frac{n+1}{2}} \text{ for } n \text{ is odd} \\ \hline \frac{1}{2}\left(\frac{T_n}{2} + \frac{T_{n+2}}{2}\right) \text{odd for } n \text{ is even} \end{cases} \tag{7}$$

Sen's (Q_i) is depending upon n which is either odd or even. Q_{median} is calculated using a 100 (1-α)% confidence interval which is depending upon normal distribution. The negative and positive values of Q_i signify the decreasing and increasing magnitudes of the slope in rainfall time series data.

Coefficient of Variation

The coefficient of variation is a statistical technique to measure the dispersion of each data spot or point in the data concerning the mean (Tables 1 and 2). In this paper, annual and seasonal variabilities of the rainfall have been calculated for the study area using coefficient of variation. The larger (greater) value of the coefficient of variation represents the greater spatial variability and lower values of coefficient variance mean less spatial variability in the data set series (Landsea, 1992).

$$\text{CV} = \frac{\text{SD}(\sigma)}{\text{Mean}(\mu)} \times 100 \tag{8}$$

where CV is the coefficient of variation, σ is representing standard deviation, μ is the mean value of the rainfall (average rainfall).

Analysis of the Rainfall Prediction (SMOreg. and Linear Reg. Method)

SMO Regression Method

To solve the smallest optimisation problems, the SMO algorithm is used. That is, only two Lagrange multipliers are chosen to be jointly optimized, and the support vector regression (SVR) is updated to the new optimal values without the need for a time-consuming QP optimization algorithm at each phase. Platt proposed a Sequential Minimal Optimisation algorithm for classification problems, iteratively selecting the working set of size two and optimising the objective function according to them by solving sub-problems analytically. This algorithm will be briefly described in this paper, as shown below Yang et al. (2007).

$$L_p(\alpha^*, \alpha) = \varepsilon \sum_{i=1}^{n} (\alpha_i^* + \alpha_i) - \sum_{i}^{n} \gamma_i (\alpha_i^* - \alpha_i)$$
$$+ \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} (\alpha_i^* - \alpha_i)(\alpha_i^* - \alpha_i) k(\chi_i, \chi_j)$$
$$\sum_{i=1}^{n} (\alpha_i^* - \alpha_i) = 0,$$
$$0 \le \alpha_i^*, \alpha \le C, i = 1, 2, ..., n. \tag{9}$$

In equation ** α_i, α_i^* are language multipliers.

$$f(\chi, \alpha) = \sum_{i=1}^{n} (\alpha_1^* - \alpha_i) k(\chi_i, \chi) + b \tag{10}$$

If $\lambda_i = \alpha_i^* - \alpha_i, |\lambda_i| = \alpha_i^* + \alpha,$ the new value for λ_i will obey the box constraint $-c < \lambda_i < c, i = 1, 2, ..., n.$ substitute λ_i and $|\lambda_i|$ into (9) and (10), thereafter the equation is written as–

$$L_p(\lambda) = \varepsilon \sum_{i=1}^{n} |\lambda_i| - \sum_{i=1}^{n} \lambda_i \gamma_i + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \lambda_i \lambda_j k_{ij} \tag{11}$$

Subjected to:

$$\sum_{i=1}^{n} \lambda_i = 0 \qquad -c < \lambda_i < c$$

and
$$f(\chi, \lambda) = \sum_{i=1}^{n} \lambda_i k(\chi_i, \chi) + \lambda_0 \tag{12}$$

Linear Regression Method

Linear regression is a mathematical technique that can be used to estimate future values based on past values. It is often used as a quantitative method to assess the underlying trend and whether rates have become overextended. A linear regression curve employs the least-squares method to draw a straight line through prices to minimize the distances between the prices and the resulting trend line. For each data point, this linear regression indicator plots the trend line value.

$$\gamma_t = \beta_0 + \beta_0 \chi_t + \varepsilon_{t.} \tag{13}$$

where, β_0 is forecast value of γ when $X = 0$; β_1 is the slope of the line and its intercept; ε_t is denoted the random error.

Discussion of the Result

Monthly Rainfall Trend Analysis

In the research study, monthly, seasonal, and annual rainfall variations seen in the Uttar Dinajpur district have been analysed and evaluated using 119 years of rainfall data (1901 to 2019) series. M-K Statistical Method and Sen's slope estimation were used for the analysis of the data. The months of January (0.29), February (1.17), April (0.02), May (1.49), June (1.05), July (1.64), August (1.48), November (0.97), and December (0.63) has a positive value of Z statistics test, which indicates the increasing trend or upward trend of rainfall occurrences whereas March (-0.43), September (-0.80), and October (-0.2) represents a decreasing trend. The maximum significance of Z-statistics is shown in July (1.64), while September (-0.80) represents the minimum significance of the trend (Figure 2).

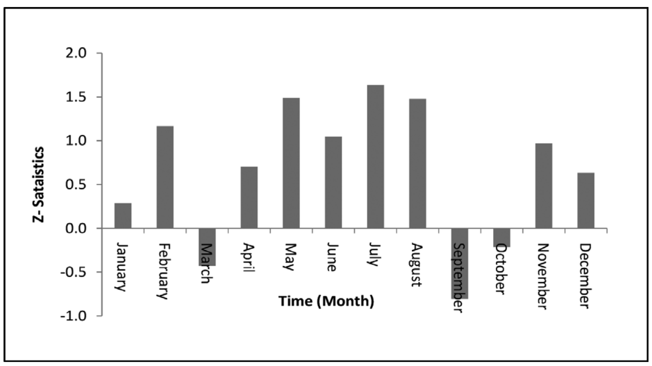

Figure 2: Trend analysis using the Mann-Kendal Z-statistics (Month-wise)

Similarly, the Sen's magnitude of the slope (Qi) was calculated for each month from January to December. The months of January (0.006), February (0.154), April (0.246), May (0.544), June (0.630), July (1.411), August (1.439), November (0.032), and December indicate an upward magnitude slope, while other three months i.e. March (-0.052), September (-0.725), October (-0.132) represent a downward magnitude slope and the maximum magnitude of slope showed August (1.439) and the lowest magnitude of trend represents September (-0.725).

From the above analysis (Figures 2 and 3) it is found that January, February, April, May, June, July, August, November, December show an increasing trend (upward) due to the positive value of both M.K Z-Statistics and Sen's Qi statistics, while March, September, and October indicate the downward (decreasing) trend due to negative value of both Z and Qi Statistics.

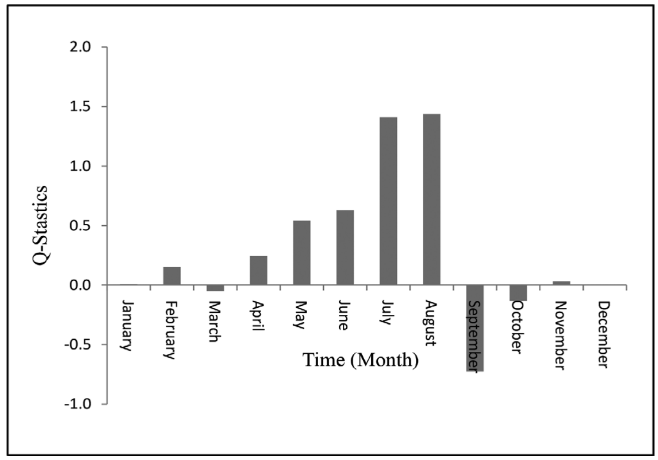

Figure 3: The monthly magnitude of the trend using Q-statistics.

Annual and Seasonal Characteristics of the Rainfall

Rainfall characteristics of Uttar Dinajpur district (1901 to 2019) such as mean rainfall and coefficient of variation of the rainfall were analysed using hydro-meteorological rainfall time series data. From the temporal variation of the annual and seasonal rainfall of Uttar Dinajpur (Figure 4), it is found that there is a similarity between the trends of monsoon rainfall and the trend of annual rainfall patterns. The nature of the pre-monsoon and post-monsoon rainfall variation is virtually similar but the shift in the post-monsoon marginally increased relative to the pre-monsoon (Figures 4a and 4e), while the pattern in the winter rainfall series had decreased (Figure 4d). The annual average rainfall of Uttar Dinajpur district is 1,605.93 mm, including an average value of 183.48 mm in pre-monsoon, 1,219.8 mm in monsoon, 157.4 mm in post-monsoon, 46.3 mm in the winter season respectively. The highest recorded rainfall in this district was 2,326.69 mm in the year 1978 and the lowest rainfall was 1,017.28 mm in the year 1935. The cyclonic storm and the frequency of the Jet stream over the Indian Ocean are the main motivating forces for a monsoonal depression to spawn. The south-west monsoonal wind may be a viable cause of the maximum rainfall in the year 1971 and minimum rainfall that happened in the year 2010 (Sharma, 2010). The contribution of the monsoon season rainfall in Uttar Dinajpur district is about 75.92%, whereas the winter season is the minimum contribution (2.87%).

Rainfall Variability Patterns

Frequent rainfall variability has an impact on the agriculture sector. In this study, the annual and seasonal variations of the rainfall was analysed to estimate the

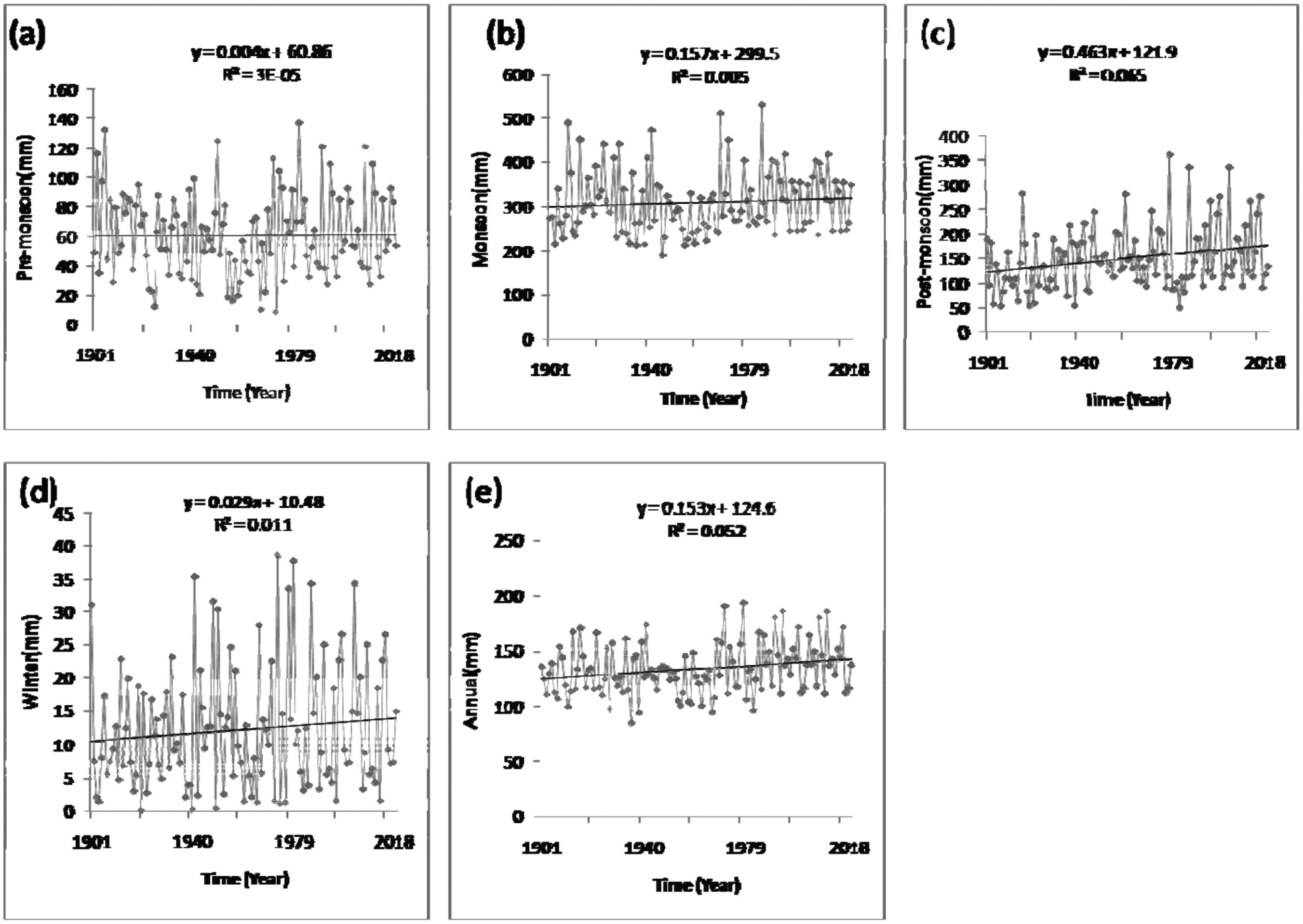

Figure 4: The analysis of temporal rainfall variation: (a) Pre-monsoon, (b) Monsoon, (c) Post-monsoon, (d) Winter and (e) Annual.

water resource requirement in the district. From the estimation, it is found that the maximum coefficient of variation is 72.9%, which indicates the winter season and the lowest coefficient of variation is 17.2%, which represents the annual rainfall. The coefficient of variation for pre-monsoon, monsoon, and post-monsoon is 46.4%, 20.4%, and 56.0%, respectively (Table 1). The highest value of CV represents greater variability in rainfall and vice-versa (Pandey, 2001).

*5% Significance Level of a Two-tailed Test

The rainfall variation of Uttar Dinajpur district for the years 1901-2019 is shown by a simple line graph (Figure 5) for a better understanding of the characteristics of rainfall patterns. The maximum average rainfall has occurred in August with 355.8 mm rainfall (CV 31.1) and the minimum average rainfall has occurred in December with 6.4 mm rainfall. It has been estimated that the variation of the rainfall in August is almost similar every year. But in the months, rainfall variations are in dissimilarity nature due to greater coefficient of variation like December (228.3), November (125.5), January (118.5), March (108.6) May (98.1), February (93.3), April (81.0), October (59.1), September (50.6), June (49.2) and July (36.7).

Prediction of the Rainfall

Rainfall forecasting is the use of science and technology to predict the amount of rain that will fall in a given area. It is critical to precisely calculate rainfall to make the best use of groundwater, increase crop production, and prepare water structures ahead of time. In this research study, the prediction of future rainfall changes has been a comparative analysis between the SMO reg. and linear regression, i.e. the forecast of rainfall is assessed by using SMOreg. (Eq. 12) and linear regression (Eq. 13) SMO regression estimation. From the estimation of SMO regression, it is found that there is a downward trend in rainfall occurrence in pre-monsoon rainfall from 69.85 (2020) to 64.84 (2025)

Table 1: Statistical overview of annual and seasonal rainfall in the district of Uttar Dinajpur (1901–2019)

Season	*Mean*	σ	*Coefficient of variation (mm)*	*per cent Contribution to rainfall (mm)*
Pre-monsoon	183.48	85.22	46.44	11.43
Monsoon	1219.8	248.45	20.38	75.92
Post-monsoon	157.4	88.04	56.03	9.79
Winter	46.3	33.64	72.93	2.87
Annual	1605.93	276.33	17.2	100.00

Table 2: Estimated Mann-Kendal's *Z* value and Sen's Slope Q_i values (1901 to 2019)

Time Series	*Mean (mm)*	*Median (mm)*	*Maxi (mm)*	*Mini (mm)*	*St.Dev*	*Coef.Var*	*Mann-Kendall trend*	*Significant. ()*	*Sen's Slope*
January	12.7	6.2	63.3	0.0	15.0	118.5	0.29		0.006
February	27.1	19.2	120.2	0.3	25.3	93.3	1.17		0.154
March	36.7	20.0	177.2	0.4	39.9	108.6	-0.43		-0.052
April	53.0	43.3	208.6	0.6	42.9	81.0	0.70		0.246
May	93.7	84.7	259.2	9.2	54.4	58.1	1.49		0.544
June	258.3	230.9	796.9	41.6	127.0	49.2	1.05		0.630
July	313.0	294.0	748.0	109.5	114.9	36.7	1.64		1.411
August	355.8	358.1	892.1	167.2	110.8	31.1	1.48		1.439
September	292.1	254.7	635.5	70.7	147.7	50.6	-0.80		-0.725
October	139.5	124.2	376.0	1.3	82.5	59.1	-0.21		-0.132
November	17.7	7.8	90.6	0.0	22.2	125.5	0.97		0.032
December	6.4	0.2	77.4	0.0	14.5	228.3	0.63		0.000
Annual	1605.9	1580.2	2326.7	1017.3	276.3	17.2	2.01	*	0.355
Pre-monsoon	183.5	167.1	411.3	27.2	85.2	46.4	0.97		0.250
Monsoon	1219.2	1165.3	1859.6	719.1	248.5	20.4	2.50	*	1.172
Post-monsoon	157.1	139.9	423.4	2.4	88.0	56.0	-0.83		-0.375
Winter	46.1	40.6	164.9	0.5	33.6	72.9	0.91		0.089

*5 per cent significance level of a two-tailed test

whereas it is 72.35 (2020) to 69.75 (2025) in case linear regression analysis. Similarly, there is a downward trend in rainfall occurrence in annual average rainfall with 115.97 (2020) to 110.32 (2025) in the case of SMO regression analysis and 125.1 (2020) to 117.18 (2025) in the case of linear regression calculation. However, the rainfall changes in the future in different seasons are displayed in Table 3 and Figure 6.

Discussion

The prime objective of this case study is to conduct a trend analysis of seasonal and annual rainfall for the Uttar Dinajpur district of West Bengal. In contrast to the annual and other seasons, the monsoon and winter seasons exhibit a large degree of variability in rainfall. Annual precipitation in Uttar Dinajpur has been declining significantly, although the mean annual rainfall is 1605.93 mm. Annual rainfall has shown a declining trend ranging from 0 to 1. Uttar Dinajpur exhibits significant negative trends in monsoonal rainfall. Whereas in the pre-monsoon period, Uttar Dinajpur exhibited significant positive trends in the state's northern region. Monsoon precipitation decreased by a maximum with a coefficient of variation of 20.38. The year 1972 was designated as a year of a dramatic shift in precipitation throughout the region. There is an increasing trend in annual precipitation with a

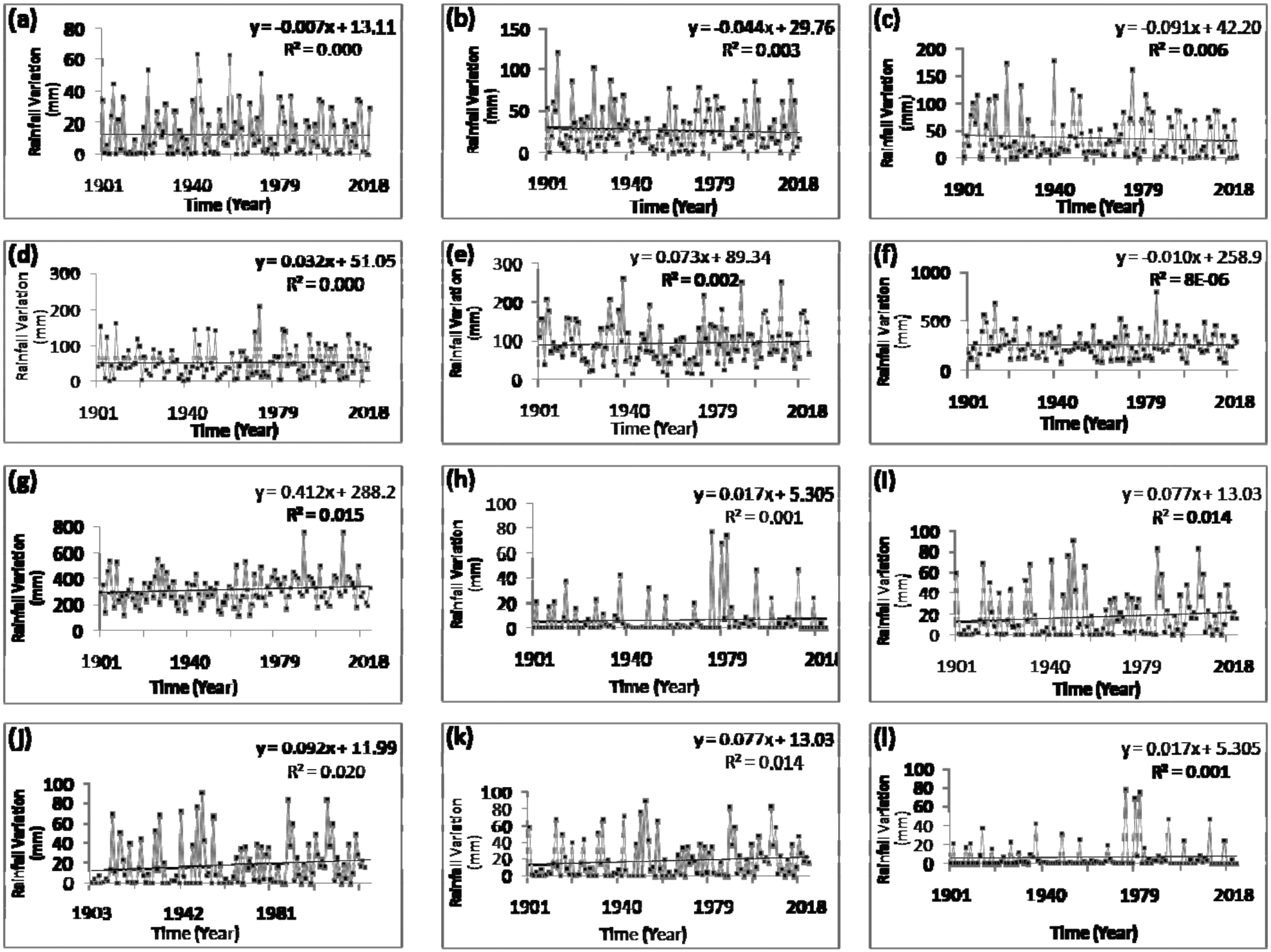

Figure 5: Month wise rainfall (mm) variation analysis (1901-2019); (a) January, (b) February, (c) March, (d) April, (e) May, (f) June, (g) July, (h) August, (i) September, (j) October, (k) November, (l) December.

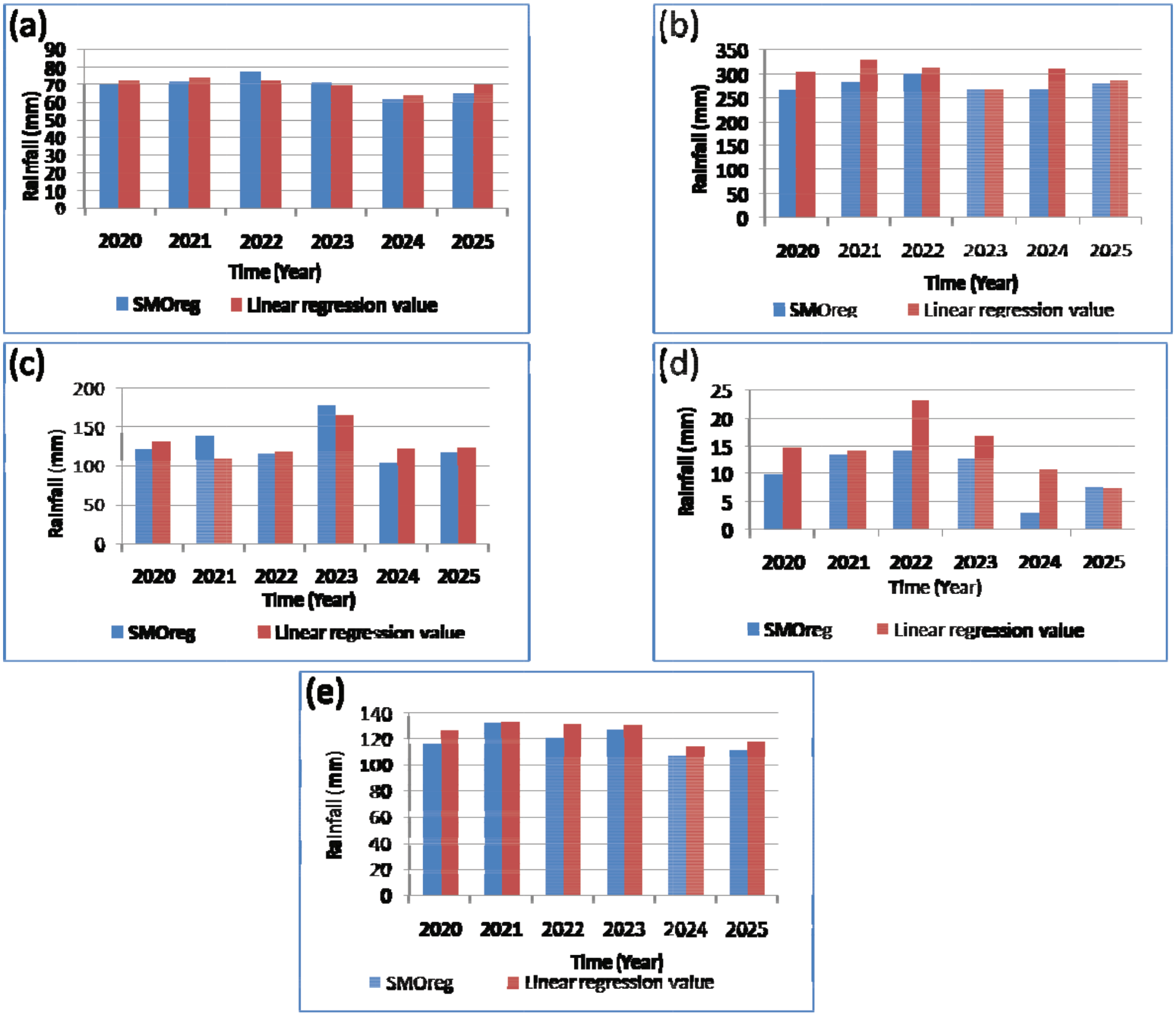

Figure 6: Rainfall prediction (2020-2025); (a) Pre-monsoon; (b) Monsoon; (c) Post Monsoon; (d) Winter and (e) Annual.

Table 3: Rainfall forecast of Uttar Dinajpur District (2020-2025)

Year	*Pre-monsoon*		*Monsoon*		*Post-monsoon*		*Winter*		*Annual*	
	SMOreg	*Linear regression value*	*SMOreg*	*Linear regression value*	*SMOreg*	*Linear regression value*	*SMOreg*	*Linear regression value*	*SMOreg*	*Linear regression value*
2020	69.85	72.35	265.77	304.7	120.63	131.36	9.9	14.7	115.97	125.1
2021	71.91	74.45	282.24	330.08	138.64	110.38	13.47	14.27	131.84	132.7
2022	77.54	72.35	301.46	313.56	116.77	118.96	14.17	23.2	119.67	130.27
2023	71.41	69.05	266.65	266.75	178.77	166.66	12.92	16.78	126.32	130.04
2024	61.5	64.07	267.12	312.21	104.21	122.52	2.87	10.8	107.07	113.62
2025	64.84	69.75	279.21	288.6	117.22	123.93	7.57	7.54	110.32	117.18

coefficient of variation of 17.2 in the study area from 1901 to 2019. Monsoonal rainfall variance in the study area has a detrimental effect on rice cultivation in the study regions. The future assessment of the climatic data such as rainfall can assess policymakers to implement different strategies to stand with future climate changes. The above research and findings would aid policymakers and agricultural specialists in adopting the most appropriate irrigation facilities and water management strategies for micro-level (block-level) planning and development in the study field.

Results in Comparison to Prior Research

Between 1901 and 2019, no major changes in annual precipitation have been observed in the study region. The Indian Meteorological Department (IMD) performed a patterns research report from 1901 to 2000 using data from 1,384 gauge stations located in India and discovered no statistically relevant trends in precipitation (Joshi and Pandey, 2011). Madhya Pradesh is located in central India, and a district-level analysis in Madhya Pradesh reveals no noticeable trend in annual rainfall for the entire state from 1901 to 2000 (Duhan and Pandey, 2013). Annual and seasonal rainfall decreased in the Brahmaputra and Barak river basins (Deka et al., 2013).

Conclusion

The main objective of the present investigation was to assess the variations of monthly, seasonal and annual precipitation from 1901 to 2019 based on hydro-meteorological precipitation evidence. The data were analysed using the Mann-Kendall (M-K) test and the extent of variability in precipitation level was examined by Sen's slope estimator. Using Z-test technology, the importance of precipitation time series data was calculated. The observational evidence suggests that there is a substantial upward trend in January (0.29), February (1.17), June (1.05), July (1.64). (0.63), while on the other hand, the MK statistic value shows a negative trend in March (-0.43), September (-0.83), October (-0.21). Comparably, Sen's slope value shows evident positive change in January (0.006), February (0.54), May (0.544), June (0.630), July (1.41), August (1.439), and November (0.032). The other three months are showing downside trends like March (-0.052), September (-0.725), October (-0.132), respectively. The maximum rainfall is observed in 1978 (approximately 2,326 mm) and the lowest rainfall in 1953, which was 1,017 mm, but the total annual rainfall was 1,605.93 mm. Heavy rainfall occurred in Uttar Dinajpur during the monsoon season (1,219.8 mm), although in pre-monsoon (183.48 mm) and winter seasons (46.13 mm) the amount of rainfall is significantly low. Different crops were lost each year during the monsoon season. A comparison of the SMOreg and linear regression was then used to forecast possible changes in rainfall. Irrigation is compulsory in the Kharif season (May to October) to cope with moisture stress due to delay of monsoon arrival or absence of rainfall. It was inferred from the above discussion that this paper may help agriculture planners discover the correct scenario for their agricultural production and water resource management planning. It can also be suggested that the ideal weather prediction is mandatory to minimise the negative impact of climatic hazards like floods in the study area.

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Conflict of Interest

The authors hereby state that there is no conflict of interest and no involvement or harm of humans or animals in the course of these investigations.

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