Analysis of Long-Term Rainfall Trends in The District of Tinsukia, Assam: Implications for Climatic Adaptation and Water Resource Management

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Abstract: Understanding long-term rainfall trends is essential for climate change impact assessment, sustainable agriculture, and water resource planning. This study investigates over a century of rainfall data (1901–2023) for the Tinsukia district in Assam, India—an area highly dependent on seasonal precipitation. Using robust statistical tools, namely the Mann-Kendall trend test and linear regression analysis, the research evaluates monthly, seasonal, and annual rainfall patterns to detect statistically significant trends and climatic variability.

Results from the Mann-Kendall test revealed a significant decreasing trend in rainfall for key months such as January, February, April, June, August, and September. Seasonal analysis showed notable declines in winter and monsoon rainfall, with annual rainfall also showing a statistically significant downward trend, especially during agriculturally crucial periods. These patterns suggest increasing climatic stress in the region.

The linear regression analysis further indicated weak correlations between rainfall and time, with several months showing downward trends; however, most were statistically insignificant, highlighting possible influences from other climatic or anthropogenic factors. The regression results suggest that while some decline is observable, the relationship lacks strong statistical support in certain months.

These findings underscore the importance of integrating trend analysis into climate adaptation strategies and regional water management planning. The research provides critical insights into changing precipitation dynamics in Tinsukia and contributes to a broader understanding of hydro-climatic variability in northeastern India, offering valuable direction for policymakers, planners, and researchers in developing resilient water and agricultural systems in the face of ongoing climatic shifts.

Key Words: Mann Kendall Trend Test, Linear regression, Trend analysis, Seasonal trend

I. INTRODUCTION

Climate change and its implications on local and regional weather patterns have become critical areas of research in recent decades. Among these, precipitation trends are particularly important due to their impact on agriculture, water security, and ecological stability. Understanding rainfall variability helps formulate climate adaptation and water resource management strategies, especially in rain-dependent regions like Tinsukia district in Assam.

In this context, numerous studies have utilized long-term data to evaluate changing rainfall patterns using robust statistical techniques. For instance, Anie John and Brema (2018) conducted a rainfall trend analysis using the Mann-Kendall test and Sen's slope estimator in the Vamanapuram River Basin, Kerala, where monthly rainfall data from 1984 to 2013 revealed both rising and declining trends in different months, helping assess monsoon patterns and flood risk potential.

Similarly, Dondo (2020) analysed seasonal rainfall trends in Zimbabwe using a simultaneous trend analysis of bioclimatic variables from two climatic data sources. The study applied Mann- Kendall tests via XLSTAT and found significant seasonal declines, highlighting the impacts of climate change on precipitation and underscoring the need for resilience strategies in climate- sensitive regions.

These studies provide valuable reference points and highlight the growing global consensus on the importance of statistically robust rainfall trend analysis in regional climate studies. Building on these frameworks, the present study analyses over a century of rainfall data (1901–2023) from Tinsukia to detect long-term monthly, seasonal, and annual trends using similar methodologies. Precipitation, as one of the fundamental components of the hydrological cycle, plays a pivotal role in agriculture, water resource management, and ecological sustainability. Understanding rainfall trends and their variations over time is essential for devising strategies to adapt to climate variability and mitigate associated risks. This study focuses on analyzing rainfall patterns in Tinsukia, a region with significant agricultural dependency, over a span of more than a century using statistical tools and techniques.

The dataset comprises monthly, seasonal, and annual rainfall records spanning over 100 years, allowing for a comprehensive assessment of trends and variability. Two primary analytical methods Mann-Kendall trend tests and linear regression were applied to determine the presence and magnitude of trends. These methods, complemented by statistical software XLSTAT, enabled a detailed exploration of the temporal evolution of rainfall patterns.

Tinsukia, located in the northeastern state of Assam, India, is a vibrant district known for its natural beauty, cultural diversity, and economic significance. It lies in the upper Brahmaputra Valley and is bordered by Arunachal Pradesh to the east. Tinsukia town serves as the district headquarters. The region is characterized by lush greenery, tea gardens, wildlife sanctuaries, and a significant contribution to Assam's economy through industries such as tea, oil, and natural gas.

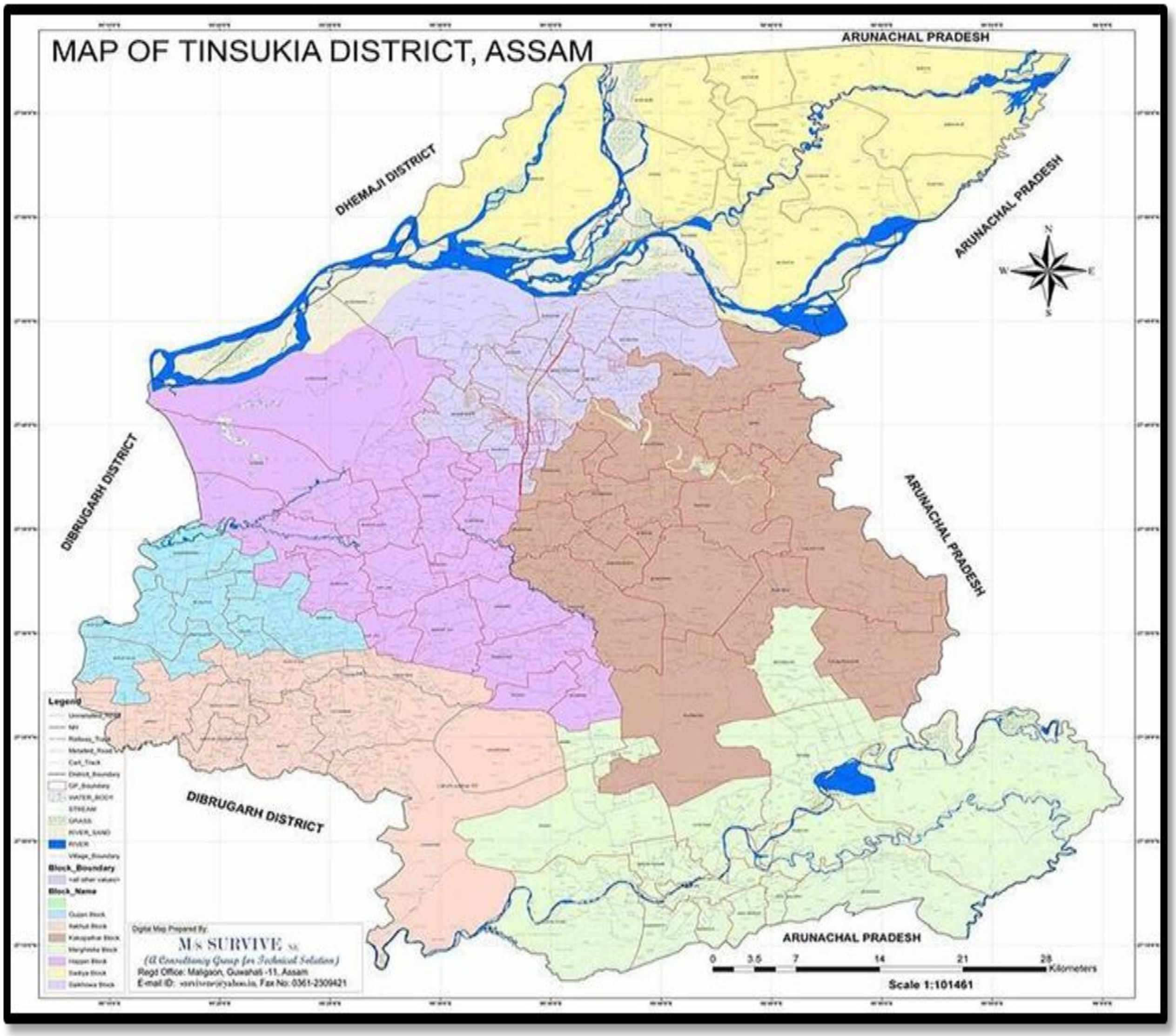

Fig 1 Political Map of Tinsukia District Source: Google.com

The district is a part of the subtropical monsoon region, with a landscape dominated by alluvial plains, rolling hills, and wetlands. It experiences three main seasons according to district administration:

a) Summer (March to May): Hot and humid, with temperatures ranging from 24°C to 36°C.

b) Monsoon (June to September): Heavy rainfall, influenced by the southwest monsoon.

c) Winter (October to February): Cool and pleasant, with temperatures dropping to 10°C. Tinsukia is home to diverse communities, including Assamese, Bengali, and indigenous tribes such as the Tai Ahom's and Sing Phos. Its ecological assets include the Dibru-Saikhowa National Park, a biodiversity hotspot known for its rich flora and fauna.

d) The district receives substantial rainfall, with annual precipitation ranging between 2000 mm and 3000 mm according to Indian Meteorological Department, Pune. Its rainfall is a key driver of its agriculture and ecology.

- Monsoon Dominance:

About 80-85% of the annual rainfall occurs during the monsoon season (June to September).
The southwest monsoon brings torrential rain, which often leads to localized flooding in low- lying areas.

- Pre-Monsoon Showers:

The region also experiences pre-monsoon rainfall in April and May, known as "nor' westers," which are accompanied by thunderstorms and gusty winds.

- Winter and post-monsoon:

Rainfall during winter and post-monsoon months is minimal, contributing less than 10% of the annual total.

II.MATERIALS AND METHODS.

Using historical rainfall data from the Indian Meteorological Department (IMD), INDIA (WRIS)and processed through XLSTAT software, this study identifies statistically significant trends. Notable findings include declining monsoon rainfall and reduced winter and post- monsoon precipitation, highlighting potential challenges for agriculture, water availability, and aquifer recharge. The low R^2 values in some analyses suggest additional environmental and anthropogenic factors influencing rainfall variability.

The trend analysis of rainfall was done by extracting the IMD rainfall data yearly from INDIA- WRIS (India Water Resource Information System) and from Indian Meteorological Department, Ministry of Earth Sciences Pune, of TINSUKIA district, Assam from the year 1901-2023.

The climate of the area is wet, sub-tropical with summer from December to March, rainy season from April to September and winter from October to November. This area has experienced rainfall for 8-9 months. The temperature varies from a maximum of 36º C to a minimum of 6º C. The area receives an average annual rainfall of 2964 mm based on rainfall data of Margherita NEC office. The area has high humidity (87 – 91%). The dry period of about 150 days in full year lies between Decembers to March.

Linear regression was conducted to further investigate the relationship between rainfall (dependent variable) and time (independent variable). This method complements the Mann- Kendall test by offering insights into the proportion of variability explained and the consistency of trends over time. Key metrics used in this analysis include:

- R^2 (Coefficient of Determination): Measures the proportion of variance in rainfall explained by the regression model.
- Regression Coefficient: Indicates the rate of change in rainfall per unit of time.
- p-value: Determines the statistical significance of the trend, with $p<0.05$indicating significance.

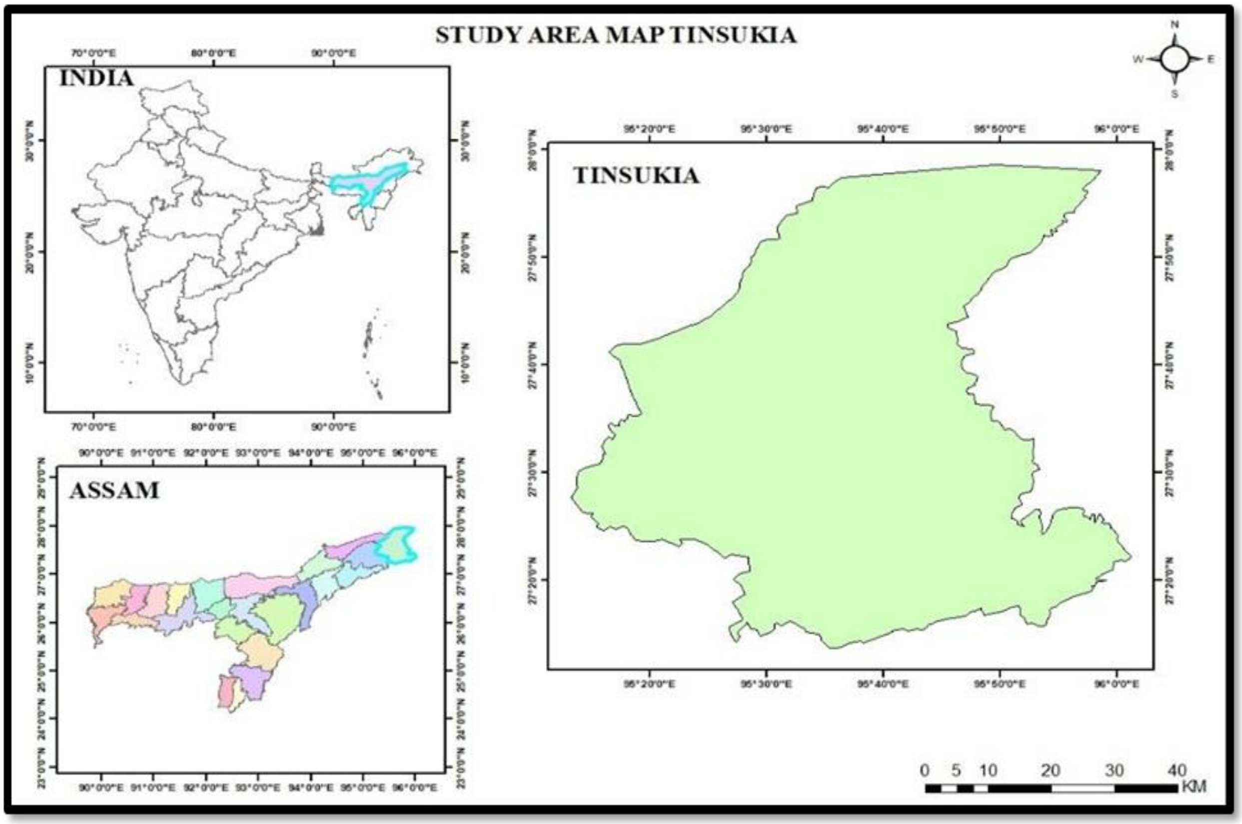

Fig 2. Study area Map in ARC-GIS

The analyses were performed using XLSTAT, a statistical software integrated with Microsoft Excel. XLSTAT was chosen for its advanced statistical functionalities and user-friendly interface, which facilitated the following:

1. Data Management: XLSTAT's automated handling of missing data and outlier detection enhanced data preparation efficiency.
2. Statistical Computations: Both the Mann-Kendall test and linear regression analyses were executed with high accuracy, ensuring robust and reliable results.
3. Visualization: Graphs and charts generated by XLSTAT provided a clear representation of trends and residuals, aiding in result interpretation.

III. RESULTS AND DISCUSSIONS

The Mann-Kendall test was employed to analyse rainfall trends over a century, with the null hypothesis *Ho* assuming no trend in the data and the alternative hypothesis *Ha* suggesting the presence of a trend. The test's significance level (α=0.05) was used to determine whether to accept or reject *Ho*. A computed p-value less than 0.05 indicates a significant trend, either increasing or decreasing. The magnitude of the trend was assessed using Sen's slope estimator, which provides the rate of change in rainfall over time.

Corrections were applied for ties and continuity in the dataset to ensure the robustness of the results. The test outcomes are summarized as follows:

i. Monthly Trends:

a) Significant Decreasing Trends:

- January: With a Kendall's tau of -0.205 and a p-value of 0.001, the null hypothesis is rejected, indicating a significant declining trend. The Sen's slope (-0.191) suggests a steady reduction in rainfall.
- February: The p-value of 0.004 supports rejecting *Ho*, with a slope of -0.256 confirming a decreasing trend.
- April, June, August, and September: These months also exhibit significant decreasing trends (p-values < 0.05), with Sen's slopes ranging from

-0.629 (April) to -1.000 (September).

b) Non-Significant Trends:

- Months like March (p-value = 0.307) and May (p-value = 0.601) show no significant trends, as *Ho* cannot be rejected.
- November and December display negligible slopes, indicating no discernible changes in rainfall patterns.

ii. Seasonal Trends:

a) Winter (JF): A significant decreasing trend is observed (p-value < 0.0001; Sen's slope = -0.441), rejecting *Ho* and highlighting reduced rainfall.

b) Pre-Monsoon (MAM): Although a negative slope is noted (-0.859), the p-value (0.072) suggests insufficient evidence to reject *Ho*.

c) Monsoon (JJAS): With a p-value < 0.0001 and a Sen's slope of -2.852, the null hypothesis is rejected, indicating a substantial decline in monsoon rainfall.

d) Post-Monsoon (OND): The p-value of 0.041 supports rejecting *Ho*, with a slope of -0.356 pointing to reduced rainfall.

iii. Annual Trends:

The annual data shows a significant declining trend (p-value = 0.001; Sen's slope = -3.778), leading to the rejection of *Ho*. This reflects a consistent reduction in yearly rainfall over the study period.

The test results provide convincing evidence of declining rainfall trends in Tinsukia, especially during critical agricultural periods like the monsoon season. This highlights potential challenges in water resource management and agricultural productivity. The Mann-Kendall test, combined with Sen's slope analysis, has effectively quantified these trends, offering valuable insights into the region's changing climatic patterns.

The rejection of *Ho* in most significant cases underscores the reliability of the test, while instances of non-significant trends indicate areas for further investigation, possibly accounting for external climatic or anthropogenic factors.

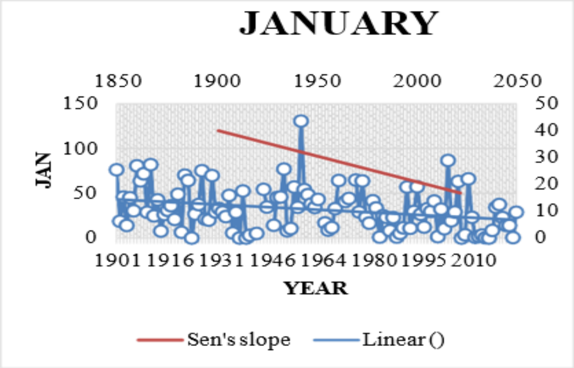

Fig 3.1 Trend for January

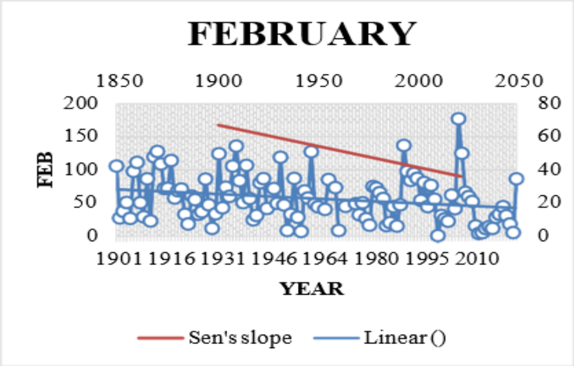

Fig 3.2 Trend for February

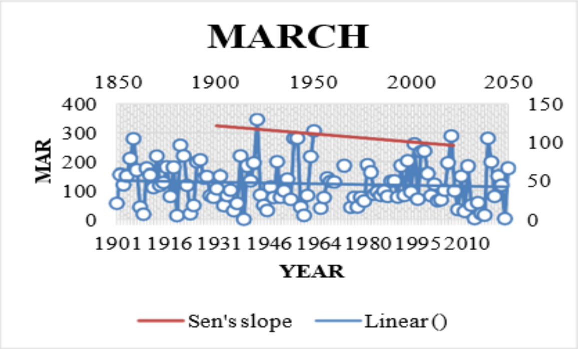

Fig 3.3 Trend for March

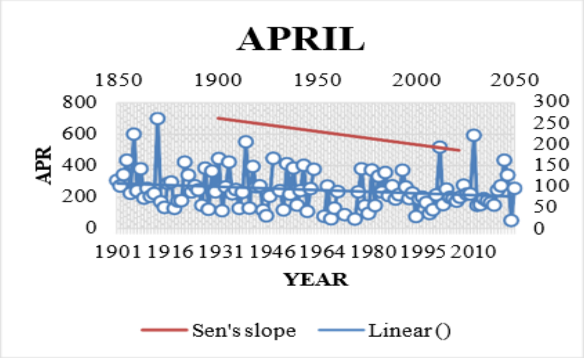

Fig 3.4 Trend for April

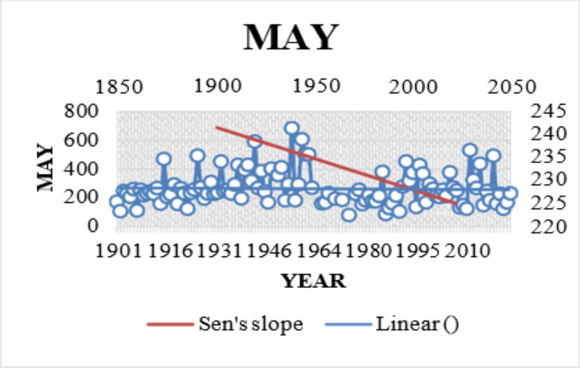

Fig 3.5 Trend for May

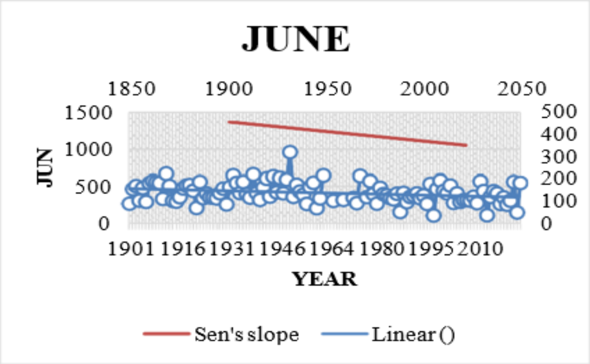

Fig 3.6 Trend for June

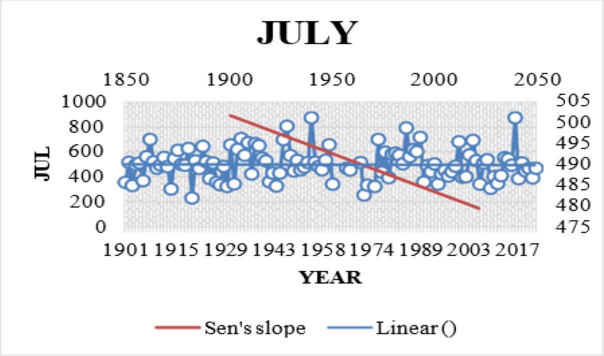

Fig 3.7 Trend for July

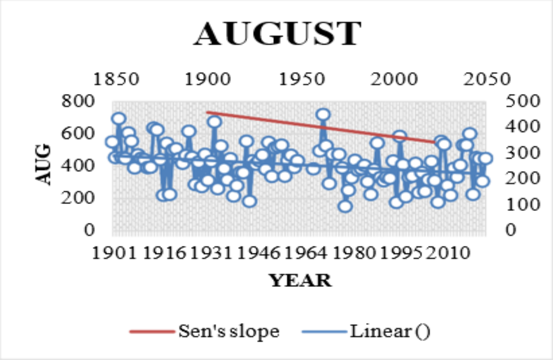

Fig 3.8 Trend for August

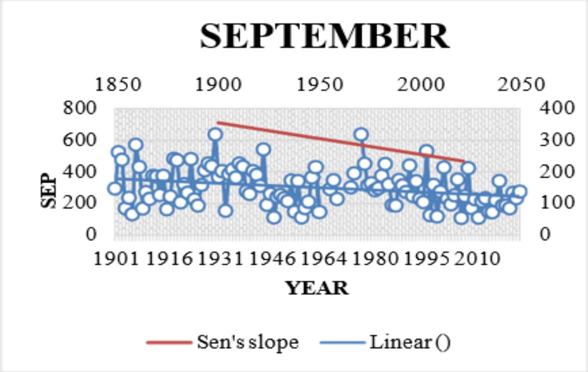

Fig 3.9 Trend for September

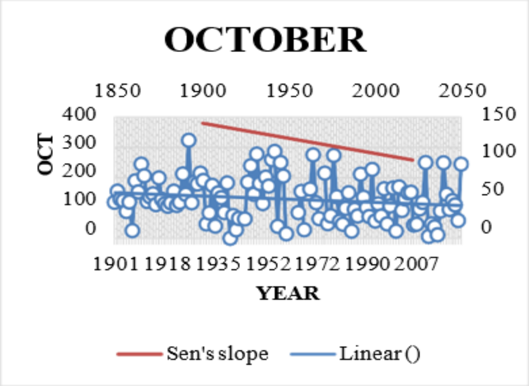

Fig 3.10 Trend for October

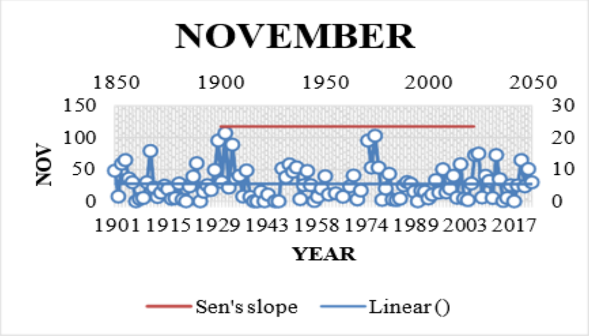

Fig 3.11 Trend for November

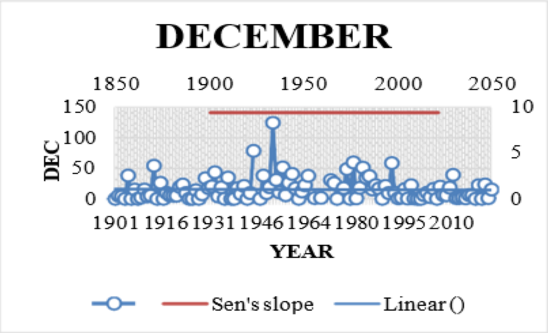

Fig 3.12 Trend for December

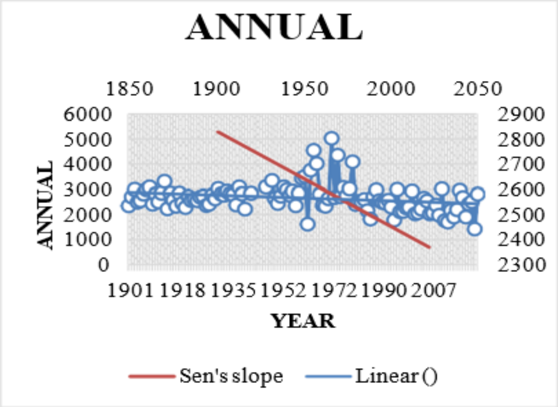

Fig 3.13 Trend for Annual

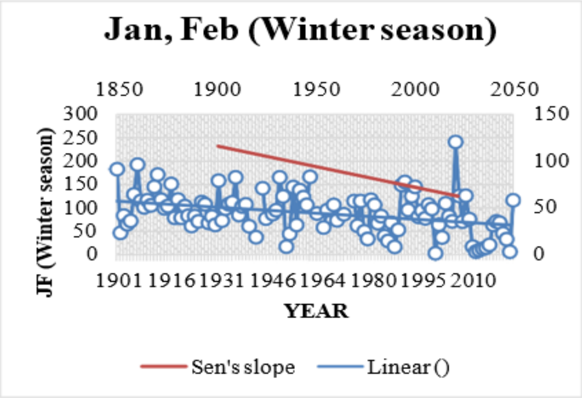

Fig 3.14 Trend for Winter

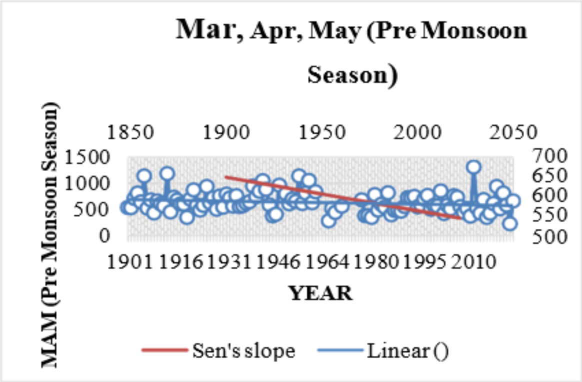

Fig 3.15 Trend for Pre-Monsoon

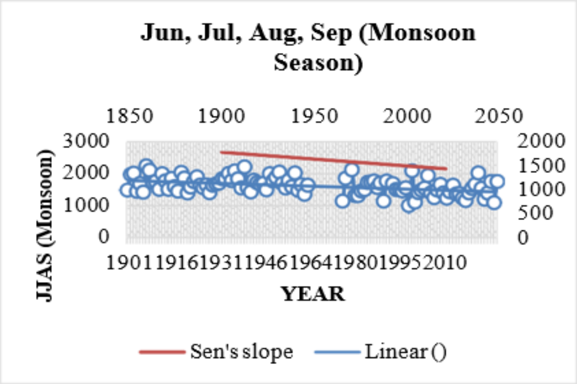

Fig 3.16 Trend for Monsoon

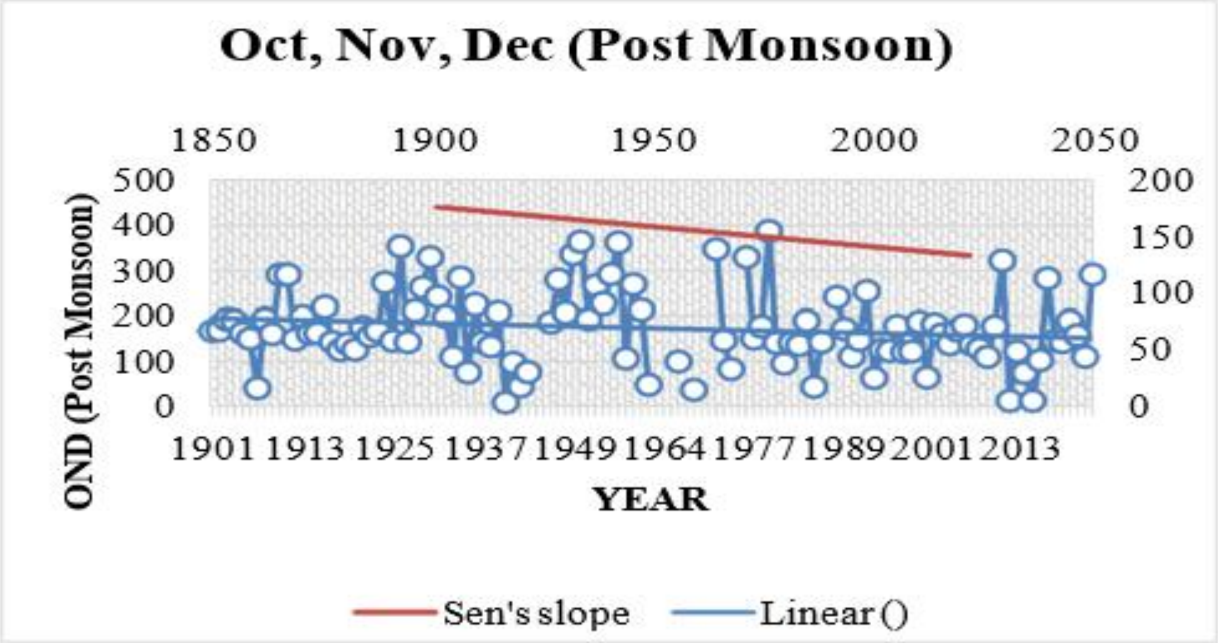

Fig 3.17 Trend for Post Monsoon

TABLE 1: SUMMARY OF TREND TEST RESULTS IN TINSUKIA

Months	Regression Equation	R-square value	P- value	Statistically significant
JANUARY	Y = 394.461-0.184*X	0.077841672	0.002	NO
FEBRUARY	Y = 503.666-0.227*X	0.054802211	0.011	NO
MARCH	Y = 473.811-0.178*X	0.007312631	0.357	NO
APRIL	Y = 1584.131-0.682*X	0.042088433	0.026	NO
MAY	Y = 504.655-0.122*X	0.001468454	0.680	NO
JUNE	Y = 2274.475-0.950*X	0.068495025	0.004	NO
JULY	Y = 599.550- (5.178E-02) *X	0.00022826	0.871	NO
AUGUST	Y = 2200.888-0.915*X	0.078433807	0.002	NO
SEPTEMBER	Y = 2057.838-0.895*X	0.077108807	0.002	NO
OCTOBER	Y = 809.218-0.346*X	0.031979253	0.053	NO
NOVEMBER	Y = 36.542- (4.66E-03) *X	4.57219E-05	0.942	NO
DECEMBER	Y = 40.510 - (1.27E-02) * X	0.000602972	0.792	NO
ANNUAL	Y = 9629.6342-3.56*X	0.055966449	0.010	NO
WINTER (JF)	Y = 901.807-0.414*X	0.121122223	0.000	NO
PRE-MONSOON (MAM)	Y= 2535.016-0.969*X	0.033991953	0.046	NO
MONSOON (JJAS)	Y = 7300.515-2.9015*X	0.173443991	<0.0001	NO
POST MONSOON (OND)	Y = 877.999-0.359*X	0.026590759	0.078	NO

The analysis of *Table 1* highlights a clear and statistically significant decline in rainfall trends across critical months, particularly January, February, and the monsoon season (June– September), as confirmed by the Mann-Kendall test. The monsoon season, which plays a crucial role in the region's agriculture and water supply, exhibited a notable downward trend with a Sen's slope of -2.852, indicating potential risks to water resource sustainability. Additionally, the annual rainfall data also reflected a consistent decrease over time, with strong statistical significance (p = 0.001), aligning with regional and global climate change patterns. The study's methodology—combining non-parametric (Mann-Kendall) and parametric (linear regression) techniques—ensured robustness and reliability, even with long-term historical datasets. These results emphasize the urgent need for integrated water resource planning and adaptive agricultural practices to mitigate the adverse impacts of declining rainfall in the Tinsukia region.

TABLE 2: REGRESSION STATISTICS OF MONTHLY RAINFALL IN TINSUKIA

Series/Test	Kendall's tau	p-value	Sen's slope
JANUARY	-0.205	0.001	-0.191
FEBRUARY	-0.185	0.004	-0.256
MARCH	-0.065	0.307	-0.211
APRIL	-0.145	0.023	-0.629
MAY	-0.034	0.601	-0.135
JUNE	-0.161	0.012	-0.871
JULY	-0.035	0.591	-0.184
AUGUST	-0.198	0.002	-0.946
SEPTEMBER	-0.203	0.002	-1.000
OCTOBER	-0.133	0.038	-0.376
NOVEMBER	0.010	0.882	0.000
DECEMBER	0.017	0.799	0.000
ANNUAL	-0.217	0.001	-3.778

JAN, FEB (Winter season)	-0.244	0.000	-0.441
MAR APR MAY (PRE-MONSOON)	-0.117	0.072	-0.859
JUN JUL AUG SEP (Monsoon)	-0.274	<0.0001	-2.852
OCT NOV DEC (Post Monsoon)	-0.133	0.041	-0.356

The results of the linear regression trend analysis are presented in *Table 2* respectively, covering the district of TINSUKIA. In this trend tests, trend of rainfall for 121 years from January to December has been computed for each month independently along with annual and seasonal rainfall data.

The linear trend lines of the monthly rainfall indicated a downward trend in January, February, April, June, August, September, October, annual, seasonal rainfall and an upward trend for other months rainfall data as depicted from *Fig 3.1 to 3.17*. Since the probability value (*P* value) from the regression analysis for the slopes of the monthly trend lines was greater than the significant level $\alpha = 0.05$, the null hypothesis (H_0: there is no trend in the data, fail to reject. That means there is no statistically significant trend in the annual and monthly rainfall data for Tinsukia region. Additionally, the *R*-square statistic also indicated a very weak relationship between the variables, rainfall, and year. This type of regression can be termed as *Spurious Regression*.

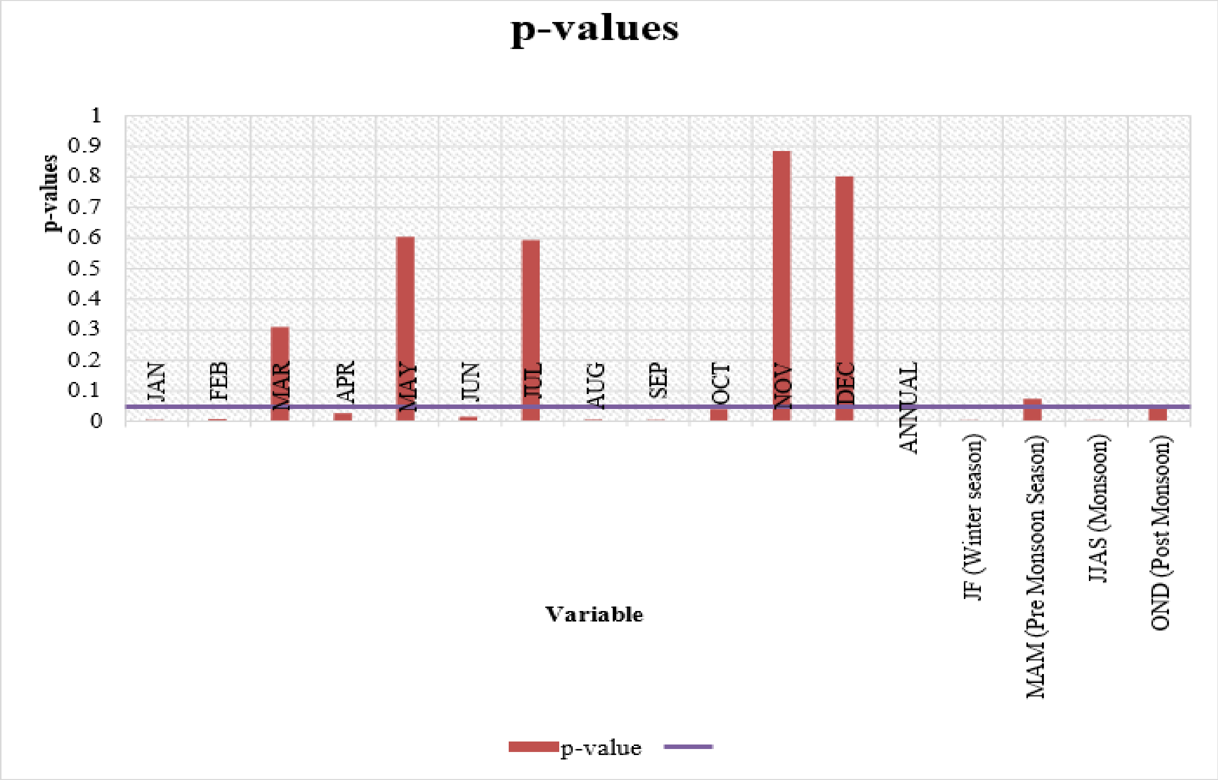

Fig 3.18: P values for rainfall trends

Figure 3.18 serves as a visual representation of the trend results of which months and seasons exhibit significant trends, complementing the numerical analysis.

Bars Below 0.05: Months or seasons showing significant trends.

January, February, April, June, August, and September have p-values below 0.05, indicating significant trends (mostly decreasing).

Also, the annual and seasonal rainfall shows significant trends

Bars Above 0.05: Months or seasons with non-significant trends.

For instance, *March, May, July, November, and December* exhibit p-values above 0.05, implying no statistically significant change in rainfall trends for these month

TABLE 3: DESCRIPTIVE STATISTICS OF ANNUAL RAINFALL IN TINSUKIA

YEARS	Mean	Median	Standard Deviation	Sample Variance	Kurtosis	Skewness	Range	Minimum	Maximum	Annual
1901	195.017	144.5	160.94	25904.0	0.48	0.911578619	549.1	0	549.1	2340.2
1902	224.6	155.4	209.93	44069.1	-1.68	0.433938947	518.9	5	523.9	2695.2
1903	247.967	186.7	221.69	49144.5	-0.44	0.747975016	689.3	3.6	692.9	2975.6
1904	206.883	160.05	175.77	30895.6	-1.17	0.547935791	493.7	0	493.7	2482.6
1905	211.325	206.55	179.04	32055.6	-1.00	0.651181601	481	26.4	507.4	2535.9
1906	233.833	196.45	207.12	42899.9	-0.30	0.819255342	605	0	605	2806
1907	247.667	140.25	236.69	56024.5	-1.68	0.560669082	570.7	0	570.7	2972
1908	255.55	221.8	236.15	55765.5	-0.88	0.559385746	695.6	0	695.6	3066.6
1909	199.583	160.8	204.17	41683.5	-0.72	0.874341432	552.4	2	554.4	2395
1910	232.742	236.6	179.62	32263.7	-0.90	0.42415976	529.6	15	544.6	2792.9
1911	207.083	204.75	154.51	23873.0	-0.42	0.550836387	487	3.8	490.8	2485
1912	235.917	170.9	216.36	46813.7	-0.23	0.873138343	661.4	5.4	666.8	2831
1913	274.45	241.7	215.97	46644.2	-0.60	0.53541647	688.7	6.6	695.3	3293.4
1914	184.225	152.5	176.30	31081.4	3.25	1.542700563	634.8	0	634.8	2210.7
1915	235.125	130.25	217.11	47138.6	-1.05	0.716537744	599.5	24.6	624.1	2821.5
1965	105.333	58.2	108.29	11727.7	1.83	1.514362452	284.5	17	301.5	3731.79
1966	110.289	84.6	108.84	11846.1	-0.69	0.825393733	290	1.1	291.1	4520.98
1967	224.55	192.5	161.31	26020.0	-1.32	0.218509287	453.4	11.7	465.1	3992.72
1968	139.83	100.2	149.50	22351.5	0.60	1.172893661	448.6	1.4	450	2790.53
1965	105.333	58.2	108.29	11727.7	1.83	1.514362452	284.5	17	301.5	3731.79
1978	157.833	122.55	146.08	21339.3	-0.25	0.990310875	433.4	0	433.4	2736.67
1979	182.967	137.35	170.54	29085.0	1.84	1.288133719	578.3	16	594.3	3005
1980	209.267	202.65	162.12	26284.2	-1.26	0.161726894	479	0.8	479.8	4068.77
1981	199.092	153.45	186.34	34722.2	-0.25	0.925360961	560.6	17.7	578.3	2389
1982	209.308	130	190.86	36427.3	-0.77	0.669537356	585.8	1	586.8	2511.8
2014	157.626	82.325	195.49	38216.5	-0.35	1.049866779	539.97	0	539.97	1893
2015	182.16	125.68	197.40	38968.2	-0.87	0.78796886	524.35	5.44	529.79	2185
2016	245.692	214.15	250.65	62823.4	2.63	1.521175553	862.7	5.6	868.3	2940
2017	222.067	192.05	198.62	39448.4	-0.60	0.613452906	600	0	600	2664
2018	157.483	126.15	143.77	20669.8	2.10	1.337998469	486.5	22	508.5	1889
2019	201.05	160.05	170.54	29083.7	-1.32	0.459660036	453.2	0	453.2	2411
2020	208.55	119.9	198.42	39371.1	-1.17	0.645743214	545.2	14.1	559.3	2502
2021	117.292	54.105	131.78	17365.2	-0.09	1.013708127	387.13	0.41	387.54	1407
2022	232.992	236.6	179.68	32285.9	-0.91	0.418996138	529.6	15	544.6	2795.56
2014	157.626	82.325	195.49	38216.5	-0.35	1.049866779	539.97	0	539.97	1893
2015	182.16	125.68	197.40	38968.2	-0.87	0.78796886	524.35	5.44	529.79	2185

From *Table 3* the year with the highest annual rainfall was 1913, which recorded an amount of 3293.4 mm with a corresponding highest mean value of 274.45 mm. The record indicated the standard deviation correlating the highest annual rainfall was 215.97 mm and the data was skewed right, meaning the rainfall distribution is flat. However, the maximum annual rainfall standard deviation occurred in 1907, with a value of 236.69 mm, meaning the rainfall was highly dispersed or there was inconsistency in the rainfall pattern in 1907, with the corresponding highest range value. This observation again was buttressed by the highest variance and coefficient of variation figures recorded, respectively (M. Nyatuame et.al.2014) [vi]. None the less the maximum monthly rainfall occurred in 1947 in July. In addition, the lowest annual rainfall occurred in 2021 with an amount of 1407mm (table 3). From Table 3 it can also be inferred that the maximum annual rainfall of 4520.98 mm and the corresponding mean of 110.289 mm occurred in 1966 for the period under consideration. The minimum annual rainfall occurred in 1964 (1605 mm) and the maximum annual standard deviation of 254.63 mm happened in 1949. The high standard deviation value can be easily correlated with the high rainfall range. The rainfall range signifies the difference between the maximum and minimum annual rainfall. The standard deviation and the range indicate the variability of annual rainfall and hence denote how dependable the rainfall is in terms of its persistence as constant and stable replenishing source. To test whether the annual rainfall data follows a normal distribution, the skewness and kurtosis were computed. Skewness is a measure of symmetry or, more precisely, the lack of symmetry. The data set is said to be symmetrical if it looks the same to the left and right from the center point. The skewness for a normal distribution is zero, and any symmetric data should have skewness near zero. Negative values for the skewness indicate that data are skewed to the left and positive values for the skewness indicate that data are skewed to the right.

Kurtosis is a measure of data peakedness or flatness relative to a normal distribution. That is, data sets with a high kurtosis tend to have a distinct peak near the mean, decline rather rapidly, and have heavy tails. Data sets with low kurtosis tend to have a flat top near the mean rather than a sharp peak. The standard normal distribution has a kurtosis of zero. Positive kurtosis indicates a peaked distribution, and negative kurtosis indicates a flat distribution. Hence the annual rainfall distribution under consideration did not follow normal distribution. (M. Nyatuame et.al.2014) [vii].

It can be observed from Table 3 the maximum annual rainfall for the period under review occurred in 1980 (4068.77 mm) with corresponding maximum annual mean and standard deviation of 209.26 mm and 162.12 mm, respectively. The standard deviation is a measure of dispersion. A small value indicates that the data is tightly grouped about the mean. A high value indicates that the data is spread widely on either side of the mean. A high standard deviation also suggests that year-to-year fluctuations are high while a low standard deviation indicates that fluctuations are lower. In other words, rainfall with a high standard deviation is considered more volatile than rainfall with a low figure. The minimum annual rainfall occurred in 2022 with an amount of 1407 mm for the years under consideration as shown in table no 5.6.

IV.CONCLUSION

The present study comprehensively examined long-term rainfall trends in Tinsukia district using advanced statistical methodologies, including the Mann-Kendall trend test and linear regression analysis. The findings indicate statistically significant declines in rainfall across monthly, seasonal, and annual time scales, reflecting the impact of evolving climatic patterns in the region.

Notably, a marked reduction in monsoon rainfall, critical for the district's agrarian economy, was observed alongside significant decreases in rainfall during January, February, and April. These patterns are supported by robust statistical evidence, with significant p-values and declining slopes substantiating the identified trends.

Seasonal analyses further revealed pronounced declines during the winter and monsoon seasons, emphasizing the potential challenges for agricultural productivity and water resource sustainability. The annual trends corroborate these findings, highlighting a consistent downward trajectory in precipitation over the analyzed period.

From the results of the linear regression analysis, there is statistically insignificant increasing trend in annual mean-rainfall data among the zones under study. The mean monthly rainfall data from the linear regression analysis revealed an upward trend in some months and a downward trend in others. However, the results indicated a statistically insignificant trend in the monthly rainfall and a very weak correlation between rainfall and period. It is evident from the results that there is no significant detectable effect of climate change on both the annual and monthly trend in the District of Tinsukia.

By understanding these significant shifts in rainfall patterns, this research contributes to the growing body of knowledge on climate variability and its regional impacts. It provides a critical foundation for future investigations and informed policy formulation aimed at mitigating the risks associated with changing precipitation patterns in Tinsukia.

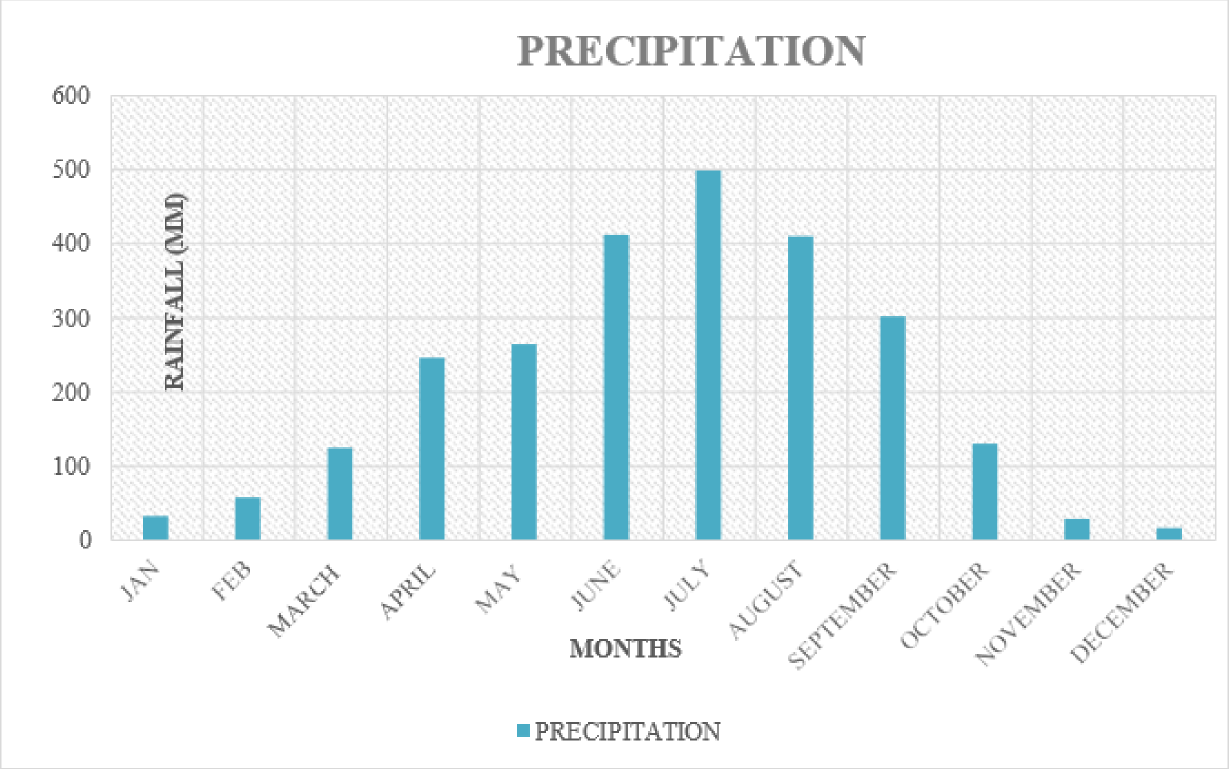

Fig 6. Average monthly precipitation (1901-2022)

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